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Making Sense of Learning in VR

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Abstract

The goal of this qualitative study was to answer the question: How do educators make sense of learning in virtual reality? This study utilized multimedia learning theory and cognitive load theory to explore how educators understand virtual reality in education. Pre- and post-interviews as well as a VR experience were conducted with 13 educators from higher education institutions. The data was transcribed, coded, and developed into themes that created the data chapters.

The findings from this research study revealed that educators identified two themes for extended reality in education. First, the design of virtual reality experiences for students was an important element the educators discussed when creating the types of experiences. Second, the educators discussed the importance of presence in virtual reality for students to feel immersed in the virtual spaces which eliminated distractions. The educators discussed how emotions increase presence which creates deeper connections to the content. The educator's discussions of design and presence called attention to the importance of extended reality in education.

The results of this study give insight into the understanding the educators have for using extended reality in the classroom. This study focuses attention on how educators discussed design and presence as it relates to student's learning in extended reality. The shift that the educators in this dissertation study had in teaching and research after their first introduction to extended reality was also discussed in this dissertation. Their outlook for the future of extended reality in education is full of promise.

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by

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Chapter 1

Introduction

The first time I took off my virtual reality headset, I knew I was hooked. Thoughts and emotions washed over me like a tidal wave. I remember looking at the headset in stunned silence thinking about the opportunities it presented for education. I had previously experienced a virtual reality experience through a cardboard device that you inserted a phone into. This device allowed the viewer to look at the phone screen through a stereoscopic lens and let the viewer see a 360-degree picture or sphere. The virtual reality headset experience I had was much more than this. I felt like I was transported to another place and embodied something else completely, except I never left the room I was in. I knew from that moment on that extended reality technologies would shape the future of education.

I believe extended reality technologies offer limitless opportunities to innovate and change how students learn. The term extended reality (XR) is defined as a combination of real and virtual environments that broadly encompasses three realities; (1) augmented reality (AR), (2) mixed reality (MR), and (3) virtual reality (VR) (Alnagrat et al., 2022). I will define each of these realities and their effect on education later in the manuscript. In this chapter, I want: (1) introduce my thoughts on XR in education; (2) state the problem I want to engage regarding this technology; (3) discuss the significance of this study; (4) define the XR continuum; (5) briefly discuss research in XR; and (6) give an overview of the chapters in this manuscript.

Thoughts on XR in Education

Many educators see technology as a distraction for students, but other educators talk about how it increases creativity and content creation for understanding (Aagaard, 2015). In

short, there is a contestation over technologies in education. Some educators fear the ease of access to information. Others are concerned by the effects social media are having on students as well as the rise of artificial intelligence (AI) (Akgun & Greenhow, 2022). Other educators embrace the open access to that data and are attempting to teach digital literacy that educates students on how to sift through the fake and real information (Williamson, 2017). As for researchers, they are similarly divided on the effectiveness of educational technology stating that it either takes away from learning or vastly improves it. There seems to be no definitive middle ground (Dunlosky et al., 2013).

Bear with me for a moment. I see the use of XR in education as a personal *Magic School Bus.* Just like the adventures with Ms. Frizzle, instead of the bus, the use of XR technologies can transport students to anywhere at any time in history. The use of XR for simulations also allows students to practice techniques and procedures as many times as they want. For scientific experiences performed in a virtual environment, simulations that involve toxic substances can be handled safely and it allows students to fail safely.

The medical profession has shifted to using XR to practice medical procedures. Medical schools have found that they save money on supplies such as cadavers and disposable equipment due to students being able to practice extensively in XR before they perform in the physical labs (Mergen et al., 2023). AR technology is being used by doctors to project images and information over the patient's body as they operate on them. The healthcare field is leading the charge with the innovation of XR technologies from medical devices that require no physical contact to experimenting with new learning styles (Shaikh et al., 2022).

The capabilities of XR technologies have incrementally increased over the past ten years (Zabel & Telkmann, 2021). The opportunities for anyone that wants to create XR experiences has

become unlimited. Computers that have high-scale processing power and graphic capabilities coupled with software available to build XR experiences are now obtainable. The consumer market has become competitive with several different stand-alone VR headsets that do not require a computer to operate. Companies such as Apple and Microsoft have developed higher-end XR technologies that are setting the standard of innovation for future development (Marr, 2021). The use of XR technologies have been increasing in the medical, industrial, fashion, entertainment, and engineering professions. As an educator, I believe that if we teach our students how to create and innovate with XR, it will better prepare them for future career opportunities. This led me to the questions: What do other educators think about these capabilities? Do they use XR in their teaching and research?

Research Question

I realized that exploring XR's capabilities in education would be a life-long pursuit in my professional career. I say this because XR technology is changing and improving yearly. In addition, the integration of XR technologies in education is still in early development and we do not know the long-term effects of student learning. For this study, I was motivated to understand how educators in higher education made sense of learning in VR. In this manuscript, I will discuss the theories I used as well as the methodologies that helped me answer this research question:

How do educators make sense of learning in VR?

In the following section, I will discuss the significance of this question and why it is important to research.

Significance of Study

This study looks to understand what has influenced educators in higher education to gravitate toward XR in their teaching and research. This study's goal is to understand how these educators make sense of XR. These perspectives inform the choices they make when engaging XR technologies. Another goal of this study is to understand how these educators view the opportunities for XR to change the future of education. This includes understanding how they make sense of their students interacting and creating with these technologies. Again, XR technology has many definitions. In the next section, I look to define this term.

Extended Reality Continuum

XR reality-virtuality continuum consists of Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) (Webster R, 2016). Milgram et al. (1995), defined the Reality-Virtuality Continuum as a scale ranging from a completely real environment (reality) which we can observe when viewing the real world to a completely virtual environment (virtuality). Each of the realities on the continuum immerses digital assets into their environments differently.

Closest to the reality side of the continuum is Augmented Reality (AR). AR is characterized by digital content superimposed on the user's real surroundings. In addition, AR can involve real content superimposed on the user's virtual environment (Flavián et al., 2019). AR has contested definitions. One way AR is defined is by "augmenting natural feedback to the operator with simulated cues" (Milgram et al., 1995). Others highlight and define AR as "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world" (Vatavu et al., 2020). Azuma (1997), defined AR based on a system that fulfills three basic criteria: (1) combination of real and virtual, (2) interactive in real-time, and (3) 3-dimensional registration of virtual and real objects (Nincarean et al., 2013). To be a true AR

system, the experience must include a camera able to track the user's movement for merging the virtual objects as well as a visual display, like glasses or a screen, that a user can see the virtual objects overlaying the physical world (Cipresso et al., 2018). This tracking keeps the virtual objects anchored in place and gives the illusion that it belongs there as the viewer looks around the real world. This is where AR differs from VR because it superimposes virtual objects onto the actual physical world (Bown et al., 2017). When AR is connected to innovative technology such as a mobile device, the term Mobile Augmented Reality (MAR) arises (Nicarean et al., 2013). Over the years, with the introduction of better camera systems, faster internet and cell coverage, and faster computer chips, AR use has seen exponential growth in marketing, social media, and among casual users (Anderson et al., 2021).

In the middle of the XR continuum, the space between the real environment and the virtual environment is called Mixed Reality (MR) (Nincarean et al., 2013). Another way of thinking of MR is that it is conceived as the different points of the continuum at which real and virtual objects are merged (Flavián et al., 2019). There is a plethora of interchangeable terminologies consistently used with MR, such as Virtual World (VW), Virtual Environment (VE); Multi-User Virtual Environment (MUVE); Immersive Virtual World (IVW); Immersive World; Immersive Online Environment; 3D Virtual Learning Environment; Synthetic World; Virtual Learning Environment (VLE), and Cave Automatic Virtual Environment (CAVE) (Nisha, 2019). Each of those terms refers to virtual immersion using projectors in a room to immerse the users in a virtual environment. They can create a mixed experience between the virtual worlds and real interaction. With the release of the Apple Vision Pro, Apple is trying to redefine MR as Spatial Reality which is a mix between real and virtual environments. The use of spatial reality in

the Apple Vision Pro is a feature that allows users to go from seeing the world around them to being fully immersed in a virtual reality world.

VR differs from AR and MR in that it is defined as a computer-generated environment where the user can navigate and interact, triggering real-time simulation of his or her senses (Guttentag, 2010), and providing a sensory immersive experience (Flavián et al., 2019). VR has also been defined as a real or simulated environment in which a perceiver experiences telepresence (Steuer, 1992). Mikropoulos and Strouboulis (2004) defined VR as a "combination of high-end computing, human-computer interfaces, graphics, sensor technology and networking which allows the user to become immersed in, interact, and experience in real time, a three-dimensional artificial environment representing realistic or other situations" (Webster, 2016, p. 1320). The technical goal of VR is to replace real sense perceptions with computer-generated ones derived from a mathematical database describing a 3D scene, and animations of objects within the scene including changes caused by the intervention of the participant (Slater & Sanchez-Vives, 2016).

The Head Mounted Display (HMD) that users wear, delivers two computer-generated images, one for each eye. The 2D images are computed and rendered with an appropriate perspective to the position of each eye in the three-dimensionally described virtual scene (Slater & Sanchez-Vives, 2016). Think of three-dimensional movies with the special glasses one would wear to watch them bundled into a little box and sitting right in front of your eyes. Enclosed around your face, it is intense and all-encompassing. The goal of immersive VR is to let the user experience a computer-generated world as if it were real, producing a sense of presence, or "being there," in the user's mind (Bowman & McMahan, 2007). In short, VR is immersive enough to break the connection with physical space and simulate virtual presence and create the

illusion of reality (Nisha, 2019). The ability for the user to have a sense of "being there," has changed over the years with new technologies and software.

Research

In developing this dissertation study, my goal was to look at how educators make meaning of XR. There have been multiple studies over the years on the use of VR in education and most of them reach the same conclusion as many other educational technologies. Hattie (2008), stated that educational research studies in general, including those focused on educational technology, often yield findings amounting to ‘‘no significant differences." According to Tallent-Runnels et al. (2006), this finding often occurs because the researcher compares learning with the new technology to learning without the technology. Reeves & Oh (2017) suggested that as each new technology has been introduced into instructional contexts (films, teaching machines, radio, television, interactive videodisc, e-learning, serious learning games, etc.), numerous studies have been done to compare the effectiveness of the new delivery mode or approach with business-as-usual instruction. This concept is important because it highlights the potential shortcomings of studies that use a comparative analysis of teaching methods.

There are studies that look at how users interact with the VR experiences, but they appear to come away with more questions than answers. Chen (2006) asserts:

> *although VR is recognized as an impressive learning tool, there are still many issues that need further investigation including, identifying the appropriate theories and/or models to support learning, finding out whether its use can improve the intended performance and understanding, and investigating ways to reach more effective learning when using this technology, and investigating its impact on learners with different aptitudes (p. 39).*

This statement is similar to the research into education because we are constantly trying to find the best ways to engage students and the methodologies and technologies that will help increase learning. The difference is that XR is deploying the lessons through an extension of reality. With XR, the classroom itself can be changed in so many ways.

Overview of Chapters

To begin understanding how educators make sense of XR, I want to give an overview of the chapters in this manuscript. In chapter two, I will review the literature about XR technologies as well as discuss the theories that inform my thinking and this study. Additionally, I will discuss the studies that inspired my research and insight into XR research.

In chapter three, I discuss my rationale for using qualitative methodology in this study. I will give insight into the pilot study I conducted that helped inform this dissertation study. I will introduce the qualitative methods design in addition to the VR experience that was used with the think-aloud method, to better understand how these educators made sense of XR.

Chapter four is the first data chapter of two. Here, I analyze how the educators discussed Design in relation to XR. I will discuss how the educators conversed about XR as it relates to educational design, storytelling, and accessibility. This chapter will also present how the educators saw XR's future in society and education.

The focus of chapter five is on Presence in XR. This chapter is centered around the educators who talked about how to increase students' immersion in XR experiences and how that affects their learning. This chapter is key because it discusses how presence can create emotional connections to the content for students.

I conclude with chapter six, where I discuss my findings as well as discuss the implications of these findings. In this concluding chapter, I will also discuss the limitations of

this study as well as the future research opportunities that are possible from this study. I will end this chapter with my thoughts on the potential and limitations of XR.

Chapter 2

Literature Review and Theoretical Framework

With the creation and release of the Oculus Rift in 2016, consumer-level Virtual Reality (VR) access and content creation increased exponentially. In the seven years since its release, VR technology for hardware and software has far exceeded what most early Extended Reality (XR) pioneers' thought was possible (Anderson et al., 2021). The newest VR headsets or head-mounted displays (HMD) boast an 8K display screen in each eye that can create a hyper-realistic image for each eye. In comparison, the newest commercial televisions you can buy for your home are currently 4K displays. With the Meta 3 and Apple Vision Pro, the use of Mixed Reality (MR), or what Apple refers to as Spatial Reality, has become popular (Rose, 2021). Development of XR has reached a point where the technology is ahead of what the creative opportunities and usage for multiple professions, such as medicine, manufacturing, military, entertainment, and education can conceive. I start the literature review with these insights because the technology is evolving quickly, and educators need to understand how they can transform students learning with XR. As Chris Milk (2015) said "It's a machine, but inside of it, it feels like real life, it feels like truth" (Rouse, 2021). In the upcoming sections, I will describe a brief history of XR technology and its inclusion in education.

A Brief History of XR

The history of XR spans several decades and has only recently evolved exponentially with the introduction of new technologies. The earliest use of XR technology was through Charles Wheatstone (1838) as he created a stereoscopic image that used twin mirrors to project a single image to give users a sense of immersion (Nisha, 2019). Soon after, Robert Barker was creating panoramic paintings in the mid to late 1800's and early 1900's in Scotland (Bown et al.,

2017). These panoramic paintings were created in the large castle rooms for the townspeople to come and view such wonders as London and Paris without having to travel there. One could technically argue that this was one of the first large-scale MR Caves. These pieces were thought of as immersive, but the advent of highly immersive XR technology wasn't developed until Morton Heiling, who is often regarded as the father of VR, invented this technology (Carlson, 2007). Heiling created two versions of his vision: the Telesphere Mask (1955) and a single-user console called the Sensorama (Bown et al., 2017). Their designs were meant to captivate the audience's attention by keeping them surrounded and immersed in the device's environment (Merchant et al., 2014). The Sensorama was a simulated experience of a motorcycle running through Brooklyn characterized by several sensory impressions, such as audio, olfactory, and haptic stimuli, including wind to provide a realistic experience (Cipresso et al., 2018). Its design shuts out that participant's physical world by engaging the user's senses and included a motion-controlled seat (Nisha, 2019). In between the Telesphere and Sensorama in 1961, engineers Charles Comeau and James Bryan at Philco Corporation developed a Head Mounted Display (HMD) called Headsight (Bown et al., 2017). This design, along with the Telesphere, would soon become a mainstay design in XR. With that brief history, I want to describe more contemporary developments in VR in this next section.

Virtual Reality's Development

The concept of VR could be traced to the middle of 1960 when Ivan Sutherland, in a pivotal manuscript, attempted to describe VR as a window through which a user perceives the virtual world as if it looked, felt, and sounded real, in which the user could act realistically (Cipresso et al., 2018). In 1965, Sutherland created the first HMD to incorporate computer technology to facilitate a VR system, which came to be known as the "Sword of Damocles." The

name arises from the Greek story of Damocles. In Damocles' story, a sword was suspended in the air by a hair, directly above the King's head, and at any moment, the hair could break, killing the king. This reference to the sword was a comparison to an enormous amount of technology precariously situated above the user in the HMD (Bown et al., 2017). Essentially, the system was comparable to having a small fridge hanging over your head and the technology the user was interacting with was holding on by a "string."

In the 1980s and 1990s, VR emerged again based on a different generation of technology hardware (e.g., CRT displays rather than vector refresh). In the 1980s, a company called VPL Research, led by Jaron Lanier, became a driving force of VR developments. He constructed several different VR technologies such as, the Eyephone HMD, tracked data gloves for interaction, whole body tracking, and reality built for two (Slater & Sanchez-Vives, 2016). Jaron Lanier, in an address to the SIGGRAPH Panel in 1989 defined Virtual Reality for the first time by saying, "VR gives us this sense of being able to be who we are without limitation; for our imagination to become objective and shared with other people" (Slater & Sanchez-Vives, 2016). Jaron Lanier is said to be a pioneer of VR and continues to push the envelope as to the capabilities of the technology. Jaron's work has shown what XR can achieve. The use of XR technologies has also been incorporated into education over the years, in the next section, I will discuss how XR is used in education.

XR and Education

The field of education has embraced immersive 3D environments (Coffey et al., 2017). The introduction of VR technology in K-12 and higher education began in the early 1990s with projects such as Science Space, Safety World, Global Change, Virtual Gorilla Exhibit, Atom World, and Cell Biology (Merchant et al., 2014). These projects sparked the interest in the

possibility of immersive worlds. The immersive worlds allowed users to travel to different places big and small, without having to leave the classroom. Freina and Ott (2015) found that one of the main motivations to use VR in education was that it made it possible to experience situations that were either inaccessible, in time or space, or problematic, dangerous, or unethical (Jensen & Konradsen, 2018). The unique affordances of an immersive VR learning environment include virtual agents and avatars that act as personalized and interactive learning partners that cannot be easily arranged in a physical setting. They also include the open-endedness in creating and customizing VR environments that enables the provision of multiple perspectives and scenarios for the targeted concepts and skills. It also introduces the potential to transform sensory representations to enhance virtual learning actions (Ke et al., 2020). It offers a powerful possibility of presenting learners with an illusion that situates their imagination into a simulated reality (Nisha, 2019). In addition, Huang et al. (2019) pointed out the influence of sense of presence and cognitive load structure on learning in virtual environments. The cognitive load can develop into deeper learning and spark students' curiosity. I will elaborate on cognitive load later in the manuscript.

AR development has fit in the scope of XR in education with its ease of use and content creation. According to Dunleavy et al. (2009), AR's most significant advantage is its "unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem-solving, and communicating through interdependent collaborative exercises" (Akçayir & Akçayir, 2017, p. 2). Squire and Klopfer (2007), also suggested that AR, in the form of games, can simulate students' prior knowledge and increase the level of engagement in academic activities (Nincarean et al., 2013). AR brings a mix of reality into learning that helps students

bridge the gap between real and virtual. Several AR applications have been developed in the last few years showing the positive effects of this technology in supporting learning such as an increase on content understanding and memory preservation, as well as in learning motivation (Cipresso et al., 2018). XR technologies engage in different ways, immersing learners in virtual environments previously unheard of. With limited effort, the new digital technology simply makes learning much more interesting, even exciting (Gudoniene & Rutkauskienne, 2019). With the increased use of cell phones, the technology facilitates student engagement. I will discuss how the use of new XR technologies increases presence in XR and how presence can be used to increase learning in educational XR.

