AN EVALUATION OF VIRTUAL REALITY (VR) AS A LEARNING TOOL FOR STUDENTS WITH THE AID OF AN INTERACTIVE VR SIMULATION PROGRAM

by

G00376142

A thesis submitted in the Thesis in Education Science module, in partial fulfilment of the requirements for the Master of Arts in Teaching & Learning programme in the Galway-Mayo Institute of Technology

Research Advisory Panel

Barry McMillan, Dr. Marie English, Dr. Pauline Logue, Dr. Kate Dunne & Mary McGrath

DECLARATION OF ORIGINALITY

I declare that the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes. I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

ABSTRACT

The concept for this research began with the realisation that Virtual Reality (VR) could be used in education. This inspired an interest in the applications of VR and its possible benefit as a teaching and learning tool in higher education. The aim of the research is to perform a literature analysis of VR as a learning tool, and evaluate a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program. Objective one is to critically analyse existing literature regarding the implementation of VR in education. Objective two is to perform a literature analysis of the learning theories that underpin VR as a learning tool. The final objective is to evaluate the students experience when using VR for a computer networks application in an educational environment. Participants in the research were required to wear a VR headset and interact with a virtual environment which was a representation of a computer network. An interpretivist paradigm was used as the lens of the research as the participants' experience was a key feature of the aim of the research. A mixed approach was chosen to enrich the research with both quantitative and qualitative data. The research methods used were a questionnaire and a subsequent focus group. A limitation of this research was the number of participants which was 21. The limited access to resources to develop the VRLE restricted its operation and appearance. The literature analysis identified eight themes for the research which were Motivation, Novelty, Immersive Effect, VRLE Design, Possible Immersive Environment Discomfort, Alignment with Experiential Learning, Alignment with Situated Learning and Alignment with Constructivism. These themes were used to underpin the questionnaire questions and focus group discussion. The findings of the research indicated a positive reaction from participants to the usage and benefits of VR as a learning tool. However, they indicated a preference for limited use. The research finding argued an alignment with VR and the learning theories of Experiential Learning, Situated Learning and Constructivism.

KEYWORDS:

Virtual Reality, Education, Computer Networks, Learning Theories

DEDICATION

To Aoife, thank you for your support and patience throughout this thesis.

ACKNOWLEDGEMENTS

I wish to express sincere gratitude to my lead supervisor Dr. Marie English for her knowledge, guidance and kindness throughout this research.

Thank you to Mary McGrath for her shrewd advice and generosity of her time.

Thank you to Barry McMillan for his dedication and excellent guidance of the module.

Thanks to Dr. Pauline Logue for your wisdom, reassurance and kindness.

Thank you to Dr. Kate Dunne for her attention to detail and giving of her time.

I wish to acknowledge Dr. Niall Murray (AIT) for his advice on Virtual Reality and generosity with resources.

Thanks to Dr. Abhishek Bhattacharya (AIT research student) for developing the VRLE for the research.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

This chapter outlines the context for the research and the aims and the objectives of the research are introduced. The methodological approach to the research is presented to rationalise the implementation of the research. There is an acknowledgement of the scope and limitations of this research followed by an overview of the thesis structure.

1.1 CONTEXT

The concept for this research began with the realisation that Virtual Reality (VR) could be used in education. This inspired an interest in the applications of VR and its possible benefit as a teaching and learning tool in higher education.

A Virtual Reality Learning Environment (VRLE) provides real-time simulation of 3D graphics to mimic the real world (Huang, Rauch, & Liaw, 2010). Immersive VR is recognised as having excellent potential in education (Bricken, Byrne, & Washington Univ, 1992). Examples of its application are discussed in Section 2.2.1.3. As a lecturer, effective teaching methods and tools are of great interest in the quest to enhance teaching practice and provide support for student learning. Considering the increasing media attention of Virtual Reality (VR) in Education, the interest in this technology is gaining traction. Indeed, a report by Greenlight VR indicates that the desire for education outweighs the desire for gaming content by 63.9% to 61% ("Insights for the Experience Economy," 2016). The increase in processing power of computers, improvement in software, increased clarity in graphics and reduction in costs of VR has made it a viable and sought-after technology for use in the classroom.

The theory, which underpins the study of computer networks, can be somewhat abstract as it involves the students visualising the movement of packets of data when sending and receiving information across the computer network. As I am currently teaching the module Networks 1 in Athlone Institute of Technology (AIT), I have an appreciation of the student's sentiment towards this theory. This lack of visualisation of the data packets is the rationale for proposing a computer network as a suitable topic for use in a VR application.

There has been significant research in area of VR in education. Bibliometric results show that the number of articles on VR in education has been increasing since 1995 exponentially (Liu, Bhagat, Gao, Chang, & Huang, 2017). Much of this research was around the effectiveness of VR applications and how they compared to the real-world implementation. There would appear to be little research in the area of VR and its alignment with learning theories.

Arguably the three most dominant learning theories associated with VR are experiential learning theory, situated learning theory and the constructivist learning theory. Each theory is critically analysed and particular attention is given to how the learning theories underpin the approach of using this technology as a learning tool. It is hoped that this research will compliment any existing research on a students' experience of using VR in education.

1.2 AIMS & OBJECTIVES

1.2.1 AIM

To perform a literature analysis of Virtual Reality as a learning tool, and evaluate a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program

1.2.2 OBJECTIVES

1. To critically analyse existing literature regarding the implementation of VR in education.
2. To perform a literature analysis of the learning theories that underpin VR as a learning tool.
3. To evaluate the students experience when using VR for a computer networks application in an educational environment.

1.3 RESEARCH METHODOLOGY

A methodology is used to guide the researcher as to how they are going to do the research. The methodological approach and choice of methods for this research was determined by the aims and objectives of the research.

An interpretivist paradigm was used as the lens of the research as the participants' experience was a key feature of the aim of the research. A mixed methods approach was chosen to enrich the research with both quantitative and qualitative data. The research was deemed a case study as it was bound by a single iteration of a cohort of participants using a unique VRLE. The research data was derived from a questionnaire (Appendix 4) with a subsequent focus group (Section 3.3.3).

1.4 SCOPE & LIMITATIONS

The participants taking part in the research were required to have some basic prior knowledge of networking for them to engage with the VRLE computer networks application. The participants were from the first year *Networks 1* module class of 2019/2020 and had networking experience from Semester 1 before engaging with the research in Semester 2.

One of the limitations of the research is that the sample size of participants is relatively small. The participants are from the module Networks 1 which has approximately 54 students attending for the 2019-2020 academic year. Only 21 of these students chose to participate in the research.

Another limitation of this study is that it is based on one single VR application. It would have been preferable to use a number of applications with different interactive capabilities to get a more comprehensive student perspective which would further contribute to meeting the objectives of the study. This was not possible due to time restrictions and the resources required to build such applications. However, the findings of this research have the potential to be used to stimulate further research.

The VRLE attributes such as graphics and interoperability did not meet its full potential due to the time limitation on the building of the VRLE and available

resources. It takes a considerable number of man-hours to develop a professional looking VRLE. The application that was used for this research had a basic level of interaction within the VRLE. A commercial product would have a superior VRLE effect. This may limit the results of the study as student engagement may have been better if the environment had the look and feel of a commercial video game.

The questionnaire and focus group were also bound by the engagement and self-reflection honesty of the participants.

1.5 THESIS STRUCTURE

This thesis consists of five chapters. Chapter One presents the context of the research and introduces the aims and objectives. The research methodology is summarised and the scope and limitations of the research are discussed.

Chapter two details the literature analysis of VR in education that was undertaken to achieve objective one of the research. A general overview of VR in education is followed by an analysis of its application for Problem Based Learning (PBL) and collaboration. Initially, there were five common themes identified throughout the research analysis which were used as part of this research. These themes were Motivation, Novelty, Immersive Effect, VRLE Design and Possible Immersive Environment Discomfort. Objective two of the research required a literature analysis of the learning theories that underpin VR as a learning tool. This analysis is also outlined in chapter two with a further three of the total eight themes of the research identified. These themes were Alignment with Experiential Learning, Alignment with Situated Learning and Alignment with Constructivism.

Chapter three explored the research methodology and methods. An analysis of paradigms identified the interpretivist paradigm as the lens for this research. A mixed methods approach was evaluated and chosen for the benefit of both quantitative and qualitative data. A questionnaire and focus group were chosen as the research methods. This chapter explored the research ethics that required consideration before a questionnaire or focus group could be implemented. Following ethical approval from both GMIT and AIT a pilot study was performed and is detailed in this chapter. The VR setup for carrying out the research and the VRLE used are also described with the aid of images.

Chapter four details the research findings and discussion. The chapter begins with the profile of the participants that took part in the research. For clarity, the findings from both the questionnaire and focus group are presented together under the headings each of the research themes. The subsequent section discusses these findings and offers derived recommendations. Again, for clarity, these are presented under the headings of each of the research themes.

Chapter five is the concluding chapter. It reviews and rationalises the research process. There are concluding comments on each of the research themes followed by final thoughts on the research.

CHAPTER TWO: LITERATURE ANALYSIS

2.1 INTRODUCTION

This chapter is a literature analysis of the use of Virtual Reality (VR) technology in education with particular emphasis on its application in higher education. The first part of the chapter, Section 2.2, introduces the concept of using the VR technology in an educational environment. It analyses how VR may be implemented as a learning tool, with examples based on Problem Based Learning (PBL) and collaborative learning. The use of VR to encourage student engagement is also evaluated in this part with reference to student motivation and the novelty effect of using this technology. The section concludes with an analysis of the constraints of the tool which may be impacting its widespread deployment in education to-date. The second part of this chapter, Section 2.3, analyses the application of VR through the lens of learning theories. Based on the literature reviewed, arguably the three most dominant learning theories associated with VR were identified. These theories are experiential learning theory, situated learning theory and the constructivist learning theory. Each theory is critically analysed and particular attention is given to how the learning theories underpin the approach of using this technology as a learning tool.

2.2 THE IMPLEMENTATION OF VIRTUAL REALITY IN EDUCATION

The term virtual reality is defined as a computer-generated, interactive, three-dimensional environment in which a person is immersed (Amin & Govilkar, 2015) . A Virtual Reality Learning Environment (VRLE) provides real-time simulation of 3D graphics to mimic the real world (Huang et al., 2010). An example of this is Google Earth VR which allows a person wearing a VR headset to virtually travel around the earth with the ability to zoom in to explore cities and structures of interest as if they were there in reality (Google, 2017) . Virtual reality is interactive because users are not just observing the phenomena of their surroundings, but they can interact with objects which respond to their actions. An example of this is the Stanford Virtual Heart which allows medical students to examine congenital heart anomalies by allowing them to inspect and manipulate the affected heart, walk around inside it to see how the blood is flowing, and watch how a particular defect interferes with the

heart's normal function (Silva, Southworth, Raptis, & Silva, 2018). Virtual reality involves immersion because users can exist in a virtual world with the assistance of some equipment (Serrano, Botella, Baños, & Alcañiz, 2013). Therefore, virtual reality is defined as immersive and interactive (Chung-Ho & Ting-Wen, 2019). Immersive Virtual Reality (VR) is recognised as having excellent potential in education (Bricken & Byrne, 1992).

2.2.1 APPLICATION OF VR AS A SCAFFOLD FOR LEARNING

It is argued that VR allows the educational task to become much more intuitive as information is passed between the environment and the student with increased efficiency and selectivity (Brelsford, 1993). Arguably, this would appear to be a suitable environment to assist students with meeting their learning outcomes.

2.2.1.1 PROBLEM BASED LEARNING

Problem Based Learning (PBL) is a popular modern teaching strategy and may be regarded as a critical skill for learning. A critical skill is when a student is presented with a problem or scenario where they are required to propose solutions. The solution should be based on previously acquired knowledge and new learning which is inspired by the challenge of working on the problem. While there may not be a solution to the problem there is inherent learning by way of communication and collaboration. PBL aims to improve the possible weaknesses in traditional methods (lecturer-student power relationship) by encouraging learners to develop the ability to think independently and learn collaboratively (Brenton et al., 2007).

The VRLE can be used to demonstrate a scenario for PBL. Students can interact with each other and engage with the problem within the VRLE. To enhance this experience it may be possible for the group to alter parameters which instantly change the simulation (Holmes, 2007). This ability is a portrayal of a unique contribution that the VRLE can make to student learning. The immersive and interactive environment provides an engaging atmosphere which may aid with student learning. The VRLE assists the students to understand and solve visualization problems in a group (Wollensak, 2002). VR may aid problem-solving due to enhancement of visualisation. While this PBL approach using VR would

appear to have its merits, it should be noted that Kirschner, Sweller, & Clark (2006, p. 75) have strongly argued that research shows that PBL "is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process". They refer to PBL as minimally guided instruction. If the interactive features of a VRLE were to provide more than minimal guidance, of which it should be capable, then this could counteract their argument. PBL could also be used to support collaboration as outlined in the next section.

2.2.1.2 COLLABORATION

Collaboration occurs when a number of students work together. Collaborative learning ensues when students at various performance levels work together in small groups toward a common goal (Gokhale, 1995). Collaborative learning is an effective instructional method in both traditional and distance learning settings (Bernard & Rubalcava, 2000). The VRLE facilitates learning in a collaborative environment. A case study of a collaborative VRLE was implemented where students interacted with a 3D Human Organ Learning System (3D-HOLS). The students agreed that the experience helped them gain a better understanding of structure, orientation, positioning and shape of human organs. They found the environment realistic and it helped them to increase concentration. The collaborative environment was also a positive experience. They deemed it was a good learning tool which would strengthen their intention to learn (Huang et al., 2010). There are, of course, an infinite number of possible applications of VR in education, some of which are outlined in the following section.

2.2.1.3 EXAMPLES OF APPLICATION

There are a number of applications where VR has enhanced student learning. A VR setting can be created which replicates a place or scenario that students can explore without ever having to leave the classroom. Visiting or experiencing these locations may not have been feasible otherwise. One example is the grand structure of the Pantheon in Greece, which can be discovered in the VR world by students. A commercial milk powder processing plant was simulated in VR also (Abdul Rahim et

al., 2012). The ability to view and interact with this plant may be very beneficial to chemical and processing engineers. Another example is a virtual wind farm (Abichandani, Fligor, & Fromm, 2014). This farm introduced the concepts of wind energy. To enhance the students understanding of this field, the VR afforded the opportunity for the student to adjust parameters associated with the wind farm. The student could then observe the effects and the impact of the changes that were made. These applications present educational opportunities which are difficult to replicate in a traditional educational setting.

2.2.2 USING VR TO EHANCE STUDENT ENGAGEMENT

It can be argued that, not only does VR contribute to the students' understanding of a topic, it also has the benefit of enhancing the student engagement. Introducing enjoyment into learning has the capability to captivate students and contribute to their capacity to understand. A student who is enjoying the learning experience should have better engagement with the learning material.

2.2.2.1 MOTIVATION

Motivation is defined (in the educational field) as the student's desire to engage in the learning environment (Reiser & Dempsey, 2012). Motivation to learn is a very important aspect of student engagement, indeed better motivated students have a tendency to learn better (Sutcliffe, 2003). A survey carried out by Jocelyn and Mayer (2018) on student sentiment towards VR in comparison to the more traditional PowerPoint presentation approach, revealed that students reported that they felt more motivated to understand the material when using VR. It was cited by Huang et al. (2010) that several sources of existing research indicate a correlation between motivation and VR. The reason for this motivation may be due to the VRLE's ability to immerse the student in the digital world. Research has shown that students are more motivated by 3D graphics than 2D (Limniou, Roberts, & Papadopoulos, 2008). With ever increasing advancement in graphics this may reflect in greater student motivation in the future. The effect of VR on student motivation does not appear to be just novel as the continual use of the interactive environment can both improve student motivation and retention (Burdea, 2004). The VRLE provides a domain which can accommodate the creation of games and scenarios to enhance

motivation. The technology facilitates the development of captivating software and activities to motivate the students with greater effect than traditional methods (Gieser, Becker, & Makedon, 2013). However, according to Carbonell-Carrera & Saorín (2017), the impact of virtual reality on teaching–learning processes from a motivational approach has not been studied in depth.

2.2.2.2 NOVELTY

One could argue that the use of VR compared to traditional teaching methods could create quite a novel setting for students. Students may welcome a change of teaching strategy in the classroom. It would appear that this novelty should not be underestimated as novelty of interactive technology, including VR is attributed to improved student motivation (Ewert, Schuster, Johansson, Schilberg, & Jeschke, 2013; Huang et al., 2010; Zavalani & Spahiu, 2012). According to Clark (1983) improvements in learning are not due to an enhancement in teaching methods but are actually due to the novelty effect of a new technology.

2.2.2.3 IMMERSIVE EFFECT

The VR environment facilitates students immersing themselves in the scenario that is presented. This immersion presents the opportunity to captivate the student's attention. It is argued that the environment has a strong effect on the learner, and that education should be experimental and experiential (Dewey, 1985). VR would appear to inspire learning with the aid of an interactive environment. When the student does becomes immersed in this environment it contributes to time-on-task, exploratory learning and deeper learning (Kananagh, Luxton-Reilly, Wuensche, & Plimmer, 2017). This environment did not cause the student to 'lose' themselves but helped them to engage and focus on the task and gave them a sense of presence (Jacobson & Holden, 2005, p. virtual heritage section). This would appear to attribute more credibility to the environment than just a virtual digital display. In an aircraft evacuation training scenario, Sharma & Otunba (2012) reported that the person's sense of immersion facilitated a more accurate judgement of how they would react in a real-life scenario. However, the simulated world cannot replace the real world, and

according to Chittaro & Ranon (2007), learners may have a negative attitude toward learning in a VRLE since current VRLE's only approximate reality.

2.2.3 CONSTRAINTS OF THE VRLE

The VRLE would appear to provide benefits to aid students understanding of a topic and offer an environment that is appealing to the student, but it is not without its constraints. It can be costly to implement, has many design considerations and may be an uncomfortable environment for some students as discussed in the following sections.

2.2.3.1 COST

Creating a VRLE can be an expensive project. It is reasonable to argue that it requires a considerable investment in man-hours for both the design and build of the environment. It also requires state-of-the-art software and equipment to implement the project. One of the biggest challenges remains the high cost of building a VRLE (Huang et al., 2010). Lack of funding for the education sector is always a contentious issue. It may be difficult for any college to gain approval to invest in VR. The technology can be quite expensive, and cost is a frequent reason for the lack of investment of VR in education (Budziszewski, 2013; Huang et al., 2010; Kaufmann & Meyer, 2009; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014; Mossel & Kaufmann, 2013; Takala, 2014). Any college that does invest in VR has the added expense of maintaining the associated equipment. There is also the expense of training teachers on how to effectively use the equipment. Teachers may also need to train the students with the added consequence of detraction from the amount of time available for teaching (Le, Pedro, & Park, 2015). With such cost overheads associated with VR, there is a reduced market for the technology which will impact its widespread manufacture. This will likely decrease both the adoption of VR technologies in education, and the quality of those that are produced (Ray & Deb, 2016).

2.2.3.2 INEFFECTIVE VRLE DESIGN

When designing an environment for VR, there are a number of factors which must be considered. Students may be familiar with playing video games or using VR for

entertainment purposes, therefore, they will be accustomed to a certain standard of graphics. Future research on the development of high quality graphics should aim to match students' expectations (Yahaya, 2006). The graphics should be sufficiently realistic otherwise it may detract from the learning experience (Huang et al., 2010; Le et al., 2015). The graphics and environment should have an intuitive design as learners may easily get lost in the virtual environment or be unable to navigate their VRLE's (Chittaro & Ranon, 2007). It was also reported by Huang et al. (2010) that it was common for students to get lost while exploring badly designed virtual environments.

The overall design of the domain should be concise and not contribute extraneous content. Superfluous content may contribute to the extra cognitive load and detract from learning (Sweller, 1994, p. 301). The design of the environment should be intuitive and contribute to student learning. One of the most significant concerns of the VRLE was poor instructional design (Chen, Toh, & Ismail, 2005; Riva, 2003; Wong, Ng, & Clark, 2000). The design should correlate with good practice in educational game design. Games should provide learners with the opportunities to strategize their moves, test hypotheses, and solve problems (Ang & Rao, 2008; Dondlinger, 2007).

There should be a mechanism for feedback so that the student has an awareness of their navigation and progress in the VRLE. Students perform better when such guidance is provided in simulations (Lee, 1999). The type of feedback used should be given careful consideration as it is an important factor in determining the effectiveness of VRLE design for teaching and learning purposes (McNamara, Jackson, & Graesser, 2010).

Another of the shortcomings of the VRLE is when the student is immersed in the environment, they cannot visually interact with the real-world. One of the consequences of this is student's inability to take written notes while learning through the VRLE (Kananagh et al., 2017).

2.2.3.3 IMMERSIVE ENVIRONMENT DISCOMFORT

To be conducive to learning, a VRLE should afford a certain level of comfort for the student. There has been criticism of the VRLE that it has created problems such as

motion sickness for the user (Sutcliffe, 2003). In a previous systematic literature review, the issue would not appear to be prevalent as only 2 out of 35 papers analysed reported issues with motion sickness (Abdul Rahim et al., 2012; Nolin et al., 2016). These issues with motion sickness may have been a consequence of poor design or testing. There have been other reports of physical and psychological discomforts that users experienced in the VRLE. These included “strenuous posture demands, repetitive strain injuries, headset weight and fit, simulator sickness, disorientation, hallucination, and dissociation” (Costello, 1997, p. 18). While the prevalence and situations where these have occurred is not fully known, these are issues that VRLE designers need to be cognisant of to comply with the safety and comfort requirements of the user. The equipment for user interaction with the VRLE also needs consideration. There have been reports of ‘gorilla arm syndrome’ by Carmody (2010) and recognition problems including occlusion, gestural ambiguities and simple recognition inaccuracy (Gieser et al., 2013).

2.3 VR AS A FACILITATOR OF LEARNING THEORIES

Learning theories explain the mechanisms or processes underpinning particular learning experiences (Mayes & De Freitas, 2004). Theorising of how virtual world experiences bring about learning can help educators determine what their students can learn from virtual world experiences (Loke, 2015). It is the view of Anderson (2016) that when learning with emerging technologies, the learning and its design can be enhanced with the application of learning theories. It is the learning theories that help us understand the how and why of learning which adds value to the learning activities. While it is acknowledged by Anderson (2016) that new technology is not without it challenges, he advises that the theoretical basis will guide its use. This is further compounded by Leung, Zulkernine, & Isah (2018, p. 5) as the “convergence of learning theories with VR technology permits learning to be enhanced”. In an effort to ascertain the extent and possible alignment of VR and learning theories a critical review by Loke (2015) was identified. This review referenced four other similar literature reviews on the subject. Further reviews by Sommerauer & Müller (2018) and Leung et al (2018) were also studied. These papers identified a considerable number of learning theories that are claimed to be associated with VR but there were three overall predominant theories. These are:

experiential learning theory; situated learning theory; and constructivist learning theory which are outlined in the following sections.

2.3.1 EXPERIENTIAL LEARNING

According to Kolb (1984) the experiential learning theory was founded by John Dewey, Kurt Lewin and Jean Piaget. Kolb drew extensively from Dewey's work, and it is Kolb's experiential learning model that will be the focus here. The theory itself critiques the transmission model of teaching which is teacher-centred learning where students are passive absorbers of information and that the purpose of learning is memorization of facts (Loke, 2015). Instead, it proposes that students learn through their personal lived experiences. The model consists of four stages, Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation Kolb (1984). The concrete experience refers to a new experience or situation that is encountered. In the reflective observation stage students reflect of the results of the experiment. This is a critical stage of the Kolb cycle. The abstract conceptualization stage gives rise to new ideas, or a modification of an existing abstract concept. The person has learned from their experience. At the active experimentation stage the learner applies their idea(s) to the world around them to see what happens. A critique of the experiential learning theory suggests that not everyone learns from experience, learning happens when there is reflective thought and internal processing of the experience (Fenwick, 2001).