Presence in XR

One of the draws to utilizing VR in education is the sense of presence that VR creates in an experience. When people connect via a screen using a web-conference tool, they are looking through a "window" at the other users in the meeting. In VR, the users can move through space and feel a sense of presence or engagement. Engagement, which can be conceptualized as a sense of involvement or connection (Wiebe et al., 2014), may build on a sense of presence. Presence includes a sense of involvement and realness of the experience. Presence also includes embodiment, that can feature the perceptual experience of another (Schutte & Stilinović, 2017). Studies have found that VR fosters a higher level of immersion than standard media. In turn, that immersion could facilitate learning through positive emotions such as enjoyment (Makransky & Lilleholt, 2018).

The use of simulations in education allows the learner to observe cause and effect, and learning becomes more experienced based (Leder et al., 2019). The emergence of VR technologies offers a training supplement for skills that impact multiple professions, such as

surgeons, pilots, heavy equipment operators, etc. It is a faster, safer, and less costly way to enable students to practice their professional procedures through these simulations (Gudoniene & Rutkauskiene, 2019). The argument is that VR can be used for simulation-based education, where students and learners can practice new skills in a simulated environment that enables correction, repetition, and non-dangerous failure. At the same time, it offers access to interaction with expensive or far-away environments (Jensen & Konradsen, 2018).

Medical students can now study complex anatomical structures in 3-D virtual environments, without relying solely on high-cost, unsustainable cadavers, or animal models. When coupled with haptic input devices, these systems support direct manipulation and exploration of the anatomical structures. Students who have worked in medical virtual environments have expressed their comfort and minimized stress in working with computer models over working with cadavers (Jang et al., 2017). Additionally, considering the benefits of improved learning, repeated use, and versatility, VR can also reduce the costs of laboratory material, supervisor staff, and even simulated patients (Chen et al., 2020).

Bloom's taxonomy suggests that there is not simply one way information is processed and learned (Bloom et al., 1956). Instead, it presents learning as a hierarchy of learning, consisting of six stages that involve cognitive processes from simplest to most complex; remember, understand, apply, analyze, evaluate, and create. When it comes to creativity, the highest level of the hierarchy, VR offers a powerful possibility of presenting learners with an illusion that translates learners' imagination into simulated reality and allows them new ways to create and interact with content (Nisha, 2019).

According to Barab et al. (2000), the use of 3D virtual reality models allows:

> *students to set viewpoints that permit them to dynamically explore snapshots of their model. That is, by placing the viewpoint at different locations in their*

> *model students could jump from one location to another and explore astronomical events as they unfold (p. 743).*

This ability to explore and discover increases students' level of learning through analysis and evaluation (Bloom et al., 1956). The simulating, immersive experience may also spark the learner's interest through interacting with the lesson or experience (Parong & Mayer, 2018). The repetitive use of VR and the ability to engage in Bloom's higher levels of learning are important when dealing with cognitive load. In the next section, I will define cognitive load and how it affects learning in XR.

Cognitive Load in XR

Some studies suggest in VR learning environments that the sense of presence takes up the user's attention, resulting in an increase in cognitive load (Huang et al., 2020). Cognitive load has been defined in many ways. Sweller (2010) defined cognitive load as based on the limited processing capacity of working memory. Paas & van Merriënboer (1994), defined cognitive load as a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system (Paas et al., 2016).

Most literature studies consider three different types of cognitive load: The intrinsic load of the learning task, the extraneous load of the learning situation, and the germane load of the learning process (Frederiksen et al., 2020). Intrinsic load is defined as the load resulting from the complexity of the learning material or task. The more elements kept in working memory simultaneously, the higher the intrinsic load. Extraneous load is a result of the design of learning materials. The learner-friendly presentation of learning content lowers extrinsic load by facilitating access to relevant information and thus aiding understanding. Germane load is described as the load used for the construction of mental representations from learning content required for storing the information in long-term memory (Skulmowski et al., 2016). The

germane load is where what students learn becomes part of their thinking and how they apply it. In addition to these three main loads, XR enables spatial cognition, which is the ability to visualize in the mind's eye and is an enabler of the creative process (Nisha, 2019). Spatial cognition and the ability to envision with the mind is a critical aspect of learning to design (Oxman, 2004). The general relationship between spatial cognition and learning suggests that there may be a similar relationship between learning and virtual presence. This relationship is directly related to the VR system used (Selzer et al., 2019). Cognitive load is the key to changing the relationship between the sense of presence and learning outcomes (Huang et al., 2020). This is important because the more realistic a space is in VR the easier it will be for the participant to draw comparisons to the actual object. This will reduce the participant's cognitive load and increase learning.

High cognitive load is not overwhelming, as increasing the germane load can have positive effects on learning. When VR experiences are repeated and content is incrementally increased, this causes a lower cognitive load to be induced. In the design of the experience, elements must be added throughout the training and include building learning sessions so that complexity matches the current skills. Considerations also need made to match the transfer of skills from one learning setting to more complex learning situations and finally to real life (Andersen et al., 2018). Providing well-integrated and organized materials (ex: images, texts, videos) can help to prevent incidental cognitive loads (Akçayir & Akçayir, 2017). This means that all cognitive load resulting from content or interactions not directly contributing to learning should be avoided (Skulmowski et al., 2016). Cognitive benefits are described as improved understanding and application as well as a more positive perception of learned material (Makransky & Lilleholt, 2018). Overall, a scaffolding of instructional design will play an

important role in the development of educational XR. Understanding how VR stories that evoke empathy can help students understand content is another important component of VR development. In the next section, I will discuss how creating XR stories that increase empathy in the students can increase engagement, learning, and memory.

Empathy

One of the major draws of XR and particularly VR is that it is known as an "empathy machine" (Rouse, 2021). VR induces feelings of connection through the immersive stories. When viewing a movie in a theatre or home, you are looking at a 2D screen and at any moment, you can look away and detach yourself from the story. In VR, you cannot look away, because you are still immersed in the story. VR is all-encompassing, and with that immersion in the virtual space, comes the immersion of your emotions.

In a virtual environment, viewers who are close to characters, and share the same space, may feel their emotions or situations more strongly (Bombari et al., 2015). To absorb oneself in VR can stimulate empathy. Stimulated empathy with others in VR can make the virtual environment seem more realistic to users (Shin, 2018). Hollywood has used this approach for years through their different techniques and inclusion of different visual effects from *E.T.* to *The Notebook*. For VR, stories like *Tree*, an immersive climate change story, has you growing up from a seed into a full-grown tree in the forest in 10 minutes. In the *Tree* experience, you embody the life span of a tree, and it creates emotional connections between you and your environment. The immersive story draws you in to see what it is like to be a part of a rainforest, only to have you pulled from the embodiment of the tree at the end. As you are pulled from the tree at the end, you watch from above as loggers chop down the forest for lumber. You witness the destruction of your "home." The emotional connection and awareness you get from the

embodiment of the tree is profound. Because I experienced the *Tree* VR, I now look at every piece of paper I use differently and try to find ways to recycle every chance I get. That emotional connection was driven by my empathy for the tree I embodied and the forest life around me. Through stories like *Tree*, researchers have documented the impact the VR experiences had on participants. In the next section, I will discuss how stories like *Tree* can affect the memories of students and their retention of the content.

Memories

There are several other stories in VR like *Tree.* They draw the viewers in and show them what other people, places, and things experience. VR storytelling triggers an embodied experience in an unchangeable narrative that allows queries of the environment without altering an individual's story trajectory (Shin, 2018). In education, the draw to historical people, places, and things can help enable different emotions through engagement with the content. Like all great stories, the more the viewer feels a part of the story, the more their emotions are engaged (Song et al., 2021). If a lesson can get a student to embody a famous person and have them internalize their struggles and their thoughts, they can develop empathy for their decisions and their viewpoint.

As with embodying different avatars, the effect of embodiment of different historical figures could change how people perceive and learn from moments in time. VR storytelling does not merely make users feel, it also changes who they are in the virtual space. Fully immersive VR can offer users a sense of embodiment, through which they see themselves as part of the VR environment (Shin, 2018). Education can bring those emotions and experiences into the XR world and enable students to feel how their words and actions can help them understand themselves, others, and the world around them.

For instance, imagine being in a VR experience, walking around the Oval Office as John F. Kennedy during the Cuban Missile Crisis. The user would have to weigh options while aides are giving information about events as they unfold. Imagine having the ability to sit in the crowd as Martin Luther King Jr. gives his "I Have a Dream" speech in Washington D.C. To feel the energy and undercurrent of excited voices in the crowd and the feelings of hope building all around. These experiences can change how students understand history. Will these scenarios be believable if they are cartoonish or not life-like? In the next section, I will discuss how realistic environments and avatars can increase learning from stories like these in XR experiences.

Introducing Realism to XR

As humans are very sensitive to viewing facial expressions, and it is very difficult to represent all the fine details of facial movements in an avatar, the use of photogrammetry and volumetric capturing have been used when creating realistic avatars (Hillsmann et al., 2020). This is important because until 5-10 years ago, XR content designers could make something look realistic in XR but was very difficult to replicate the mannerisms of that thing. With the advancement of photogrammetry and volumetric capturing technology, developers can now capture the realism of the avatar or object along with all the details that are missed in the modeling process.

Photography and video capturing have been utilized for avatar and model creation for years, to either help act as a template for a 3D object or capture motion itself. The American Society for Photogrammetry and Remote Sensing defines the term photogrammetry broadly as "the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena" (American Society for Photogrammetry

and Remote Sensing, 2019). Volumetric capturing is the addition of motion into the capture of physical objects. In simple terms, they are both the recording of light, whether it is still or in motion. Again, this is important because this technology will facilitate becoming a content creator with XR (Wallgrün et al., 2019).

Recently, with the increase of capturing technology, avatars started taking on more humanistic features and believability. By using photogrammetry and volumetric capturing, creators could avoid deviations that caused the designers to manually edit the features of the avatar. With countless measurements in the process, a much higher level of detail could also be achieved without a costly investment of work hours and hiring teams of animators (Wallgrün et al., 2019).

I believe the adoption of these new technologies will be crucial for XR content creation in education. The use of this photogrammetry and volumetric capturing technology can be used for more than just avatars, it can also be used to capture objects and spaces. This technology helps enhance the best part of XR, which is the ability to go anywhere. Photogrammetry and volumetric capturing can be done almost anywhere. For example, visual data can be gathered from underwater, on tops of mountains, to distant planets, most recently Mars. Almost every type of object or place can be created and subsequentially preserved and used to educate future generations (Gardner, 2021). In the next section, I will discuss the effect realistic environments and avatars as facilitators can have on participants. I want to discuss this because realism in XR can facilitate direct relationships to real-world content.

Realistic Engagement in Educational XR

With the recent development of accessible photogrammetry devices and software over the last 5-10 years through cameras that capture objects through point clouds and mobile phones that

use LiDAR, it has been easier and easier for developers to create realistic interactions for users. For photogrammetry, devices can capture realistic objects and render them as 3D models that can be placed in an XR platform such as A-Frame or Unreal engine. I want to highlight these technologies because the presence of realistic and visually credible social entities can thus unfold positive effects on learning, satisfaction, and engagement in online learning environments.

There are instances in which knowledge should be simplified to allow learners to grasp the essential information. There are several scenarios in which a high level of realism is advantageous for learning (Bergin et al., 2003). A great example of how simple is effective is Microsoft's Minecraft game. People love playing the game because of its simple design and throw-back 8-bit look. Everything in Minecraft is pixelated and has a block design. Several universities during the pandemic recreated parts of their campus in Minecraft and students enjoyed interacting with it through 2D monitors and VR (Supraja et al., 2022). To cite another example, Minocha & Reeves (2013) research asked, 'How should 3D learning spaces be designed for student engagement?' In their study, they looked at how students interacted with another 3D world called Second Life. The avatars and space in Second Life were not blocks like Minecraft and they were not hyper-realistic. In their study they found that for some of their participants, there was a clear link between the level of visual realism and the effect on learning. I have experienced lab simulations for chemical reactions and bond identification that were simplified images with little detail. If a student can interact with a photorealistic representation of the anatomical part, their analysis and transferable learning from digital to real will increase (Koh et al., 2023). In the next section, I will discuss how use of realistic avatars as facilitators could affect learning in XR experiences.

Realism in Avatars

Over the years, digital avatars have taken on many shapes and styles in games and interactive media. There has been an intensive effort to create digital avatars to mimic human movements and non-verbal cues. I want to highlight these new technologies in this chapter because, with the release of Quixel's Metahumans, they have come extremely close to achieving that goal. Metahumans utilize human facial movements by using motion tracking software from an application on a person's mobile phone camera. The controls and pre-visualization are controlled via Unreal Engine's real-time rendering software and allow the users to customize and mimic their facial cues.

Studios, and some schools, utilize motion capture technologies that can create a "skeleton" frame that can be attached to an avatar and give the illusion of movement. When animation of virtual humans is required, usually computer graphics models are used. They allow for arbitrary animation, with body motion usually being controlled by an underlying skeleton while facial expressions are described by a set of preset motions. The advantage of full motion control comes at the price of significant modeling effort and sometimes limited realism (Hilsman et al., 2020). The motion capture process that studios have traditionally utilized for avatars is time-consuming and cannot represent all detailed motions of an actor, especially facial expressions, and the motion of clothes (Schreer et al., 2019).

In several studies, they have found that cartoon-like characters are more effective than photorealistic representations in educational VR games (Parong & Mayer, 2018). Even for VR social platforms, content designers have resisted creating avatars and characters that are "too real," because of fear of the uncanny valley. I will elaborate on the uncanny valley later in the manuscript. As stated earlier, the less conflicting the image, the lower cognitive load there will

be on the student. With the immersion of photogrammetry and volumetric capturing, the load on students should decrease due to the realistic illusion of "being there" (Marougkas et al., 2024).

Recently, several studies looked at how students learned and interacted with different avatars and tried to push the boundaries of realism with avatars that appeared human. In just about every study, researchers noticed the students felt eerie about the realistic avatar and its interactions. They also found that students felt like they were present in the experience but were distracted by the overt realism (Jensen & Konradsen, 2018).

The research is starting to change as the avatar's realism changes through better technology and volumetric capturing software. Several researchers have found that photorealistic avatars can also improve the learning process, among other things, given the attractiveness of the visual stimuli (Weidner et al., 2023). The context implies that deeper understanding processes in multimedia learning occur when cues direct the learners' attention to relevant information or highlight the organizational structure of the core content (Mayer & Fiorella, 2014). That is, the more focused the content is to the learner, the more the learner will be able to be able to analyze and remember. The realism will only enhance the information and not distract from it. The technology is advanced enough that there are minimal differences in what is real and what is computer-generated. The interactions students have had growing up with video games and new media have decreased the cognitive load on the learner when they interact in photorealistic environments and volumetrically captured avatars. More studies are needed on immersive photorealistic environments and avatars, but the mindset and adaption of the technology are changing, and the cognitive load is decreasing as the users are exposed to more and more realistic content (Korte, 2020). Integrating realistic avatars and assets into XR experience can

also create an uneasiness in the participant. In the next section I will discuss the effect of the uncanny valley with realistic avatars and assets in XR experiences.

Uncanny Valley

In many virtual environments, the avatar that the student is interacting with could even be a pre-programmed character, like that of a game avatar. This can increase the feeling of presence for the user, but it may also cause people to react with increased caution if a virtual creation starts to resemble or replicate the prowess of a human. This is important because it can cause participants to not trust the VR space. This distrust is due to the student trying to understand if they are talking to a real human or a computer program. In one study, students preferred human-like replicas to be limited to a certain set of characteristics and did not appreciate it when they behaved in an empathic or social manner (Stein & Ohler, 2017). In another study, Gray and Wegner (2012), found that digital avatars bereft of any emotions were also rated as eerie. This study hinting at the possible uncanniness of emotional experience from the opposite side of the man-machine continuum (Gray & Wegner, 2012). They found it was an eerie sensation coming from “doubts about the animation or non-animation of things” (Stein & Ohler, 2017). In computer animation, the uncanny is identified with inadequately life-like human features, for example ‘dead eyes.’ ‘Dead eyes’ are where everything on the character’s face moves realistically, but the eyes do not move at all.

Japanese robotics engineer Masahiro Mori (1970) developed Uncanny Valley Theory. Uncanny Valley happens when human-like replicas approach a high level of realism while still featuring subtle imperfections (Stein & Ohler, 2017). Mori discussed how there is a level of realism that humans can understand and adjust to. When the robot or digital animation crosses over to the illusion of being human, there is a dip in the mental capacity of the viewer to

comprehend. The doubt that is instilled as to whether the entity is real or robotic is the valley part of uncanny valley. On the other side of that valley is the acceptance of that robot or animation as real. The uncanny valley hypothesis predicts a negative emotional appraisal of human replicas that appear or behave not quite human (MacDorman & Chattopadhyay, 2017). Humans use a combination of perceptual cues and former experiences to categorize a subject (e.g., as "human" or "robot") so that they can efficiently anticipate its' behavior. Once they encounter an entity that violates their expectations, however, observers are likely to experience cognitive dissonance, which then manifests emotionally as uneasiness, disgust, or fear (Stein & Ohler, 2017).

Against the background of unstoppable technological progress, any effort to explore an uncanny valley of mind will hold great value, as it supports the harmonious co-existence of humans and their machinery in the long run (Stein & Ohler, 2017). In parallel to the uncanny valley theory is the realism inconsistency theory. The realism inconsistency theory predicts that features at inconsistent levels of realism in an anthropomorphic entity cause perceptual processes in viewers to make conflicting inferences regarding whether the entity is real. Like the uncanny valley, the realism inconsistency theory predicts viewers will experience cold eerie feelings when perceiving animated avatars that have features at different levels of realism (MacDorman & Chattopadhyay, 2017). The level of cognitive load on students to perceive if an avatar is real or not can be a distraction from the information being presented. This is important because if the student's focus is on the avatar, they are not engaging with the content in the space. In the next section I will discuss the possible negatives of using realistic environments and avatars in XR experiences.

Drawbacks of Realism in XR

There is concern about VR environments that are too realistic. Several studies on cognitive load have stated that the introduction of realistic assets or images induce cognitive overload and may interfere with the learning process (Nebel et al., 2020). In contrast, several studies show that physically attractive stimuli in environments and avatars have had a positive effect on the learners' emotional response and learning performance (Segaran et al., 2021). The presence of realistic and visually credible social entities can have positive effects on learning, satisfaction, and engagement in learning. Social cues in instructional media environments (e.g., a photorealistic pedagogical facilitator) prime a social activation schema in the same way that the social processes of human-to-human communication trigger (Perez et al., 2023). In Oh et al. (2016), it was shown that the more facial expressions the avatar had, the more of a connection was created with the user and cognitive load was reduced. Users felt more comfortable and at ease with the realistic model facilitating what needed to be done in the experience. Realism in XR has the capability to change how participants learn in the space, in the next section, I will discuss how integrating accessibility into XR can make learning inclusive.

Accessibility in XR Spaces

In the summer of 2018, I had the privilege of joining other XR specialists, developers, innovators, and educators to talk about XR in higher education at the EDUCAUSE/HP XR Summit at Yale University. One of the guest speakers, Emory Craig, posed the question; "How do we guarantee that a student in a virtual experience can be safely brought back to the real world in a crisis? Imagine a student that is deaf or has limited hearing abilities in a VR experience and fire alarms are going off, how do they know they are in danger?" He continued and asked, "how do we, as developers and educators, make XR accessible to all?" I hadn't

thought of these issues. These questions made me rethink my concepts of this space. I had a responsibility to make the experiences accessible to all from the start. Educators must do better in addressing these issues. Several companies are integrating accessible solutions into their platforms or making accessible add-ons that can be incorporated into already existing experiences.

The group A11Y Project (the 11 stands for the 11 letters in accessibility) or Ally, is a community-driven effort to make digital accessibility easier. The A11Y Project (2021) helps developers come together and test the accessibility of their experiences and offers solutions via suggestions or software solutions. Brian Tice, a software engineer for VR, lead the design and development of utilizing hand gestures for the HoloLens that are integrated with non-verbal communication such as ASL.

Social VR platforms like FrameVR, are integrating speech-to-text bubbles over the avatars and text streams on the screen to help with closed captioning. For visually impaired users, different XR experiences are being created that utilize spatial audio that allows the user to move within a space accordingly with the use of 360-degree volume levels. In spatial audio, as the user moves closer to a sound, it becomes louder, the reverse for when they move away from the source of the sound. For several platforms, the microphones in the headsets are being programmed to recognize high-pitch frequencies that notify users with hearing disabilities that a fire alarm is going off in the real world. When it comes to being fully accessible, the XR community knows it has not reached its capacity. Movement in VR spaces is another issue that is discussed as an ability that needs to improve. In the next section I will discuss how motion sickness has affected VR participants.

VR Sickness

The biggest obstacle over the years for the use of virtual reality for many people is the motion sickness or "ghost" feeling they have gotten from movement in an experience. The reason they feel this way in some experiences is that they move in virtual reality but not in real life. This creates an "out of body" sensation or ghost feeling of floating in space. In many cases, motion sickness can also come from the user turning their head quickly and the VR headset display cannot keep up with the motion. This lag in the images for the user's view causes the user to get disoriented. Both movements can be very unnerving for people. In the HMD, the screen is close enough to the user's face, that their eyes are crossed. This can cause headaches during long-duration exposure and use. Companies like HTC and Oculus/Meta have printed on the side of their HMD product boxes that children younger than 13 should not use their devices due to it possibly causing permanent damage to their eyesight. Jeremy Bailenson, from Stanford's Virtual Mind Lab, suggests that users only spend approximately 20 minutes in VR experiences because of the stress on the user's eyes and cognitive load (Bailenson, 2018). He asks the users to "reset" by looking out the window or going outside before going back into the experience. AR and MR have an easier task with their motion sickness due to the vision through the AR or MR devices incorporating the real world by overlaying the digital objects over it.

In the next section, I will talk about my theoretical approaches for my research. With the access and ease of new technologies, educators could create experiences just as easily as they have for 2D images and videos. As I stated earlier in the chapter, the attraction to XR in education is the addition of immersion, emotions, and realism in the experience. The theories of multimedia learning and cognitive load need to be further explored with these new technologies

to see how users are learning in VR. In the next section, I will discuss how Multimedia Learning Theory and Cognitive Load Theory guided my research thinking about my research questions.

Theoretical Approach

According to Dunleavy et al. (2009), AR's most significant advantage is its "unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem-solving, and communicating interdependent collaborative exercises" (Akçayir & Akçayir, 2017). In one study by Chiang et al. (2014), the researchers concluded that the Mobile AR approach to XR integration can improve students' learning performance. They suggested that Mayer's (2002) spatial and continuity principles from multimedia learning theory explain their results (Akçayir & Akçayir, 2017).

The principle known as the multimedia principle states that "people learn more deeply from words and pictures than from words alone" (Mayer, 1997, p. 2). In AR, when the experience adds spatial and continuity principles, for many students, this increases their engagement and decreases their cognitive load due to them being able to envision the scenario and interact with it. AR has been said to be useful for visually supporting students, and for enabling their visualization of intangible concepts. An example is the ability to visualize abstract concepts or unobservable phenomena, such as electron movements or magnetic fields (Akçayir & Akçayir, 2017). The ability to enlarge objects or metaphorically "shrink" users to be able to see microscopic information at a larger scale helps students visualize and understand how systems work on the micro-scale. Brucker et al. (2014) found that learners with lower visual-spatial abilities achieved better recognition performance in schematic visualizations (2D charts, maps, drawings, etc), while learners with higher visual-spatial abilities achieved better

performance in realistic visualizations (Nebel et al., 2020). Several AR applications have been developed in the last few years showing positive effects in supporting learning, such as increased-on content understanding and memory, preservation, as well as on learning motivations (Cipresso et al., 2018). One study found that content learned through AR experiences is memorized better than through non-AR experiences (Gudoniene & Rutkauskiene, 2019).

This study looks at how learning is understood in VR and these two theoretical approaches helped guide this study. As I stated, the Multimedia Learning Theory and Cognitive Load Theory created a layered approach to looking at how educators understood learning in VR. In the next sections I will explain each.

Multimedia Learning Theory

According to Mayer (1997), multimedia learning occurs when a learner builds a mental representation from words and pictures that have been presented. This definition is broad enough to include book-based environments consisting of text and illustrations, computer-based environments consisting of narration and animation, and virtual game environments consisting of interactive speech and animated microworlds. Technically, VR is considered a game environment, but it was not what Mayer was referring to. With the addition of immersion into virtual environments through VR, does this theory still apply? Do students learn better using 3D assets that are interactive and immersed within VR? Does this increase their learning, or does it overload their cognitive capacities?

Guo et al. (2019), discussed how students have become accustomed to multimedia teaching, especially the students of digital media, while their non-cognitive ability is declining. The implications of this research mean that students require the continuous use of new stimuli to

stimulate and maintain students' learning motivation, promote students' engagement, and improve cognitive ability. In their study, they looked at how to integrate the subject content and learning process into the planning and design of virtual museums to assist in teaching (Guo et al., 2019). Their research found that the use of virtual museums in classroom teaching plays a role in two aspects. The first aspect was the improvement of learning motivation and knowledge construction in the learning process. This promotes students' participation and improves their non-cognitive ability. Second, the application of the learning task lists under the guidance of multimedia teaching information design principles in virtual museums is a new form of teaching design. This is beneficial to students' learning in guiding attention, organizing, and integrating information (Guo, et al. 2019). With the use of virtual spaces for students, they can now design and create their own stories for others to see and learn from. This is also the reason why multimedia learning researchers have changed their attention from the organization and presentation of verbal and visual information to the knowledge base, learning motivation, and learning style (Guo et al., 2019).

Ainley (2006), discussed how situational interest can be triggered through attention to the way learning is presented. Presenting new learning tasks in novel ways such as using new computer technologies triggers immediate student interest. Having triggered interest, the problem then is to maintain the interaction and build on the information-seeking aspects of interest. Many critics of the inclusion of educational technology state that once the novelty of the technology wears away, the interest of the students disappears with it. If the story is compelling and enables the students to action, the use of the technology becomes crucial to increasing their interest. Ainley (2006), discussed how triggering interest activates a system that generates positive feelings, and focuses attention on the object that has triggered interest. For example, the research

noted that a student noticed images of destruction from a recent earthquake in a magazine. Interest is triggered, which means the student feels enlivened as they are attracted to pick up the magazine. A connection has been established between them and the information source (Ainley, 2006). With the immersive elements of XR, it is possible that the interest be triggered and interacted with at a much higher level than just a magazine. The ability for students to be immersed in the information increases their feelings and their curiosity about the story.

Um et al. (2012), investigated whether multimedia learning environments can be designed to induce positive emotions in learners. They also analyzed at whether these positive emotions enhanced comprehension of the content of the multimedia materials. They then analyzed if both facilitate the construction of mental models that allow for the transfer of the new knowledge to different situations. The cognitive theory of multi-media learning describes, based on the dual channel assumption of dual coding theory (Paivio, 1986), how multimedia information is processed in separate channels for verbal and visual information (Mayer, 1997). Their findings showed that emotions induced through a positive emotional design resulted in a lower reported task difficulty (Um et al., 2012). This shows the possibility that a positively designed immersive XR space could reduce stress in the students and allow them to understand the material easier.

In another study by Heidig et al. (2015), the researchers discussed how emotional factors have been neglected in multimedia learning research. In their study, they looked at how emotional design in multimedia learning can evoke positive emotions and therefore facilitate learning. In the context of multimedia learning, Um et al. (2012) showed that applying emotional design principles to multimedia learning materials can induce positive emotions. In addition,

positive emotions facilitated cognitive processes and learning. Their study provided further evidence that emotional states can facilitate complex learning processes (Heidig et al., 2015).

I want to engage in Multimedia Learning Theory because it addresses several factors that affect learning with media that are transferable to XR. To successfully engage students with media, there needs to be a connection to the story, engagement, emotional ties, and space. I believe XR technologies excel in each of those areas compared to traditional media. In the next section, I will define Cognitive Load Theory and how it can influence learning in VR.

Cognitive Load Theory

Cognitive Load Theory (CLT) (Chandler & Sweller, 1991) is one of the fundamental theories used to analyze mental effort and predict the learning effectiveness with new technologies (Sweller, 2010). Cognitive load is the amount of cognitive processing a person incurs to find information. It is the cost of a cognitive task (Huang et al., 2020). Cognitive load is considered in three parts: (1) the intrinsic load derived from the learning task itself, (2) the extraneous load caused by the learning situation and the way the learning is presented, and (3) the germane load of the learning process (Anderson et al., 2018). The main goal of cognitive load theory is to optimize learning of complex tasks by efficiently using the relation between limited working memory and unlimited long-term memory (Paas & Ayres, 2014).

Fredrickson et al. (2020), discovered that as the complexity of the scenarios in immersive VR increases, so does the risk of cognitive overload. To minimize this, different instructional design strategies to lower cognitive load need to be explored. Designing VR experiences that do not overtax the user's cognitive abilities becomes a crucial part of how instructional design in VR is constructed. Reducing intrinsic and extraneous cognitive load promotes learning and skills acquisition. This has recently been corroborated by a large meta-analysis, based on a broad range

of studies on education and learning in which a lower cognitive load was found to improve retention and transfer of multimedia learning (Anderson et al., 2018).

Cognitive load is the key to changing the relationship between the sense of presence and learning outcomes (Huang et al., 2020). The cognitive load theory of multimedia learning (Mayer, 1997) and cognitive load theory (Sweller et al., 2011) suggest that XR can foster generative processing by providing a more realistic experience (Slater & Wilber, 1997). The cognitive processes by which users experience quality, presence, and flow determine how they will empathize with and embody XR stories or lessons (Shin, 2018) The cognitive benefits in different experiences are described as improved understanding and application as well as a positive perception of the learned material (Makransky & Lilleholt, 2018).

Virtual Reality learning could be designed to include multiple learning methods, so learners can choose to engage with the learning materials in the manner that interests them, as students prefer multiple modes of information presentation (Allcoat & von Mühlenen, 2018). This method would help with student's cognitive load while learning and create a "building block" model of learning that would increase the difficulty of the subject as students interacted with the environment or lessons. For example, in one study, students learned how to perform laparoscopic surgery utilizing VR to practice the surgery throughout the semester (Frederiksen et al., 2020). As the students became comfortable with the procedure of the surgery, they would add additional components to the VR scene to simulate the surgery room such as monitors and other devices. As they performed more virtual surgeries, more "distractions" were added to help them practice staying focused and maintaining their cognitive load at a level that helped increase learning but did not take away from the procedure. The study found the students were able to

successfully transfer their experience in the VR experience at the end of the semester to a real surgery (Frederiksen et al., 2020).

Mayer (1997) cognitive load theory of multimedia learning and Sweller et al. (2011), cognitive load theory suggests that XR could foster generative processing by providing a more realistic experience (Slater & Wilber, 1997). However, they also suggest that any material that is not related to the instructional goal should be eliminated to minimize extraneous processing (Moreno & Mayer, 2002). Cognitive Learning Theory holds that our limited working memory capacity requires learning materials to be designed in a manner that leaves as much memory capacity as possible reserved for the actual learning contents (Skulmowski et al., 2016).

In the following chapter, I will discuss how cognitive load theory and multimedia learning theory guided the methodology used for this dissertation study.

Chapter 3

Qualitative Methodology

My research question asks: How do educators make sense of learning in VR? I believed qualitative methodology afforded me a means to explore the perspectives of the educators. Quantitative methodology was not an option because it did not provide a means to explore the participant's perspectives around XR, at a deeper level.

Qualitative methodology is an iterative process. Qualitative methodology involves generating questions and procedures, data typically collected in the participant's setting, data analysis that inductively builds from particulars to general themes, and the researcher making interpretations of the data (Creswell & Creswell, 2017). I believed that through qualitative methodology, I would be able to gain more insight from the educators and get their experiences on VR.

Many qualitative researchers utilize grounded theory. Grounded theory is one of the most popular data analysis theories for qualitative research. It lets researchers discover, generate ideas, and explanations from the data (Hussein & Nätterdal, 2015). Grounded theory is used to delve deeper into an experience by identifying the key elements of that experience. The researcher can then categorize the relationships of the experiences to the context and process of the study. I believe this data analysis theory is important in XR research because it helps allow the research to tie together concepts and identify common themes. More importantly, I get to use the language, concepts, and perspectives of the participant's experiences.

In the following sections, I will first explain the qualitative methods I used in this study, as well as a description of the participants.

Qualitative Method

Bogdan & Biklen (1997) state that interviews allow a researcher to gather descriptive data in a participant's own words that show how they interpret their world. Thus, interviews were instrumental for me in my research methods. For this study, I utilized semi-structured interviews. No interview can be considered unstructured; however, some are relatively unstructured and are equivalent to guided conversations (DiCicco-Bloom, & Crabtree, 2006). I chose the semi-structured interview method because it allows for more of a back-and-forth conversation between the interviewer and interviewee. This was important to me as a qualitative researcher because I wanted the educators to discuss their thoughts and feelings about XR freely. Additionally, this method enables the interviewer to adjust their follow-up questions based on the answers that the participant gives (Pedersen et al., 2016). I wanted the educators to be comfortable discussing their experiences and have a conversation about their experience and exploration in XR. I conducted three interviews: (1) a pre-interview, (2) a think-aloud interview, and (3) a post-interview. I will elaborate on these later in my data collection section.

In the section below, I will discuss the selection of educators for this study along with an overview of their backgrounds.

Participant Selection

For this study, I recruited 13 educators who were professors or instructional support at five different universities. They all utilized XR in their classroom and/or in their research. The educators represented five different universities. To recruit the participants, I used an XR community of practice, which is a community of educators that meets monthly to showcase XR research and teaching. Through "snowballing," several of the original participants helped recruit educators for this study who worked with XR (Streeton et al., 2004). I was able to recruit eight

female educators and 5 male educators to participate in the study (See graphic in Appendix 1). Their disciplinary backgrounds ranged from communications, art history, pediatric XR, therapy, architecture, design, instructional design, and XR research.

As a requirement, each of the participants had to utilize XR in their educational research, teaching, or instructional support. The reason I wanted educators who had experience with XR technology was because I wanted to hear their perspectives on what was working well in XR as well as how they integrated the technology into the classroom. It was imperative to hear their ideas on the experiences they have encountered with XR in their educational settings over the years. These educators are known as subject matter experts in XR for higher education.

Description of Participants

The group of educators came from five different universities and colleges. The group consisted of members of their universities' schools of pediatrics, public communications, architecture, education, and human dynamics. Each of the universities and colleges are in the northeast region of the United States. I mention some of their disciplines because there was a diverse set of experiences and examples the educators gave of their VR experiences.

The thirteen participants identified as eight females and five males. The educator's ages ranged from mid-20s to late 50s. Almost all the educators identified racially as Caucasian with one identifying as Middle Eastern, and one as Pacific Islander. The educational backgrounds of the participants included different master's degrees and three participants with Ph.Ds. (See the full participant list in Appendix 1)

Pilot Study

I conducted a pilot study before engaging in this doctoral research. I conducted the pilot study because I wanted to establish an understanding of how educators in higher education

interacted with XR and used it in their teaching and research. The interviews were conducted in February and March of 2022 at a local university. I was able to interview five educators that worked at the same university but in different colleges.

From those interviews, I was able to collect data that built a foundation of understanding how educators in higher education made sense of XR. From this study, I constructed several themes: (1) Presence in VR, (2) Future of XR, and (3) XR design.

These three themes foregrounded some of the themes in this dissertation project. I say this because I used several of the codes and categories from the pilot study interviews in the dissertation study. Interviewing people from the same university helped me realize that they had similar experiences in VR because of their shared history on campus. For example, four of the five participants talked about a VR experience they participated in that was at the same event they attended. This prompted me to expand the participant pool to a wider geographical area and include more participants from a variety of schools in the northeast area, for the dissertation study.

Additionally, the feedback from the pilot study about the VR experience also guided me to creating a more robust experience. For example, in the pilot study VR experience, there were no virtual hands connected to the controllers. When the participants had their hands out in front, there was no virtual representation of this. I noticed a disjointed effect because of this. For the doctoral research VR experience, I added digital hands to the experience that were tracked to the controller. This addition allowed the educators to better understand their distance from objects in the experience by sticking their hands out in front of them. I could also see what the educators were pointing at in the space instead of them trying to describe it to me.

Another change that I made was correcting the patterns of the fish in the experience. In the pilot study, the fish swimming just beyond the reef tended to "sync." The longer the educators stayed in the experience, more of the fish would swim in the same direction at the same time. This caused an uncanny feeling in the educators. I will discuss this concept of "uncanny" later in the manuscript. I corrected this swimming action for the fish in the dissertation study.