The theory proposes that, by reflecting on their real-life experiences, students will be able to act creatively in new situations in the real world. It is argued by Loke (2015, p. 115) that "it is implausible that students undergo a concrete experience of the real-world phenomenon in virtual worlds". I would counter argue that the virtual experience could be even more enriching and beneficial than the real-world experience because narrated or written assistance could be added to the virtual experience. The reflection phase is key to Kolb's theory and it is the belief of Loke (2015) that the experiential learning does happen where there is opportunity to reflect on the experience whether it is a virtual or real-world experience. Many

educators and researchers such as Jarmon, Traphagan, Mayrath, & Trivedi (2009) implement VR as part of experiential learning instructions.

The experiential theory could be applied to this research with the use of the VR scenario that is developed. The concrete experience and the active experimentation can possibly be achieved as the student interacts with the VR network. It was noted by Roussou (2004) that interactivity is a key determinant of the effectiveness for experiential learning. This may be achieved with a hand controller which is used in this research. The reflective stage of the Kolb's cycle is realised through questions asked during the VR scenario. There are other possibilities of implementation of the Kolb's cycle where the concrete experience is provided by a real-world practical lab and the VR scenario provides the active experimentation and reflection. However, it is not envisaged that a real-world practical lab will be used as part of this research.

2.3.2 SITUATED LEARNING

With situated learning, the general methods to support learning are based on Vygotsky's cognitive theory of "zones of proximal development" (Lave & Wenger, 1991). According to the situated learning theory proposed by Lave & Wenger (1991), learning is situated in a specific context and embedded within a particular social and physical environment. Situated learning enables the student to take an active role in their learning (Yasin, Darleena, & Isa, 2012). The theory critiques the idea that learning is a purely cognitive process which is independent of context. Instead, it proposes that the way people learn is coupled with their sociocultural context (Lave, 1988). A critique of this context by Hummel (1993, p. 15) suggests that 'instructional designers who apply situated learning theory by implementation in electronic media should realize that they take an important step away from this theory ... courseware becomes the learning environment and not the authentic situation'.

When situated learning theory is applied to VR, it is implied that the virtual world would provide a realistic enough context to lead students to think and act as they would in real-world situations (Loke, 2015). VR facilitates situated learning by (a) giving the student the ability to control and modify the environment (b) providing a

realistic ‘real-world’ environment to give context and (c) allowing opportunity for multiple practices (Leung et al., 2018).

2.3.3 CONSTRUCTIVISM

The constructivist theory is underpinned by the belief that learners construct their own knowledge. The core ideas of this theory have existed for over a century, with Jean Piaget and John Dewey as among the first few to develop a clear idea of it (Doolittle & Camp, 1999). Constructivism as a learning theory emphasizes the combination of inputs from the senses, existing knowledge, and new information to develop new meaning and understanding through active, authentic, cooperative and reflective learning activities (Chen et al., 2005). It was in Burris (2017) that Champney, Lackey, Stanney, & Quinn (2015) championed the constructivist learning theory approach in the implementation of VR for educational purposes due to its ability to involve the learner in “authentic inquire and active observation”. They believed that because the learner is involved in active and experiential ways, he is able to then construct his own context, understanding, and knowledge through reflection.

The VRLE has the capacity to support these active, authentic, cooperative and reflective learning activities. Constructivism uses interactive teaching strategies to empower students to construct knowledge based on their own experiences (Sommerauer & Müller, 2018). According to Leung et al (2018, p. 3) “characteristics of VR and the axioms of constructivist learning theory are entirely compatible”. This is also evident in the literature reviews by Chen (2010) and Fokides & Tsolakidis (2008) which claim that people learn better when they are actively involved in constructing knowledge in a learning-by-doing situation. Furthermore, VR provides an exploratory learning environment in which learners can navigate, manipulate, and observe the effects of virtual environment around them through experimentation. However, it should be noted that the design of the learning environment to facilitate the constructivist learning theory is vulnerable to the competencies of the instructional designer. It is the belief of Kirschner et al (2006) that constructivism is a minimally guided instruction and is likely to be ineffective.

The VRLE that will be used for this research will be an authentic learning scenario as it will replicate a ‘real-world’ networking operation. It will also require the students to

answer questions based on what they observe in the network. This would appear to support a constructivist learning theory, as according to Jonassen (1997), it is crucial to provide problems to the learners in constructivist learning environments as they learn through their attempt to solve the problems. He also states that constructivism stresses the importance of presenting an authentic problem.

2.4 CONCLUSION

This literature review provides a solid argument for the potential of VR by using an interactive experience with objects in the virtual environment as noted by (Blascovich et al., 2002). This immersive environment can be a reasonable and viable substitute for the real-world experience. This was exemplified by Jonassen (2005) when they compared the performance of a simulation laboratory and a traditional laboratory, and the results showed that students using the simulation laboratory received higher grades on written tests. The review also indicated how VR can also be used in tandem with real-world experiments to improve the learning process, as they are a complementary way to help students learn more efficiently and actively (Ángel, 2015). The VRLE has the added potential to enable students to engage in experiments, which cannot be completed or are difficult to achieve in a real laboratory (Rafael, Bernardo, Ferreira, Rasteiro, & Teixeira, 2007). However, it is important to note that VR is merely a tool. Tools by themselves do not teach. They have to be carefully and effectively implemented to assist in the learning process (Chen, 2010). It was acknowledged by Mahdi et al. (2018) that VRLE design is a complex activity with both technical and cognitive challenges.

According to Leung et al (2018) the implementation of VR has the potential to align with many learning theories such as constructivist learning theory, situated learning theory, embodied cognition theory, and social cognition theory. It was cited in Burris (2017) that Champney et al (2015) emphasised the need to ensure learning theories guide the design of VR solutions. Each of these theories has its own advantages as well as limitations. It may be more sensible to design a learning environment which uses a combination of these theories to improve the students' chances of achieving

the learning outcomes (Chen, 2010). A criticism by Dalgarno & Lee (2010) claimed that VRLE design is based more on intuition than learning theories. Furthermore, Savin-Baden et al (2010) reported from its literature reviews that the pedagogical basis for using virtual worlds is under-theorised. Indeed, studies to gain more insights into such theoretical foundations are indispensable to enable effective, efficient, and appropriate utilization of the technology for education purposes (Chen, 2010). This would appear to support the research proposal objective of evaluating the student learning experience when using a VR interactive simulator with a view as to how VR is a facilitator of learning theories.

CHAPTER THREE: RESEARCH METHODOLOGY & METHODS

3.1 INTRODUCTION

The purpose of this chapter is to provide an analysis of the methodological framework of the research, which will subsequently inform the selection of the research methods. The methodological approach and choice of methods will be determined by the objectives of the research. The methodology is used to guide the researcher as to how they are going to do the research. This chapter will explore four different paradigms: positivist, interpretivist, critical and pragmatic. A rationale will be provided for the paradigm which best guides the research. Following this, a mixed methods approach to the research is presented and it is argued that a case study approach is the most suited research strategy. The merits of the use of a questionnaire and a focus group as instruments for data collection in the research are also explored. The methodological framework is bounded by the aim of the research which is to analyse Virtual Reality as a learning tool, and evaluate the students' perspective of its implementation with the aid of an interactive VR simulation program.

3.2 RESEARCH METHODOLOGY

Following the awareness that VR had an application in education, it provoked the question of how effective it could be as a learning tool. The research for this thesis

began with a literature review, and before the process of data collection could occur, consideration had to be given to the research approach. It is however important to acknowledge that different kinds of research approaches produce different kinds of knowledge about the phenomena under study (Blaxter, Hughes, & Tight, 2001). This is why careful consideration must be given to the methodological approach to the research. To understand what is meant by methodology, it is useful to make a comparison between methodology and methods. The term 'methods' refers to the techniques or tools that are used to collect the data, for example, an interview. Methodology has a more philosophical meaning and usually refers to the approach or paradigm that underpins the research (Blaxter et al., 2001). For example, carrying out an interview which is guided by different philosophical approaches will produce different kinds of knowledge. According to Teddlie & Tashakkori (2009) the research methodology is a broad approach to scientific inquiry and one which includes worldview considerations. Figure 3.1 is an overview of the methodological approach to this research. In this figure, the term methodology is used to signify the overarching procedural approach to meeting the objectives of the research.

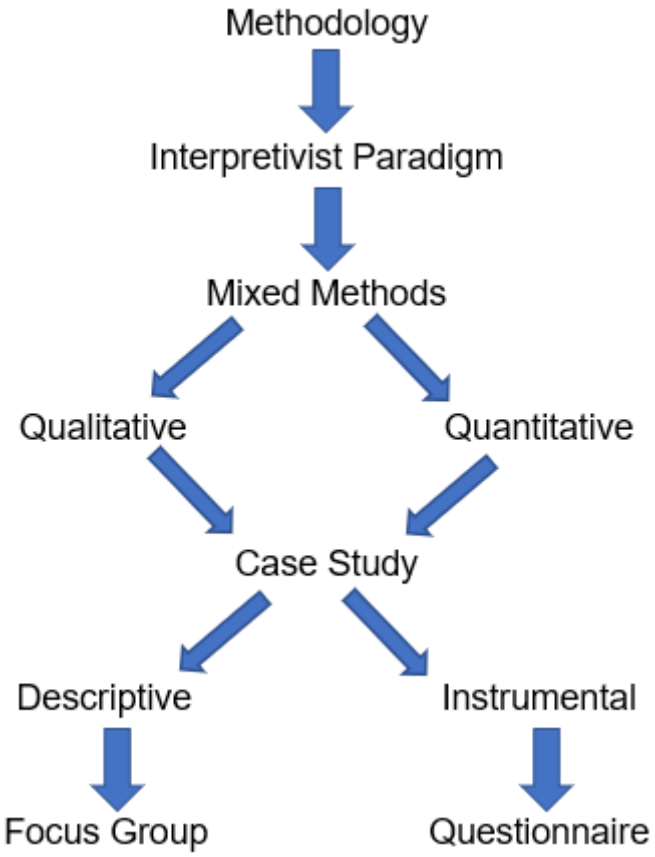

Figure 3.1 Methodological Approach

3.2.1 PARADIGMS

Once the aims and objectives of the research were decided, it was important to consider the lens through which the research would be realised. Research itself has been described as a systematic investigation to find answers to a problem (Burns, 2000) or inquiry whereby data are collected, analysed and interpreted in some way in an effort to "understand, describe, predict or control an educational or psychological phenomenon or to empower individuals in such contexts" (Mertens, 2005, p.2). This systematic investigation or medium would require the guidance of a research paradigm, which is the lens through which a researcher looks at the world. It determines the research methods that will be used and how the data will be analysed (Kivunja & Kuyini, 2017, p. 26). Paradigms are important because they influence what should be studied, how it should be studied, and how the results of the study should be interpreted (Kivunja & Kuyini, 2017, p. 26). It is explained by Willis (2007, p. 8) that “a paradigm is thus a comprehensive belief system, world view, or framework that guides research and practice in a field”. It may also contribute to the philosophical intent or motivation for undertaking a study (Cohen & Manion, 1994, p. 38).

According to Candy (1989), paradigms can be Positivist, Interpretivist or Critical. A fourth paradigm known as Pragmatic has been suggested by other researchers (Tashakkori & Teddlie, 2010). The research to be undertaken will be guided by the assumptions, beliefs, norms and values of the chosen paradigm. Without nominating a paradigm as the first step, there is no basis for subsequent choices regarding methodology, methods, literature or research design (Mackenzie & Knipe, 2006, p. 2).

Each of the paradigms will be analysed in terms of the prescribed elements of a paradigm. These elements are epistemology, ontology, methodology and axiology (Lincoln, 2007, cited in Kivunja & Kuyini, 2017) . Epistemology is the nature of

knowledge. The positivist researcher believes that knowledge is accurate and certain, whereas the interpretivist researcher believes that knowledge is constructed and is subject to ones beliefs, values, reasons, and understanding (Aliyu, Singhry, Adamu, awuya, & Abubakar, 2015). Ontology is the study of what is reality, being or existence (Aliyu et al., 2015). The positivist paradigm seeks verifiable data as part of its ontology whereas the interpretivist paradigm viewpoint is that reality is what the observer perceives. Axiology refers to the values associated with the research. It is important for researchers to recognise and understand the ontological and epistemological orientation within the research paradigm as it is able to determine the entire course of the researcher's project (Hussey and Hussey, 1997, cited in Aliyu et al.,2015).

The paradigms are summarised in Table 3.1. The contents of the table was predominantly influenced by Kivunja & Kuyini (2017). The paradigms will be analysed in the following sections.

Paradigm	**Paradigm Elements**				**Characteristics**	**Validation**
	Epistemology (how we come to know something)	Ontology (belief/perspective of reality)	Methodology (design, methods, approaches and procedures	Axiology (ethical issues) 4 criteria and 4 four principles PAPA		
Positivist Paradigm (scientific method of investigation)	Objectivist (independent of the values, interest and feelings of the researcher)	naive realism (5 beliefs including sense-experience)	Experimental (predictor variable and explanatory variable) test and to accept or reject hypotheses	Beneficence (maximizing good outcomes for project, for humanity for participants)	truth or knowledge is 'out there to be discovered' -results of inquiry can be quantified	internal validity, external validity, reliability, and objectivity
Interpretivist/Constructivist Paradigm (try to interpret the viewpoint of the person being observed)	Subjectivist epistemology (construct knowledge via subject)	relativist ontology (multiple possible realities)	naturalist methodology (interviews etc)	balanced axiology (reflects the values of the researcher)	belief that realities are multiple and socially constructed. That knowledge is created by the findings	Credibility (is data /data analysis believable), Dependability (reliability in respect of 'human nature'), Confirmability (bias eliminated) Transferability (relate to other research)
Critical/Transformative paradigm (political, social and economic issues)	Transactional (knowledge interaction between the researchers and participants)	historical realism (shaped by history)	Dialogic (analyse communication for embedded significance)	respects cultural norms	Address human rights, power oppression and increase social justice,	
The Pragmatic Paradigm (combination approach)	relational epistemology (everything is related, dynamic, interrelationship -so researcher deems what's appropriate)	non-singular reality (all individuals have their own interpretations of reality)	mixed methods methodology (combination of quantitative and qualitative research methods)	value-laden axiology (Values play a large role in interpreting results)	Choice of research methodology/methods depending on the purpose of the research	

Table 3.1 Paradigm Summary adapted from Kivunja & Kuyini (2017)

3.2.1.1 POSITIVIST PARADIGM

The Positivist paradigm is sometimes referred to as 'scientific method' or 'science research'. It is "based on the rationalistic, empiricist philosophy that originated with Aristotle, Francis Bacon, John Locke, August Comte, and Emmanuel Kant" (Mertens, 2005, p.8, cited in Mackenzie & Knipe, 2006, p. 2). It "reflects a deterministic philosophy in which causes probably determine effects or outcomes" (Creswell, 2002, p. 7). Positivists aim to test a theory or describe an experience "through observation and measurement in order to predict and control forces that surround us" (O'Leary, 2004, p. 5). This paradigm relies on deductive logic, testing of hypotheses and use of calculations, extrapolations and expressions to derive conclusions.

The positivist epistemology is one of objectivism, meaning that positivists go forth into the world impartially, discovering absolute knowledge about an objective reality (Scotland, 2012). It aims to provide explanations and to make predictions based on measurable outcomes. This rigidity and precision is not conducive to the research of human behaviour or reaction so a derivative known as the Postpositivist paradigm evolved. The Positivist paradigm maintains the belief that reality is out there to be studied, captured and understood, the Postpositivist accepts that reality can never be fully understood; but at best, only approximated (Guba,1990, cited in Kivunja & Kuyini, 2017).

The research reported in this thesis requires the participants to view a networking scenario while wearing a VR headset and subsequently report on the experience. Given that the positivist researcher believe that everything is perceived through the senses, it could be argued that a positivist approach could be taken to this research. This would be the case if the participants were required to report on their senses of the experience in a binary fashion, such as yes/no answers in a questionnaire. Since this research will probe the experience of the participants, such as how they felt when they were using the VR, this will require a subjective response and a construction of their meaning making as part of their interaction with the physical world. The positivist researcher has an objective epistemology, as shown in Table 3.1, which suggests that the positivist approach is not suitable for this research.

3.2.1.2 THE INTERPRETIVIST PARADIGM

Interpretivism and constructivism are related concepts that address understanding the world as others experience it. The interpretivist researcher tends to rely upon the "participants' interpretations of the situation being studied" (Creswell, 2002, p. 8). Interpretivists do not generally begin with a theory (as do the postpositivist) as throughout the research process they "generate or inductively develop a theory or pattern of meanings" (Creswell, 2002, p. 9). The central endeavour of the interpretivist paradigm is to understand the subjective world of human experience (Guba & Lincoln, 1989, cited in Kivunja & Kuyini, 2017, p .33). Hence, the key tenet of the interpretivist paradigm is that reality is socially constructed (Bogdan & Biklen,1998, cited in Kivunja & Kuyini, 2017, p. 33).

With reference to the elements of a paradigm in Table 3.1, the assumption of a subjectivist epistemology means that the researcher makes meaning of their data through their own thinking and cognitive processing of data informed by their interactions with participants (Kivunja & Kuyini, 2017). The researcher will create an interpretation of participants' interpretation of their experience. There is the understanding that the researcher will construct knowledge in the context of the real life within the natural settings investigated (Punch, 2005). The interpretivist paradigm requires that our personal perspectives, along with those of our research participants, are 'given voice' (Taylor & Medina, 2013, p. 8). The assumption of a relativist ontology means that the researcher believes that the situation studied has multiple realities, and that those realities can be explored and meaning made of them or reconstructed through human interactions between the researcher and the subjects of the research, and among the research participants (Chalmers, Manley & Wasserman, 2005, cited in Kivunja & Kuyini, 2017). In assuming a naturalist methodology, the researcher utilises data gathered through interviews, discourses, text messages and reflective sessions, with the researcher acting as a participant observer (Carr & Kemmis, 1986, cited in Kivunja & Kuyini, 2017, p. 33). A balanced axiology assumes that the outcome of the research will reflect the values of the researcher, in trying to present a balanced report of the findings. The ontological

position of interpretivism is relativism. Relativism is the view that reality is subjective and differs from person to person (Denzin & Lincoln, 2000, p. 110). One of the most important characteristics of this research is the interpretation of data. The participants who view the VR networking scenario will be required to give their perspective of the VRLE which is based on their interpretation of what they see. This perspective will also be based on how they felt when they were using the technology. Arguably, each participant will have a different interpretation and experience of the VRLE. This would mirror the relativist ontology of the interpretivist paradigm as depicted in Table 3.1. The interpretivist researcher is concerned with trying to make meaning of each participant's perspective. The researcher will endeavour to gather data, where "efforts will be made to get inside the person and understand from within" (Cohen, Manion, & Morrison, 2000, p. 22). This strategy is aligned with the subjectivist epistemology of the interpretivist paradigm as presented in Table 3.1.

The aim of this research is to perform a literature analysis of Virtual Reality as a learning tool, and evaluate a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program. The evaluation is based on the researcher's interpretation of the students' interpretation of their experience of using VR. This aim and its alignment with the literature as discussed in this section is the rationale for using the Interpretivist paradigm as the lens for this research.

3.2.1.3 THE CRITICAL/TRANSFORMATIVE PARADIGM

The Critical/Transformative paradigm situates its research in social justice issues and seeks to address the political, social and economic issues, which lead to social oppression, conflict, struggle, and power structures at whatever levels these might occur. According to Denzin & Lincoln (2000, pp. 279-313) the critical research paradigm enables the researcher to practise 'deep democracy' which involves identifying and transforming socially unjust social structures, policies, beliefs and practices.

The ontological position of the critical paradigm is historical realism. Historical realism is the view that reality has been shaped by social, political, cultural, economic, ethnic, and gender values (Scotland, 2012, p. 13). From an epistemology

perspective, Cohen, Manion, & Morrison (2007, p. 27) explains that, “what counts as knowledge is determined by the social and positional power of the advocates of that knowledge.”

This paradigm does not align itself with the aim or objectives of this research. The social basis of this research refers to the qualitative focus group interviews. There are no social justice issues, therefore, this paradigm will not be used to guide the research.

3.2.1.4 THE PRAGMATIC PARADIGM

The pragmatic paradigm originated due to a criticism of the mono-paradigmatic approach to research. Philosophers such as Alise & Teddlie (2010), Biesta (2010), Tashakkori & Teddlie (2003) and Patton (1990) as highlighted by Kivunja & Kuyini (2017) argued that what was needed was a worldview which would provide methods of research that are seen to be most appropriate for studying the phenomenon at hand. Pragmatism is not committed to any one system of philosophy or reality (Mackenzie & Knipe, 2006, p. 4). The pragmatic paradigm places "the research problem" as central and applies all approaches to understanding the problem (Creswell, 2002, p. 11). The pragmatic paradigm provides an opportunity for "multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis in the mixed methods study" (Creswell, 2002, p. 12).

John Dewey was one of the forefathers of the pragmatic paradigm (Kaushik & Walsh, 2019). It is suggested by Morgan (2013), who uses the work of John Dewey to develop his approach to pragmatism, that pragmatists focus on the nature of experience unlike other philosophies that emphasize nature of reality. This focus would align with the sociological pragmatist approach of this research where the aim of the research is focused on the participants’ experience of using the VR.

While it is suggested that this research can be viewed through the interpretivist lens, there is an affiliation between the researcher’s view on research and that of the pragmatist researcher. I believe, as suggested by Creswell, that research should not be limited to a single method, worldview or assumption and it is for this reason that I

would embrace a mixed methods approach. The combination of both a quantitative and qualitative approach is a feature of the pragmatic paradigm as depicted in Table 3.1. A quantitative and qualitative mixed methods approach could be more enriching to meet the research objective of evaluating the students' learning experience. This would, as Creswell suggested, place the research problem as central, and not the paradigm. Therefore, while this research will be viewed through the interpretivist lens, there is also a pragmatic paradigm influence in the use of a mixed methods approach to data collection.

Regarding educational research, it was suggest by Scotland (2012, p. 14) that "the scientific paradigm seeks to generalize, the critical paradigm seeks to emancipate and the interpretive paradigm seeks to understand". Furthermore, I would suggest that the pragmatic paradigm seeks to solve. The methods and instruments which support the methodological approach to this research are outlined in the next section.

3.3 RESEARCH METHODS

This section explores the rationale for using quantitative research, qualitative research and its combination known as mixed methods research. A justification for the mixed methods approach is provided. The use of a case study as a research method with a questionnaire (Appendix 4) and focus group as instruments is also rationalised. Consideration of the ethical requirements of the research is also outlined.

3.3.1 MIXED METHODS

Quantitative research involves the collection and analysis of numerical data, whilst qualitative research considers narrative or experiential data (Hayes et al., 2013, cited in Halcomb & Hickman, 2015).

There are merits and critiques of both quantitative and qualitative methods which are discussed as follows. It is argued that quantitative research may not give recognition or promote understanding of the context or setting in which people talk and that the voices of participants' may not be directly heard (Creswell & Plano Clark, 2006). This

is because quantitative researchers may view the participants' responses as subjective, which may lack vigour and may be difficult for the quantitative researcher to replicate with authority. However, frequencies and patterns in speech is a driver for quantitative data. For qualitative researchers the view the participants' is seen as a strength, as the subjective nature of qualitative research allows the researcher to probe for underlying values, beliefs, and assumptions. There may also be an accusation from quantitative researchers that qualitative researchers are prone to bias and a concern that the interpretations from a sampled limited number of participants studied are not generalizable to a larger population (C. Anderson, 2010). However, when verbatim accounts are presented, it refutes the argument of bias. This criticism is addressed in the case study section below. When combined, the use of quantitative and qualitative approaches, as used in this research, may provide a better understanding of research problems than either approach alone (Creswell & Plano Clark, 2006). This is because each approach views the research question from a different perspective. When applied to the research objective of evaluating the students' learning experiences, the quantitative method of acquiring questionnaire data combined with the qualitative method of acquiring focus group data may provide a more holistic perspective than either approach alone. The combination of qualitative and quantitative methods is known as mixed methods research.