The pilot study analysis informed me of possible themes that I could discover in the doctoral study. As I went through the analysis for the pilot study, there were consistent concepts that were identified early in the analysis. I was able to construct three themes that summarized the feedback from the original five participants. Those three were: (1) Design of XR, (2) Presence in XR, and (3) Future of XR.

When analyzing my notes from the pilot study with the dissertation study, the perspectives from the educators in the dissertation study supported two of the themes from the pilot study. I will elaborate on the data analysis for this dissertation later in this chapter. In the following section, I will discuss the data collection during the semi-structured pre- and post-interviews and the think-aloud during the VR experience for the dissertation study.

Data Collection

The data collection for this dissertation study was an addition to the pilot study and was conducted in June 2023 over two days at a hotel conference room. The rest of the sessions were conducted in July 2023 at an off-sight location.

Each interview was conducted individually with the educators over an hour and a half for each session. The data collection proceeded in this order for all 13 participants: (1) pre-interview,

(2) VR experience (think-aloud), and (3) post-interview. In total, I conducted 39 sessions, 13 pre-interviews, 13 think-aloud, and 13 post-interviews.

Pre-Interview

For the doctoral study, the educators participated in an introductory interview to establish their background knowledge of XR and to discuss how they used the technologies. I asked questions to help discover how they perceived XR technologies, particularly VR, and its uses in education. I asked questions such as: (1) What was their first VR experience? (2) What did they like most about their favorite XR experience, and what made it engaging? (3) What are the advantages of XR for education? (See the pre-interview protocol sheet in Appendix 2)

From the original series of questions, I asked several follow-up questions to clarify their answers. Several of the participants elaborated on their answers and gave insightful responses. All the educators spoke passionately about their experiences with XR. They were all able to explain the rationale for their answers and were excited to talk about their favorite XR interaction. Even though I recorded the entire interview, I took notes on some of their answers that were important to me. I did this because I wanted to highlight comments and phrases that impacted me at that moment so I could look at the video and transcripts later to better understand why.

Some of the ideas that I generated from these pre-interviews were: (1) AR technologies are ingrained in everyday life, to the point where most people do not notice its use, (2) higher education needs to do a better job of addressing accessibility in XR, and (3) haptic feedback is a powerful tool for creating presence in VR. In the next section, I will discuss the design of the VR experience and the technologies used to create it. In addition, I will talk about the data collected during the experience using the think-aloud method.

Virtual Reality Experience

After the pre-interview, the educators were immersed in a virtual reality coral reef experience that I created in Unreal Engine 4.27. The coral reef experience was based on images from the Florida Keys around the 1980s. The participants were able to move freely through the space and explore the coral and life in the reef area. As they were exploring, they were encouraged to think-aloud about what they saw and ask questions. After putting them in a digital holding space, they were brought into another coral reef experience representing images from reefs in the Florida Keys around 2020. They repeated the same process of walking around and exploring while continuing the think-aloud and asking questions about the reef.

During the VR simulation, the participants were able to discuss what they were observing, thoughts they were having, and feelings about the space. As they were speaking, I was asking questions and recording their responses. I collected this data using think-aloud methods (Eccles & Arsal, 2017). Charters (2003), defines "think-aloud" as where participants, while completing a task, can speak aloud any thoughts or words in their mind. This method allowed me to ask the participants questions as they explored the VR experience. Collecting their experiences within the VR experiences was important here because it gave me insight into how they perceived the VR experience and interacted with the virtual space.

Both reef experiences were digitally designed to fit within a 12-foot by 10-foot space to help the educators stay within the boundaries of the physical room of the VR experience. The digital coral rocks in the experience created a digital barrier. This digital barrier allowed me to turn off the digit boundary barrier that is built into VR experiences. Traditionally, this boundary barrier appears as a blue digital wall in the experience. When the participant gets too close to a barrier in the real world, such as a wall or chair, the software will show the boundary barrier. I

felt this digital barrier would be a distraction to the educators and I turned this feature off. As the educators moved through the coral reef, I was constantly monitoring their movement in the virtual space and real space to make sure they did not run into anything. I felt this design would allow the educators to feel more present in the space and freely move around. From watching the videos of the participant's movements, I noticed: (1) the educators initially moved in tight circles in the room/experience, and (2) once the educators discovered they had six degrees of freedom to move, they would reach down to touch the sand on the ground and lean into the coral to inspect closer.

After putting on the head-mounted display (HMD), the educators started the VR coral reef experience standing on the ocean floor without having to submerge through the top of the ocean like they would have in real life. In most VR experiences that have a large space, the experience is designed for the participant to be able to teleport from spot to spot. What that means is they can use their controllers to point and essentially jump to that spot. In this experience, the educators were able to move around the reef with six degrees of freedom. They could physically crouch down, jump up, and move all around without the use of teleportation. I designed this to eliminate the disjointed feeling that many VR users talk about when using that function.

There was an added layer of audio that sounded like scuba tank breathing and water noises you would hear while scuba diving in real life. In the reef experience, there was a mix of photorealistic 3D assets from the Smithsonian and digitally created assets from Unreal Engine's marketplace or created in Blender. The educators would transition from the 1980 reef to the 2020 reef experience and be able to witness the changes in the reef from the two interactions. I wanted

this experience to have two separate time periods to show the changes to the reef over the last 40 years.

For the virtual reality experience, the participants used the HP Reverb G2 Omnicept SDK (software development kit) HMD tied to the HP tower. The long cable on the HMD allowed the educators to move freely in the space without fear of pulling on the cable. The Reverb G2 Omnicept HMD was designed to measure heart rate, eye tracking, facial tracking, and cognitive load bio-analytics in the device itself. With the HP Reverb G2 Omnicept SDK headset paired with the experience designed in Unreal Engine, I was able to record real-time biometric feedback of the educator's heart rates while they were in the experience along with their cognitive load.

Through observing the feed from the headset during the experience, I was able to view how the educators were learning from the experience through the cognitive load measurement. In addition, I was able to monitor if there were any stressors from the experience itself through the heart rate monitor. This feedback helped shape and guide follow-up questions for the post-interview (Siegel et al., 2021). However, I decided not to use this quantitative data for the dissertation study because I wanted to utilize it in real time to better understand the educators qualitative experiences.

During the think-aloud, I encouraged the participants to talk about what they were seeing and what they thought of the coral reef. The educators were given time to explore and discuss the experience as they moved around the VR experience. I asked the participants several guiding questions such as: (1) What do you know about coral reef life? (2) What could they identify in the reef? and (3) What changes stood out to them the most from the first reef to the second?

Some of the initial data I noticed during the VR experience were: (1) the educators tried to reach into the seaweed to move it or use their hand to stir the sand; (2) all of the educators

were able to correlate fish in the first experience to fish they had seen in *Finding Nemo*; and (3) the educators expressed a range of emotions when they experienced the changed reef from 2020. Once the educators were done exploring the coral reefs in VR, I conducted the post-interview.

Post-Interview

After the VR experience, I interviewed all the educators in a post-interview. I followed the same process as the pre-interview with note taking or comments and observations. I used a second questionnaire protocol (See the post-interview protocol sheet in Appendix 3). The educators answered questions such as (1) What was their impression of the experience? (2) What did they learn? (3) What do they feel the future of XR in education will be? Like the pre-interviews, I asked follow-up questions and gave them the opportunity to elaborate on their answers. I finished the post-interviews by asking them to add any additional thoughts they had or return to any questions they wanted to go back to. I concluded the session by encouraging them to contact me if they had anything they wanted to add later. Some of my notes from the post-interviews included: (1) the design of the experience was immersive but needed to be more interactive, (2) the importance of stories in XR, and (3) the pandemic introduced educators to the use of social VR in education.

After each of the interviews, I would highlight the responses in my notes that were important. I would then write a memo of possible quotes that were relevant to me. I would look for these quotes later in the transcript. I also added notes after watching parts of the VR experience. I did this because I wanted to explore and compare what was said during the think-aloud to their actions in the VR experience. With the data collected and highlighted, I started to analyze the data and develop the themes for this dissertation. In the following chapter, I will discuss my data analysis process.

Data Analysis

Bogdan & Biklen (1997, p. 7), stated "that the process of data analysis is like a funnel: things are open at the beginning (or top) and more directed and specific at the bottom." The pre-interview and post-experience interviews were audio and video recorded and transcribed to help identify the topics and themes. The educators were also video recorded in the room walking around during the VR experience. The perspectives of the educators in the HMD were recorded while they were in the experience to help me observe what they saw and their interactions with the VR technology. The screen recording also captured a live feed of their cognitive load and heart rate feedback from the HP Reverb G2 Omnicept SDK HMD. As the interviews were occurring, notes were taken to highlight thoughts or responses from the educators that stuck out during the session. All the data was viewed in real-time and video replay to help construct the themes. In the sections to follow, I am going to discuss how I coded the data as well as constructed the themes.

Coding

After the interviews, I edited the video recordings to produce a complete re-creation of the session. In the recording, I created a split screen of the participants in the VR experience and the screen from the participant's HMD. I then exported the full video with audio and then separated the audio track into another file. The audio file was uploaded to Otter.ai and it produced a transcript of each of the sessions. Sutton & Austin (2015, p. 228) described transcribing as "an arduous process, even for the most experienced transcribers, but it must be done to convert the spoken word to the written word to facilitate analysis." Even though the original transcript was done by Otter.ai, I went through all the transcripts and manually synced them with the video file to check for discrepancies between what was said in the video and what

was produced by Otter.ai in the transcripts. The notes I took during the interviews were then added to the transcripts to add any details that I may have missed.

I read all the transcripts, looking for key words, phrases, thoughts, or ideas. These would be my initial codes. Then, I took the transcripts and created a word cloud to discover the key words from all the interviews. Next, I analyzed the video and audio transcripts to create codes. The different codes covered a variety of quotes, from the interview responses to the conversations in the VR experience. From the quotes, notes, and the word cloud, I was able to create 43 different codes. For example: (1) training in medical fields, (2) VR Museums, (3) training resources, and (4) holodecks. (See the complete code list in Appendix 4)

From these codes I was able to start building concepts. I went through the transcripts a second time to find quotes that matched other educators' quotes. Through the quotes and the set of codes, I constructed several threads, which started to form common ideas. For example: (1) The Future of XR, (2) Empathy in VR, and (3) XR Technology. (See the complete threads list in Appendix 5). There were some common codes from this doctoral study that complemented concepts from the pilot study. For example: (1) Social VR, (2) Focus, and (3) Interactivity.

Theming refers to the drawing together of codes and concepts to present the findings in a coherent and meaningful way (Sutton & Austin, 2015). After discussions with my advisor, I was able to group the concepts into two main themes: Design of XR and Presence. I felt the participants discussed these two themes repeatedly in the doctoral study. Strikingly, these were two themes discussed in the pilot study.

In the data chapters, I will write about how the participants spoke about design as a component in understanding learning in VR. The educator's understanding of how students

interact with the experiences and how they view their own learning in VR helped guide the Design of XR theme.

Secondly, the educators repeatedly discussed the concept of presence in the dissertation study as well as the pilot study. The educators all talked about the importance of presence for themselves and their students in VR. They also talked about how it could shape the future of education.

I was able to categorize several of the remaining concepts into sub-themes under those two main themes. This built a solid foundation of support for each of the themes. Some of the subthemes that support Design are: (1) Educational Design, (2) Storytelling, and (3) Accessibility. For Presence, some of the subthemes are: (1) Memory, (2) Focus, And (3) Emotion Machine. There were limitations to this dissertation study. I now turn my attention to addressing those limitations in the next section.

Limitations

The VR experience was designed to fit inside a designated space on campus for the pilot study. When I traveled to interview the educators for the doctoral study, I was fortunate to have rooms that were larger than the original room I designed for the study. In the pilot study, when participants were close to the wall in the room, they were close to the coral reef boundary in the VR experience. When the participants reached out to touch the rock, they would touch the wall and it would give haptic feedback. I was able to situate the VR experience closely to the boundary in other locations, but it was not completely the same. They were able to experience it on at least two of the four walls. This was a limitation because, as I will discuss later in the manuscript, it could affect a person's spatial relationship with the space.

I had a small pool of participants who were located only in the northeast. This was a limitation because a larger demographic area and participant pool could bring the data closer to the saturation point (Thomson, 2010). Marshall et al. (2013) concluded that there are no cited qualitative methodologists in defense of their sample size (p. 16). There is a saturation point of data that qualitative methodologists strive to reach (Marshall et al., 2013). Thomson (2010) stated that theoretical saturation generally occurs between 10 and 30 interviews. In addition to the data from the participants, I had to be cognizant of my positionality of XR in education. In the next section, I will discuss my experiences and positionality for this research project.

Positionality

Since watching Star Wars as a youngster, I have been fascinated with animation and visual effects. Over the years, I have had the pleasure of teaching both at the high school and collegiate level over the years. When I was introduced to my first 360-degree VR video eight years ago, I immediately was intrigued by the possibilities for the use of XR technologies for education. I did not just want to be an observer in the VR experience though. This led me to look at the possibility of creating VR experiences that allowed me to freely move through the environment and interact with it. XR technology and its adoption is important to me.

The XR community in higher education is a small enough group where we all know each other through one community or another. I have collaborated on projects, papers, and conferences with 10 of the 13 participants. I had an established rapport with most of the educators. That familiarity with several of them was an advantage for me to talk with them comfortably. Establishing a safe and comfortable environment for sharing the interviewee's personal experiences and attitudes is an important component in building rapport (DiCicco-Bloom & Crabtree, 2006).

Since I am 6’4” cis-gendered white male with a beard and a large build, I recognize on face value that can be intimidating for many people. With that recognition, I made sure to introduce myself before the start of the pre-interview. Next, I would discuss the protocol for the session, and allow the participant to ask any questions. Throughout the interview I would allow for them to speak and take any breaks they needed.

When analyzing the data and writing memos to create the themes for this dissertation, it was hard not to draw upon my experiences in XR. In short, my expertise could have limited my ability to analyze the data. However, I believe the answers that I interpreted for each of the educators was accurate. I did not “fill in the blanks” of what they might have meant when talking about XR. The educators in this study had a wide breadth of knowledge and I had to let what they said and did in the study speak for itself. I believe I did not steer the data where I thought it was supposed to go.

Going through this data analysis process helped me understand how the educators viewed design and presence in XR. Through their actions and statements made during the pre-interview, VR experience, and post-interview. I was able to hear their experiences, their fears, their hopes, and their perspectives on these technologies. In addition, I had to grapple with making sense of how these themes influence XR in education. In the following chapters I will present my findings. In the next chapter, I will discuss how the educators discussed the concept of design in XR.

Chapter 4

Designing for Virtual Reality

The immersion of XR has opened the boundaries of storytelling. Traditionally, most stories have parameters that confine them. For example, movies are contained to a screen, images are framed, and plays are limited to the stage. Each of these could be immersive, where someone from the play comes out into the crowd or an art piece's canvas is extended to multiple places. This does not happen because they are location-based. The dynamic that makes XR exceptional is that you can make experiences fully immersive no matter where you are. To do this, you must consider how to design for creating an experience that could take you anywhere or happen anywhere.

When discussing design in XR, the educators addressed several different design factors that need to be considered for VR experiences. If you look at the explanation of what XR is and the three main realities of AR, MR, and VR, the definitions of each reality refer to design in XR. In AR, the experience is designed to have a digital asset overlaid in the real world. For MR, the digital asset is designed to interact with the real world. Lastly, in VR, the digital world is designed to take you somewhere completely different (Skarbez et al., 2021). At a large scale, XR is addressing the design categories that all three technologies engage. The participants in this study discussed the different design categories necessary for educators to understand as they learned to utilize these technologies in the classroom. Additionally, the participants discussed how to think about design when it comes to VR use for interactive experiences.

In the conversations with the educators, they discussed design in several ways. In the following sections I will outline how the educators made sense of different designs in XR. The participants talked about XR design in these five ways; (1) Educational design; (2) Storytelling;

(3) Realism; (4) Accessibility; and (5) Future of XR. I will describe and analyze how each of the educators perceived these complex design elements in the following sections.

Educational Design

The use of VR opens educators to new ways of facilitating student's interaction with content. The ability to immerse students in stories and experiences that develop deeper connections with the content without having to leave the classroom is a powerful resource. For example, Sue stated, "Virtual Reality, Augmented Reality, XR gives us the ability to show it (content) in an interesting way which I think is incredibly innovative for education." Sue's comment implies that educators now can shape content in novel ways. This is educational design. This example epitomizes what this study is about. I want to look at how the educators perceive the design of the educational learning experience through XR.

Educational Design or better known as Instructional Design, is the development of learning experiences and environments that promote the acquisition of specific knowledge and skills by students (Merrill et al., 1996). Using instructional design, educators are constantly assessing how to design their lessons for their students to help them understand the materials so they can apply that newly acquired knowledge in the future. Over the years, researchers have discussed several different educational learning designs that have included VR (Radianti et al., 2020). In this study, the educators discussed three main educational learning designs when talking about VR: (1) experiential learning; (2) skilled-based learning; and (3) personalized learning. In the following section I will discuss each of the ways the educators talked about VR as it relates to educational design.

Experiential Learning

Experiential Learning is the process of learning by doing. Carl Rogers (1969) conceptualized experiential learning by trying to define its essence: It has a quality of personal involvement, the whole person in both his feeling and cognitive aspects are involved in the learning event (Middleman & Goldberg, 1972). Providing students with experience through computer simulations can facilitate learning and develop students' procedural and functional knowledge, as well as reflective and descriptive thinking (Kaneko et al., 2018). By engaging students in hands-on experiences, they are better able to connect theories and knowledge to real-world situations. Experiential learning is best known for experience-based lessons where educators engage the students in field trips such as visiting museums or cultural institutions.

All the educators agreed that VR has the capability to engage all students. James stated, "We need to explore VR more as an educational medium, because there will be subject matter and student populations for which it does the thing that nothing else will do." Here, James suggests that being able to explore new ways to engage students with content in VR is an exciting premise. James also discussed how utilizing VR as an educational medium allows educators to expand the borders of their classroom and do more than they have ever done before, or to go places that they would not be able to go as a physical class. In addition, Morgan added, "it could provide an experience that might help someone learn in a different way." She is addressing how students with different learning abilities can now experiment with how they learn the content through different VR experiences. Both educators suggest that experiential learning, the ability to take students anywhere and experience a new place together in VR, elevates learning to a higher level of engagement.

Several educators agreed that the ability to travel through time in VR has a different effect on the learner. The educators talked about students' ability to not only read about a moment in time but to walk around in it and interact with the space has a profound effect on their learning. Jessica stated, "For students to be able to walk across the battlefield in Europe and see the intensity in the swath and that scope or scale and understand why it was so problematic the way that things worked." Notice, Jessica explains the effect VR can have on student's learning. In fact, the idea of traveling through time to interact with Martin Luther King Jr.'s "I Have a Dream," speech and hear the crowd talking and the energy of the place and to see the whole picture of what was happening at that time was brought up by two of the participants. The idea of being immersed in another time in history changes the dynamic of how students look at field trips.

All the educators discussed how their ability to learn in VR spaces changed how they want to interact with information. They discussed how the boundaries and barriers of physical learning spaces disappear when using VR. James pointed out that "It (VR) changed my whole internal set of expectations and understanding of my own limitations, just because it opened a door that I didn't think was openable." Notice James's words here: "it opened a door that I didn't think was openable." He suggests that VR creates opportunities for students to learn and engage with material they never thought they could.

When a student is experiencing a new virtual experience, such as a dive in a coral reef, there is a "wow factor" that draws their attention. For example, Ben pointed out, "(VR) sucks someone in with the experience with that wow factor and along the way, they're picking up little tidbits whether they realize it or not." Once their attention is engaged, details and information they would normally ignore is slowly picked up through their actions in that space and their

focus on the space itself. As Morgan stated, “thinking as a student like me, who would require to see, to hear, to do. I also think that it would motivate students to be more engaged.” As another participant stated, “I think that this can help in terms of strengthening some of that, because you're really paying attention, when you're sort of hyper focused when you're in that space.” VR allows one to experience different places, engage new perspectives, and understand spatial relationships.

When asked if they or their students had ever created any VR experience that stood out to them, several of the participants talked about museum projects that they created or one their students created. One participant discussed a museum experience that was designed around a physical space. The participants of this museum were physically and virtually confined to the area, and it utilized the space to make the experience interactive. Because his student was able to take a common space and integrate art and interactivity into it, one participant remembered that VR experience. Kai pointed out that, “the ability to you know, put a three-dimensional type of creative structure in space and then move around through it and add to it and so forth is kind of satisfying.” Ten of the participants discussed the different museum projects they have been in or helped build. Because of VR, they were able to see and interact with artifacts that would not have been possible in real life.

A few of the educators not only talked about the ability for students to travel to other places or to another time, but the ability to learn about content at micro or macro levels. By “micro” level, I mean extremely small spaces such as an atom. For “macro” level, I mean large scale such as looking at the earth from afar. For instance, James pointed out, “some idea or concept that would have been very abstract in, in words, like, you're not just aware of it as a fact, but you can feel it, like you feel the impact of that thing.” Here, James implies that interacting

with micro and macro elements that students normally do not interact with can have more of an impact on understanding the scale of that thing. At the micro level, a couple of educators talked about how students can experience being inside the vein of a human where they would be able to look at blood cells as they travel to and from the heart. Or at the macro level, look at the whole solar system in space. Jen pointed out for many students, “I think that it can also make the abstract more pertinent.” VR allows students to understand the abstract ideas of scale and relationships on a micro or macro scale while being immersed in that space.

Several of the educators’ agreed VR has a deeper impact on a person than looking at images in a book. Kai supported this by stating:

> *there's a lot of skill-based exercises and things that people are learning in virtual environments, that there's also things to where, certain things about science and others where being able to visualize it, from a 3D perspective, it can be much more effective than just reading about it and say, textual based types of things.*

What Kai is implying is that to understand how something works and being able to interact with it in a virtual environment can have a deeper impact on learning. Eric added that he was able to learn more by interacting with content in VR than by reading about it.

Another way the experiential experiences were discussed in VR was that all the educators discussed how movement in a virtual space, such as the coral reef, and seeing changes over time made them question many things that they never would have thought of otherwise. After going through the experience, Morgan said, “I think that this could be educational in the way of showing people like the actual impacts of what we're doing to the environment.” For many of them, they talked about how they have never been scuba diving. The VR experience was the first time that they have seen a coral reef in 3D. They all agreed that the experience made them understand the effect of climate change and how it had affected them. Traveling to that time and

place in the reef created an experience that seven of them never had. For two of them, it has inspired them to go scuba diving in a reef as soon as they can. This was but one of three ways the educators discussed experiential learning through VR. In the next sections, I will discuss the second way.

Skill-Based Learning

A second way the educators talked about experiential learning through XR was "skilled-based learning." Skill-based learning is an educational approach that prioritizes the development and acquisition of specific practical abilities, competencies, and aptitudes (Gajjar, 2017, p. 11). Skill-based learning develops students learning through hands-on practice and real-world application. The ability for VR to incorporate skill-based learning into its educational design is prevalent in multiple ways (Merchant et al., 2014).

Several of the participants agreed that the premise of performing skill-based functions and learning the basic physical mechanics before moving to real-life situations is a better instructional practice than reading about it and then immediately performing the skill at a high level. Kai discussed, "For certain skill-based types of things, there's evidence that this is a strong structural way of doing this (in VR)." Jane added:

> *(VR) definitely gives hands-on and more experience to people going out into the world and actually knowing what they're doing when they get there. You've been there in the virtual space, so you know how to act and what to do.*

Both comments above capture the idea that the capability to perform procedures and understand how things interact digitally for an unlimited number of times before getting into them in real life can change how students learn and handle the cognitive load of the information being given to them. If the experience is designed properly, the skills training can be slowly increased to help the user build up their understanding of the activity and not be overwhelmed in the real world

when they are exposed for the first time. Six of the educators pointed out that being able to scaffold learning in VR so that the student's cognitive load is not overwhelmed helps ease students into the content and makes it easier to perform functions and gain mastery. I will elaborate on cognitive load in the next chapter.

Several participants discussed how being able to perform the functions in a safe environment with the ability to fail without consequences helps the student learn problem-solving skills easier and quicker. Chris said:

> *Imagine the impact if we had something like this, you could be in the back of an ambulance on your way to a case, you could put on the headset, and practice the procedures that, you know, you're going to need when you get there.*

Chris went on to compare this capability to the scene in the movie *The Matrix* where Neo (Keanu Reeves) learned kung-fu right before he fought Morpheus (Laurence Fishburne) by having the information downloaded into his brain. We are not at that level of information transfer yet, but as Chris said, this gets the students close to it. Being able to practice the procedure in a digital space before being exposed to it in real life helps students with repetition and visually processing that information.

Several participants agreed that when students create in XR, it is a great way to observe how a student perceives the content visually and spatially. Morgan talked about this:

> *VR could be a helpful tool for being able to show that you understand the information or that you've retained the information. It'd be cool, like, if you were an illustration teacher, or a game design teacher, to be able to like, immerse yourself within someone else's project like to see what they see or experience what they're experiencing.*

Morgan believes that the ability to be immersed in that space can change one's perspective. Additionally, Jane discussed how "being able to produce something, put a three-dimensional type of like, you know, creative structure in space and then move around through it adds to it and so

forth is kind of satisfying." Kim explained how architecture students can bring their building designs into a virtual space and then walk around them and see how the spatial relationships and structural design work together. Kim pointed out, "traditionally, a student would not be able to do that until they entered the workforce and had one of their designs physically built." All these comments on virtual practice help students experience the impact of their work before any materials are even purchased. This not only exemplifies skill-based learning, but also makes the student's learning more personal. This was the second of three ways educators discussed experiential learning through VR. In the next section, I will discuss the third way.

Personalized Learning

A third way that educators talked about experiential learning through XR was "personalized learning." Personalized learning is an educational design approach that aims to customize learning for each student's strengths, needs, skills, and interests (Shemshack & Spector, 2020). For instance, Sue was excited about this learning design when stating, "Soon we'll be able to create more personalized learning, give students experiences that they would have never had the classroom before."

VR adds a whole new layer to the learning process and allows for students to understand the materials by exploring the content in a new way. James discussed:

> *There are students who are not able to effectively learn or gain insights in other mediums. And for those people, VR offers a different approach to an educational model that can reach those people. And to me, that's important, right? And that's worth exploring.*

As an educator, designing experiences that can explore new ways for the student to interact with the content is, as James said, "worth exploring." In addition, several of the participants discussed how VR can take different forms of information, such as audio, video, images, etc. and surround

a student with it in a digital space. For example, 360-degree videos are videos that surround the viewer in a digital space and allow for the participant to look around as the video plays. This VR interaction adds a new level of learning for a student.

With this new form of personalized learning, several participants discussed how XR is creating an incredible opportunity for education to change the paradigm and how students interact with content. As Liz pointed out:

> *these (VR experiences) are great ways that we can change the style of teaching we've been using for the past 100 years and benefit people. Here's a student, and then let's wrap the education and experience around them versus the opposite.*

What Liz is saying here is that the benefits of wrapping an experience around students has the potential to make students feel more connected to the content and for students to move through the material at their own pace and cognitive comfort level.

For several education subjects, there is not a large selection of VR experiences commercially made. Because of this, the educators encouraged their students to create VR experiences. Eric discussed:

> *I think we'll see that XR becomes not just a device for like, absorbing content, but it will also be a way that students are making work. I would say my students are already sort of doing that, are encouraged to do that. So yeah, Ready Player One. School will be in XR.*

Here, Eric suggests tasking students to create interactive and immersive environments relevant to a topic has numerous learning outcomes. Jane stated:

> *Being able to get hands-on, I think making sense of it would be to me at least, where does it apply the best? What situations can we use it for? In raising awareness, learning, teaching, even having fun, if need be.*

Jane's comment struck me, the ability for a student to analyze how an event happened or could happen and map out the space to facilitate learning helps the students create the experience and

immerse themselves into the content. For a student to teach about the different relationships and relevance in their experiences could engage them at the highest level of learning.

Almost all the educators agreed that not all subject matter will align with VR development. However, there are different areas to explore currently. Eric stated, “Virtual reality is really cool. It's really cool. But it needs to solve a problem, XR needs to solve certain problems.” Eric’s comments are direct. Like many educational technologies that have disappeared into the closets of modern antiquities, XR could be doomed to a short educational stint if educators rely on the wow factor to carry the educational content. As stated earlier, simply creating an experience that could easily be interchanged with other media is not solving a problem with this technology, it is not innovating how students learn.

One educator asked, “what do we think will happen to people that are afraid of swimming or being underwater, will this cause undue stress?” This question introduced the premise of how educators can design or utilize different virtual spaces safely without causing students to have a traumatic experience or creating false narratives from what they experienced. Kai discussed, “We're going to have to be very careful from an educational perspective of how we, what types of experiences we recreate.” The issue of how students are exposed to virtual spaces became a discussion for several educators on ethics and how to have an open conversation about the spaces. The topic of ethics will be discussed later in the manuscript.

In summary, the educators talked about educational design in three ways: (1) Experiential Learning, (2) Skill Based Learning, and (3) Skill-based Learning. In the next section, I want to discuss other ways the educators discussed XR design, namely storytelling.

Storytelling

Stories explain the world and reaffirm our position in relation to others. Storytelling design involves using visual elements to create a narrative for your audience. Audiences in traditional storytelling want to feel and form connections, they want to be able to relate to the motivations, struggles, hopes, and desires in that story (Duarte, 2010).

Storytelling is often embedded within academic courses as well; at times, it is used in a purposeful and consistent manner, as well as in short increments. The purpose of "storytelling is to 'humanize' the process of learning by appealing to the students' imagination" (Woodhouse 2011, p. 212). The ability to tell effective stories is a staple of teaching. A good story, well told, is an experience that opens us to new perceptions, emotions, and behaviors (Leonard, 1990, p. 12). According to the educators, effective storytelling in XR experiences could enhance and increase learning for students. For example, Chris stated, "But it's (VR) just like any medium, you have to be a good storyteller, you have to be able to engage with your audience, you have to leave your audience enriched at the end of the experience." Kai added, "how you use the technology in a way to tell the story that's important." The following sections will discuss how the educators talked about how XR created a new dimension in storytelling and how the experience of the story itself in XR can change learning.

New Dimensions of Storytelling

The educators discussed how VR gives storytellers the ability to break out of the traditional pattern of engaging a story. When most of the educators were first introduced to VR, it was through a 360-degree video experience. Liz stated, "what I love about that is just that it breaks out of the rectangles." Her words conjure up being in a box and 360-degree VR freed her. Some of the participants discussed how the 360-degree videos gave them the ability to look

around and explore the whole space captured and not just a rectangular screen. This new storytelling capability allowed them to be fully immersed in the story and not only see what the director wanted them to see, but everything happening all around the story. As Kevin said, “it (360-degree VR video) is exciting, but it is very limiting.” What Kevin is referring to is that 360-degree VR video only allows the participants to see the perspective of where the camera is in the experience, and it is being fixed on that location. According to Kevin, this experience seemed to only open the ability to get a full 360-degree view of space and not truly make the participant feel immersed.

As several of the participants discussed how using 360-degree videos in VR is a great way to introduce people to the capabilities of VR spaces, several of the educators talked about their need for more. For example, Chris stated:

> *Yeah, so passive 360 video, an introduction to getting an MRI, you know, for, you know, for a kid, for instance, I was talking with our team about that, you know, so kid can go into doctor's office, put on a VR headset, you know, they can look around, but I wouldn't consider that interactive 360 video, so they really can't move out of the chair and so that's passive.*

Chris points out that the patient can look around in the 360-video VR, but they are not active in the experience. He went on to say, “that's just not the best use of the technology to me. And active is where the user is influencing the environment.” According to Chris, interaction is what he is looking for in a VR experience.

Using 360-degree videos in VR is a beginning point, but being able to move through a space in VR opens so many more opportunities to explore and feel immersed. As several educators pointed out, the ability to move through a story and follow it as a spectator has a different outcome on them. When they were able to move around and explore the space freely and not be confined to the viewpoint of the camera, they felt that they were more engaged with

the space. This is also known as having six degrees of freedom or the ability to freely move up/down, left/right, and forward/backward. As Ben said, “little bit of sort of the endless possibility scenario that it poses.” The ability to fully move through different spaces and explore that story in different ways makes it, as Jen said, “enthralling.” How can educators tell stories that go deeper into those possibilities? Chris discussed:

> *Fundamentally, from reading in a book, this dimension of the space, what we want to know, it's not, what were the dimensions of that space, we want to know what it felt like to be in it, because that feels like something intense, like a major point of difference.*

What Chris is saying here is that being in a fully immersive space introduces possibilities for stories that not even a book can give. Again, notice his words, “because that feels intense, like a major point of difference.”

The ability to go places, such as the reef, and not physically endure that space and still be able to explore it, has great potential. This is a new way to experience a story. After going through the coral reef experience, Liz stated:

> *the potential for creativity beyond bounds was my favorite part of that (VR experience), like just, it gives you a potential. The reason I like it is, it gives you a potential for exploration without, like, the physical input implications of whatever that actually was.*

Notice Liz’s words “the potential for creativity beyond bounds was my favorite part of that (VR experience), like just, it gives you a potential.” She is saying that VR opens the door for new creative possibilities in interacting with content. The ability to experience different stories without the physical limitations of having to swim or wear a space suit to explore opens the ability to create stories that engage in new ways.

With this new dimension of learning and engagement comes a new way to tell stories. However, the media literacy for XR is still being developed. Kai pointed out:

> *We don't have, people learn a certain amount of media literacy from early on watching television shows, watching other types of things and so forth from very early ages, in terms of how the story is what how would accuse you, ooh, screen with wavy and fluffy oh, we're going to go into a flashback. You know, we don't necessarily have those cues yet, but language yet that people have either established or learned for navigating throughout a story in VR.*

Kai makes a powerful point here; because we are fully immersed and encapsulated in the story, the ability to utilize different visual cues that are used in traditional media are still being discovered. Several educators pointed out the ability to fast-forward through time in an experience is possible but can be jarring. Several of the educators discussed that over time, some of those different media literacy skills from traditional media will find their way into XR experiences in new and exciting ways, and that will enhance the storytelling experience. In the next section, I want to discuss how the educators talked about how the experience of the XR story design can facilitate how they engage with students.

Experience in XR Stories

In storytelling, there is a fundamental difference between a story told from a first-person perspective or telling the story from a second-person or third-person perspective. A story told from a first-person perspective is going to give more details and insight into the story itself. When a person that experienced an event tells the story, they have more of an emotional connection to the event (Murphy et al., 2021). Almost all the educators discussed that when a participant can experience a story in VR, that connection to the story and the information is experienced differently than just reading it or hearing about it secondhand. As Kai pointed out, "It (VR) has potential also for teaching concepts that are better shown and experienced rather than actually read about or seen in a 2D environment. Lots of potential for things like data visualization." Here, Kai is suggesting, that the ability to take data that is traditionally viewed in two-dimensional spaces and give it the third dimension of depth and then allow the users to

interact with it can fundamentally change how students view the impact of that data. Kevin stated:

> *Spatially, if you think about trying to understand data, data points, as it relates to complex issues in three dimensions, that you can interact with. And literally be surrounded by, that's interesting, multi-sensory input kind of experiences. I think it's very powerful. It could tap into different parts of your brain and make it more sticky, and help you understand complex things.*

Notice Ken's statements "you can interact with" and "it could tap into different parts of your brain." This is important because it points out the importance of interaction with spatial information. For example, Kim described a VR experience that took heat maps of the sun warming a room throughout the day. She took the data and built a 3D heat map of colored spheres that covered the width, length, and height, of the room. In the VR experience, throughout the simulated day, the color of the spheres changed from a cool blue color to a warm red color all over the room. The students were able to see that the temperature of the room changed not only across the floor and wall but also in the middle of the air in the room. This 3D visual data helped the students understand how the design of the windows facing the sun all day can affect room temperatures.

Several of the educators agreed and spoke about their experiences in VR helping make the stories they interacted with more relevant and helped them retain more information. Ben discussed that, "I think the ability to bring things to people that you normally can't is huge." Here, Ben is referring to the ability to travel to locations that most participants have not yet visited. Several educators added that having students be able to interact with stories and spaces that they normally would not have access to travel to is an educational benefit. Liz stated, "it's experience-based, so you experience it, and someone's not saying, this is how this goes like you

experience it for yourself." Notice, Liz is explaining how when participants are present in the space, they are having their own experiences and creating their own stories.