It is the belief of Trochim (2006) that in almost every applied social research project there is value in consciously combining both qualitative and quantitative methods in what is referred to as a "mixed methods" approach. He also states that "all quantitative data is based upon qualitative judgements; and all qualitative data can be described and manipulated numerically" (Trochim, 2006). In general, mixed methods research involves collecting, analysing, and interpreting quantitative and qualitative data in a single study or in a series of studies that investigate the same underlying phenomenon (Leech & Onwuegbuzie, 2009). According to Teddlie & Tashakkori (2009) it is the research questions that guide the mixed methods research. Furthermore, Teddlie & Tashakkori (2009) stated that in mixed methods research these questions will be answered with both numerical and narrative form. This is true of the research to be undertaken here as there will be numerical data from the questionnaires to capture the frequency of response and there will also be

narrative contributions from the focus groups to capture the participants' experiences.

When choosing a mixed methods approach it is important to examine the rationale for using it as the research questions should reflect the rationale for undertaking mixed methods research and clearly demonstrate the qualitative and quantitative dimensions of the project (Lavelle et al., 2013 as cited in Halcomb & Hickman, 2015). The aim of this research is to perform a literature analysis of Virtual Reality as a learning tool, and to evaluate a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program**.** This evaluation will have a qualitative approach where the students will be invited to participate in a focus group to capture narrative contributions. The evaluation will also take a quantitative approach where questionnaire data will be analysed to capture the frequency of responses. This approach to VR research has also been used by Kim, Lee, & Koo (2017) when evaluating user experiences on virtual reality indoor bikes.

Having chosen a mixed methods approach, consideration was also given to the various typologies of mixed methods designs. It is believed that sequential explanatory as depicted in Figure 3.2 is the mixed methods design strategy best aligned to this research. Sequential explanatory is characterized by an initial phase of quantitative data collection and analysis followed by a phase of qualitative data collection and analysis (Creswell, Plano Clark, Gutmann, & Hanson, 2003). It is believed that this would be the best approach to this research as the data from the quantitative research can be used to guide the qualitative focus group. This would serve to give direction to the focus group questions which could add value or seek clarity to the quantitative questionnaire answers. The sequential explanatory, mixed methodology is regarded as a popular approach to undertaking research, but not easy to implement (Ivankova, Creswell, & Stick, 2006).

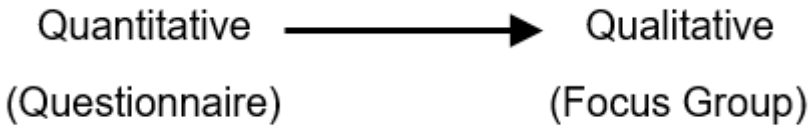

Figure 3.2 Sequential Explanatory Approach

It takes time and resources to collect and analyse both quantitative and qualitative data (Creswell & Plano Clark, 2006). However, they also add that the value of mixed methods research has the potential to outweigh the difficulty of its approach.

Consideration was given to the suitability of four different educational research methods. These methods were Ethnographic Research, Grounded Theory, Action Research and Case Study.

Ethnographic research relies on up-close, personal experience and possible participation, not just observation, by researchers trained in the art of ethnography (Genzuk, 2003). While it may have originated as a method to research a particular culture, it may also be used be used to study a group of students. If this research was using VR as a collaborative learning tool or if there were observations to be made of the students' social interaction while using the VR then ethnography may have been chosen as a suitable method. Since the focal point of the research is more on the individual student's Quality of Experience (QoE) of the VR, ethnography was not chosen as a research method.

Grounded theory is a research method concerned with the generation of theory (Glaser, Strauss, & Strutzel, 1968) which is 'grounded' in data that has been systematically collected and analysed (Strauss & Corbin, 1994). It can be an intensive research method which requires systematic rigour and according to Opie & Sikes (2004) is not likely to be a research choice of Masters students. Grounded theory approach will not be used for this research due to the time it takes to implement the iterative nature of developing a theory. Furthermore, its approach does not align with the aim of this research as there is no intention to construct, develop or test a theory.

Action Research (AR) is research conducted by a professional into their own activity with a view to achieving an improvement in their practice (Birley & Moreland, 1999). It is a powerful tool in a situation which requires problem solving or where a change results in a more desirable outcome (Cohen et al., 2007). It usually involves a reflective cycle where a process is studied, an adjustment is made, the result is observed and the cycle begins again. There are a number of variation of AR and in

some cases there may only be one iteration of the cycle. If this research were seeking to improve the VR experience for students' then AR would have been considered as a method. The VRLE could have had changes made it and the outcome could have been analysed by way of questionnaires or the use of other instruments. Since the research to be undertaken is an observation of the QoE of students with no deliberate action to be taken, AR will not be chosen as a research method.

The mixed methods research will be implemented using a case study approach as discussed in the following section.

3.3.2 CASE STUDY

Case study is defined as "an empirical inquiry that investigates a contemporary phenomenon (the 'case') in depth and within its real world context" (Yin, 2013, p. 16). This research is considered to be a case study as it is an investigation of a case, the case being a group of students and their use of a VR scenario. It will involve an in-depth inquiry guided by the objectives of the research and will have real world context as it is a social research study. Further justification of the alignment of this research with a case study is given by the description of a case study from the Centre for Innovation in Research and Teaching (CIRT) by Grand Canyon University where it describes it as:

> A case study research refers to an in-depth, detailed study of an individual or a small group of individuals. Such studies are typically qualitative in nature, resulting in a narrative description of behaviour or experience. Case study research is not used to determine cause and effect, nor is it used to discover generalizable truths or make predictions. Rather, the emphasis in case study research is placed on exploration and description of a phenomenon. The main characteristics of case study research are that it is narrowly focused, provides a high level of detail, and is able to combine both objective and subjective data to achieve an in-depth understanding (CIRT, 2016).

This description clearly represents the kind of research process that will be carried out in this study and is mirrored as follows:

- The aforementioned group of individuals will be the students from the Networks 1 class who will be the research participants.
- There will be a narrative description of the participants' experience of the VR.
- The core elements of this research will be the exploration and description of a phenomenon: the phenomenon being the QoE of the students' using the VR.
- This study will include the objective and subjective data from the questionnaires and focus group interviews.

Furthermore, a case study provides an example of real people in real situations which aids the reader to understand ideas better than using theories and principles (Cohen et al., 2000, p. 181). Denzin & Lincoln (2008) emphasize the qualitative essence of case study, while acknowledging its evolution and fluidity with regard to accommodating varied ontologies, epistemologies, methodologies, and methods. This ability to accommodate a range of philosophical positions is seen as an advantage whereby case study enables the opportunity to design research that can be specifically tailored to the complexity of the research problem (Stake, 2013; Yin, 2013). The case study is ideally suited to the small-scale researcher and endorses the focus on possibly one example within the researchers place of work (Blaxter et al., 2001, p. 72). This is aligned with the single VR scenario that the participants will use within AIT for this research.

While much literature refers to a case study as a qualitative method, Tellis (1997b, p. 4) suggests that including both quantitative and qualitative data in a case study helps explain both the process and outcome of a phenomenon through complete observation, reconstruction and analysis of the cases under investigation. This is further compounded by Yin (2013) who encourages the use of quantitative and qualitative data in a case study. The quantitative data from this research, such as the participants' previous experience of using VR will give context to the qualitative data, such the users' perception of ease of use of the VR hand controls.

There is frequent criticism of the generalisability of a case study research given that it uses a small sample size (Gerring, 2007; Tellis, 1997a; Woodside, 2010). It is argued by Yin (2013) that the case should be considered as an experiment where they can lead to analytic generalisations, i.e., a generalisation on a conceptual higher level than the case. The insights yielded by case studies can be put to

immediate use for a variety of purposes (Nunan, 1992), such as forming an archive of descriptive material available for reinterpretation by others (McDonough & McDonough, 1997). It is hoped that the results of this research will yield such insights and will form the basis of a 'step to action' (McDonough & McDonough, 1997).

Both Yin (2009) and Stake (1995) propose different categories of case studies. These categories are discussed in the following sections. The categories which align best to this research are summarised in Figure 3.3 Adopted Case Study Categories.

There are different types of case study. Yin (2009) proposes three categories, exploratory, descriptive and explanatory. Exploratory explores any phenomenon in the data which may warrant further investigation, for example, a pilot study. Descriptive case studies set to describe the natural phenomena which occur, creating a narrative of what has occurred. An explanatory case studies examine the data closely both at a surface and deep level in order to explain the phenomena in the data. This may result in the research forming and testing a theory. Part of the research to be undertaken here would align with the descriptive case study as it is proposed to describe the students' perspective on the VRLE. An objective of the research is to evaluate the students' learning experience when using VR for a computer networks application. This evaluation will require the gathering of qualitative data from the research participant. This data will be analysed, and a description of its content will be provided to the reader followed by the researcher's interpretation of the data. The use of a focus group will be a key instrument in the descriptive element of the case study.

It was proposed by Stake (1995) that there are three different ways of categorising the case study: intrinsic, instrumental or collective. An intrinsic case study is where the researcher is studying the case for the researchers own 'vested' interest. With the instrumental case study, the researcher selects a small group of participants in order to examine a certain pattern of behaviour to gain further insight into a theory or gain a broader appreciation of an issue. The collective case study collects data from a collection of cases to create an insight into the investigation. There are aspects of this research which mirror the instrumental case study. The instrumental case study mirrors the aspect of the research which explores the alignment of the VRLE with

learning theories which underpin it. The focus in instrumental case study is the relationship between these. A focus group is to be used as an instrument of the case study.

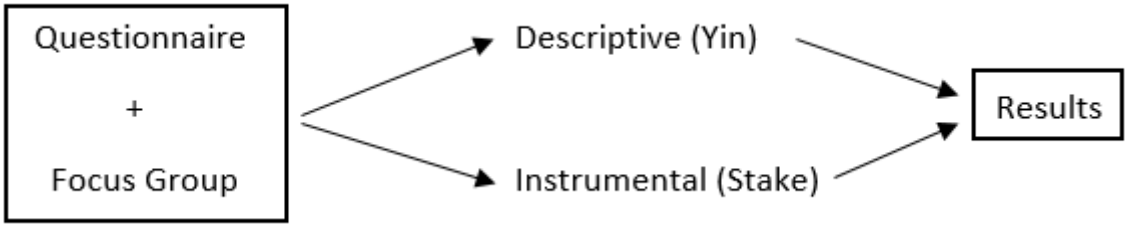

Figure 3.3 Adopted Case Study Categories

3.3.3 FOCUS GROUP

A focus group is a type of interview. Interviewing has become a prominent research method in the social sciences (King, Horrocks, & Brooks, 2018). Interviews enable participants (researcher or interviewee) to interpret the world from their point of view (Cohen et al., 2000, p. 277). This aligns with the relativist ontology of the interpretivist paradigm as outlined in Table 3.1. Relativism can be implied in the interview situation as relativism is the view that reality is subjective and differs from person to person (Guba & Lincoln, 1994, p. 110). The assumption of a relativist ontology means that the researcher believes that the situation studied has multiple realities. There will be an open-minded approach taken to the focus group sessions encouraging the participants to express their point of view.

There are three different types of research interviews: structured, semi-structured and unstructured (Gill, Stewart, Treasure, & Chadwick, 2008). Structured interviews follow a predefined schedule of set closed questions which usually require short answers. They are not usually designed to allow for elaborate answers or follow-up probing questions from the interviewer. Unstructured interviews usually begin with a general open question and the course of the interview develops based on the answers given. The interviews tend to be time consuming and may require a number of iterations. They are sometimes used to discover the inner feelings of the participant. Semi-structured interviews usually consist of several key questions where the interviewer manages the development of the answers. The flexibility of

this approach allows for the interview to diverge in order to pursue an idea or response in more detail. This may result in the discovery of information which the interviewer may not have considered. A semi-structured interview approach will be taken to this research as the interview will be a follow-up to the questionnaire. The results of the questionnaire will be the guide for the structure of the questions and will allow for the participants to elaborate on the questionnaire results. This also aligns with the sequential exploratory mixed methods design strategy as discussed earlier. Sequential explanatory is characterized by an initial phase of quantitative data collection and analysis followed by a phase of qualitative data collection and analysis. The structured interview is unsuitable as it is too similar to the questionnaire and doesn't permit development of answers. The unstructured interview is also unsuitable as time is a limitation of this research.

There are three important considerations for interview as eluded to by Cohen et al (2000): there should be a relationship between the researcher and interviewee that rises above personal interests to gain the most from the interview. The researcher should have a curiosity that overcomes the difficulty of setting up the interview and encourages him to conduct a successful interview. Finally, there should be a naturalness about the interview that creates an unobtrusive environment where information flows freely.

A strength of the interview is that it allows for greater depth than other data collection methods, such as a questionnaire, as it provides opportunities for the probing and the explanation of questions. A weakness is that it may be prone to subjectivity and bias on behalf of the interviewer (Cohen et al., 2000, p. 269). Therefore, to address this, it is important to give more attention to ensuring that each question is understood by the interviewee rather than ensuring that they are given the exact same wording of the question (Oppenheim, 1992, p. 86). If the interviewee doesn't fully understand the question, then their answer may not be reflective of the intended question. A possible shortcoming of structured interviews is that they use the exact same wording of questions in interviews without the flexibility of explaining the question.

According to Cohen et al. (2000, pp. 273-287), there are seven steps to planning an interview.

1. Set out the objectives of the interview.

2. Design the questions to align with the objectives.

3. The setting up and conducting of the interview.

4. Transcribing the interview without losing data.

5. Analysis of the data.

6. The validation of all seven stages of the interview plan.

7. The reporting structure of the interview.

It is proposed to use a focus group as an instrument of the research method. A focus group is a type of group interview. Group interviews can generate a wider range of responses than individual interviews (Lewis 1992). Focus groups tend to follow a format similar to the unstructured interview. They are more time-saving than individual interviews as you interview several students at the same time. Focus groups are useful to triangulate with other types of instrument such as observations and questionnaires (Cohen et al., 2000, p. 288). It is suggested by Morgan (1997) that you should have more than one focus group and use between four and twelve participants per group. More than one group helps to eliminate the possibility of the result of the interview being unique to that group. There is intention to invite six participants to the interview to allow for the possibility of participants not arriving.

According to Opie & Sikes (2004) the focus group interview should be designed based on the questionnaire questions. The interview questions will be developed when the questionnaire is finalised. The order of the questions and how the responses will be collected is also important (Opie & Sikes, 2004). A laptop with a USB attached microphone will be used to record the focus group. The location for the interview will be a suitable room in AIT. The interviewees and interviewer will be seated around the table at one end forming a C-shape. It is less formal so the interviewee may feel more relaxed. It may also result in better audio pick-up on the microphone. Another instrument to be used as part of the case study is the questionnaire.

3.3.4 QUESTIONNAIRE

It is also proposed to use a questionnaire (Appendix 4) which provides a quantitative approach to enrich and provide depth to the research. According to Wilson & McClean (1994) as cited in Cohen et al (2000), questionnaires are widely used and very helpful in collecting survey data which can structured and easily analysed by the researcher. However, it was also noted that they do take time to develop, pilot and refine. The questionnaire will be developed before the focus group interview. This use of the questionnaire before the focus group interview will align with sequential explanatory mixed methods approach as described earlier. The design of the questionnaire questions will align with the literature review of chapter 2 which explored the relationship of the following topics to VR:

1. Motivation
2. Novelty
3. Immersive effect
4. VRLE design
5. Possible immersive discomfort
6. Alignment with experiential learning
7. Alignment with situated learning
8. Alignment with constructivism

Following an analysis of the questionnaire results, the focus group will be used to further investigate the findings of the questionnaire. Before any questionnaires or focus groups can be implemented, due consideration has to be given to the research ethics.

3.4 RESEARCH ETHICS

Ethics is a matter of principled sensitivity to others (Bulmer, 2001, p. 45). A research ethics proposal document was submitted to the MA in Teaching and learning Research Ethics Committee for approval. This document included a declaration of ethical compliance of the researcher and the ethics documentation that is provided to the research participants. A letter from the ethics committee was provided to AIT (where the research will be conducted) to confirm that this research study has been

examined by this committee and has been given full ethical clearance. The main ethical considerations of this research are discussed in the following sections.

3.4.1 RISK OF HARM

The field of VR has attracted much attention in regard to ethical considerations (McEvoy, 2018), but it is predominantly related to the gaming and commercial sector. There have been reports that the use of a VR head mounted display may cause motion sickness, nausea, disorientation, blurred vision, eye strain, eye fatigue or other discomfort while viewing virtual reality content (Costello, 1997; Nolin et al., 2016; Sutcliffe, 2003). This may occur in a content-rich simulation environment which includes virtual motion. The short duration of use of the headset and unsophisticated design of the VRLE in the proposed research should alleviate any concerns. Furthermore, since the VR application used in this research will be simplistic in comparison to high-end graphics and effects, these concerns are not deemed to be very relevant.

3.4.2 STUDENT-LECTURER RELATIONSHIP

The participants in this research will be students from the *Networks 1* module. This module is taught in AIT to first year students of the Bachelor of Engineering in Computer Engineering, and Software Design with Mobile Apps and Connected Devices. It is anticipated that approximately two thirds of the participants will be students of the researcher. There is an awareness that there is a 'power-relationship' between the researcher and the participants of the research. It is the belief of Taber (2007) that because of this relationship, students might feel under pressure to give up their free time to take part in an activity that may potentially make them feel uncomfortable. Participants will be invited to take part in the research, and under no circumstances will they be made feel under pressure to engage with the research. It is the opinion of Al-Hinai (2018) that researchers who are teachers, are familiar with the students and could help in making research access and communication easier and produce more fruitful results. The student-lecturer

relationship was addressed by informing the participants of the context of the research and this would be a researcher-participant relationship.

3.4.3 RIGHT TO WITHDRAW

Participants in the research have the right to withdraw at any time during the recruitment and data gathering phases. This was outlined as part of the participant information leaflet and they were reminded that they have volunteered to engage with the research and will not lose any benefits if they do wish to withdraw. The participants have to actively confirm their understanding of this by answering yes or no on the informed consent form**.** However, if the participants wish to withdraw their contribution to the research at a later stage, they must confirm this within one month of participation so as not to jeopardise the research results. The time frame of one month was deemed a fair duration by fellow researchers and research supervisors.

3.4.4 INFORMED CONSENT

Informed consent will have to be obtained before the research commences. Much social research necessitates obtaining the consent and co-operation of the participants of research (Cohen et al., 2007). Documents relating to the required consent for this research are provided in the appendices section. Participants will first be required to read and sign a participant information leaflet. This will briefly explain the purpose of the research, outline how the research will be conducted and answer possible concerns that the participant may have. Having read the participant information leaflet, those who wish to participate in the research will have to complete informed consent form 1. This form requires the participant to given written consent that they are aware of what is involved in the research. This form must also be signed by the researcher. Participants who take part in the focus group interviews are required to fill out informed consent form 2. This form requires the participant to

given written consent that they are aware of how the research will be conducted and what will happen to the data that is gathered.

3.4.5 CONFIDENTIALITY

In a research context, confidentiality means not discussing information provided by an individual with others, and presenting findings in ways that ensure individuals cannot be identified (Wiles, Crow, Heath, & Charles, 2008). The participant information leaflet states that no identifying factors relating to participants will be in evidence in the final thesis report and/or any disseminated research. In an effort to maintain this confidentiality, any paper documents submitted by the participant will be stored in a locked cabinet in AIT. Any computerised information related to the participant will be stored in a password protect file on Microsoft OneDrive cloud.

3.5 PILOT STUDY

In social science research, the term ‘pilot study’ refers to a mini version of a full-scale study, as well as the specific pre-testing of a particular research instrument such as a questionnaire or interview schedule (Van Teijlingen & Hundley, 2001). In this study the pilot was used to pre-test the questionnaire and according to Van Teijlingen & Hundley (2001), pilot studies are a crucial element of a good study design, as they can identify modifications that may be required before implementation of the actual research.

The second year students on the BSc in Network Management three year programme were invited to participate in the pilot study. These students were chosen as they completed the Networks 1 module as first year students and therefore had an understanding of networking which is used in the VR scenario. These students are not known to me, but know that I am a lecturer in AIT. Permission was sought from their lecturer to invite the students to participate in the pilot study. They were given an overview of the purpose of the research and an outline of how the pilot study would be implemented. Three students took part in the pilot study. The purpose of the research and their participation in the pilot study was explained again to each student when they entered the room. They were asked to read the

Participant Information Leaflet as per Appendix 1 and the Informed Consent Form as per Appendix 2. Although these students were not taking part in the actual research, these forms provided an opportunity for them to be more informed of the research. They were asked to read these forms with a view to understanding the content, in case modifications to the text were required. No issues were reported after they read these forms.

The students began by answering section A of the questionnaire, they then used the VR headset to view the networking scenario. Finally, they completed Section B of the questionnaire. The students had no issues or confusion with how the questions were phrased in the questionnaire. However, they did seek clarification regarding the phrasing of the questions for the tasks within the VR setting. Following a discussion with the students, changes were made to the following steps of the VR setting based on student approval:

1. Step 1: This was originally written as: Drag and drop the labels to the appropriate network components. This was changed to read*:* Drag and drop the labels below to the yellow boxes under the appropriate network components. This added more clarity to where the labels were to be placed as shown in Figure 4.2
2. Step 2: This was originally written as: Click on the appropriate server that will assign the PC with an IP address. This was changed to read*:* Click on the server that automatically assigns a PC with an IP address. This change was made to simplify the question.
3. Step 4: This was originally written as: Click on the appropriate server to translate the webserver URL to an IP address. This was changed to read*:* Click on the server that translates a URL to an IP address. This change was made to simplify the question.
4. Step 5: This was originally written as: Drag/Drop the packet at the PC with appropriate Source and Destination IP addresses. This was changed to read*:* In order for the red packet to send a webpage request, drag/drop the appropriate source and destination IP addresses into the yellow box at the PC. This change was made as the request was incorrectly phrased and additional text was added to inform the student of the purpose of the task.

5. Step 9. This was originally written as: Drag/Drop the IP packet at the webserver with appropriate source and destination IP addresses. This was changed to read*:* In order for the red packet to reply with a webpage, drag/drop the appropriate source and destination IP addresses into the yellow box at the Server. This change was made as the request was incorrectly phrased and additional text was added to inform the student of the purpose of the task.

The pilot study was timed. I took approximately five minutes to complete the questionnaire and approximately 10 minutes to complete the VR. This timing was an important metric for the scheduling of participants for the actual research. It was realised during the pilot study that the verbal description of the research process was not exactly the same for each student. It was decided that a written description of the research process would be read to each participant. This would avoid over-explaining, repeating, or forgetting important information relating to the research process. This description is outlined as follows:

> You are very welcome and thank you for attending.
>
> I wish to remind you that your participation in this research is voluntary.
>
> I'm going to ask you to fill out a consent form. Following this, I will then ask you to fill out Section A of a questionnaire. You will then be invited to wear a VR headset and complete the steps within the VR environment. Afterwards I will ask you to complete Section B of the questionnaire. When filling out the questionnaire can you please be 100% honest with your answers. There is no such thing as a right or wrong answer in a questionnaire.
>
> The VR environment is intended to replicate a networking environment. There are 12 steps, 11 of which require user interaction. The first step will help you to become familiar with the controller. I will be at your side if you need assistance.
>
> When using the controller, point with your thumb and pull the trigger switch with your index finger to grab/select an item. Release your finger to drop the item.
>
> The VR equipment, research procedure, and virtual environment that the participants will interact with is described in the next section.