Creating stories that are engaging and impactful is not easy in VR. Participants immersed in a 360-degree story that has a single focal point to follow is limiting. The educators pointed out that creating a VR experience this way is not the best use of the technology. When 360-degree VR videos were first introduced to the mainstream, educators were initially excited. As time went on, the educators realized 360-video VR had its limitations. Chris discussed:

> *you could get away with an awful lot in 2016, because it was sort of like the fact that it worked in that you could do things that wowed people. And we're now sort of more to a point where it's got to be sort of a point to do it. You know, there's got to be a good story.*

Chris's comments support the idea that technology needs a story dimension for it to be engaging after the excitement of the initial technology fades.

As exciting as it sounds to travel in time and experience re-created stories, there are several ethical challenges in VR. By "ethical challenges," I mean, depending on the age of the participant, how accurate should the experience be? Huang et al. (2022), discussed the need for historical VR interactions to be age-appropriate to optimize the content that the users interact with. Kai went further and pointed out that the ethical challenge of creating historical experiences, "re-experiencing history, which sounds good on the surface and makes sense, but history, from whose point of view? And what's the actual impact that experience?" Kai is pointing out that the ethical challenge of having multiple perspectives and historically correct information is a challenge that cannot easily be dismissed.

Additionally, several educators pointed out the possibility of introducing trauma to participants by exposing them to an event they may fear, such as being in a large body of water. Several educators discussed that as XR designers and educators move forward with designing

these experiences, these ethical questions need to be addressed in the initial stages of creation. Liz stated:

> *You don't know what people what lived experiences people have been through and what could cause you know, you know, it becomes so immersive, and it becomes so real, that you don't know necessarily what is going to impact people in specific ways.*

Liz talked about her fear of submerging her head underwater. After exiting the VR coral reef experience, Liz discussed that it could have been an issue for her. She was at ease with going into the experience because I had explained the VR experience to her, and she was able to see the environment on the computer screen before putting the HMD on. Her feedback on communicating about the experience before starting shows the importance of alleviating risks of harm. Eric added:

> *I was always scared ever since I was a little kid of of the ocean. So being able to feel at peace in that same environment, is a, I feel a really beautiful thing and it shows even more potential behind VR.*

Eric's statement shows the potential for VR to help manage fears as well as reduce trauma if the experience is done correctly.

Some of these problems can be alleviated by limiting the realism of the experience. But even that begs the question: How real should the experience be? Who decides? Speaking of realism, in the following section, I will discuss how the educators talked about perceived realistic experiences in VR and how they discussed its effect on learning.

Realism

An initial goal of this research was to investigate how realism in VR could possibly affect learning. Perroud et al., (2017, p. 3) defined "realism" in VR as something beautiful looking, for its common use is entertainment. As discussed earlier, the coral reef was designed with a mix of

photo-realistic assets and assets that were created in a 3D modeling program. Most of the participants noticed the realistic models and tended to gravitate toward those assets in the scene and ask more questions about them. The participants talked about realism in two ways: (1) Immersion in Environments, and (2) Uncanny Valley.

Immersion in Environments

The definition of immersion is to involve someone completely in an activity. In VR, to be fully immersed in an experience, they must, as Chris said, “have a suspension of disbelief,” of where they are. According to many of the educators, students need to believe they are in this virtual location, they need to feel like they are at this location and not in a physical space. Chris said, “I was immersed in the experience, I felt like I was there, you know.” Chris pointed out that even though he was in a physical room, he felt like he could be underwater exploring the reef. He felt like he suspended his disbelief. Indeed, he believed he was in a coral reef.

All the educators discussed how realistic assets in VR caught their attention and engaged them with the experience. When this happened, they felt immersed in the environment. For example, Chris stated after getting out of the coral reef experience:

> *I was immersed in the experience, I felt like I was there, you know, it's, so I, I have, one of the things I often say to people is, we only need to make it as real as needed for the person to have an experience.*

Chris speaks to how the experience doesn’t have to be as real as real life but has enough realism to it to make participants feel like they are in that actual space.

Many of the educators discussed how the experience made them believe it was momentarily realistic to forget about the real space. Liz stated, “I felt like it was, you know, obviously, being in a virtual space, it takes your bearings away, you know, there's like an uncomfortableness to it. There's an awkwardness.” Here, Liz is suggesting that when participants are in the VR

experience, they constantly are checking their relationship to the real space. After being in the space for a little time, you start to forget about the real space and focus solely on the virtual space. This was evident when observing the participants moving around the coral reef. At first, all of them moved in an awkward and tight movement through the real space. As they got more immersed in the virtual space, the more they moved around, and they seemed to suspend their connection to the physical room. For example, Ben said, "you can get lost in it. When you feel like you have to duck because you think something that, like it draws you in." Morgan talked about how, "when you told me that I was close to the wall. I thought I was in that corner. I felt like I actually got drifted by the water." Notice, Morgan believed that she was in another location because she drifted in the virtual water.

They each talked about how the lighting in the coral reef as well as the breathing sounds of the tank made them feel like they were underwater. Jen added:

> *I have like that visceral, visceral kind of interaction with this space so as I was saying, like, I kept checking where were the sharks, 100% know that they're fake, but Yeah, and the fish and everything and it really honestly it did because I'm somebody who loves sun and water and I really did I felt like, like a short reprieve.*

At one point during the experience, Jen stood with her face looking up at the virtual sun through the water and talked about not having to go on spring break because she could "feel the sun on her face." After finishing the experience, Jane stated, "feel like I was underwater, felt like my ears got filled at one point." All these comments suggest that not only did the realism make them feel immersed in the space, but also their secondary components such as the sun peeking through the surface of the water and the sound of breathing from the scuba tank make the experience real.

Several of the educators discussed when a participant in VR feels immersed in a virtual space, it positively affects their learning. Kai talked about this, stating:

> *some of the learning may be occurring more in an implicit level than an explicit level where we are absorbing the experience of the world around me what that actually feels like, what that looks like, what it sounds like, as opposed or emotionally, what this interaction feels like, where am I what actually is going on here?*

Kai's words suggest that implicit learning is occurring because of the environment. They are taking in information by simply being immersed in the space and observing or interacting with it. Several educators talked about how they recognized different species from movies they had seen, especially the "Dory" fish, and they were able to identify the different fish they interacted with. Throughout the experience, several educators discussed how they noticed the changes in the spaces and were pondering what could have possibly caused the differences. As they kept exploring, more and more questions were asked, and they started analyzing different elements of the reef. This immersion in the space shifted, as Kai said, their implicit learning to more analytical thinking. These observations are important because they show how realism in VR can engage participants with information using comparable environments to real life along with increasing their curiosity about the space from those easily identifiable objects.

During the initial testing of creating the coral reef before the pilot study, I tried to make the space as hyper-realistic as possible. By "hyper-realistic," I mean as close to the actual reef as possible. When I tested it out on several people to see how they responded, they were overwhelmed by the amount of assets and color. I quickly realized that making it hyper-realistic may be too taxing on the participant's cognitive load. I decided to find a middle ground where there was a mix of photo-realistic and 3D-modeled assets without being too overwhelming. Kai said. "I was not conscious, I was immersed, high level of presence. Not necessarily high level of realism, but high level of presence." She talked about how there was enough realism that he felt present in the space, and it made her believe she was there. She was not overwhelmed.

If it is not realistic enough, will the students be able to associate the information with real life? What if the realistic action of the asset gives students a creepy feeling, will that affect their learning? In the next section, I will discuss how the uncanny valley could affect how students perceive realism.

Uncanny Valley

The Uncanny Valley is defined as the phenomenon whereby a computer-generated figure or humanoid robot bearing a near-identical resemblance to a human being arouses a sense of unease or revulsion in the person viewing it (Vukadinović et al., 2023). Several of the educators noted that the uncanny valley could be applied to more than just avatars. Each of the educators discussed how they were affected by the realism in different experiences and how certain aspects of the experience either drew them in more or made them, as Ben stated, "scratch their head." As stated earlier, it was observed that the participants tended to gravitate towards the more realistic assets in the experience and they all discussed how they felt more immersed in the space when it is more realistic.

The educators discussed how the actions of different elements in the environment caused them to have an uneasy feeling when the elements in the space did not respond as expected. For one educator, while they were in the VR experience, a bunch of the fish unintentionally synced up and all started swimming in perfect unison. As they were walking through the space, they kept checking back to see what the fish were doing. That moment of uneasiness caused the educator to disengage from the space. This was an example of an uncanny valley with the environment and not just an avatar. In discussing the fish incident, Kai stated:

> *our brains are old, our brains, we know that something is not real. But we process everything as if it were real you know, you know? And so how does having that experience, what is the long-term impact of that?*

Kai's observation is key here: participants can easily be distracted and drawn out of the immersive experience because of something not looking natural. Kevin added, "There's a little bit of lag or something when I do this, or Gaussian flickering on the edges. Okay. So that's, I noticed that like, it makes me think about the technology." Kevin's statement shows that when something uncanny happens, his feeling of immersion switches to a focus on what the technology is doing. This highlights how distractions can cause participants to disengage with the space.

There are several popular games on the market that are low resolution and not realistic looking and students are enthralled with them (Jensen & Konradsen, 2018). Minecraft is a game that uses very low poly (low realistic) assets that are all block-shaped. Students of all ages play that game and spend hours building and interacting with it. After coming out of the coral reef VR experience, several of the educators pointed out that consistently using low-resolution assets in an experience can have a positive educational effect on the participants too. Jessica discussed an experience where the avatars were low resolution, "(the character) looked like a shitty little avatar, the kids who were playing were like, that's a real, that's a real dude, who, who really wants me to…" Jessica is saying that even though the avatar is not realistic looking, the interactivity of the experience makes the participant feel like they are talking to someone. This shows that if the actions or representations of objects in the space do not cause an uneasy feeling, the educators all agree, even low-resolution assets could help students feel immersed in the experience.

The educators also discussed the accessibility of VR technologies. In the next section, I will discuss how the educators talked about the accessible design of XR experiences and how

they address accessibility as a learning design as well as financial access issues for these technologies.

Accessibility

When discussing accessibility in education, there are two definitions that are covered exclusively. The first examines accessibility challenges for people with visual, motor, hearing, and cognitive disabilities who are often excluded (Valakou et al., 2023). The second, the financial cost of modifying the technologies for accessibility (Dwivedi et al., 2022). When discussing XR resources, an educator's ability to afford or gain access to the technology is at the forefront (Simon-Liedtke & Baraas, 2022). In the next two sections, I will discuss how the educators discussed accessibility with VR technologies as well as the financial consideration for these technologies.

Accessibility Matters

When designing educational experiences, it is critical that all learning abilities be addressed at the outset of the conceptualization of the experience. Chris discussed a situation that was posed to a community of XR educators, "what do you do if you have a student who has a hearing impairment in an experience by themselves and the fire alarm goes off? How do they get out of the experience safely?" In the interviews, many educators spoke to this issue or a similar issue regarding VR design. Jane stated:

> *I think it means providing different learning tools to this new generation of students that we are gaining that have grown up with technology and are more accustomed to using it. And along with that, children and students who have special learning disabilities and need that extra sense of learning that XR can provide.*

Jane points out that XR technologies can enhance learning through multiple senses and abilities. She states that content designers and educators need to explore the possibilities. Chris agreed

with that point when he said, “especially as we, as practitioners look, to move these (VR experiences) out, we need to be challenging the vendors to do better.” Chris is suggesting that educators should not just accept commercial products that do not address different learning abilities.

The other major topic the educators discussed as it relates to different abilities was visual. If done correctly, several educators pointed out that XR can enhance engagement for all learners. Kim stated:

> *I've seen people who were legally blind put on a VR headset and have like a really great experience. But obviously, for anyone who's totally blind, this is not going to be very exciting, necessarily. There's not Braille for VR yet. Maybe there will be.*

Kim points out that VR can engage participants with more senses than just visual. VR has the potential to create environments that can engage and enhance other senses in the participant.

Many of the educators discussed the accessibility of movement in VR. Kai discussed, “there still are issues related to VR sickness, some potential health, differential risks and so forth.” Kai’s comment raised a series of issues, such as motion sickness being a deterrent for participants wanting to enter a VR experience. Kai referred to the need to create experiences that allow for full movement or teleporting around the space to help alleviate motion sickness. As several participants discussed, the ability to move without physically moving can be a jarring experience. But Jessica pointed out that teleportation can be just as disruptive to the user since it pulls you from one spot and drops you into another quickly. As she stated, “It can be disorienting and cause confusion.”

Several educators discussed their personal experiences with movement in VR. For example, Jessica stated:

> *I get pretty sick, pretty much no matter what, like not vomit notorious or anything... But I just, I'm really sensitive to misalignments and jitter and all kinds of things. And so it is. It is sad that now I'm I feel like the more I know about it, the further it feels like we are, but I think we are going to get there.*

Even Jessica, who is an expert in VR, has a difficult time in VR. Her words remind us of how important the design of the experience is for all people. Several educators agreed that they have experienced motion sickness while in VR. They each pointed out that being able to move the same in the virtual space as they are in the physical space is still the best solution.

Several of the educators pointed out the adaptability that VR brings with being able to pivot from an experience where you must walk around to being seated to accomplish the task. Many stated that being able to sit down and move around is less jarring and easier to comprehend their positioning. For instance, Chris discussed that experiences that allow people to sit to interact with the space allow more people to be able to engage.

VR experiences can enhance abilities if done correctly. Chris stated, “we need to ensure that these are accessible to all audiences, that these aren't experiences that will potentially leave some behind or leave some with less engaging experiences.” Here, Chris is suggesting that XR has the capability to enhance learning and by creating experiences that could alienate learners will deter educators from using VR in the classroom.

Several educators agreed that limiting the experience to only one of the senses is a limiting factor for VR. Liz added:

> *I love making experiences fully accessible to for a wider range of needs for humans. And so by limiting to just one sensory, like to, you know, engaging one sensory input, or you know, one modal, it, it reduces the number of people who you're including in your experience. So by having multiple sensories, you, including you make your experience available for more people.*

Liz is suggesting that making experiences that engage participants with one sensory, such as sight is a limiting factor. Notice her words “it reduces the number of people who you're including

in your experience." This is important because the ability to be inclusive with the design can enhance the experience for more participants.

A couple of educators discussed participants with limited hand-control capabilities. They said there is the option to allow users to switch all the menus and navigation to one controller instead of two. With some of the newer VR technology, users can use their hands or limbs as a controller, or in some VR headsets, they can use their eyes, and they do not have to hold onto anything. In the next section, I will discuss how the educators spoke about financial issues related to accessibility.

Financial Access

Over the years, educational technology in the classroom has been identified as a financial strain on most schools in the United States (Hew & Brush, 2007). The strain became a focal point in education during the COVID-19 pandemic when the schools had to pivot to online or distance learning. Wealthy schools with financial resources were able to easily transition to online learning and support students remotely (Ferri et al., 2020). This left schools that have been underfunded with little to no resources for students (Ferri et al., 2020).

As several educators pointed out, most commercial laptops that students use in the classroom average around the same price as a stand-alone VR headset. Eric stated, "I don't think that it's fair, that some communities get this advanced technology and this retention of learning, whereas others do not, you know, they, everybody deserves this tech." Again, Eric is talking about the ethics of equality of access to educational technology, especially in underserved communities.

Integrating XR hardware and software technology into the classroom is costly for educators interested in using these technologies. Kim stated, "It's not accessible. It cost a fortune.

The content that's available right now, it's not something that most educators are probably aware of." As Kim suggested, it's not just that the software is expensive, but educators do not know what software they can use in VR. Since new VR software is coming out, school districts have minimal experience or expertise in what is good for the classroom (Psotka, 2013). That leaves the educators testing, exploring, and spending money on different hardware and software to find what works for their classrooms.

Another accessibility issue that several educators discussed was how XR technology is constantly changing. As Kim stated, "one more negative is that it's changing really quickly." By "its," Kim is referring to the hardware (HMD) used to view the experiences. In 2015, Oculus released the first all-in-one headset that did not need to be tethered to a computer. Since then, Oculus has released another two versions of the technology in the last 3 years, and for each release, the hardware and the capabilities of the devices have grown exponentially. James discussed that over the years, he has lost several projects because of hardware changes and updates in software. Several of the educators discussed the financial hardship for schools that invest in VR hardware that becomes obsolete within a year or two.

For those schools that do explore the use of XR technology, they tend to start small scale. As several educators discussed, they would use two or three VR headsets to introduce to students in a classroom. Ben pointed out:

> *I think it's more of it's the hurdles of trying to level the field than anything else. Given like, you have a room that normally sits 15, but really only one person can probably run the experience in here at a time.*

He went on to explain how this does not seem like an efficient use of the student's time in this situation.

Several of the educators believe that even though XR technologies are expensive, the return on investment is worth it. As Chris stated, “People talk a lot about the costs. And I'm less concerned about the costs. Because I think with the right use cases, with the right experiences introduced the right way, this stuff sells itself, the value is there.” He went on to say:

> *You know, that or, you know, being able to be inside a volcano or travel to Egypt to you know, these, these are difficult, expensive, potentially dangerous, where you can make those experiences accessible to students, you know, in a chair in a classroom.*

Several of the educators agreed with Chris. Money spent on the technologies to engage with these experiences far outweighs the money spent to travel or put students at risk in real-life situations. Several of the educators agreed, that over time, prices would come down. In addition to the lower prices, in the next section I will discuss how the educators discussed the future of XR and the effect it will have on education.

Future of XR

All the educators agreed that over the last ten years, XR technologies have improved and changed at a rapid pace. In the interviews, they were all asked about the future of XR technologies, and its impact on education. Many of them noted some design components of XR need to change. In the following sections, I will discuss how the educators talked about the future of VR experiences pertaining to the simplicity of UX/UI and the function of the different XR technologies.

Simplicity

In designing the user interface or user experience (UI/UX) for any experience such as websites or games, the interface needs to be simple to use and accessible for novices. Chris discussed how the original set-ups for commercial VR attached to computers; the UX/UI, was

not simple. He described his school's first VR system, "So like, 12 hours later of dabbling, like, by the time it was sort of, like, gosh, if this was under the Christmas tree, this would not have been a good experience." Chris' words convey that most participants want to be able to get to the experience and not have to spend hours figuring out how to navigate the system to get to the experience.

Once the educators figured out how to streamline the process of getting the systems up and running, many then experienced students were unfamiliar with the use of VR technology. Kai pointed out that, "one of the problems we had was we spent 15 minutes just getting people logged in with the signal." Kai's statement points out how difficult it is to simply get the students logged in. Additionally, Kai talked about needing to teach students how to navigate the interfaces.

Several of the educators agree that the simpler the design for the participants to understand and access, the easier it will be for them to access the experience. A couple of the educators pointed out that for the Personal Computer VR (PCVR), it was easy to mirror the experience while a student was in VR on a second monitor. You can try to walk them through the interface. Several discussed that they got motion sickness from watching the monitor and seeing the participant move around. For standalone VR systems, such as the Meta headsets, it is harder to stream it to another monitor, and the ability to guide students is hampered. Chris pointed out that even for experienced VR users, "At some point, it's just, you know, if it's, if it's, if there are too many steps to try to get to the good stuff. There's plenty of other good stuff around to do." Here, Chris means that if the interface is too complicated and does not allow easy access to the experience, the participants will find other alternatives to the experience.

Many of the educators discussed the beauty in simplicity when it comes to designing experiences. James stated, “Sometimes it's just discovering that simple, obvious mechanic that once you've seen it, you can't unsee it.” He discussed how the little details will come as you experience the interactions and keep playing. Ben added, “I do think if your experience is done poorly, like, you don't get the result that you, that you want.” What Ben is saying is that if the experience does not facilitate the participants reaching their objectives, it does not help the students. Many educators pointed out that the design of the interface could dictate how immersed a participant can be in an experience. One educator talked about whether participants can utilize the UX/UI easily, and it becomes an extension of what they are doing, like using a pencil to write. The students are more focused on the experience and able to learn more.

Simple interfaces and interactions in VR excited each of the educators. Jane discussed how she had her husband play a cooking VR game for the first time. After learning the mechanics of the game, it became exciting, “It just, learning the mechanics, I remember the chef one was super funny because it was the first one, I put my husband into, and he said the whole kitchen was on fire immediately.” Having a simple experience, as Liz explains, “it's like breaking the rules. But without getting in trouble. We already have too many rules, we don't need, we don't need anymore.” She explained that the more rules the user must follow hinder the experience. On a similar thread, Jane discussed how having freedom in that space to play as she wants can create unexpected, but fun results. The educators highlighted that the simplicity of the design helps the users enjoy the experience more. In the next section I will discuss how the educators discussed the functional design of VR technology.

Function

The original designs of VR hardware were, literally, much bigger than they are today (Stein, 2016). Many of the educators discussed how the VR systems are currently designed as oversized ski goggles that are heavy on the front of the participant's face. As Jessica stated, "prolonged use could cause severe neck issues." However, one educator pointed out how the design intrigued them. Liz said, "so just walking through the trade shows, and they just had different companies and all that. And I was like, those people look funny. What are they doing? I'm intrigued. I want to look funny, too." Here, Liz is pointing out that part of experiencing VR is looking funny to other people since the participant is moving differently in the virtual space.

A couple of the educators discussed how the newer XR hardware has begun addressing this issue, but they said it needs to become an extension of the user, like a cell phone. Chris stated, "So I think the future of XR will be the technology become less and less visible." Many pointed out that the easier it becomes to make it part of the user's everyday use, the more it will become attractive to users. Like cell phones, several of the educators discussed their everyday functions. Chris stated:

> *I think is where we're headed with XR, where that form factor becomes the point where you don't leave the house without that without your XR device, whatever form factor that takes, but that that becomes the piece, because it'll just be kind of this essential overlay that you really just don't do without.*

Chris talked about how if he left his computer at home by accident, that he could still go through his day as normal. If he left his phone at home by accident, he is positive he would go back to get it because it has become part of his everyday use. He feels that XR is on that path where people would turn around and go home to get their XR technology if they forgot it.

Many of the educators see the potential for XR technology to become part of our everyday experience like the movie *The Minority Report*, where images and videos are

experienced in 3D as people walk through real spaces. James added, “I think that the medium of XR has things that it can do, which are wonderfully powerful and rich, that we just, I don't think are aware of yet, we're still discovering those things.” James’ words suggest that educators have yet to understand what the potential of XR can be in the classroom. A couple of the educators talked about how this technology could change how companies advertise and interact with their users. They talked about how they are already seeing the changes with the ability to add furniture to their rooms in AR to see if it would fit properly in the real space or how it would look with existing furniture.

All the educators discussed how the future of XR is exciting to think about in education and everyday life. Eric’s comments make this point:

> *when I tried on virtual reality, for the first time, I realized I wanted to get involved with innovative technologies because I feel as though we are part of the future, like our legacy and the work that we're doing in these technologies will last thousands, millions, billions of years will truly affect how we live our ever how we live and work in our everyday lives.*

Again, Eric’s words convey XR technology can change the future of society. Several of the educators talked about how XR technology is not going anywhere and the advancement of other technologies over the years, has shown how impactful it can be. In addition to the excitement is the sentiment that educators need to be constantly looking at the ethics behind what is made and used in the classroom. As Ben said, “I think, too, we need to stop blaming technology for our problems because we're the ones who make it. We need to start taking responsibility for it and using it for the right reasons.” Several educators agreed that this is going to be a constant battle. Next, I conclude this chapter with a summary of the key findings for this chapter.

Summary

This chapter focused on the discussions around "Designing For XR." The chapter began with a discussion around Educational Design. James' statement set the tone for how important VR is for education when he said "(VR) does the thing that nothing else will do." All the educators agreed with this statement in discussing how VR can engage students through different learning models. Moreover, the educators talked about educational design to make this point. In fact, they talked about experiential learning, skill-based learning, and personal learning.

The educators highlighted the importance of storytelling in XR experiences They broke out of the traditional ways of storytelling. If the story in VR is crafted effectively, it will allow the participants to participate and become a part of the story. The educators stressed that being able to interact with the story is key. They believed this new medium would produce new ways of learning. The ability to bring participants into a realistic environment and, as Chris said, "suspend their disbelief" can influence the student's learning.

When looking at XR technology, all the educators echoed that accessibility needs to be considered from the outset when designing and evaluating XR experiences. As Jane pointed out, VR can engage student's multiple senses in ways that other technologies have not been able to. Each of the educators discussed how it is important to constantly be assessing the opportunities to utilize experiences that enhance the capabilities of all users. Several of the educators addressed the disparity in access to XR technology due to financial constraints. For several, the return on investment in the use of XR technology in education far outweighs the cost.

In this chapter, the educators talked about how their sense of presence was increased when the design of the experience incorporated different aspects such as educational design,

storytelling, and accessibility. In the next chapter, I will discuss how educators made sense of learning through their sense of presence in VR.

Chapter 5

Presence in Virtual Reality

Have you ever had someone tell you a story and then they follow up with, “you should have been there.” If you were there, you too could have had a story to tell. If we were there together, we could have a shared story and be able to talk about it forever. Being present allows a person to truly experience an event. In education, many of the events that students learn about, they were not present to watch. Many of the systems students talk about, such as envisioning how blood flows through the human body, they cannot be present to view. There is something to be said about being present in a story. We tend to remember more details of the space when we feel present in that event (Rubin & Umanath, 2015). XR experiences allow students to be present in the stories because there are several ways educators can use presence in their teaching.

To be present in an XR space or an XR experience, you must believe you are there. Biocca (1997), defined presence as the illusion of “being there” whether “there” exists in physical space. Lee (2004) wrote that presence is often referred to as telepresence, virtual presence, or mediated presence. Witmer and Singer (1998) referred to it as “the subjective experience of being in one place or environment, even when one is physically situated in another” (p. 225). Presence in XR suggests that the viewer does not simply *watch*, but rather they feel that they are in that space themselves (Çöltekin et al. 2020, p. 4). Several of the educators stated that when they experience a space for real, it does not take much for them to convince themselves that they are present there. In XR, it takes some convincing or “tricking” of the mind to persuade participants to believe they could be someplace real. Being present in XR can affect a participant’s learning in different ways (Ziker et al., 2021).

The educators talked about ways that XR could help students better understand concepts, ideas, and events by being present. They were able to elaborate on the definition of presence as it relates to XR. When students are present in XR experiences, they are existing in that space, or as several educators pointed out, they are present in that space. They talked about presence in XR in these five ways; (1) Sense of Place; (2) Memory; (3) Engagement; (4) Focus; and (5) Emotion Machine. In the following sections, I will highlight some of their insights and analyze how they perceived learning through presence in XR.

Sense of Place

The allure of VR allows users to be immersed in new places that they could never experience in real life. Many of the educators stated that to be present in a virtual environment and see that space from another perspective could change how students learn and understand relationships. In fact, the educators talked about spatial relationships and realism.

Spatial Relationship

All the educators discussed how they had a difficult time navigating their physical location while in the virtual space. What they were trying to adjust to was their spatial relationship between the two realities. Harrison and Dourish (1996), identified that the concept of spatial as a space and place relative to the structure of the world, the three-dimensional environment in which we inhabit. When participants are in VR, their real world is engulfed by the virtual world, and they are completely immersed in all aspects except physical. Liz stated, “I felt like it was, you know, obviously, being in a virtual space, it takes your bearings away, you know, there's like an uncomfortableness to it. There's an awkwardness.” Liz’s comments epitomize the duality that participants in VR experience with trying to navigate the real space while experiencing a virtual environment.

Each of the educators discussed how the spatial relationship was difficult to navigate the first couple of times in VR experiences. As they got more comfortable, they all talked about how they were able to get their physical and virtual bearings to align. As the educators discussed in the previous chapter, if the experience is designed correctly, they felt they could trust their own spatial abilities within the VR experience. The educators could trust where they were physically, but they understood the need for precaution.

For many of the educators, they discussed how they were able to navigate spaces by trying to envision where they were in the physical room. They talked about how they tend to casually "feel" for objects around them so that they do not bump into anything. Sometimes, they get into the VR experience and forget where they were as Chris talked about in the post-interview:

> *going into these environments where you forget, you're in the room, you know, I mean, so that, you know, I had my hands out, because I don't want to run into the wall. But, um, but it is, you know, you're just there. So, you really, completely forget that you're in the room.*

Chris's comment illustrates how virtual spaces can make participants forget that they are in a real space too. They all talked about how they tried to keep in the back of their mind that they are in a physical room and not present in a coral reef underwater. Liz stated, "like the proprioception in kinesthesia, like the sixth sense, you know, like understanding where your body is, without having to see it." According to Liz, participants' "sixth sense" activates and participants can sense where they are. What happens when participants "suspend disbelief," like Chris said. Chris's statement highlights how VR can persuade the participants to believe they are present in the virtual space and not where they really are. Many of the educators said they felt immersed in the virtual space and had a hard time spatially recognizing where they were. This is important

because this exemplifies that they felt present in the virtual environment and “forgot” about the real space.

The way that the educators navigated through the virtual spaces influenced the participants’ spatial relationships in the virtual environment. In VR, there are several different ways you can move through a space, such as using the controller to move like you would in a game. You can teleport, which allows you to “jump” from one place to another. Another option is that you physically move through the virtual experience like you would in a real environment. Jessica talked about how moving around via teleporting causes her to get motion sickness quickly due to losing her spatial relationships when she teleports or “jumps” from spot to spot. Her words highlight that this method causes a disorienting feeling due to the participant losing their bearing. Kim stated,

> *I think some of the negatives are things like making my client afraid that they were going to fall, or that kind of low level of anxiety, like, I don't want to move around, because I'm afraid I'm going to hit something.*

Notice how Kim’s words highlight a fear people have about VR and the spatial relationships that they want to maintain with their surroundings. Eric countered that with, “being able to physically move around with the thumb stick or using the teleport function is also neat. That's, that's very cool. But it's a lot more immersive when you can physically move in the environment.” Most of the participants discussed how physically being able to move through the space is preferred. They talked about feeling more spatially aware of their physical surroundings compared to their virtual surroundings when they could walk around. This is a key point because it shows how they drew on their virtual spatial relationship as compared to their real space relationship. If they feel they could move through their real space safely while in VR, they are more likely to do as Chris said, “suspend disbelief” of where they are. The educators began to trust the virtual space.

The ability to have spatial relationships with the virtual space helps the educators feel more immersed in the experience. As the participants became more comfortable moving through the reef experience, they would kneel to look at the sand or lean in and look at the details of the coral. When they were able to cast away their awareness of the physical space, they appeared to look more comfortable with their spatial awareness in the virtual space. Liz stated:

> *you have like more of a spatial awareness, like the things that you would normally get in a physical connection or space, you get better, you get more of that. In a so like, a social VR experience, like, the opportunity for connecting with people is even greater, when you break down the barriers of your physical limitation, spaces.*

Liz's words highlight that the more comfortable people feel in a virtual space, the more of a connection they can have with the space and with others they share that space with. Many of the educators talked about how there is the possibility of replicating spatial relationships we have in real life through VR. A couple of the educators talked about how we have the capability to have spatial relationships with the virtual environment and with other people in that space even though they may be miles apart in reality. These comments are important because they illustrate how VR can facilitate people feeling more connected to each other. It shows the possibility for people who are physically isolated from others to become virtually connected. Some of the educators discussed that they met friends in social VR locations such as virtual coffee shops. This location imitated the real environment where they would normally meet their friends. They felt that the realism of the conversation, space, and avatar sitting across from them, made them feel more present in the space. In the next section, I will discuss how the educators perceived how their presence was affected by the realism of the virtual space.

Realism

The gap between reality and virtual reality appears to be getting smaller every year (Lanier, 2017). New technologies allow for quicker refresh rates in the HMDs and the latest video cards can create hyper-realistic images in game engines. The ability to create realistic environments in VR experiences is getting better and better (Newman et al., 2022). With the abilities of the technology to create realistic assets and environments, the educators discussed if this impacted student learning in any way. Additionally, they discussed the different effects that realism in VR had on them and how it affected their presence in virtual spaces.

In the movie, *Ready Player One,* the characters all interacted within a virtual world called *Oasis*. In the story, the real world was dystopic. To escape the depression of the cities, the people would escape into the *Oasis.* In there, they would live out the lives they wished they could have. They would interact with people from all over the world and live in their virtual society. Currently, several companies are creating virtual worlds that are mimicking the *Oasis*. Eric highlighted that the need to be present in the real world is a necessity, but the mixture of exposure to the real and virtual worlds opens many possibilities:

> *Reality is still it's still a beautiful thing. You know reality has some place in this world and the metaverse is the combination of our digital worlds and real world together in harmony, the evolution of the internet, the evolution of communication.*

Eric's words highlight ambivalence: the ability to leave the real world for a new harmonious virtual space could be a good thing, but we still need to be exposed to the real world.

Several of the educators agreed that the use of realistic environments and assets drew them into the VR experiences and helped them be engaged with the virtual space. After leaving the coral reef experience, Jen stated, "it didn't feel like something I wanted to get out of." Jen's statement shows how the realism of being in the sun and water made her feel connected to that

space. Because of that realism and belief that she was at the coral reef, she didn't want to leave. Additionally, in the post-interview, Jane stated, "I felt like I was actually underwater. Kind of got me for a minute. I felt like I got water in my ears." Jane's statement highlights the impact of the realism of the environment. It had her believing she had a physical reaction.

For many of the educators, the immersion in a realistic VR environment evoked mixed feelings. A couple educators discussed their experience with feeling uneasy. Others struggled with the uncanny valley. James talked about how the differences in the coral experiences caused him to look at the reality of the space differently. In the first experience, he pointed out that there was an abundance of realistic features to view. If one of the pieces of the reef did not look realistic or caused an uncanny feeling, there were plenty of other things to look at that made him feel immersed again. In the second scene, where there is less life, James said he could not find a realistic asset to make him feel present again.

A couple of the educators stated that being in realistic spaces can be a distraction due to wanting to inspect the assets and not truly experience the space. A couple discussed how realism truly drew them into the space due to its visual appeal. Several participants talked about how they constantly were mentally checking their interactions with the space, because of the realism. Jen stated:

> *I have like that visceral, visceral kind of interaction with this space. So as I was saying, like, I kept checking where were the sharks were, 100% know that they're fake, but yeah, and the fish and everything. It really honestly (felt real), it did because I'm somebody who loves sun and water and I really did I felt like like, like a short reprieve.*

Notice Jen's words, "it felt real," and she used the word "honestly." Jen believed she was there, and it took her to another place in that short time. Even though she was mentally negotiating her

space and some of the inhabitants of the space such as the sharks, she still felt the realism made her feel like she was underwater. She went on to say:

> *you're physically feeling and sensing things it's just like you like I could definitely I didn't move around too much because I didn't know it was around me, but I also had the sense that if I moved around that I would feel swimmy or like, I might tip over something.*

Jen's use of the word "swimmy" suggests that at any moment she would have had to wave her arms and legs around to stay upright in the virtual water like she would if she were swimming in real life. To add to the realism of feeling present that Jen discussed, Ben asked, "could you drop me in a vat of gel so that I had felt the resistance of moving in water?" Ben's question connects realism to the possibility of haptic feedback to also simulate that realism. I will elaborate on haptic feedback later in the manuscript.

Many of the educators agreed that the more realistic looking and feeling of the experience, the longer they would probably stay in the experience. Several of the educators pointed out that they constantly had to negotiate mentally in the virtual space. As Kai stated, "our brains are old, our brains, we know that something is not real. But we process everything as if it were real." Even though they knew they were in a virtual space, they checked their bearings several times. A couple educators stated that they kept an eye out for the sharks swimming around because, "you never know what could happen." Again, this supports their "suspension of disbelief" and that the sharks could pose a threat to their safety.

The educators discussed how the realism allowed for a level of presence that helped them better engage with the space. As part of the coral reef design, there was a mixture of realistic assets and environments with models that were made with software that did not look as realistic. Kai pointed this out, "I was not conscious, I was immersed, high level of presence. Not necessarily high level of realism, but high level of presence somewhat necessarily high level of

realism, but high level of presence." She pointed out that even with the mixture of realistic and modeled assets, she still felt like she was highly present in the space.

A few educators compared what they were seeing to real reef diving and snorkeling. They talked about how their memories helped them feel more comfortable with the experience and feel more present in the virtual space. Kevin pointed out, "I could associate it with the times that I've been in water, like in the ocean, and specifically snorkeling." Kevin's statement highlights how realism allows the participant to easily associate with prior experiences and feel more immersed. Kai stated that she was excited to see the hammerhead sharks swim by because when she was younger, she used to swim with hammerheads when she went diving where she grew up. This is important because that memory of prior experiences increased her excitement about being in the virtual space. It also shows that it helped her feel more comfortable in the space and feel more present. In the next section, I will examine how the educators discussed their memories in relation to being present in the VR space. I will also discuss how their presence in that space helped them remember information.