This description helps to increase the efficiency of the process of acquiring data from the participants. Also, the changes made to the description of the steps as outlined

above make the questions more succinct and therefore add to the validity of the data. Pilot studies are carried out before a research design is finalised to assist with the reliability and validity of the of the proposed study design (Thabane et al., 2010).

3.6 VR SETUP FOR ACQUIRING DATA

This section describes the equipment used as part of the VR setup. The 12 steps that the participant sees within the VRLE are outlined also.

3.6.1 VR SETUP

Participants in the research were required to interact with the virtual environment before filling out section B of the questionnaire (Appendix 4). The virtual environment was delivered using a HTC VIVE virtual reality platform as shown in Figure 3.4. This platform consists of a headset which enables the participant to view the virtual environment. A hand controller which facilitates interaction with the environment, such as pointing to and selecting icons is also used. The two base stations beam signals to the headset and controllers to track their movement. A high specification computer is also required to power the VR. A computer monitor was present to replicate what the participant could see in the headset to facilitate interaction from the researcher, if any assistance was required by the participant. There are 12 steps in the virtual environment. These steps are outlined in the Section 3.6.2.

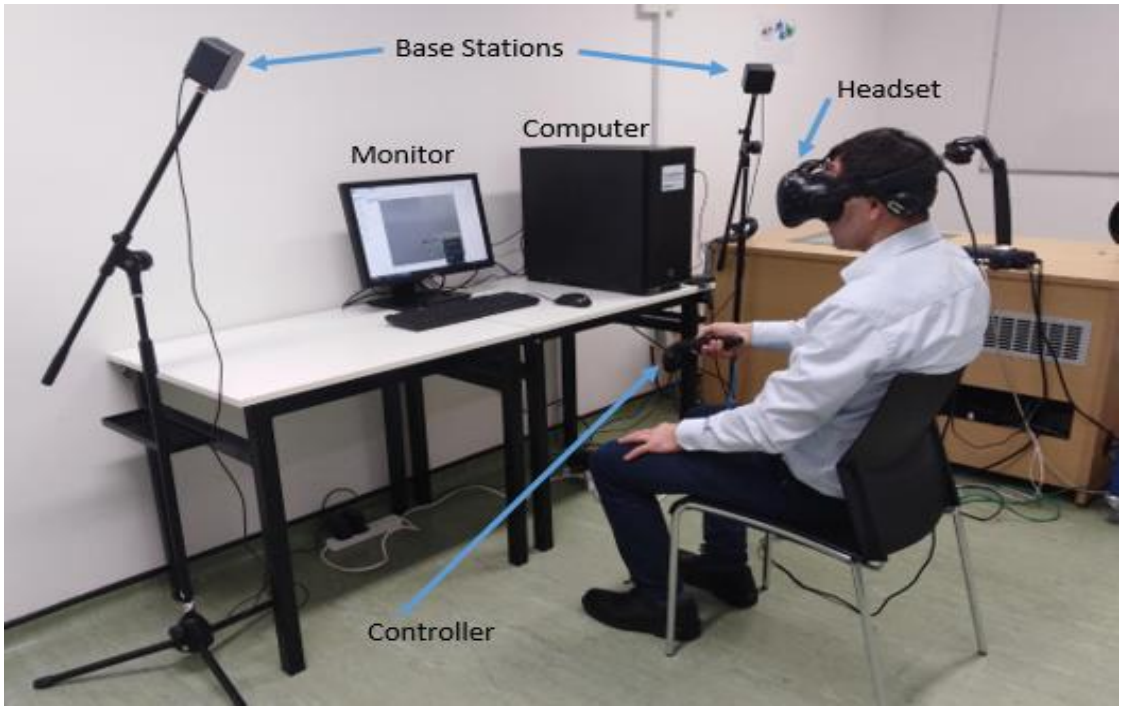

Figure 3.4 VR SETUP

3.6.2 VR ENVIRONMENT

The VR environment is a representation of a computer network. This representation, as shown in Figure 3.5, is based on a typical computer network configuration where a webpage request is made to a web server. The creation of this network for the purposes of VR implementation was made possible by a volunteer within AIT. The VR resources were provided by AIT.

The participants of the research were required to view 12 steps in the virtual environment and interact with 11 of the steps. The participant's goal in the virtual environment is to request the AIT homepage from the AIT server. Each step in the virtual environment requires the participant to engage with the process of requesting content from a web server. These steps and their purpose are outlined as follows:

Step 1 is shown in Figure 3.5. It requires the participant to drag and drop the icon labels into the yellow boxes. The purpose of this step is to give the participant a simple task to help them relax in the virtual environment and acknowledge all the components of the network. It also provides an opportunity for practising the use of the hand controller for drag and drop operations.

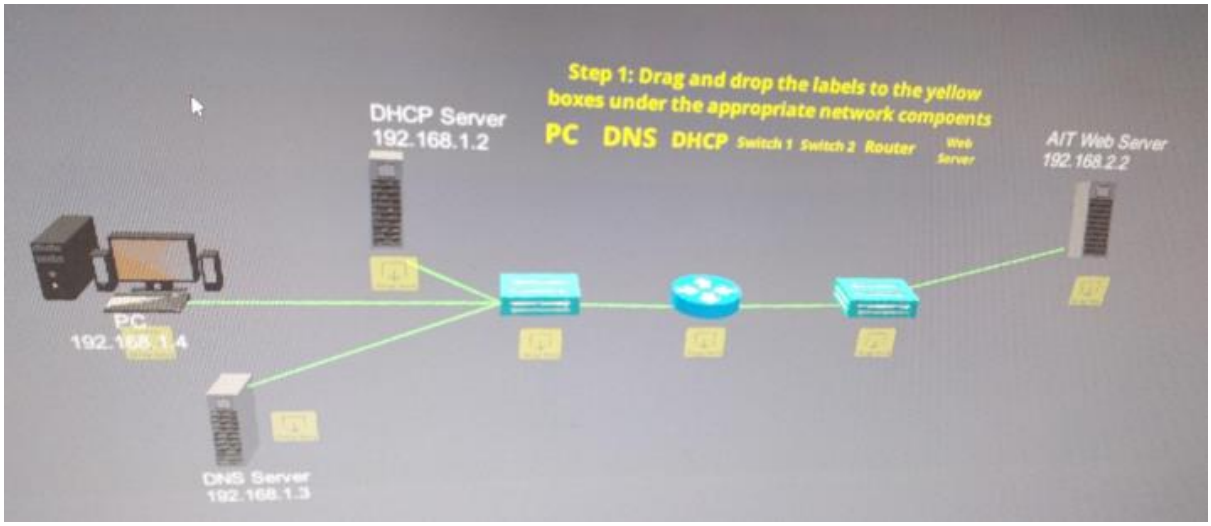

Figure 3.5 STEP 1

Step 2 as shown in Figure 3.6 requires the participant to click on the DHCP server. Any participant with a basic knowledge of networking should be familiar with the purpose of a DHCP server. When the DHCP server answer is selected as the correct answer, an IP address can be seen moving from the server to the PC, which reinforces the purpose of the server and provides visual stimulation.

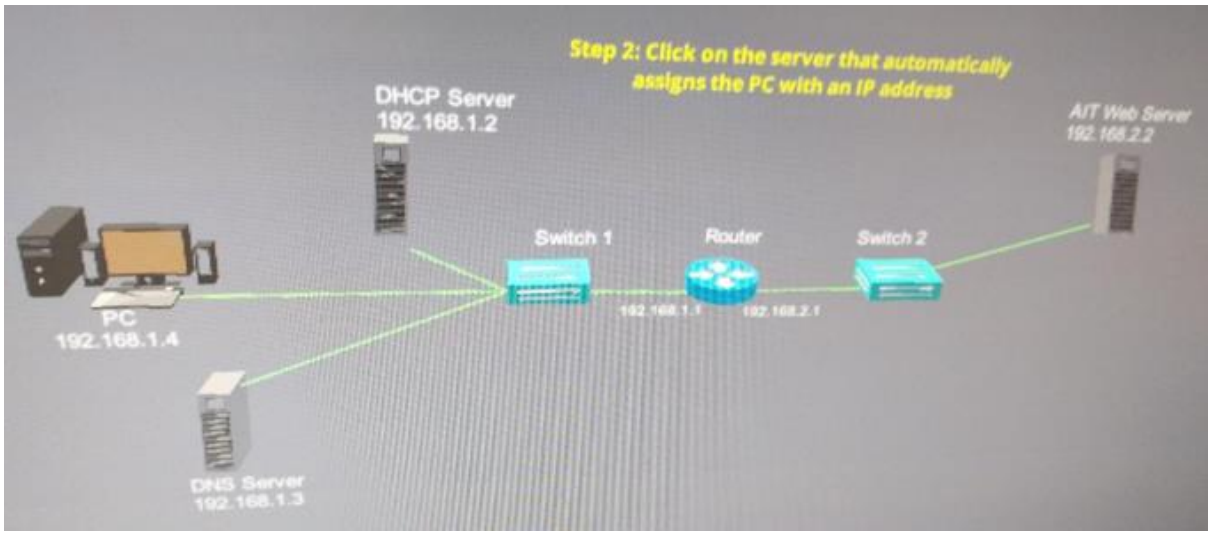

Figure 3.6 STEP 2

Step 3 as shown in Figure 3.7 requires the participant to select the appropriate URL to contact the AIT server. The answer to the question is not very difficult which helps to instil confidence in the participant's interaction with the virtual environment.

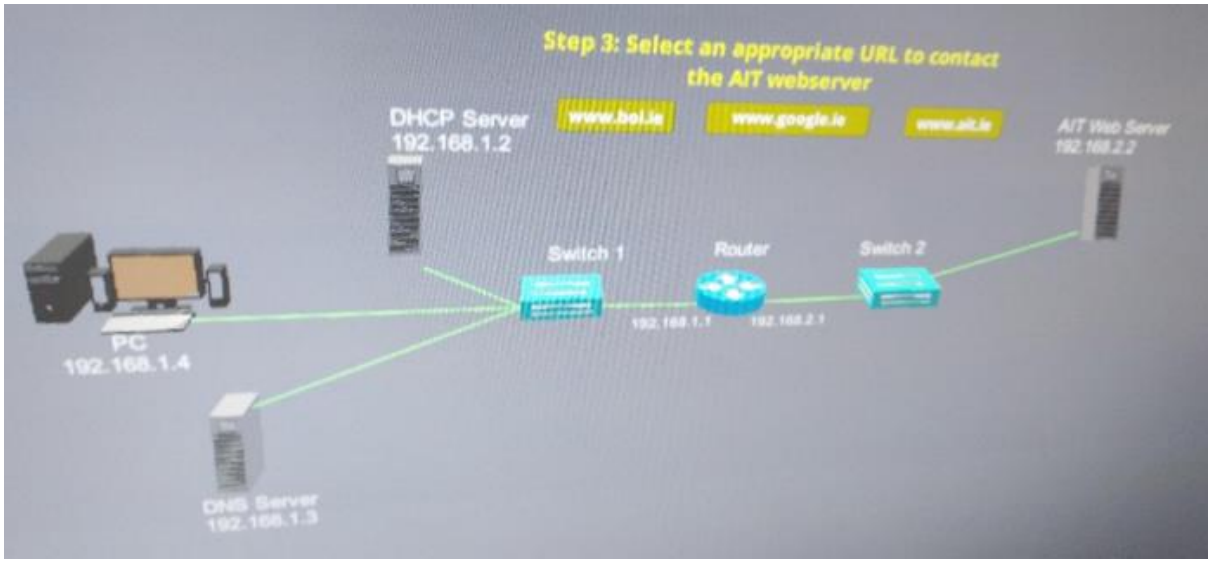

Figure 3.7 STEP 3

Step 4 as shown in Figure 3.8 requires the participant to select the server in the virtual environment that will translate a website URL to an IP address. This is the destination address of the request and is required by the PC to enable communication with the web server.

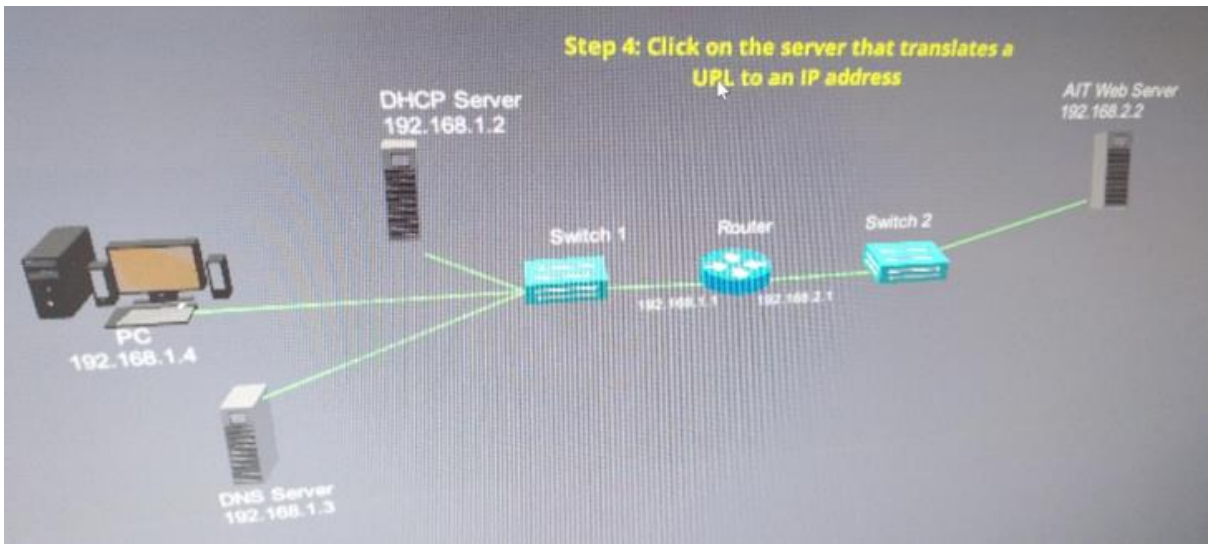

Figure 3.8 STEP 4

Step 5 as shown in Figure 3.9 has a red box at the PC. This box represents a packet. A packet is a portion of a message which carries information from a source to a destination. Each packet must have both a source IP address and a destination IP address to indicate where the information within the packet has originated and

where it is going. The participant is required to select the appropriate source and destination IP addresses from a list. The appropriate addresses are to be placed in the yellow box beside the packet using a drag and drop motion with the hand controller.

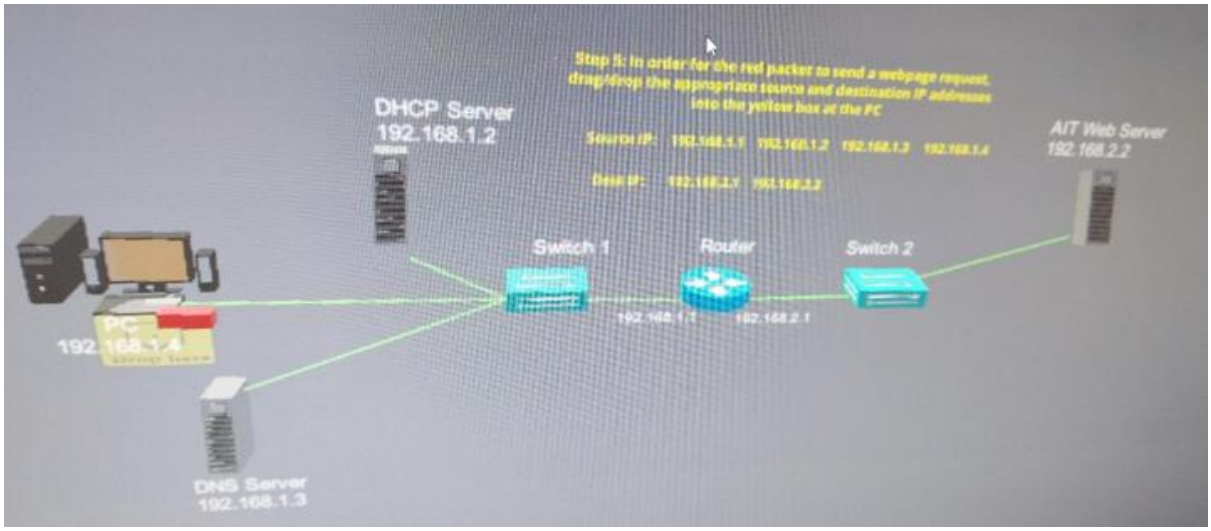

Figure 3.9 STEP 5

Step 6 as shown in Figure 3.10 requires the participant to identify the default gateway in the network. The default gateway is the IP address that the packet requires to identify the route it must take to leave the network. The participant must select the IP address of 192.168.1.1.

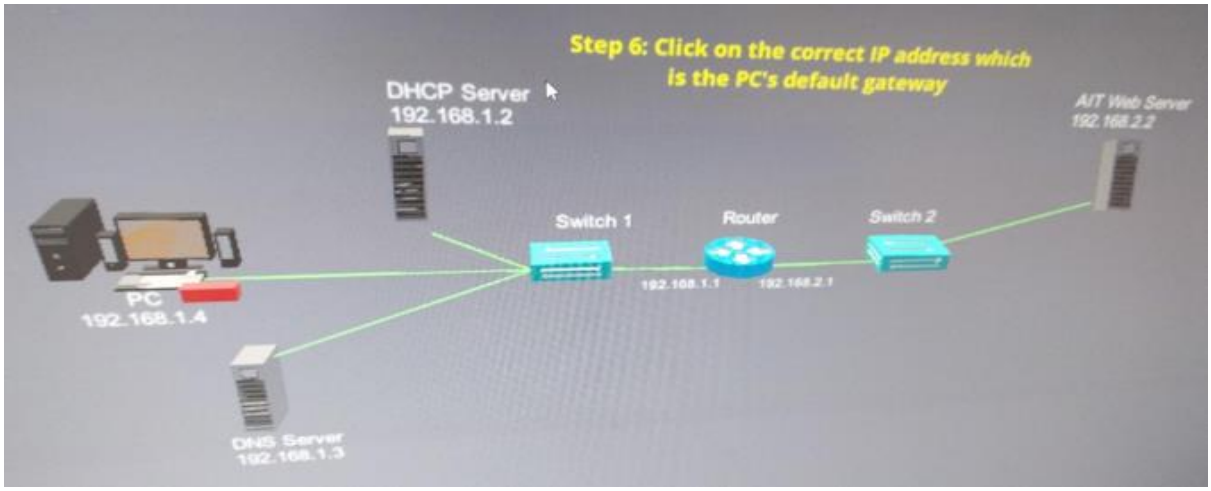

Figure 3.10 STEP 6

Step 7 as shown in Figure 3.11 requires the participant to confirm their understanding of what the default gateway is. They are required to select answer (b)

before moving to the next step. Providing a multiple choice question assisted the participant with identifying and confirming the correct answer.

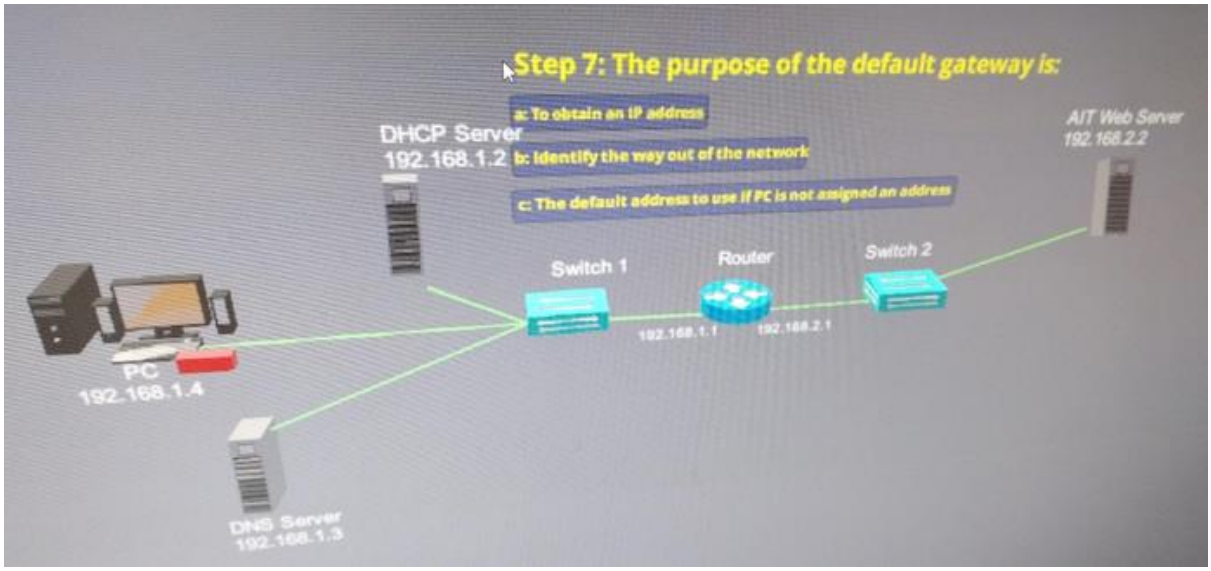

Figure 3.11 STEP 7

Step 8 as shown in Figure 3.12 gives the participant the opportunity to virtually move the packet from the PC to the webserver to request the AIT homepage. This movement is created by clicking the green arrow boxes in the virtual environment.

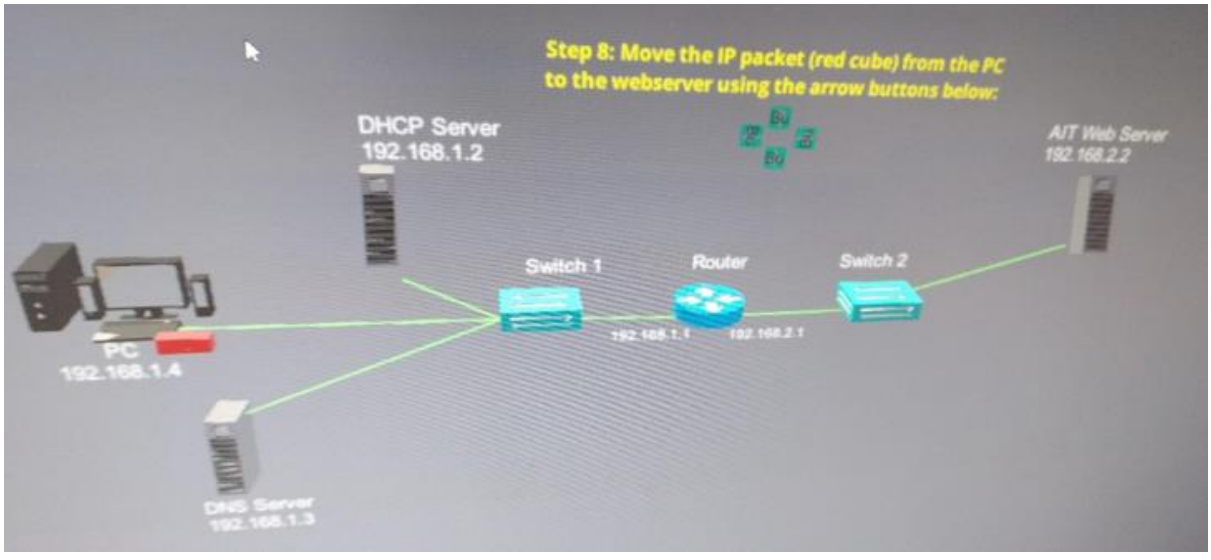

Figure 3.12 STEP

Step 9 as shown in Figure 3.13 requires the participant to identify the source and destination IP addresses when the packet is returning from the webserver. They are

required to drag and drop the appropriate addresses into the yellow box beside the packet.

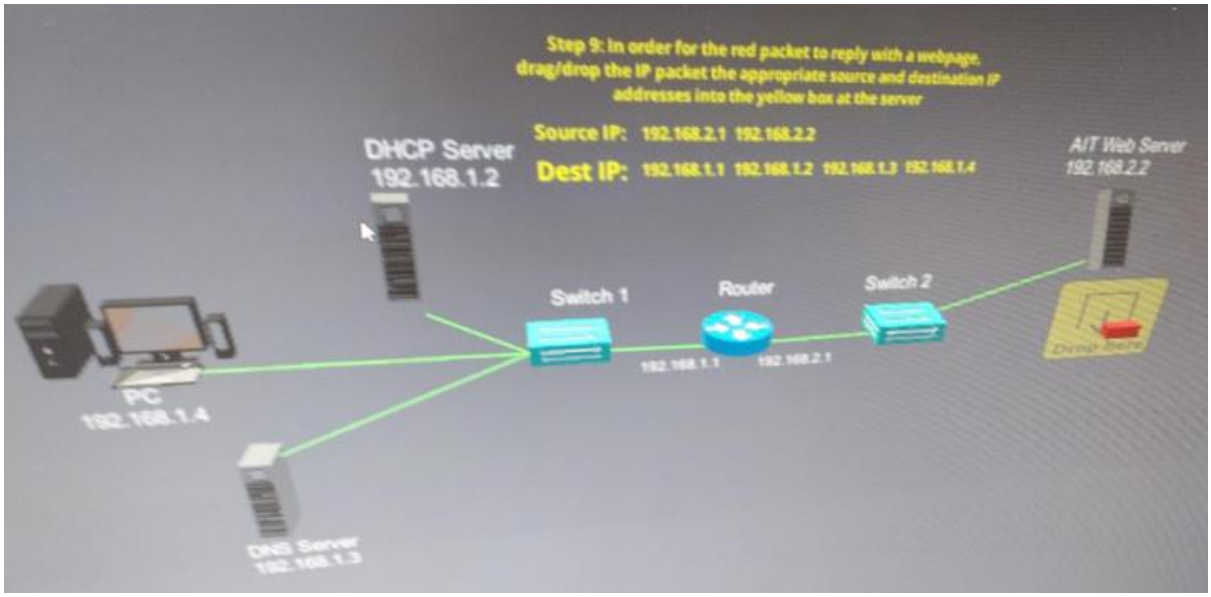

Figure 3.13 STEP 9

Step 10 as shown in Figure 3.14 requires the participant to identify the default gateway from the perspective of the AIT web server. This encourages the participant to consider the pathway that the packet will take as it travels back to the PC. Selection of the IP address 192.168.2.1 requires use of the hand controller.

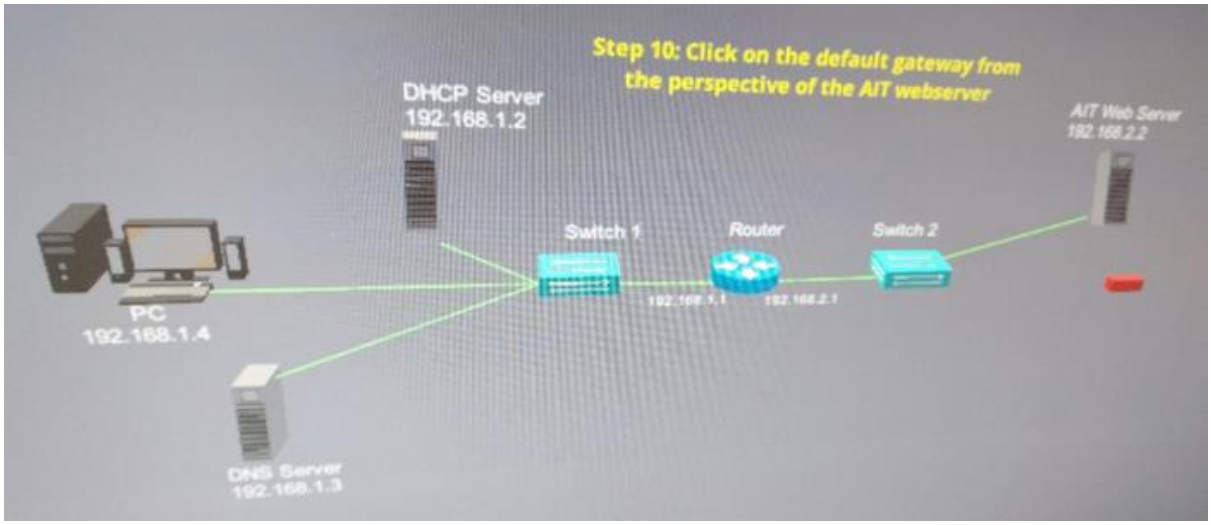

Figure 3.14 STEP 10

Step 11 as shown in Figure 3.15 requires the participant to move the packet back to the PC using the green arrow buttons.

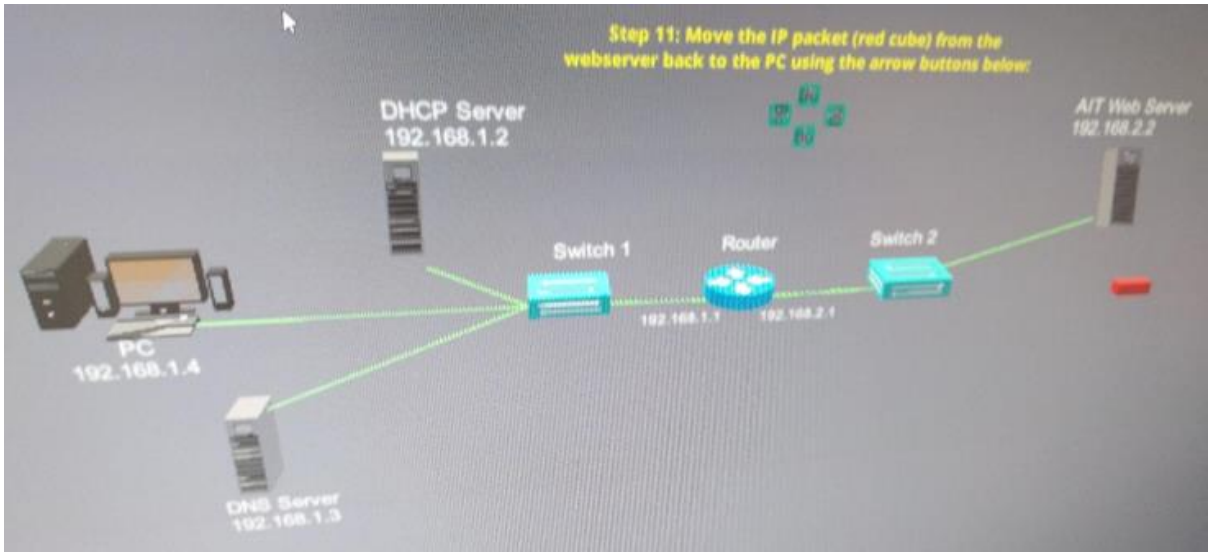

Figure 3.15 STEP 11

Step 12 as shown in Figure 3.16 is the final step and shows the participant that the AIT homepage has successfully arrived at the PC.

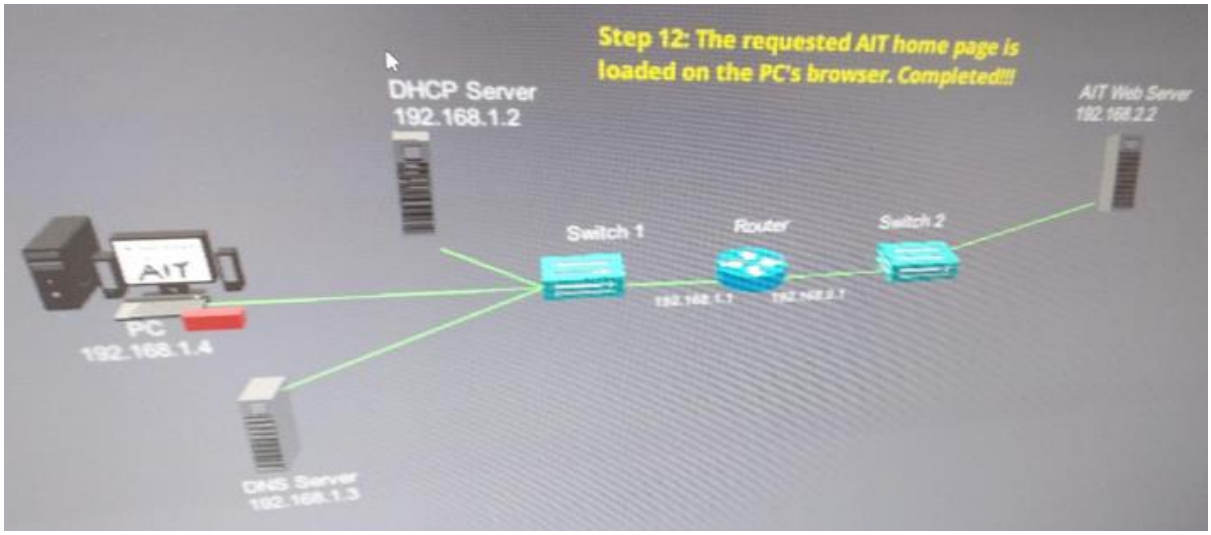

Figure 3.16 STEP 11

3.7 CONCLUSION

The aim of this chapter was to provide an analysis of the methodological framework of the research, which will subsequently inform the selection of the research methods. These methods are required to fulfil objective three of the research which is to evaluate the students experience when using VR for a computer networks application in an educational environment.

This chapter investigated the four paradigms; positivist, interpretivist, critical and pragmatic. It was determined that the interpretivist paradigm was best aligned to the research since one of the objectives required an evaluation of the students' learning experience. This evaluation would require an interpretivist position as the researcher would be required to interpret the participants' perspectives of their experience of the VR. A mixed methods approach was proposed as both qualitative and quantitative data would assist in fulfilling the objectives. This chapter provided justification for classifying the research as a case study. A questionnaire and a focus group as data collection techniques were analysed and recommended for use. Ethical consideration was given to the use of VR and the ethical importance of participant information sheets was acknowledged. It was also shown how a pilot study assessed the reliability and validity of the research. The equipment to be used in the research and the steps within the VRLE were outlined. This chapter provided consideration and justification for how the research would be conducted. The analysis and findings of this research will be presented in the next chapter.

CHAPTER FOUR: RESEARCH FINDINGS AND DISCUSSION

4.1 INTRODUCTION

The aim of this research is to perform a literature analysis of Virtual Reality as a learning tool, and evaluate a group of first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program. The latter part of this aim, the evaluation of a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program, is the focus of this chapter. This evaluation is achieved using objective three of the research. This objective evaluates the students' experience when using VR for a computer networks application in an educational environment, with the aid of the proceeding sections.

Section 4.2 presents the findings of the quantitative and qualitative data that were acquired from the questionnaire and focus group respectively. Section 4.2.10 presents of summary of the findings. Section 4.3 discusses the findings and proposes recommendations for future research.

4.2 QUANTITATIVE AND QUALITATIVE FINDINGS

This section presents the findings of the research. The quantitative data were acquired using a questionnaire (Appendix 4). A focus group was subsequently used to gather the qualitative data as per the sequential explanatory approach as outlined in section 3.3.1. The eight themes that were derived from the literature review of Chapter Two are used to frame the presentation of the results. These themes are outlined in Table 4.1. For clarity, both the questionnaire and focus group findings are presented under the headings of each theme. The profile of all participants of the research is depicted also.

The analysis of the data is based on the eight themes in Table 4.1. This type of analysis, according to Maguire & Delahunt (2017) is categoised as a theoretical thematic analysis rather than an inductive one. The data from the focus group was recoded relevant to these themes.

Theme	Name	Section
1	Motivation	4.2.2
2	Novelty	4.2.3
3	Immersive Effect	4.2.4
4	VRLE Design	4.2.5
5	Possible Immersive Environment Discomfort	4.2.6
6	Alignment with Experiential Learning	4.2.7
7	Alignment with Situated Learning	4.2.8
8	Alignment with Constructivism	4.2.9

Table 4.1 Research Themes

4.2.1 PARTICIPANT PROFILE

The participants in this research were first year students of the Bachelor of Engineering in Computer Engineering, and Software Design with Mobile Apps and Connected Devices. There are approximately 54 students currently attending this module, of which, 21 agreed to participate in the research. The age profile of the participants is shown in Figure 4.13. It was not surprising that 57% (n = 12) of the participants were aged between 18 and 20 years of age given that they were first year students.

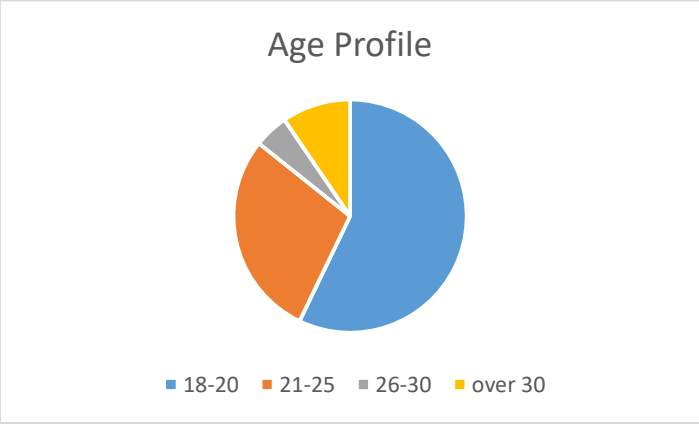

Figure 4.13 Participant Age Profile

The participants were asked if they had used VR before and if so, to what extent. This question was asked as it may influence the participants' response to questions on novelty effect and motivation to use VR. It is shown in Figure 4.14 that just over 50% (n=11) of participants had not used VR before.

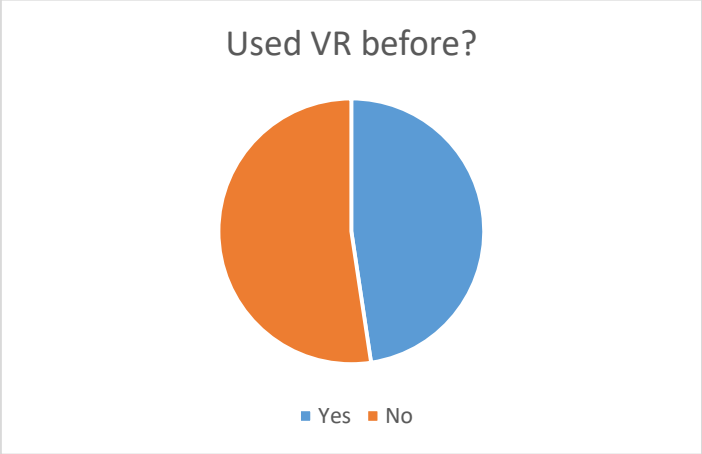

Figure 4.14 Used VR Before

Of those who had used the VR before, 50% (n = 5) of them had used it less than five times as shown in Figure 4.15. Given the computing nature of the Programmes of study of the participants and their young age profile, it is a little surprising that they did not have greater exposure to the use of VR.

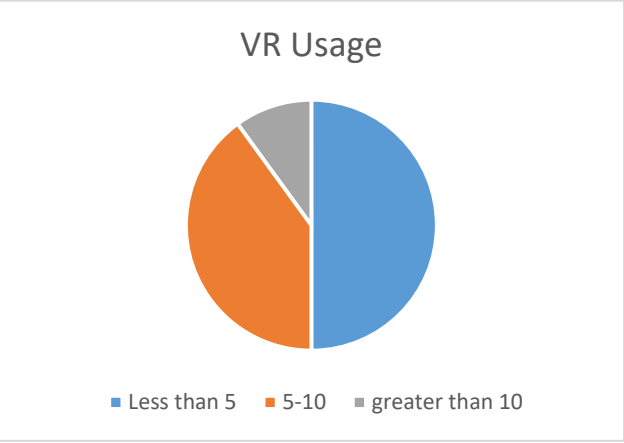

Figure 4.15 Used VR Before

4.2.2 MOTIVATION

Before the participants put on the VR headset, they were asked in the questionnaire if “the opportunity to use a VR headset was a motivation for them to participate in the research”. Figure 4.16 shows that 86% (n = 18) of the participants agreed with this, of which half of those claimed strong agreement. This indicates that the opportunity to wear a VR headset and experience VR was a motivation for the participants to engage with the research. One of the two students who disagreed with the statement had extensive experience with VR when he worked in VR sales and did not see the opportunity to use the VR as a motivation to participate in the research.

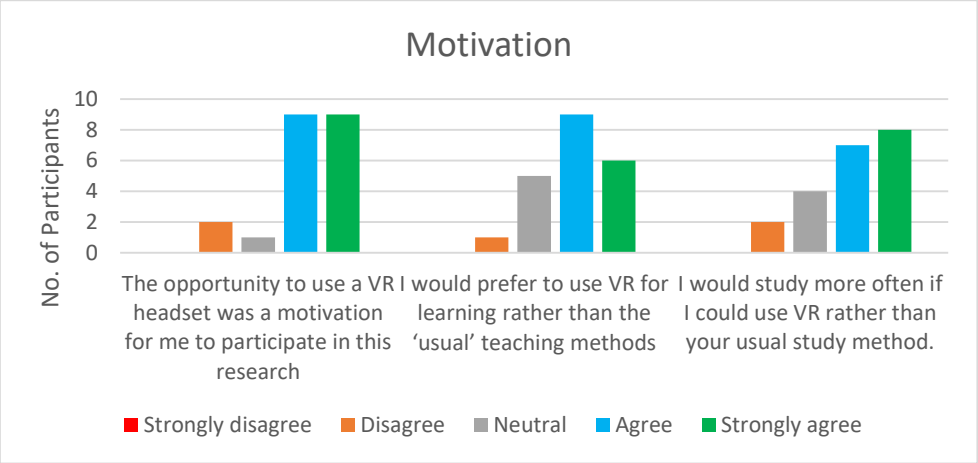

Figure 4.16 Motivation to use VR

The participants were asked, if they “would prefer to use VR for learning rather than the ‘usual’ teaching methods”. Over 70% (n = 15) of participants agreed or strongly agreed that they would prefer to use VR for learning rather than the ‘usual’ teaching methods with only one of the 21 participants disagreeing.

When asked if they “would study more often if they could use VR rather than the usual study method”, over 70% (n = 15) agreed or strongly agreed, with only 9.5% (n = 2) students disagreeing. In the focus group, participant D said he “would be more motivated to engage with study material when given the opportunity to use VR rather than a using a book or watching a video”.

4.2.3 NOVELTY

None of the participants of the focus group had experienced VR from an educational perspective.

When asked about this novelty effect, 76% (n = 16) of participants, as shown in Figure 4.17, agreed or strongly agreed that they were “more interested/engaged with the networking task because VR was a ‘new way’ of learning”. Only one participant did not agree with this statement.

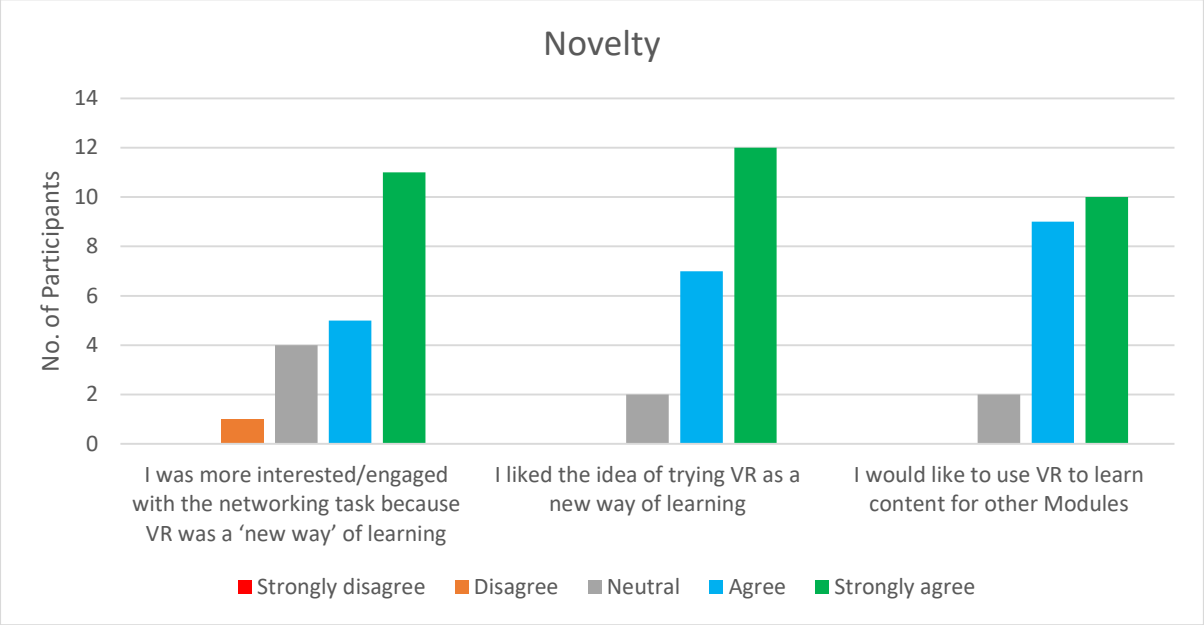

Figure 4.17 Novelty of using VR

Over 90% (n = 19) “liked the idea of trying VR as a new way of learning”. In the focus group, participant F and participant B said that, “VR was a new experience and I really enjoyed it”. Participant D said it was his “first time using VR and he found it an interesting way of learning”.

Over 90% (n = 19) said they would “like to use VR to learn content for other Modules”.

However, in the focus group there were concerns raised regarding the novelty of VR. Participant E said that, “in the beginning there is a bit a novelty to using the VR headset” but he does not know if “that would hold up for an entire semester or a

year". Participant F expressed a concern that he "might feel stressed if he had to wear a VR headset in every class". Participant A felt it "would lose its effectiveness if you were using it all the time". Participant D suggested a "balanced approach" to its use. There was collective agreement that it should be used as part of a blended learning approach.

4.2.4 IMMERSIVE EFFECT

Three questions were asked in the questionnaire relating to Immersive effect. The questionnaire responses to the immersive effect of the VRLE is shown in Figure 4.18.

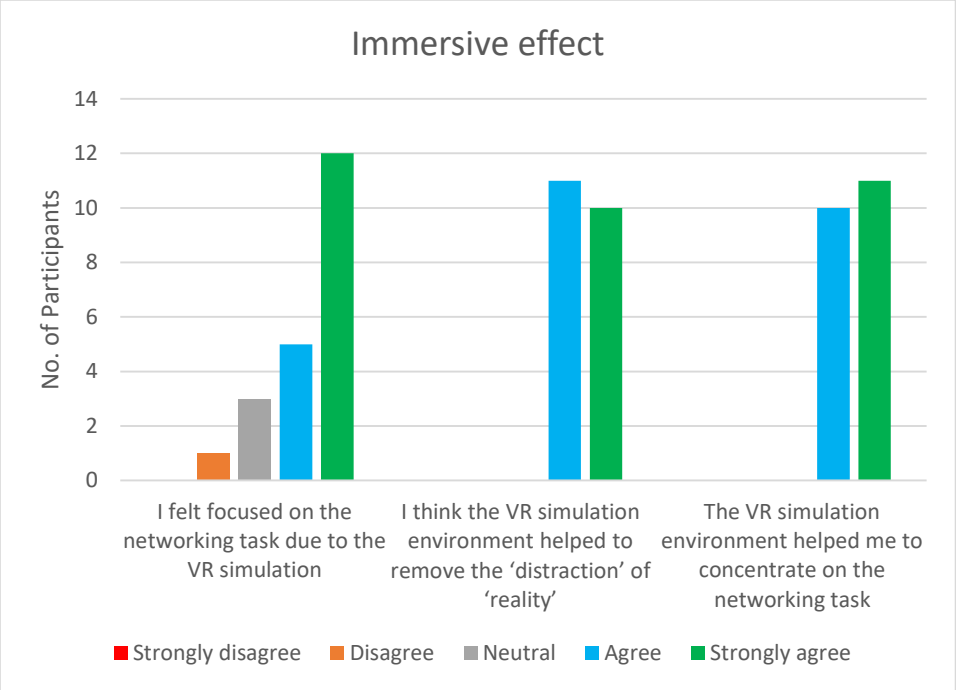

Figure 4.18 Immersive effect

It shows that 81% (n = 17) of participants agreed or strongly agreed that they "felt focused on the networking task due to the VR simulation". Only one student disagreed with this. When asked about comparing the VR program to its potential effect on a PC, student E said, "the VR takes you to another place, almost like

meditation". Participant D added that "with the VR it's actually in front of you but with a PC you're just not as interested".

All participants (n = 21) agreed or strongly agreed that, "the VR simulation environment helped to remove the 'distraction' of 'reality'". In the focus group, participant E said "the VR blocked out external distractions so that you could focus more". Participant F said "the VR engages you more to focus on your study and when you are in class there is a tendency to be distracted but not so when you have the VR headset on".

This result was further enhanced when 100% (n = 21) of participants agreed or strongly agreed that the VR simulation environment helped them "to concentrate on the networking task".

There were concerns raised in the focus group regarding the immersive effect. Participant F commented that "when wearing the VR headset, you do not have an awareness of your classmates or the lecturer which has a negative social effect". Participant B suggested that "it opens up another channel for messing as you cannot see someone interacting with you". Participant F commented that "if the lecturer did not have control of what the student was viewing then they could view something else".

4.2.5 VRLE DESIGN

The participants' opinions on the VRLE design is shown in Figure 4.19. There were four questions asked on the questionnaire regarding the VRLE design.

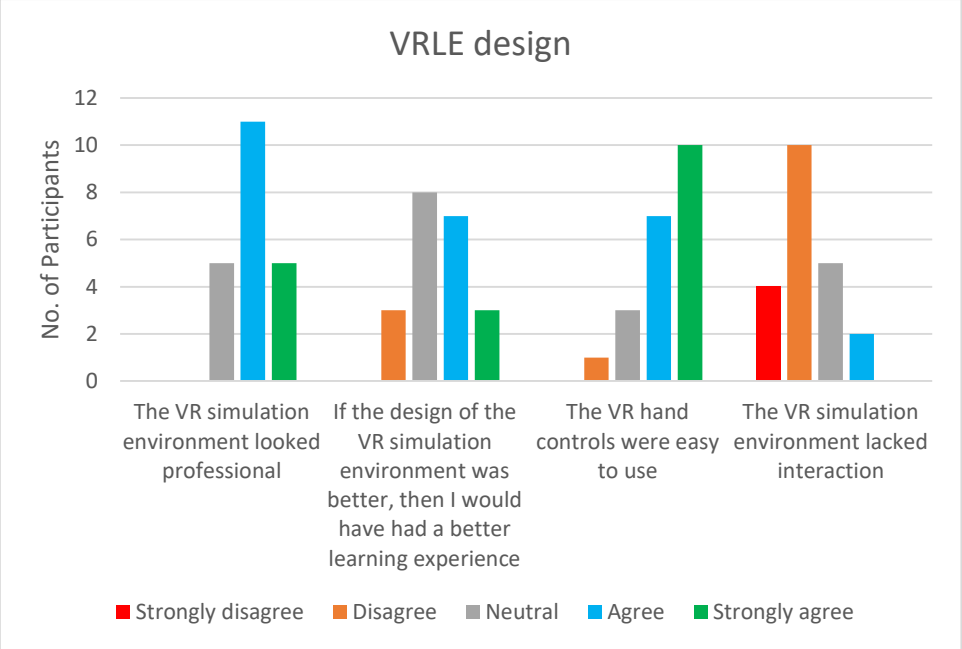

Figure 4.19 VRLE design

While 76% (n = 16) of participants reported that "the VR simulation environment looked professional", 24% (n = 5) took a neutral standpoint on this. While the content within the VRLE looked very familiar from a networking perspective. In the focus group response, participant D commented that "it was a fairly basic design". Participant A thought that "the program background could have been improved as it felt like you were in a box".

When asked if "the **design** of the VR simulation environment was better, would you have had a better learning experience", 48% (n = 10) agreed with only 14% (n = 3) disagreeing. In the focus group, participant A thought that "the VR was good for duplicating what a real-life scenario really looks like, but if the components were in 3D, they could be used to teach you like an on-the-job scenario". Participant F suggested that "the VR could be used for virtual labs". Participant D suggested interactive tuition such as "highlighting a component to get additional information as to what it does". Possibly "narrated help" as suggested by Participant E. Participant B suggested "having different views within the VRLE, one with an actual view of the equipment and the other as a model-view to aid learning".

Only one participant disagreed that "the VR hand controls were easy to use". In the focus group, participant E suggested "making the yellow placement boxes (in Figure 4.2) bigger to aid control". Participant A believed that "if the interface was better, that

would improve it" adding if that the "controller was rather annoying, if you could touch and grab things on the screen it would make it more immersive". Participant D added that he "was fascinated by the fact that when he was pressing buttons it was happening in real time in front of me, it was a really cool experience".

Only 9.5% (n = 2) of participants reported that "the VR simulation environment lacked interaction", with 20% (n = 4) strongly disagreeing with this claim. In the focus group, participant A thought that "some sort of voice interaction would make it better".

.

4.2.6 POSSIBLE IMMERSIVE ENVIRONMENT DISCOMFORT

Only 1 participant reported that he "felt discomfort while wearing the VR headset" as shown in Figure 4.20.

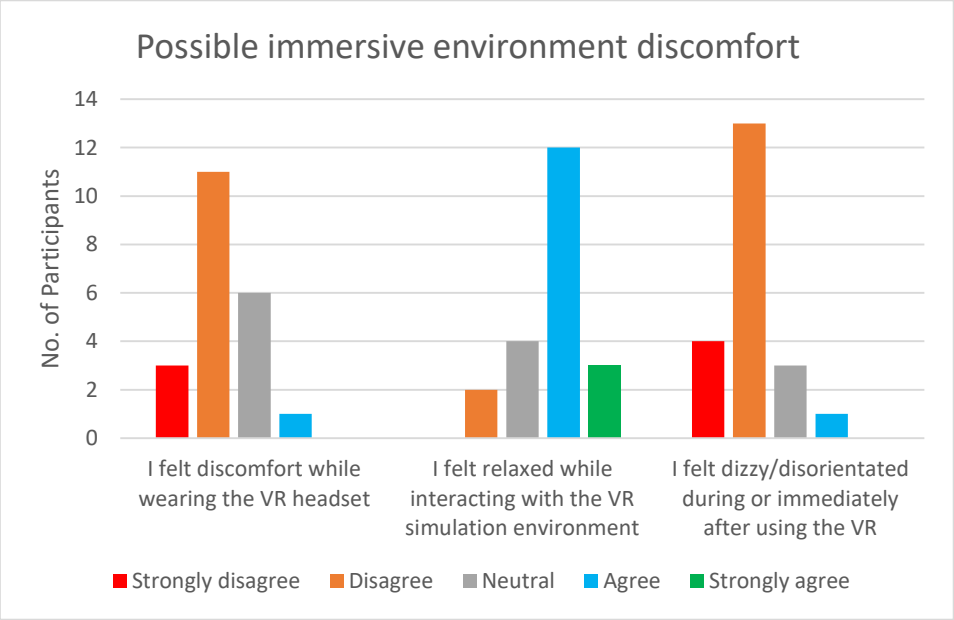

Figure 4.20 Possible immersive environment discomfort

When asked if they “felt relaxed while interacting with the VR simulation environment”, two participants disagreed.

One participant reported that he “felt dizzy/disorientated during or immediately after using the VR”. He believed this was due to not wearing his glasses when wearing the VR headset. In the focus group, participant F said that “the VR had an effect on my eyes, as it seemed too close”.

4.2.7 ALIGNMENT WITH EXPERIENTIAL LEARNING

According to Roussou (2004), interactivity is a key determinant of the effectiveness for experiential learning. The questionnaire in this research asked three questions to probe the alignment of the research VRLE with experiential learning.

The participants were asked if “the VR provided an effective interactive environment”, only 1 disagreed as shown in Figure 4.21. In the focus group, participant E said “the VR was a lot more interactive than the traditional learning”. Participant B said that “you are interacting with it; you can see your results in real-time so you can test your own knowledge which is beneficial”.

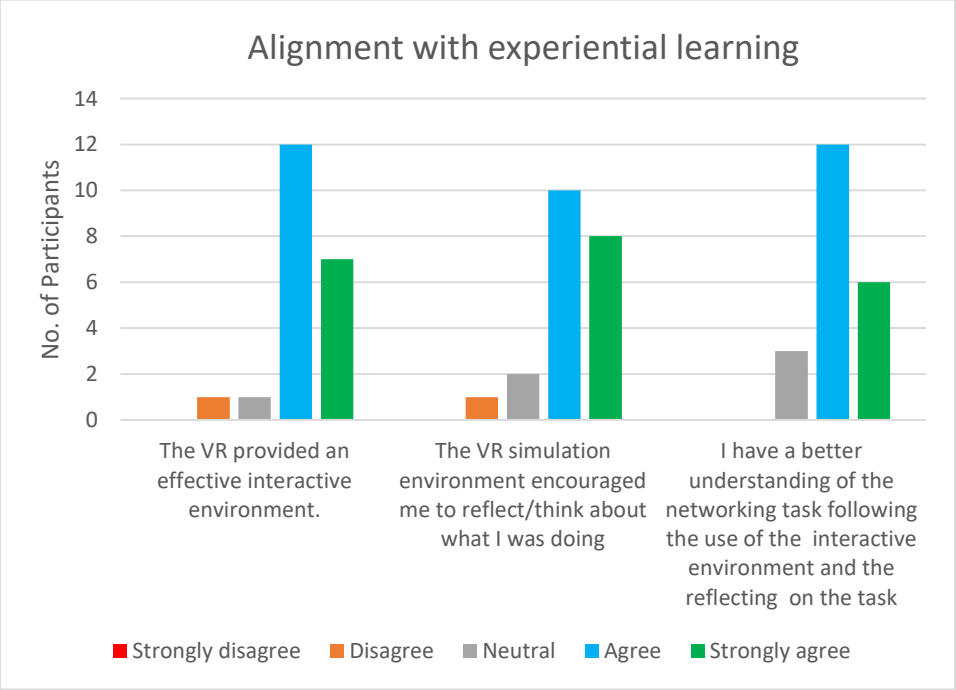

Figure 4.21 Alignment with experiential learning

When asked if “the VR simulation environment encouraged the participant to **reflect/think about** what they were doing”, only 1 participant disagreed.

Figure 4.21 shows that 86% (n = 18) of participants agreed or strongly agreed that they “had a better **understanding** of the networking task following the use of the interactive environment and reflecting on the task”. Participant B stated that “if you did the task wrong then you are getting feedback straight away so you are going to learn much faster”. Regarding the questions that were asked within the VRLE, participant B noted that “sometimes you can go through a lecture and you think you know the content but you may not, you need to test yourself”. Participant D stated that, “you can use VR to guide you for learning but you need it to question you also”.

4.2.8 ALIGNMENT WITH SITUATED LEARNING

According to the situated learning theory proposed by Lave & Wenger (1991), learning is situated in a specific context and embedded within a particular social and physical environment. Only 1 participant disagreed that “the VR networking scenario looked like an actual real network” as shown in Figure 4.22.

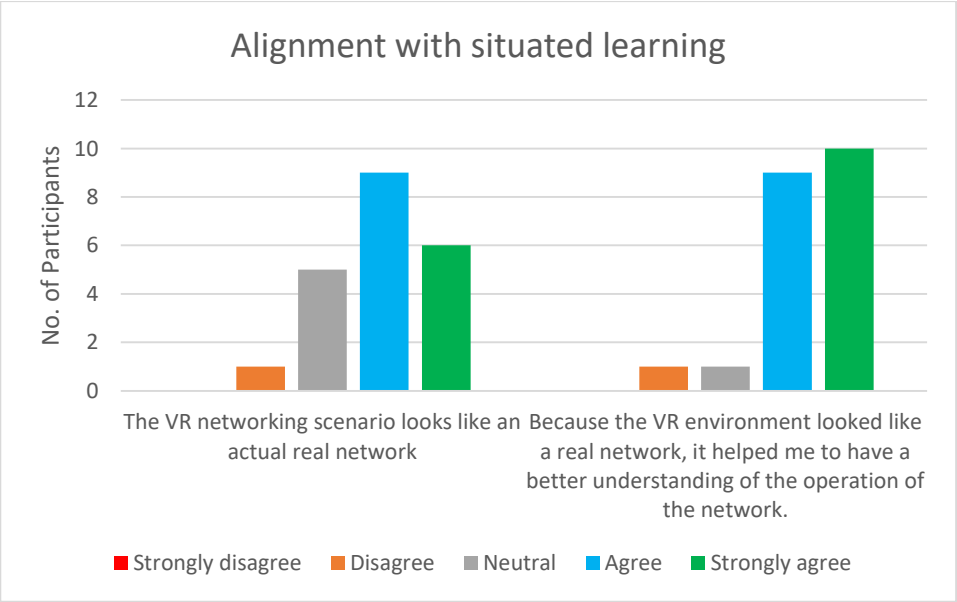

Figure 4.22 Alignment with situated learning

It was proposed that “because the VR environment looked like a real network, it helped me to have a better **understanding** of the operation of the network”. Only 1 participant disagreed with this statement. In the focus group, participant B commented that “sometimes a lecturer is talking about something and the student is not actually visualising it properly in his head”. He added, “the VR could give you this visualisation”.

4.2.9 ALIGNMENT WITH CONSTRUCTIVISM

Constructivism uses interactive teaching strategies to empower students to construct knowledge based on their own experiences (Sommerauer & Müller, 2018). When the participants were asked if they “felt like they had **control** of the navigation of the VR network”, only 1 participant disagreed as shown in Figure 4.23. In the focus group, participant D said that “sometimes when you are in class you are not listening but with the VR, you are forced to learn because you are doing a job” (in other words engaging with the task). Participant B said that “you learn a lot more and a lot faster when you are interacting with something”.

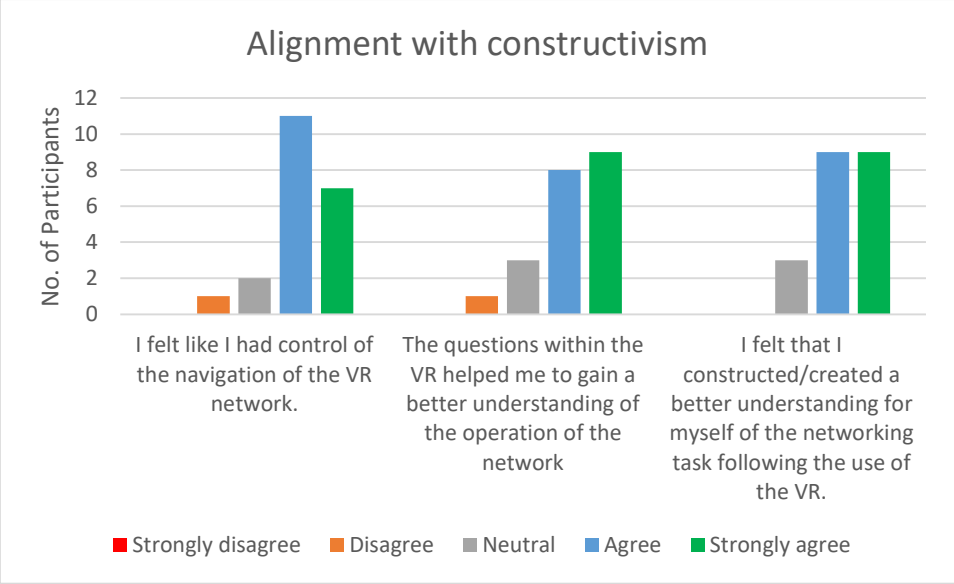

Figure 4.23 Alignment with constructivism

When it was proposed that "the **questions** within the VR helped me to gain a better understanding of the operation of the network", only 1 participant disagreed. In the focus group, participant D said that "in class you are just listening to the information but with the VR you are actually using the information that is in front of you". Participant D also stated that, "you can use VR to guide you for learning but you need it to question you also".

When asked if they felt that they "**constructed/created** a better understanding for myself of the networking task following the use of the VR", 86% (n = 18) agreed or strongly agreed. In the focus group, participant C said, "the VR helps you to visualise a lot better what you are doing". Participant D said, "the VRLE made you think about where things needed to go and what they do so it was reinforcing the learning that way".

4.2.10 SUMMARY OF FINDINGS

The table below summarises the findings based on the themes.

Theme	**Summary of Findings**
Motivation	VR was a motivation to engage with the research, prefer to use VR for learning, more motivated to study if using VR.
Novelty	Liked the idea of trying VR as a new way of learning, "new experience and I really enjoyed it", "felt it would lose its effectiveness if you were

	using it all the time".
Immersive Effect	The VR simulation environment helped to remove the 'distraction' of 'reality', "the VR takes you to another place, almost like meditation", "when wearing the VR headset, you do not have an awareness of your classmates or the lecturer".
VRLE Design	VR simulation environment looked professional, "controller was rather annoying, if you could touch and grab things on the screen it would make it more immersive", the program background could have been improved as it felt like you were in a box".
Possible Immersive Environment Discomfort	"The VR had an effect on my eyes, as it seemed too close".
Alignment with Experiential Learning	Had a better understanding of the networking task following the use of the interactive environment and reflecting on the task, "if you did the task wrong then you are getting feedback straight away so you are going to learn much faster", "you can use VR to guide you for learning but you need it to question you also".
Alignment with Situated Learning	Because the VR environment looked like a real network, it helped me to have a better **understanding** of the operation of the network, "the VR could give you this visualization"
Alignment with Constructivism	Felt that they constructed/created a better understanding for myself of the networking task following the use of the VR, "you learn a lot more and a lot faster when you are interacting with something", "you can use VR to guide you for learning but you need it to question you also".

Table 4.2 Summary of Findings

4.3 DISCUSSION AND RECOMMENDATIONS

This section discusses the findings of the research and makes recommendations based on these findings. The discussion and recommendations are presented under the heading of each theme.

4.3.1 MOTIVATION

Motivation is defined (in the educational field) as the student's desire to engage in the learning environment (Reiser & Dempsey, 2012). It is a determining factor in the

learning process, and encourages the student to participate in activities that increase their performance (Schunk, Meece, & Pintrich, 2012). Three questions relating to motivation were asked on the questionnaire. The focus group also gave opportunity for the participants to comment on the impact of VR from a motivational perspective.

Before the participants put on the VR headset, they were asked in the questionnaire if “the opportunity to use a VR headset was a motivation for them to participate in the research”. Given that 86% (n = 18) of the participants agreed with this, indicates that the opportunity to wear a VR headset and experience VR was a motivation for the participants to engage with the research. One of the two students who disagreed with the statement had extensive experience with VR when he worked in VR sales and did not see the opportunity to use the VR as a motivation to participate in the research. VR is generally associated with high-user engagement due to its potential in stimulating motivation (Garris, Ahlers, & Driskell, 2002; Ott & Tavella, 2009).

When asked if they “would study more often if they could use VR rather than the usual study method”, over 70% (n = 15) agreed or strongly agreed with this. In the focus group, participant D said he “would be more motivated to engage with study material when given the opportunity to use VR rather than a using a book or watching a video”. This declaration would correlate with Sattar et al (2020) where medical students’ motivation was observed to be the greatest in Virtual Reality settings as compared to video-based and text-based learning settings.

The questionnaire results to these questions suggest that participants are motivated to study more often given the opportunity to use VR and have a preference to using this method rather than the traditional methods. Blending curriculum with technological tools such as VR can improve students’ motivation, in turn, affecting their academic and practical performance (Elmqaddem, 2019).

Given the challenge of motivating students, it is recommendation of this research that educators consider the use of VR as a motivating factor for student engagement. However, motivation to engage with study, given the opportunity to use VR, does not guarantee an improvement in results.

4.3.2 NOVELTY

In comparison to traditional teaching methods such as ‘chalk and talk’ or PowerPoint presentations, arguably, there is a novelty associated with using a VR headset for educational purposes. It would appear that this novelty should not be underestimated as novelty of interactive technology, including VR is attributed to improved student motivation (Ewert et al., 2013; Huang et al., 2010; Zavalani & Spahiu, 2012). However, according to Falk (1983), the novelty of a setting can create both curiosity and anxiety and thus facilitate or impede learning. It was noted that none of the participants of the focus group had experienced VR from an educational perspective.

When asked about this novelty effect in the questionnaire, the results were quite positive with 76% (n = 16) of participants agreeing or strongly that they were “more interested/engaged with the networking task because VR was a ‘new way’ of learning”. Over 90% (n = 19) “liked the idea of trying VR as a new way of learning”. In the focus group, there were also some positive comments with participant F and participant B saying that, “VR was a new experience and they really enjoyed it”. Participant D said it was his “first time using VR and he found it an interesting way of learning”.

However, in the focus group there were also concerns raised regarding the novelty of VR. Participant E said that, “in the beginning there is a bit a novelty to using the VR headset” but he does not know if “that would hold up for an entire semester or a year”. Participant F expressed a concern that he “might feel stressed if he had to wear a VR headset in every class”. Participant A felt it “would lose its effectiveness if you were using it all the time”. It is important that we do not become reliant on the novelty factor for motivation, as simple technological novelty will likely diminish with continual use (Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017). Participant D suggested a “balanced approach” to its use. There was collective agreement that it should be used as part of a blended learning approach.

In light of this reaction, it is a recommendation of this research, that if VR is used as a teaching method, then consideration should be given to its use as part of a blended learning approach to compliment traditional teaching methods.

4.3.3 IMMERSIVE EFFECT

According to Cairns & Brown (2004) there are many existing ideas on what is meant by immersion in VR. It is the definition of immersive experience by Patrick et al. (2000) which aligns closely to this research. They say it is defined as the “extent to which a person’s cognitive and perceptual systems are tricked into believing they are somewhere other than their physical location”. It is reported by Bertram, Moskaliuk, & Cress (2015) that immersive environments capture the students’ attention leading to higher learning outcomes.

Three questions were asked in the questionnaire relating to Immersive effect and it was also addressed in the focus group. Participants agreed or strongly agreed that they “felt focused on the networking task due to the VR simulation”. When asked about comparing the VR program to its potential effect on a PC, participant E said, “the VR takes you to another place, almost like meditation”. Participant D added that “with the VR it’s actually in front of you but with a PC you’re just not as interested”. This would suggest that participants had experienced an immersive effect and it was a positive effect.

All participants agreed or strongly agreed that, “the VR simulation environment helped to remove the ‘distraction’ of ‘reality’”. This would appear to be a significant result given the challenge of removing distractions, such as mobile phones when students are trying to focus on studying a topic. In the focus group, participant E said “the VR blocked out external distractions so that you could focus more”. Participant F said “the VR engages you more to focus on your study and when you are in class there is a tendency to be distracted but not so when you have the VR headset on”.

However, there were concerns raised in the focus group regarding the immersive effect. Participant F commented that “when wearing the VR headset, you do not have an awareness of your classmates or the lecturer which has a negative social effect”. Participant B suggested that “it opens up another channel for messing as you cannot see someone interacting with you”. This highlighted your vulnerability when wearing the headset. Participant F commented that “if the lecturer did not have control of what the student was viewing then they could view something else”.

The benefits of the immersive effect, suggest a recommendation of VR for applications that require a high level of concentration, such as simulations of medical

operations. It is also recommended that VR users are reassured of their surroundings when wearing the headset so as not to detract from the benefits of the immersive effect.

4.3.4 VRLE DESIGN

The fundamental purpose of a VRLE is to provide users with a content-rich learning environment for them to train in and better engage with content related to what they are learning (Latham et al., 2019) . According to Mahdi, Oubahssi, Piau-Toffolon, & Iksal (2018) educational environments based on VR allow the creation of original and dynamic situations for learning. This is what was created as part of this research as depicted in section 3.6.2. It was acknowledged by Mahdi et al. (2018) that VRLE design is a complex activity with both technical and cognitive challenges. The code developer of the VRLE for this research was responsible for the technical challenges. The cognitive design challenges for transfer of knowledge were acknowledged in section 3.6.2.

There were four questions asked on the questionnaire regarding the VRLE design.

While 76% (n = 16) of participants reported that “the VR simulation environment looked professional”, 24% (n = 5) took a neutral standpoint on this. While the content within the VRLE looked very familiar from a networking perspective, the limited resources in creating the VRLE meant that that it would not look as professional as a gaming environment. In the focus group response, participant D commented that “it was a fairly basic design”. Participant A thought that “the program background could have been improved as it felt like you were in a box”.

When asked if “the **design** of the VR simulation environment was better, would you have had a better learning experience”, 48% (n = 10) agreed with only 14% (n = 3) disagreeing. This would suggest that participants placed an emphasis on the importance of VRLE design. In the focus group, participant A thought that “the VR was good for duplicating what a real-life scenario really looks like, but if the components were in 3D, they could be used to teach you like an on-the-job scenario”. Participant F suggested that “the VR could be used for virtual labs”. Participant D suggested interactive tuition such as “highlighting a component to get

additional information as to what it does". Possibly "narrated help" as suggested by Participant E. Participant B suggested "having different views within the VRLE, one with an actual view of the equipment and the other as a model-view to aid learning".

Only one participant disagreed that "the VR hand controls were easy to use". This may have been due to the slight difficultly with the drag and drop action within the VRLE. This would have been rectified if there were more availability on VRLE design resources. In the focus group, participant E suggested "making the yellow placement boxes (in Figure 4.2) bigger to aid control". Participant A believed that "if the interface was better, that would improve it" adding if that the "controller was rather annoying, if you could touch and grab things on the screen it would make it more immersive". Participant D added that he was "fascinated by the fact that when he was pressing buttons it was happening in real time in front of me, it was a really cool experience".

Only 9.5% (n = 2) of participants reported that "the VR simulation environment lacked interaction", with 20% (n = 4) strongly disagreeing with this claim. In the focus group, participant A thought that "some sort of voice interaction would make it better".

However, according to Makransky, Terkildsen, & Mayer (2019), several studies suggest that immersive VR's rich sensory environment can hinder learning because the increased amount of sensory information can lead to increased cognitive load. According to Sweller (1988) cognitive load occurs when a learner's capacity for cognitive processing is severely limited which inhibits meaningful learning. So, a recommendation of this research, is to give careful consideration to the design of the VRLE. The use of extraneous content in the VRLE may hinder the learning experience.

4.3.5 POSSIBLE IMMERSIVE ENVIRONMENT DISCOMFORT

The literature review highlighted that there have been reports that the use of a VR head mounted displays may cause motion sickness, nausea, disorientation, blurred vision, eye strain, eye fatigue or other discomfort while viewing virtual reality content (Costello, 1997; Nolin et al., 2016; Sutcliffe, 2003). The passive design of the VRLE

in this research is probably why only 1 participant reported that he “felt discomfort while wearing the VR headset”. This report may not be surprising as the headset is relatively bulky and may feel heavy after prolonged use. However, according to Weech, Kenny, & Barnett-Cowan (2019), VR devices are currently more comfortable, lighter, easier to use, and more powerful.

When asked if they “felt relaxed while interacting with the VR simulation environment”, two participants disagreed. This reporting was not noticed until the results of the questionnaire were collated so an explanation was not sought from the participants. This highlights a shortcoming of quantitative data in comparison to qualitative data- where one is looking for frequencies of responses as opposed to evaluating the reasons for the individual responses

A problem that may arise during immersion is cybersickness; this is a type of motion sickness that elicits symptoms ranging from discomfort to malaise (Stanney, Kennedy, & Drexler, 1997). Mismatches between sensations felt and observed (Rebenitsch & Owen, 2016) and visual display attributes (Moss & Muth, 2011) may induce cybersickness. One participant reported that he “felt dizzy/disorientated during or immediately after using the VR”. He believed this was due to not wearing his glasses when wearing the VR headset. Some VR headsets are not user friendly when wearing glasses but there are some possible adjustments to the headset that would make it more accommodating to wear glasses. In the focus group, participant F said that “the VR had an effect on my eyes, as it seemed too close”.

It is a recommendation of this research that consideration is given to VR users that wear glasses. This may involve having knowledge of how to adjust the VR headset for wearing glasses or procurement of headsets which are best suited to users who wear glasses.

4.3.6 ALIGNMENT WITH EXPERIENTIAL LEARNING

Experiential learning theory places the experience at the centre of the learning process and is based on the work of Dewey, Lewin, and Piaget (Kolb, Boyatzis, & Mainemelis, 2001). According to Jarmon et al (2009), VR effectively supports

experiential learning. The questionnaire in this research asked three questions to gain a further insight to this claim.

The participants were asked if “the VR provided an effective interactive environment”, only 1 disagreed as shown in Figure 4.21. In the focus group, participant E said “the VR was a lot more interactive than the traditional learning”. Participant B said that “you are interacting with it and you can see your results in real-time so you can test your own knowledge which is beneficial”.

When asked if “the VR simulation environment encouraged the participant to **reflect/think about** what they were doing”, only 1 participant disagreed.

Figure 4.21 shows that 86% (n = 18) of participants agreed or strongly agreed that they “had a better **understanding** of the networking task following the use of the interactive environment and reflecting on the task”. Participant B stated that “if you did the task wrong then you are getting feedback straight away so you are going to learn much faster”. Regarding the questions that were asked within the VRLE, participant B noted that “sometimes you can go through a lecture and you think you know the content but you may not, you need to test yourself”. Participant D stated that, “you can use VR to guide you for learning but you need it to question you also”.

In tradition classroom learning, the knowledge is acquired from teachers and the information is represented in the form of text, graphic, video and audio (Winn, 1993). Whereas, VR provides learners with a more interactive, experiential learning experience (Chau et al., 2013).

4.3.7 ALIGNMENT WITH SITUATED LEARNING

In proposing their model of situated learning, Brown, Collins, & Duguid (1989) argued that meaningful learning will only take place if it is embedded in the social and physical context within which it will be used. The VRLE in this research is acting as the meaningful learning environment based on a computer network configuration. McLellan (1994) points out that while knowledge must be learned in context according to the situated learning model, that context can be a highly realistic or ‘virtual’ surrogate of the actual work environment as depicted in the computer network configuration of the VRLE in this research.

Only 1 participant disagreed that “the VR networking scenario looked like an actual real network” which would imply that the VRLE was a suitable design in the context of situated learning.

It was proposed that “because the VR environment looked like a real network, it helped me to have a better **understanding** of the operation of the network”. Only 1 participant disagreed with this statement. In the focus group, participant B commented that “sometimes a lecturer is talking about something and the student is not actually visualising it properly in his head”. He added, “the VR could give you this visualisation”.

Situated learning, according to Brown et al. (1989), may occur with an expert-novice relationship between teacher. In the context of this research the relationship is between the VRLE and the participant. When medical students are placed in an immersive environment where not only they can observe more in detail, but can also feel the real sense of what it’s like to be in the operation theatre (Nuanmeesri, 2018). The virtual reality system promotes situated learning through the immersive experience of interactive objects, environments and processes (Greenwald et al., 2017).

It is a recommendation of this research to design a VRLE that is as realistic as possible. This will aid the students’ visualisation and contribute to their understanding of what they are being taught.

4.3.8 ALIGNMENT WITH CONSTRUCTIVISM

According to the constructivist theory, the learners’ interaction with meaningful activities helps to generate knowledge based on their prior experience (Schunk, 2012). Through interacting with the virtual world, learners could build up new concepts and knowledge based on their prior experience, with VR further enhancing the learning experience (Chau et al., 2013).

When the participants were asked if they “felt like they had **control** of the navigation of the VR network”, only 1 participant disagreed. In the focus group, participant D said that “sometimes when you are in class you are not listening but with the VR, you are forced to learn because you are doing a job”. Participant B said that “you learn a

lot more and a lot faster when you are interacting with something". The VRLE encouraged the participants to engage with the task helping them to construct knowledge.

When it was proposed that "the **questions** within the VR helped me to gain a better understanding of the operation of the network", only 1 participant disagreed. In the focus group, participant D said that "in class you are just listening to the information but with the VR you are actually using the information that is in front of you". Participant D also stated that, "you can use VR to guide you for learning but you need it to question you also". These replies which allude that the questions in VRLE were "meaningful activities" correlate with Schunk's definition of the constructivist theory at play.

When asked if they felt that they "**constructed/created** a better understanding for myself of the networking task following the use of the VR", 86% (n = 18) agreed or strongly agreed. In the focus group, participant C said, "the VR helps you to visualise a lot better what you are doing". Participant D said, "the VRLE made you think about where things needed to go and what they do so it was reinforcing the learning that way".

According to Chau et al (2013) evaluation of the students' learning experience showed that VR could indeed facilitate students in achieving learning outcomes through constructivist learning.

A recommendation of this research is to design a VRLE that encourages the student to interact with the task to aid in the constructing of knowledge. This can be facilitated by using the hand controllers to drag and drop items in the VRLE as shown in section 3.6.2. The questions asked within the VRLE also stimulate the participant to construct knowledge as they cannot move to the next step without seeing the correct answer.

4.4 CONCLUSION

This chapter presented and discussed the quantitative and qualitative data from the questionnaire and focus group. The findings were reported under the eight themes that were derived from the literature review chapter. These themes were Motivation, Novelty, Immersive Effect, VRLE Design, Possible Immersive Environment Discomfort, Alignment with Experiential Learning, Alignment with Situated Learning and Alignment with Constructivism.

In general, participants were motivated to engage with an educational task when given the opportunity to use a VR headset. The novelty effect of its use contributed to this motivation. There was a general ‘feel good’ factor associated with the experience of the VRLE and its capability. There was also an indication of alignment between the educational characteristics of VR and that of experiential, situated and constructivist learning.

However, these findings are based on a limited sample size of participants with a VRLE design that was not professionally designed.

The next chapter presents the concluding comments to this research.

CHAPTER FIVE: CONCLUSION

This chapter outlines the aims and objectives of the research and its implementation. The research methodology is retrospectively rationalised. There is a concluding analysis of the literature review which includes how it informed the objectives of the research and helped derive the eight themes of the research. Finally, there are concluding comments on these research themes.

5.1 AIMS AND OBJECTIVES

The aim of this research was to perform a literature analysis of Virtual Reality as a learning tool, and evaluate a first-year higher education students' experience of its implementation with the aid of an interactive VR simulation program. The three objectives of the research were 1: To critically analyse existing literature regarding the implementation of VR in education. Objective 2: To perform a literature analysis of the learning theories that underpin VR as a learning tool and 3: To evaluate the students' experience when using VR for a computer networks application in an educational environment. The objectives of the research were achieved in a consecutive manner.

5.2 METHODOLOGY

The methodological approach to this research is shown in Figure 3.1 of Chapter 3. The interpretivist paradigm was the lens of the research as much of the findings and discussion of Chapter 4 are reflective of the participants' interpretation of the VRLE experience. A mixed methods approach was chosen to achieve the benefits of both quantitative and qualitative findings. The research was deemed a case study as it was bounded by the inclusion a set of participants from AIT using a uniquely designed VRLE. The case study used a questionnaire to obtain quantitative data. A focus group was subsequently used to gather the qualitative data as per the sequential explanatory approach. The questionnaire findings of Chapter 4 are supported by the focus group responses which helped to enrich and underpin this research.

5.3 LITERATURE REVIEW

The analysis of the literature as per objective one exhibited a positive response from participants when surveyed on their experience of VR in an educational context. There were reports of improved academic performance from students when tested following a lesson in VR versus a lesson using traditional teaching methods. It was suggested that VR could be used to enhance or replace real-world experiences especially in dangerous or financially costly situations. However, there was a note of caution that VR is only a tool and its implementation requires careful consideration. A recommendation from this literature review is to encourage researchers to carry out more research using VR, as dated research is not reflective of the current enhancements in the technology.

The literature review also noted a deficient pedagogical basics for the testing and proposed implementation of VR. This prompted a literature analysis of the learning theories that underpin VR as a learning tool as per objective 2 of the research. This literature review revealed that there is potential for the implementation of VR to align itself with learning theories. The theories of experiential, situated and constructivist learning were the most dominant in the literature review that was carried out. This prompted the inclusion of questions relating to these learning theories as part of the research questionnaire and focus group. A recommendation from this literature review is to encourage researchers and educational VRLE designers to use a learning theory or combination of theories to underpin their VRLE design. The literature reviews, as per objective one and objective two identified eight themes.

5.4 RESEARCH THEMES

The eight research themes were the pillars of objective three of the research which sought to evaluate the students' experience when using VR for a computer networks application in an educational environment. The conclusion from this evaluation is presented by theme, as follows:

1. Motivation: Participants are motivated to study more often given the opportunity to use VR and expressed a preference to using this method rather

than the traditional study methods. Given the challenge of motivating students, it was recommended that educators consider the use of VR as a motivating factor for student engagement.

2. Novelty: Participants liked the idea of trying VR as a new way of learning and said they were more interested/engaged with the networking task because VR was a ‘new way’ of learning. However, there were concerns expressed that the novelty would wear off with participants suggesting a ‘balanced approach’ to its use. In light of this reaction, it was recommended that VR would be used as part of a blended learning approach to compliment traditional teaching methods.
3. Immersive effect: There was an overall positive reaction to the immersive effect and how VR blocked out external distractions so that participants could focus more on the task. However, there were expressions of vulnerability since the participant was not aware of what was happening in their immediate surroundings given that they were wearing a headset. It was recommended that VR users are reassured of their surroundings when wearing the headset so as not to detract from the benefits of the immersive effect.
4. VRLE design: The VRLE design that was used in this research was not very professional looking due to limited resources for its development. The participants acknowledged that the design was basic and had some suggestions as to how to improve the design. These suggestions, which are a recommendation of this research, include the adding of narrated help within the VRLE and having multiple views of the environment to enhance the learners experience. While the background of the VRLE was criticised for looking bland, it is not recommended to have extraneous content in the VRLE as this may detract from the learning experience.
5. Immersive Discomfort: The VRLE in this research was a basic design so it did not contribute to cybersickness. One participant did experience discomfort as he wasn’t able to wear his glasses when wearing the VR headset. It is a recommendation of this research that consideration is given to the procurement of headsets which are best suited to users who wear glasses.
6. Alignment with Experiential Learning: Both the questionnaire and focus group findings indicated a correlation with the experiential learning theory. The

interactive learning design of the VRLE had a positive response from participants.

7. Alignment with Situated Learning: The research participants agreed that the VRLE looked like an actual computer network. This likeness contributed to their visualisation of what they were learning. The participants also claimed that this aided their understanding of the task.
8. Alignment with Constructivism: The research findings from the questionnaire and focus group revealed that the participants had a positive experience from interacting with the VRLE. They indicated that the engagement with the VRLE helped with their understanding of the task.

5.5 FINAL THOUGHTS

Following the literature review, there was an expectation that the eight themes would produce the research results that they did. However, the richness of content from the focus group findings was unexpected. This helped to justify the sequential explanatory mixed methods approach.

It should be acknowledged, that I am also a lecturer to the participants of this research. Albeit, this was given the relevant ethical consideration. As a novice researcher, the research process created a positive personal respect for the integrity of the research cycle. The concluding comments of this chapter indicate how the research evolved and how each step informed the rationale for the subsequent chapters. At all times, the research was underpinned by its aims and objectives.

For those considering the use of VR as part of their teaching practice, consider if there is justification for implementing the application in VR or could it be implemented by using a less expensive technology. Is there a sufficient budget for the VR equipment and VRLE design? When proposing a VRLE design, consideration must be given to its purpose and effectiveness as suggested in section 3.6.2. Does the design exploit the benefits of VR and is it future-proof? The use of learning theories to underpin the VRLE design should also be considered. Finally, VR is merely a tool; tools by themselves do not teach.

CHAPTER SIX: BIBLIOGRAPHY

Abdul Rahim, E., Duenser, A., Billinghurst, M., Herritsch, A., Unsworth, K., McKinnon, A., & Gostomski, P. (2012). *A desktop virtual reality application for chemical and process engineering education.* Paper presented at the Proceedings of the 24th Australian Computer-Human Interaction Conference.

Abichandani, P., Fligor, W., & Fromm, E. (2014). *A cloud enabled virtual reality based pedagogical ecosystem for wind energy education.* Paper presented at the 2014 IEEE Frontiers in Education Conference (FIE) Proceedings.

Al-Hinai, I. (2018). Teachers Doing Research with Their Own Students: A Blessing or a Curse? In *English Education in Oman* (pp. 75-84): Springer.

Aliyu, A., Singhry, I., Adamu, H., awuya, A., & Abubakar, M. (2015). *ONTOLOGY, EPISTEMOLOGY AND AXIOLOGY IN QUANTITATIVE AND QUALITATIVE RESEARCH: ELUCIDATION OF THE RESEARCH PHILOSOPHICAL MISCONCEPTION*.

Amin, D., & Govilkar, S. (2015). Comparative study of augmented reality SDKs. *International Journal on Computational Science & Applications, 5*(1), 11-26.

Anderson, C. (2010). Presenting and evaluating qualitative research. *American journal of pharmaceutical education, 74*(8), 141.

Anderson, T. (2016). Theories for learning with emerging technologies. *Emergence and innovation in digital learning: Foundations and applications*, 35-50.

Ang, C. S., & Rao, G. S. V. R. K. (2008). Computer game theories for designing motivating educational software: A survey study. *International Journal on E-Learning, 7*(2), 181-199.

Bernard, R. M., & Rubalcava, B. R. d. (2000). Collaborative online distance learning: Issues for future practice and research. *Distance education, 21*(2), 260-277.

Bertram, J., Moskaliuk, J., & Cress, U. (2015). Virtual training: Making reality work? *Computers in Human Behavior, 43*, 284-292.

Birley, G., & Moreland, N. (1999). *A practical guide to academic research*: Kogan Page.

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry, 13*(2), 103-124.

Blaxter, L., Hughes, C., & Tight, M. (2001). *How to research* (2nd ed. ed.): Open University Press.

Brelsford, J. W. (1993). *Physics education in a virtual environment.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Brenton, H., Hernandez, J., Bello, F., Strutton, P., Purkayastha, S., Firth, T., & Darzi, A. (2007). Using multimedia and Web3D to enhance anatomy teaching. *Computers & Education, 49*, 32-53. doi:10.1016/j.compedu.2005.06.005

Bricken, M., & Byrne, C. M. (1992). *Summer Students in Virtual Reality: A Pilot Study on Educational Applications of Virtual Reality Technology*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED358853&site=eds-live

Bricken, M., Byrne, C. M., & Washington Univ, S. W. T. C. (1992). *Summer Students in Virtual Reality: A Pilot Study on Educational Applications of Virtual Reality Technology*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED358853&site=eds-live

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher, 18*(1), 32-42.

Budziszewski, P. (2013). *A low cost virtual reality system for rehabilitation of upper limb.* Paper presented at the International Conference on Virtual, Augmented and Mixed Reality.

Bulmer, M. (2001). The ethics of social research. *Researching social life, 3*, 45-57.

Burdea, G. C. (2004). Teaching Virtual Reality: Why and How? *Presence: Teleoperators & Virtual Environments, 13*(4), 463-483. doi:10.1162/1054746041944812

Burns, R. B. (2000). *Introduction to research methods* (4th ed. ed.): SAGE.

Burris, C. (2017). LDT 505: integrating mobile technologies into learning environments.

Cairns, P., & Brown, E. (2004, 2004). *A grounded investigation of game immersion*.

Candy, P. C. (1989). Constructivism and the study of self-direction in adult learning. *Studies in the Education of Adults, 21*(2), 95-116.

Carbonell-Carrera, C., & Saorín, J. L. (2017). Geospatial Google Street View with virtual reality: A motivational approach for spatial training education. *ISPRS International Journal of Geo-Information, 6*(9), 261.

Carmody, T. (2010). Why 'gorilla arm syndrome'rules out multitouch notebook displays. *Wired, Oct, 10*.
Champney, R., Lackey, S. J., Stanney, K., & Quinn, S. (2015, 2015). *Augmented reality training of military tasks: Reactions from subject matter experts*.
Chau, M., Wong, A., Wang, M., Lai, S., Chan, K. W. Y., Li, T. M. H., . . . Sung, W.-k. (2013). Using 3D virtual environments to facilitate students in constructivist learning. *Decision Support Systems, 56*, 115-121.
Chen, C. J. (2010). Theoretical bases for using virtual reality in education. *Themes in Science and Technology Education, 2*(1-2), 71-90.
Chen, C. J., Toh, S. C., & Ismail, W. M. F. W. (2005). Are learning styles relevant to virtual reality? *Journal of research on technology in education, 38*(2), 123-141.
Chittaro, L., & Ranon, R. (2007). Web3D technologies in learning, education and training: Motivations, issues, opportunities. *Computers & Education, 49*(1), 3-18.
Chung-Ho, S., & Ting-Wen, C. (2019). A Sustainability Innovation Experiential Learning Model for Virtual Reality Chemistry Laboratory: An Empirical Study with PLS-SEM and IPMA. *Sustainability*(4), 1027. doi:10.3390/su11041027
CIRT. (2016). Case Study Method - Center for Innovation in Research and Teaching. Retrieved from https://cirt.gcu.edu/research/developmentresources/research_ready/descriptive/case_study
Clark, R. E. (1983). Reconsidering research on learning from media. *Review of educational research, 53*(4), 445-459.
Cohen, L., & Manion, L. (1994). *Research methods in education*: routledge.
Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed. ed.): RoutledgeFalmer.
Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed. ed.): Routledge.
Costello, P. J. (1997). *Health and safety issues associated with virtual reality: a review of current literature*: Citeseer.
Creswell, J. (2002). *Research design : qualitative, quantitative, and mixed method approaches* (2nd ed. ed.): SAGE.
Creswell, J., & Plano Clark, V. (2006). *Designing and conducting mixed methods research*. Thousand Oaks, Calif.: SAGE Publ.
Creswell, J., Plano Clark, V., Gutmann, M., & Hanson, W. (2003). Advanced mixed methods research designs. *Handbook of mixed methods in social and behavioral research, 209*, 240.
Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10-32.
Denzin, N. K., & Lincoln, Y. S. (2000). *The handbook of qualitative research* (2nd ed. ed.): SAGE.
Denzin, N. K., & Lincoln, Y. S. (2008). Introduction: The discipline and practice of qualitative research.
Dewey, J. (1985). Democracy and education (1916). *The Middle Works, 9*, 4-58.
Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of applied educational technology, 4*(1), 21-31.
Doolittle, P. E., & Camp, W. G. (1999). Constructivism: The career and technical education perspective. *Journal of vocational and technical education, 16*(1), 23-46.
Elmqaddem, N. (2019). Augmented Reality and Virtual Reality in Education. Myth or Reality? *International Journal of Emerging Technologies in Learning (iJET), 14*(03), 234-242.
Ewert, D., Schuster, K., Johansson, D., Schilberg, D., & Jeschke, S. (2013). *Intensifying learner's experience by incorporating the virtual theatre into engineering education.* Paper presented at the 2013 IEEE Global Engineering Education Conference (EDUCON).
Falk, J. H. (1983). Field trips: A look at environmental effects on learning. *Journal of Biological Education, 17*(2), 137-142.
Feisel, L. D., & Rosa, A. J. (2005). The Role of the Laboratory in Undergraduate Engineering Education. *Journal of Engineering Education, 94*(1), 121-130. doi:10.1002/j.2168-9830.2005.tb00833.x
Fenwick, T. J. (2001). Experiential Learning: A Theoretical Critique from Five Perspectives. Information Series No. 385.
Fokides, E., & Tsolakidis, C. (2008). Virtual reality in education: A theoretical approach for road safety training to students. *European Journal of Open, Distance and E-learning, 11*(2).
Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & gaming, 33*(4), 441-467.
Genzuk, M. (2003). A synthesis of ethnographic research. *Occasional Papers Series. Center for Multilingual, Multicultural Research (Eds.). Center for Multilingual, Multicultural Research, Rossier School of Education, University of Southern California. Los Angeles*, 1-10.
Gerring, J. (2007). Is there a (viable) crucial-case method? *Comparative Political Studies, 40*(3), 231-253.

Gieser, S. N., Becker, E., & Makedon, F. (2013). *Using CAVE in physical rehabilitation exercises for rheumatoid arthritis.* Paper presented at the Proceedings of the 6th International Conference on PErvasive Technologies Related to Assistive Environments.

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. *British dental journal, 204*(6), 291.

Glaser, B. G., Strauss, A. L., & Strutzel, E. (1968). The discovery of grounded theory; strategies for qualitative research. *Nursing research, 17*(4), 364.

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking.

Google. (2017). Google Earth VR. Retrieved from https://vr.google.com/earth/

Greenwald, S., Kulik, A., Kunert, A., Beck, S., Frohlich, B., Cobb, S., . . . Newbutt, N. (2017). Technology and applications for collaborative learning in virtual reality.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of qualitative research, 2*(163-194), 105.

Halcomb, E. J., & Hickman, L. (2015). Mixed methods research.

Holmes, J. (2007). Designing agents to support learning by explaining. *Computers & Education, 48*, 523-547. doi:10.1016/j.compedu.2005.02.007

Huang, H.-M., Rauch, U., & Liaw, S.-S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education, 55*, 1171-1182. doi:10.1016/j.compedu.2010.05.014

Hummel, H. G. K. (1993). Distance education and situated learning: paradox or partnership? *Educational Technology*, 11-22.

Insights for the Experience Economy. (2016, June 21). *https://greenlightinsights.com/.* Retrieved from https://greenlightinsights.com/consumer-interest-in-virtual-reality-goes-far-beyond-gaming/

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field methods, 18*(1), 3-20.

Jacobson, J., & Holden, L. (2005). *The virtual egyptian temple.* Paper presented at the EdMedia+ Innovate Learning.

Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education, 53*(1), 169-182.

Jocelyn, P., & Mayer, E. R. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology, 110*(6), 785-797.

Jonassen, D. H. (1997, 1997). *A model for designing constructivist learning environments*.

Kananagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of Virtual Reality in education. *Themes in Science & Technology Education, 10*(2), 85-119.

Kaufmann, H., & Meyer, B. (2009). Physics Education in Virtual Reality: An Example. *Themes in Science and Technology Education, 2*, 117-130.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a Research Paradigm and Its Implications for Social Work Research. *Social Sciences, 8*(9), 255.

Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of Virtual Reality in education. *Themes in Science and Technology Education, 10*(2), 85-119.

Kim, S. u., Lee, K., & Koo, K. c. (2017). Toward an Evaluation Model of User Experiences on Virtual Reality Indoor Bikes. *European Scientific Journal, 1*(Special Edition), 22-36.

King, N., Horrocks, C., & Brooks, J. (2018). *Interviews in qualitative research*: SAGE Publications Limited.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist, 41*(2), 75-86.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of higher education, 6*(5), 26-41.

Kolb, D. A. (1984). *Experiential learning : experience as the source of learning and development*: Prentice-Hall.

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2001). Experiential learning theory: Previous research and new directions. *Perspectives on thinking, learning, and cognitive styles, 1*(8), 227-247.

Latham, K., Kot, P., Waraich, A., Al-Jumeily, D., Puthuran, M., & Chandran, A. (2019). A Review on the Development of a Virtual Reality Learning Environment for Medical Simulation and Training.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*: Cambridge university press.
Le, Q. T., Pedro, A., & Park, C. S. (2015). A social virtual reality based construction safety education system for experiential learning. *Journal of Intelligent & Robotic Systems, 79*(3-4), 487-506.
Lee, J. (1999). Effectiveness of computer-based instructional simulation: a meta analysis. *International journal of instructional media, 26*(1), 71-72.
Leech, N. L., & Onwuegbuzie, A. J. (2009). A typology of mixed methods research designs. *Quality & quantity, 43*(2), 265-275.
Leung, T., Zulkernine, F., & Isah, H. (2018). The use of Virtual Reality in Enhancing Interdisciplinary Research and Education. *arXiv preprint arXiv:1809.08585*.
Lewis , A. (1992). Group Child Interviews as a Research Tool. *British Educational Research Journal, 18*(4), 413.
Limniou, M., Roberts, D., & Papadopoulos, N. (2008). Full immersive virtual environment CAVETM in chemistry education. *Computers & Education, 51*(2), 584-593.
Lincoln, Y. S. (2007). Naturalistic inquiry. *The Blackwell Encyclopedia of Sociology*.
Liu, D., Bhagat, K. K., Gao, Y., Chang, T.-W., & Huang, R. (2017). The potentials and trends of virtual reality in education. In *Virtual, augmented, and mixed realities in education* (pp. 105-130): Springer.
Loke, S.-K. (2015). How do virtual world experiences bring about learning? A critical review of theories. *Australasian Journal of Educational Technology, 31*, 112-122. doi:10.14742/ajet.2532
Mackenzie, N., & Knipe, S. (2006). Research dilemmas: Paradigms, methods and methodology. *Issues in educational research, 16*(2), 193-205.
Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education, 9*(3).
Mahdi, O., Oubahssi, L., Piau-Toffolon, C., & Iksal, S. (2018, 2018). *Towards design and operationalization of pedagogical situations in the VRLEs*.
Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction, 60*, 225-236.
Mayes, T., & De Freitas, S. (2004). Review of e-learning theories, frameworks and models. JISC e-learning models study report.
McDonough, J., & McDonough, S. H. (1997). *Research Methods for English Language Teachers*: Arnold.
McEvoy, F. J. (2018). 10 ethical concerns that will shape the VR industry. Retrieved from https://venturebeat.com/2018/01/04/10-ethical-concerns-that-will-shape-the-vr-industry/
McLellan, H. (1994). Situated Learning: Continuing the Conversation. *Educational Technology, 34*(8), 7-8.
McNamara, D. S., Jackson, G. T., & Graesser, A. (2010). Intelligent tutoring and games (ITaG). In *Gaming for classroom-based learning: Digital role playing as a motivator of study* (pp. 44-65): IGI Global.
Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers and Education, 70*, 29-40.
Morgan, D. L. (1997). *Focus groups as qualitative research* (2nd ed. ed.): SAGE.
Morgan, D. L. (2013). *Integrating qualitative and quantitative methods: A pragmatic approach*: Sage publications.
Moss, J. D., & Muth, E. R. (2011). Characteristics of head-mounted displays and their effects on simulator sickness. *Human factors, 53*(3), 308-319.
Mossel, A., & Kaufmann, H. (2013). *Wide area optical user tracking in unconstrained indoor environments.* Paper presented at the 2013 23rd International Conference on Artificial Reality and Telexistence (ICAT).
Nolin, P., Stipanicic, A., Henry, M., Lachapelle, Y., Lussier-Desrochers, D., & Allain, P. (2016). ClinicaVR: Classroom-CPT: A virtual reality tool for assessing attention and inhibition in children and adolescents. *Computers in Human Behavior, 59*, 327-333.
Nuanmeesri, S. (2018). The augmented reality for teaching Thai students about the human heart. *International Journal of Emerging Technologies in Learning (iJET), 13*(06), 203-213.
Nunan, D. (1992). *Research methods in language learning*: Cambridge university press.
O'Leary, Z. (2004). *The essential guide to doing research*: Sage.
Opie, C., & Sikes, P. J. (2004). *Doing educational research : a guide to first-time researchers*: SAGE.
Oppenheim, A. N. (1992). *Questionnaire design, interviewing, and attitude measurement* (New ed. ed.): Continuum.
Ott, M., & Tavella, M. (2009). A contribution to the understanding of what makes young students genuinely engaged in computer-based learning tasks. *Procedia-Social and Behavioral Sciences, 1*(1), 184-188.

Patrick, E., Cosgrove, D., Slavkovic, A., Rode, J. A., Verratti, T., & Chiselko, G. (2000, 2000). *Using a large projection screen as an alternative to head-mounted displays for virtual environments*.

Punch, K. (2005). *Introduction to social research : quantitative and qualitative approaches* (2nd ed. ed.): SAGE.

Rafael, A. C., Bernardo, F., Ferreira, L. M., Rasteiro, M. G., & Teixeira, J. C. (2007). Virtual applications using a web platform to teach chemical engineering: the distillation case. *Education for Chemical Engineers, 2*(1), 20-28.

Ray, A. B., & Deb, S. (2016). *Smartphone Based Virtual Reality Systems in Classroom Teaching—A Study on the Effects of Learning Outcome.* Paper presented at the 2016 IEEE Eighth International Conference on Technology for Education (T4E).

Rebenitsch, L., & Owen, C. (2016). Review on cybersickness in applications and visual displays. *Virtual Reality, 20*(2), 101-125.

Reiser, R. A., & Dempsey, J. V. (2012). *Trends and issues in instructional design and technology*: Pearson Boston, MA.

Riva, G. (2003). Applications of virtual environments in medicine. *Methods of information in medicine, 42*(05), 524-534.

Roussou, M. (2004). Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. *Computers in Entertainment (CIE), 2*(1), 10-10.

Sattar, M. U., Palaniappan, S., Lokman, A., Shah, N., Khalid, U., & Hasan, R. (2020). Motivating Medical Students Using Virtual Reality Based Education. *International Journal of Emerging Technologies in Learning (iJET), 15*(02), 160-174.

Savin-Baden, M., Gourlay, L., Tombs, C., Steils, N., Tombs, G., & Mawer, M. (2010). Situating pedagogies, positions and practices in immersive virtual worlds. *Educational Research, 52*(2), 123-133.

Schunk, D. H. (2012). *Learning theories an educational perspective sixth edition*: Pearson.

Schunk, D. H., Meece, J. R., & Pintrich, P. R. (2012). *Motivation in education: Theory, research, and applications*: Pearson Higher Ed.

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English language teaching, 5*(9), 9-16.

Serrano, B., Botella, C., Baños, R. M., & Alcañiz, M. (2013). Using virtual reality and mood-induction procedures to test products with consumers of ceramic tiles. *Computers in Human Behavior, 29*(3), 648-653.

Sharma, S., & Otunba, S. (2012). *Collaborative virtual environment to study aircraft evacuation for training and education.* Paper presented at the 2012 International Conference on Collaboration Technologies and Systems (CTS).

Silva, J. N. A., Southworth, M., Raptis, C., & Silva, J. (2018). Emerging applications of virtual reality in cardiovascular medicine. *JACC: Basic to Translational Science, 3*(3), 420-430.

Sommerauer, P., & Müller, O. (2018, 2018). *Augmented Reality for Teaching and Learning-a literature Review on Theoretical and Empirical Foundations*.

Stake, R. E. (1995). *The art of case study research*: SAGE.

Stake, R. E. (2013). *Multiple case study analysis*: Guilford Press.

Stanney, K. M., Kennedy, R. S., & Drexler, J. M. (1997, 1997). *Cybersickness is not simulator sickness*.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology. *Handbook of qualitative research, 17*, 273-285.

Sutcliffe, A. (2003). *Multimedia and virtual reality: designing multisensory user interfaces*: Psychology Press.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive science, 12*(2), 257-285.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and instruction, 4*(4), 295-312.

Taber, K. (2007). *Classroom-based research and evidence-based practice: a guide for teachers*: Sage.

Takala, T. M. (2014). *RUIS: A toolkit for developing virtual reality applications with spatial interaction.* Paper presented at the Proceedings of the 2nd ACM symposium on Spatial user interaction.

Tashakkori, A., & Teddlie, C. (2010). *Sage handbook of mixed methods in social & behavioral research*: sage.

Taylor, P., & Medina, M. (2013). Educational research paradigms: From positivism to multiparadigmatic. *Journal for Meaning-Centered Education, 1*

Journal for Meaning-Centered Education,1Journal for Meaning-Centered Education,1Journal for Meaning-Centered Education,1.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research : integrating quantitative and qualitative approaches in the social and behavioral sciences*: SAGE.

Tellis, W. M. (1997a). Application of a case study methodology. *The qualitative report, 3*(3), 1-19.

Tellis, W. M. (1997b). Introduction to case study. *The qualitative report, 3*(2), 1-14.
Thabane, L., Ma, J., Chu, R., Cheng, J., Ismaila, A., Rios, L. P., . . . Goldsmith, C. H. (2010). A tutorial on pilot studies: the what, why and how. *BMC medical research methodology, 10*(1), 1.
Trochim, W. M. (2006). Qualitative measures. *Research measures knowledge base, 361*, 2-16.
Van Teijlingen, E. R., & Hundley, V. (2001). The importance of pilot studies.
Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: a review. *Frontiers in psychology, 10*, 158.
Wiles, R., Crow, G., Heath, S., & Charles, V. (2008). The management of confidentiality and anonymity in social research. *International Journal of Social Research Methodology, 11*(5), 417-428.
Willis, J. W. (2007). *Foundations of qualitative research : interpretive critical approaches*: SAGE.
Wilson, N., & McClean, S. I. (1994). *Questionnaire Design: A Practical Introduction*: University of Ulster.
Winn, W. (1993). A conceptual basis for educational applications of virtual reality. *Technical Publication R-93-9, Human Interface Technology Laboratory of the Washington Technology Center, Seattle: University of Washington*.
Wollensak, A. (2002). Curricular modules: 3D and immersive visualization tools for learning. *Computers & Graphics, 26*, 599-602. doi:10.1016/S0097-8493(02)00110-3
Wong, B. L., Ng, B. P., & Clark, S. A. (2000). Assessing the effectiveness of animation and virtual reality in teaching operative dentistry. *Journal of dentistry, 1*(1).
Woodside, A. G. (2010). *Case study research: Theory, methods and practice*: Emerald Group Publishing.
Yahaya, R. A. (2006). *Assessing the Effectiveness of Virtual Reality Technology as part of an Authentic Learning Environment.* Paper presented at the International Conference on Advanced Learning Technologies, Kerkrade, Netherlands.
Yasin, A. M., Darleena, Z., & Isa, M. A. M. (2012). Avatar Implementation in Virtual Reality Environment using Situated Learning for "Tawaf". *Procedia-Social and Behavioral Sciences, 67*, 73-80.
Yin, R. K. (2009). *Case study research : design and methods* (4th ed.): Sage Publications.
Yin, R. K. (2013). *Case study research : design and methods* (Fifth edition. ed.): SAGE.
Zavalani, O., & Spahiu, A. (2012). *Use curiosity for virtual reality "as a hook" in the engineering education.* Paper presented at the 2012 15th International Conference on Interactive Collaborative Learning (ICL).
Ángel, S.-A. (2015). Real and virtual bioreactor laboratory sessions by STSE–CLIL WebQuest. *Education for Chemical Engineers, 13*, 1-8. doi:10.1016/j.ece.2015.06.004

APPENDICES

APPENDIX 1

PARTICIPANT INFORMATION LEAFLET

1. **Title or working title of the study:** To evaluate Virtual Reality (VR) as a learning tool for students with the aid of an interactive VR simulation program

2. **Introduction to the study:** Virtual Reality (VR) technology is used not only for games and entertainment but can also be used for educational purposes. The purpose of this study is to analyse the educational impact of VR, that is, how it impacts on student learning. If you wish to take part in this exercise you will be asked to view and interact with a VR scenario which will involve wearing a headset. You will also be asked questions before and after the scenario. By taking part in this exercise you will help to contribute to the research that researcher is currently doing as part of his master's in teaching and Learning. Before you commit fully, you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Talk to others about the study if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

3. **Research Procedures:**

You will be required to wear a VR headset and observe a VR networking scenario.

4. **Benefits of the research:** By taking part in this research you will assist the researcher in quantifying the impact that VR has on student learning.

5. **Risks of the research**: It should be noted that the VR head mounted display will project virtual objects to the wearer's field of view and you will not be fully aware of your immediate surroundings.

6. **Exclusion from participation**: Please inform the researcher immediately (a) If you suffer from photosensitive epilepsy or any other form of epilepsy (b) You are under 18 years of age.

7. **Confidentiality:** No identifying factors relating to participants will be in evidence in the final thesis report and/or any disseminated research (i.e. conference papers and/or presentations, publications, etc.). Those who will have access to your identity include: members of the Research Advisory Panel, internal examiners and external examiner(s).

8. **Compensation:** This study is covered by standard institutional indemnity insurance. Nothing in this document restricts or curtails your rights.

9. **Voluntary Participation:** You have volunteered to participate in this study. If you decide not to participate, or if you withdraw, you will not be penalised and will not give up any benefits that you had before entering the study.

10. **Stopping the study:** You understand that If you wish to withdraw from the study please contact me within one month of your participation.

11. **Permission**: This research has approval from the MA in Teaching and learning Research Ethics Committee.

12. **Further information:** You can get more information or answers to your questions about the study, your participation in the study, and your rights, from *NIGEL FLYNN* who can be telephoned at *0906468176* or e-mail nflynn@ait.ie.

13. **New Information arising:** If the researcher or members of the Research Advisor Panel learns of important new information that might affect your desire to remain in the study, or if any conflicts of interest emerge during the course of the study, you will be informed at once.

14. **Data storage:** Any paper documents submitted by the participant will be stored in a locked cabinet in AIT. Any computerised information related to the participant will be stored in a password protect file.

APPENDIX 2

INFORMED CONSENT FORM 1:

INDIVIDUAL RESEARCH PARTICIPANTS

Project Title: AN EVALUATION OF VIRTUAL REALITY (VR) AS A LEARNING TOOL FOR STUDENTS WITH THE AID OF AN INTERACTIVE VR SIMULATION PROGRAM		
Principal Researcher: G00376142		
Background to the Study: Virtual Reality (VR) technology is used not only for games and entertainment but can also be used for educational purposes. The purpose of this study is to analyse the educational impact of VR, that is, how it impacts on student learning. If you wish to take part in this exercise you will be asked to view and interact with a VR scenario which will involve wearing a headset. You will also be asked questions before and after the scenario. By taking part in this exercise you will help to contribute to the research that researcher is currently doing as part of his master's in teaching and Learning. Before you commit fully, you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Talk to others about the study if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.		
Participant Declaration: Tick yes or no as appropriate.		
I have read or have had the information sheet read to me and I understand the contents.	**Yes**	**No**
I have been given an opportunity to ask questions and am satisfied with answers.	**Yes**	**No**
I have given consent to take part in the study.	**Yes**	**No**
I understand that participation is voluntary and that I can withdraw within one month of participation.	**Yes**	**No**
I understand that withdrawal will not affect my access to services or legal rights.	**Yes**	**No**
I consent to possible publication of results.	**Yes**	**No**

I (the participant) give my permission to: use the data obtained from you in other future studies without the need for additional consent.	**Yes**	**No**
Researcher Declaration: Tick yes or no as appropriate.		
I have explained the study to the participant.	**Yes**	**No**
I have answered questions put to me by the participant about the research.	**Yes**	**No**
I believe that the participant understands and is freely giving consent.	**Yes**	**No**

Participant's Statement:

I have read, or had read to me, this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand I may withdraw within one month of participation. I have received a copy of this consent form.

Participant's Name:

Contact Details:

Participant Signature:

Date:

Researcher's Statement:

I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Signature:

Date:

APPENDIX 3

INFORMED CONSENT FORM 2:

RESEARCH PARTICIPANTS IN FOCUS GROUPS AND INTERVIEWS[1]

INFORMATION SHEET	
Purpose of the research study?	The purpose of this study is to analyse the educational impact of VR, that is, how it impacts on student learning.
What will the research study involve?	A qualitative research interview which may be recorded.
Why have you been asked to take part in this research study?	You have been asked because you have already participated in the VR interactive scenario. You are over 18 years of age.
Will your participation in the research study be kept confidential?	Those who will have access to the research data include: the primary researcher and members of the Research Advisory Panel, internal examiners and external examiners.
What will happen to the information which you give?	The information you give will be collated with other participant's information. No identifying factors relating to participants will be in evidence in the final thesis report and/or any disseminated research (i.e. conference papers and/or presentations, publications, etc.). Those who will have access to your identity include: members of the Research Advisory Panel, internal examiners and external examiner(s). Any paper documents submitted by the participant will be stored in a locked cabinet in AIT. Any computerised information related to the participant will be stored in a password protect file.
What will happen to the results?	The results may be used as part of a thesis by the researcher.

[1] The document draws extensively on a work produced by Dr R. Swain of UCC, and is used with permission. Copyright is vested in same and all rights therein remain with Dr Swain.

What are the possible disadvantages of taking part?	The research will take up some of your free time.
What if a problem arises in relation to research participation?	You have volunteered to participate in the research. If you wish to withdraw from the study, please contact me within one month of your participation.
Who has reviewed this study from the perspective of ethical clearance?	The MA in Teaching and Learning Research Ethics Committee, GMIT.
Any further queries?	If you need any further information, you can contact me at: G00376142@gmit.ie
If you agree to take part in the study, please sign below	

RESEARCH PARTICIPANTS IN FOCUS GROUPS AND INTERVIEWS

Date:

Signature(s):

APPENDIX 4

Date: _____ Student Number: _____

Section A

Please complete this section BEFORE using the VR

Please tick to confirm that you have completed the participation information leaflet ☐

Sex: Male ☐ Female ☐

Age Group: 18-20 ☐ 21-25 ☐ 26-30 ☐ over 30 ☐

Class Group: Group A ☐ Group B ☐ Mobile Apps ☐

Have you ever used a VR headset before? Yes ☐ No ☐

If yes, used it: less than 5 times ☐ 5 to 10 time ☐ greater than 10 ☐ times

Instruction: Read the statements below and TICK the one that most applies to you.

Motivation

1. The opportunity to use a VR headset was a motivation for me to participate in this research

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Section B

Please complete this section AFTER using the VR

2. I would prefer to use VR for learning rather than the 'usual' teaching methods

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. I would study more often if I could use VR rather than your usual study method.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Novelty

1. I was more interested/engaged with the networking task because VR was a 'new way' of learning

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. I liked the idea of trying VR as a new way of learning

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. I would like to use VR to learn content for other Modules

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Immersive effect

1. I felt focused on the networking task due to the VR simulation

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. I think the VR simulation environment helped to remove the 'distraction' of 'reality'

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. The VR simulation environment helped me to concentrate on the networking task

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

VRLE design

1. The VR simulation environment looked professional

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. If the **design** of the VR simulation environment was better, then I would have had a better learning experience

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. The VR hand controls were easy to use

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

4. The VR simulation environment lacked interaction

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Possible immersive environment discomfort

1. I felt discomfort while wearing the VR headset

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. I felt relaxed while interacting with the VR simulation environment

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. I felt dizzy/disorientated during or immediately after using the VR

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Alignment with experiential learning

1. The VR provided an effective **interactive** environment.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. The VR simulation environment encouraged me to **reflect/think about** what I was doing

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. I have a better **understanding** of the networking task following the use of the interactive environment and the reflecting on the task

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Alignment with situated learning

1. The VR networking scenario looks like an actual real network

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. Because the VR environment looked like a real network, it helped me to have a better **understanding** of the operation of the network.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Alignment with constructivism

1. I felt like I had **control** of the navigation of the VR network.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. The **questions** within the VR helped me to gain a better understanding of the operation of the network

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3. I felt that I **constructed/created** a better understanding for myself of the networking task following the use of the VR.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Thank you for taking the time to complete this questionnaire