Memory

Our memory is built on experiences that we have, and they can be brought forward in our minds by different triggers or actions that happen (Pillemer et al., 2015). According to the Harvard Medical School (2024), memory is our ability to recall information. We can remember a family member from a smell, an event from a sound, or a place from a touch. Our memories shape who we are. Memories are the stories we tell ourselves about what we've done with our lives. Memory tells us who we're connected to, who we've touched during our lives, and who has touched us (Kotre, 1996). The experiences we have can shape those memories in new ways and affect how we react to future events. Our memories can cause us to have adverse reactions to

experiences. They can also open us up to new experiences (Lindseth & Norberg, 2004). In education, the experiences that students have with materials can affect how they remember the information (Herbert & Burt 2004). The educators each talked about how their memories and learning are affected by different media. The more they could interact with XR experiences and be a part of the virtual world, the more they felt they were able to remember later. In the following sections, I will discuss how they talked about their ability to recall information from their experiences in XR. Additionally, I will discuss and analyze how they talked about how their experiences impacted memory.

Memory Recall

Many of the educators discussed how XR experiences increase students' ability to recall memories from that experience later. Several of the educators discussed remembering more details after a VR experience. In addition, they were able to recall the overall experience clearly. Eric compared his childhood to his VR experiences by saying, "I can tell you every single piece of that memory, and I was eight years old, but because it was spatial, I always remembered it." Eric's words suggest he remembers his experiences better because "it was spatial." He stated that traditional learning with books and even videos did not help his ability to learn, but if it was something he experienced or was active in, his recall was better.

> *I cannot tell you a single thing I learned from an overhead projector. But those projects that I did, that egg projects where you try and protect the egg and you try and create a casing with it. And then you drop it off a building and you learn about structures and everything, I can tell you exactly what I built, exactly where every toothpick went. So, spatial memory is just better. And it there's so much evidence for it that that it is better in that virtual reality experiences create better retention of information because it's in three dimensions.*

Eric's comment highlights how important his spatial memory is compared to trying to remember something that he read. Jane stated that for paramedic training, the ability to see the environment in detail in VR compared to imagining it during simulation training helped her to analyze real-life situations quicker.

Several of the educators talked about how they could remember ideas in VR better than in traditional spaces because they could analyze and evaluate the information differently. They could also see how things worked "first-hand." Kai stated, "When we process an immersive environment, we probably process the world around us, we process it differently." By "differently," Kai is referring to how participants analyze the virtual world's similarities to the real world. For instance, several educators discussed how they remembered information from previous VR experiences because of their spatial relationships and being able to compare it to other things such as sizes and special relationships. Kim added, "all your senses are sort of wrapped into this learning environment. Everything has some kind of memory attached to it. So, it sinks in." Kim's words are key here because she discusses how the use of participants' senses heightens their ability to remember the interactions with the 3D environment easier.

Memory from Experience

The educators discussed the ability of students to experience places and times in VR that are not accessible. The spatial learning and the ability to experience a place that is not easily accessible helped enhance the memories that are created. As James stated:

> *I think that that's where VR is uniquely, I think that is why whether it is convenient or not, we need to explore it as an educational medium, because there will be subject matter and student populations for which it does the thing that nothing else will do.*

Note, that James' words highlight the possibilities for educators to engage students with materials in ways that real life cannot. The educators agreed that the ability of VR to create memories from experiences is a great benefit for VR in education. Chris stated:

> *For them (students) to be able to, like, walk across the battlefield in Europe and see the like, intensity in the swath and that scope or scale and understand why it was so problematic the way that things worked or the impact of the railway system on that process because now they're in a situation where they can only navigate that space with those railways.*

Chris' comments suggest that the experience of the space makes the story personal as if the participants experienced it themselves in real life. Each of the educators agreed that the ability to be a part of the images used in books or be present in videos can only enhance their learning and memory. Chris added:

> *I've come to understand that, that those experiences I'm describing that, that that immersive experience, that suspension of disbelief, that engagement with this virtual content is unique, you can have content that is similar to what you would watch on a YouTube video. But when you're there first person experiencing it, it's just a different experience.*

He described how our imagination could do many things, but the ability to suspend disbelief in VR and believe that you are interacting with a virtual space as if it is real has a powerful effect on the participant.

For many of the educators, it is their hope that the VR experiences will create memories that encourage students to be active with the story. James pointed out, "some idea or concept that would have been very abstract in, in words, like, you're not just aware of it as a fact, but you can feel it, like you feel the impact of that thing." James' statement expands on the idea of how VR can show the impact that abstract information can have on students through hands-on experiences. Morgan added, "To get a better understanding of what's actually happening within our reefs, I think it's really easy to not fix problems when you're not experiencing it firsthand."

Morgan is suggesting that VR experiences help inform students firsthand about spaces and this could enable them to make a positive change.

Several of the educators agreed that these experiences encourage students to interact with the information. Many stated that they had several students come back and point out things they normally wouldn't notice in the real world and tried to correct their behaviors because of an XR experience. Ben added, "had I not gone through that (VR experience), and I had only seen like Discovery Channel documentaries like I don't know that I would even have gone there." As many other educators stated, they hope that being able to go to a virtual reef will inspire them to go to the reefs for real.

As to the converse of that statement, after getting out of the coral reef experience, Jen stated, "I am not going anywhere for spring break, this is a nice experience in between my swimming now." Jen's statement highlights that the experience was enough for her to wait until the weather improves for her to be in the water again. Or as Kim stated,

> *So you kind of calmed down with that aspect of it. I'm thinking about the times that I've been like scuba diving, how uncomfortable I am, when I can't breathe, and I've got all that stuff on and how much that distracts me from the things that I might actually see through this very cloudy view. So, I prefer it in part to that experience, though.*

Kim's statement highlights how VR can help participants feel more comfortable with their virtual surroundings than experiencing it in real life. This is important because this gives students the opportunity to experience places that they feel are dangerous. In return, they feel safe to explore.

A fear that several educators discussed was introducing a student to an experience that could trigger a previous bad memory. Liz pointed out:

> *"You don't know what people what lived experiences people have been through and what could cause you know, you know, it becomes so immersive,*

> *and it becomes so real, that you don't know necessarily know what is going to impact people in specific ways."*

Liz's words suggest even though they are in digital space, the experience may trigger memories that were traumatizing and could cause their students to revive those memories. Several educators discussed experiences that could trigger a negative reaction or possibly trigger post-traumatic stress disorder (PTSD). For example, Kai stated:

> *I'm thinking about what's going on in Russia and Ukraine, and yes, through some advantage to actually creating that you are there experience, but also what are the problems with does that trigger stress reactions? You are they are in a war is, do you actually feel like you were there in a war and the fact that you're sitting in a lab does not necessarily negate that.*

Kai's statement highlights that even though students are experiencing an event in a virtual space, the stress of being present in the experience could be emotionally overwhelming.

In the coral reef experience, several digital sharks were swimming around the edge of the reef experience and one shark that swims at a safe distance over the top of the participants. While observing the participants in the experience, almost all their heart rates went up as they looked at the sharks, then went down again after looking away. As Kai pointed out, "Parasympathetic nervous system engaged. And as my body decided that fight or flight or flight preparation is a process information." Several of them discussed how they knew the sharks were fake, but it still took a moment to acknowledge it.

Many of the educators acknowledged that they are constantly evaluating the safety of the students in these experiences. They also stressed that honest communication is imperative when introducing students to possible experiences that could trigger a trauma response. Their words of concern are important here because if the experience is done right, the student's learning will be more enjoyable and memorable. However, if the experience is done poorly, it could negatively

affect their memory and possibly trigger stress reactions. In the next section I will analyze how educators discussed improving XR experiences through engagement.

Engagement

For many of the educators, the first VR experience they had was with 360-degree videos. All of them talked about how exciting it was to be able to look around a space and see what was happening in that place. The novelty of being immersed in the place subsided for them because they were being directed on where to go and, in some cases, on what to look at. Several of them felt like they were missing out on the ability to explore the spaces and inspect the details or change their perspectives. The ability to be active in XR spaces was one thing that educators all agreed upon as a necessity. In the next sections, I will discuss how the educators talked about active and passive experiences as well as social engagement in XR.

Active and Passive Experiences

The ability to be in a 360-degree VR space and look around was a great way to introduce people to the concept of VR technologies, but many of the actions in the VR space are predetermined by the creator of the experience. Jessica talked about her students who participated in a 360-degree VR experience:

> *kids were just so like impressed by the magic of the full 360. I'm actually here, I'm actually talking to this actual character. It's actually recognizing what I'm saying, even though it kind of wasn't, they like, fully bought in.*

The experience she was talking about had the user witnessing an event in the first-person point of view and one of the characters in the scene talked to them as if they were part of the story. As Jessica pointed out, the participants were passive, and the story happened no matter what they said or did in the experience. This is an example of passive engagement. By "passive engagement," I mean that the participant is a viewer of the experience and does not interact with

any part of it. The participant is in the space and can see and hear everything. They can even feel like they are a part of the story, but no matter what they do, they are still an observer. The educators agreed that some of the experiences they had in 360-degree VR were great. This new medium introduced them to a new way to tell stories, but the educators stated that they did not feel fully immersed. The educators felt like they should be able to do more in the experiences than looking around in a fixed location and being a passive observer of the story.

The ability to learn music takes patience and practice. For some people, it is a daunting task. However, using VR technology facilitated learning in novel ways. James reminisced about this as an example:

> *I don't think linearly looking at a bunch of lines with dots on it just means nothing to me, you know, and the idea of, there's a kind of terror that I feel when I look at a line of music with dots.*

He was introduced to creating music in VR. From this program, he was able to interact with the music and create different soundscapes immediately, he said "In VR, because I'm more of a spatial thinker, suddenly I was able to create music by moving things around in space in a way that I understood." He was able to work with the music in a spatial environment and move it around. He was active with the sounds and the vibrations and explored and experimented in that space. He concluded:

> *I don't make music because I need to make it in VR. I make music because the experience I had in VR gave me a new way of perceiving or understanding the, what it meant to make music. And then once I have that basic foundational language, I can do it anywhere.*

James was active with the music in new and different ways rather than just reading sheet music. He suggested that because of his active learning in the VR experience, he was able to better grasp how the notes and music worked together in harmony. This is an excellent example of active engagement. By "active engagement," I mean that participants can touch and interact with

the virtual environment. James added, “Sometimes it's just discovering that simple, obvious mechanic that once you've seen it, you can't unsee it. And the only way to find it is by playing, playing around.” His activity and playing with the music in VR made it make more sense for him.

Many of the participants spoke of the ability to be active or hands-on with materials. Some suggested it could help students be more present and develop a deeper connection with the content. Jane stated, “So I like to think of it all as a new way of learning. Hands-on but more hands-on with things that you normally don't get to get hands-on with.” Kim added:

> *I love it when you're like sort of playing with the seagrass and it's responding to you. So, I think you would get more, even more engagement if I wasn't just looking up things and describing them, but like, kicking them and playing with them and that could also be distracting. But I think that's also how we learn.*

Kim’s words suggest the more hands-on we are, the more students can understand the world around them. Kim’s use of “playing” suggests that students can learn better because they are relaxed and focused on the experience. Ben stated, “you can get lost in it. - when you feel like you must duck because you think something that, like it draws you in.” Ben’s words suggest that the interactivity and immersion make the participants feel more present in the space. Kim added:

> *I could have lectured on that as well. But the questions you get from a student who's looking at that and is actively engaged in it are radically different, then if they're just listening to me in a lecture.*

Again, Kim’s words suggest allowing students to interact and analyze an experience motivates them to critically think about the space compared to just hearing about it. The students ask different types of questions. The engagement with the materials becomes deeper because they can interact with the assets and see how they interact with the environment. Liz stated:

> *the more act, active you are in a, in an experience, the more senses are engaged, the more emotional it’s going to become. And so, the more you get to remember it, the more impact it’s going to have on you.*

Notice Liz's words "the more senses are engaged, the more emotional it's going to become." She is suggesting that as participants engage more senses in the experience, the more emotionally attached to the ideas in the space as well as the space itself. Several of the educators agreed that the interactivity of the experience reinforces what students are supposed to learn. Eric discussed:

> *You know, in my mind just kind of naturally strays pretty easily. So, to overcome that when I'm immersed in experience, what makes it more engaging is that it's interactive. I get to live in the lesson rather than the lesson talking at me.*

Eric's words capitalize on the idea that the interactivity of the lesson engages his curiosity better than other educational media. He highlights that the students can retain more of the content because of their interaction with it. The students are not passive observers.

The ability to be active in XR spaces is heightened when the space also interacts with the user. This happens when the user virtually touches an object and feels haptic feedback through the hardware. Maclean (2000) described haptic feedback as the sensation of touch. Some XR experiences use haptic technology to give the sensation of the physical within the virtual. For example, vibrations in sound installations or computer software that creates touch feedback.

Several educators discussed that the ability to interact with objects in XR spaces and get feedback from touching or hearing them is powerful. Chris told the story of a different coral reef experience he had prior to this study. In the experience, he had an inadvertent haptic feedback experience that made him feel like he was in the reef:

> *I was moving around in the space and I put out my hand and it just so happened, one of my chairs was right where the railing was, and I reached out my hand, just just sort of like, you know, kind of walking around. And I hit the chair. And all of a sudden, my brain went "Woah, wait, this is real." This explosion went off in my head. All of a sudden, I was on that boat. And that whale was going by me. And my brain was going, woah.*

Here Chris's words suggest that the ability to incorporate haptic feedback into a virtual space can increase the sense of presence in that space. The ability to get feedback while immersed in VR, for several of the educators, made them believe the experience was real. Many of the educators discussed that the ability to grab things and have the feeling that you are holding them made the experience more immersive and interactive. James discussed an experience that was designed specifically for the virtual room to match the real room:

> *The piece was so finely tuned to the original space that when you would put it on in a different location, now you're just, you're just in a space and it's very different. There was something really powerful, the one thing we kept was the pedestal. So the pedestal was sort of like the the Keystone, right because the headsets on the pedestal and you put on the headset and then you you know, put your hands down and they're down on the pedestal in both VR and in real life.*

James's experience is important here because it highlights the grounding of the participant in the virtual space with the real space. It also touches on the haptic feedback they felt from touching the pedestal in real life because it helped them feel more immersed in the space. This is important because active engagement encourages more sense stimulation in the virtual space that helps the participant feel more connected to that space. Educators also talked about connections through social engagement in VR.

Social VR

Scuba divers are warned not to swim alone. Kevin pointed out that education should follow this same rule, "no one swims alone." Several of the educators agreed that students' learning increases when they work collaboratively. For students who are working remotely, online, or unable to meet physically, VR gives them the ability to collaborate with others and feel present with their team. In the post-interview, Sue talked about how she was able to attend a VR conference and meet new people:

> *getting to meet other people, like, you know, all over the world, you can basically say, you know, talk to people that you have other avatars and be like, you know, hi, and I mean, that that was the beauty of it, like people from all over the world were there and, you know, we're happy to engage with you where it's a little more awkward if you're, you know, at a conference*

Several educators agreed that being able to bring students together from all over the world to meet and talk about topics relevant to them and to work collaboratively is an amazing opportunity that VR presents. Liz also added that even in MR:

> *XR will actually bring social back to social media. If you think about it, technically, like you go to if you go to a coffee shop or any place where like students are like, or people I shouldn't say to students, but like, people are hanging out, like social media means, like, okay, they're looking at these little screens, I can find that's right. So like, they'll be connecting to the person on the other side of the world, but then they don't even talk to the people next to them. So I see a huge value in the fact that like, you could be connecting with people in the world, other side of the world, but you can also be looking up and re-engaged in your physical actual space.*

Liz's statement highlights how people can stay remote and still feel connected to people through virtual social spaces. They can simulate real-world experiences without leaving their home.

Working with an instructor in the VR adds a new level to virtual interactions and helps make the space feel the same as a traditional classroom. Ben stated, "I think the ability to bring things to people that you normally can't is huge. The ability to actually have a guided shared experience probably becomes new." Ben's words suggest that exposing students to new virtual spaces and having guided experiences elevates the learning opportunities for the student to analyze the space and ask questions in real-time. Mixing the ability to replace a physical classroom and add 3D models to a lesson and guide the students creates new opportunities to engage students. Many educators discussed how using social VR allowed for social experiences that could not be replicated in the classroom. For instance, Liz stated:

> *you have like more of a spatial awareness, like the things that you would normally get in a physical connection or space, you would you get better you*

> *get more of that. In a so like, a social VR experience. And then also, like, the opportunity for connecting with people is even greater, when you break down the barriers of your physical limitation, spaces.*

Liz's statement highlights that breaking down the physical barriers that students are in and introducing them to virtual spaces, creates opportunities for connecting people easier. Most of the educators discussed how VR allowed students to feel like they were present in the classroom. Liz believed students felt that the spatial relationships with their classmates were the same as it was in a physical classroom.

In the post-interviews, all the educators reflected on the COVID pandemic. During the pandemic, all the educators switched to web conferencing for collaboration with their students and their colleagues. For several of the educators, they explored new ways to connect via social VR platforms such as ALT-Space and Spatial.io. Chris stated, "I liked the aspect of having it social, you know, having people there, you know, having, you know, colleagues that hadn't seen for a while you're in VR." Several of the educators discussed how they had coffee talks in VR and met with people they had not physically seen in a long time. Sue discussed:

> *I often think about, you know, elderly people and how they're the lonely especially, you know, now that we've gone through COVID, if you're locked into, like, there was no reason to feel alone because it was just like it made this, it made you feel like you were there in the presence of something else.*

As Sue explained, VR was a way for people who were isolated to feel connected. The ability for people to continue to feel present with another person, even though it was an avatar, as almost all the educators discussed, was powerful. The educators also discussed that in these social VR spaces, they felt like they were able to focus more on what was happening because they were mostly separated from distractions in the real world. Not only could the educators limit their distractions in social VR, but they could focus their attention on the space more. In the next

section, I will illustrate how the educators discussed the importance of directing the student's focus to increase presence in XR spaces.

Focus

In a traditional classroom, the educators talked about how students are distracted. Their focus is challenged by everything from text messages, and emails, to social media. They discussed how XR can eliminate some of those distractions. XR can eliminate some distractions. Several of the educators pointed out that XR can create positive distractions.

Limiting Distractions

Many of the educators agreed that one of the advantages of VR is that it immerses a student in an experience, which in turn, minimizes distractions. Sue stated, "(VR) totally immerses the student into the experience, which I find is important, especially because it keeps those outside distractions outside" They all agreed that the separation from the real world created an opportunity for the student's focus to be guided toward the content. The ability to be immersed in the lesson because there are no outside distractions also helps the students feel more present.

Being in VR, however, can also create new types of distractions. In the post-interview, Jessica discussed a large-scale study where several students were all participating in a VR experience individually. She noticed that students were focused and immersed in the experience. On several occasions during the study, when a student would finish early and be waiting outside of the VR experience for others to finish, they walked by another student in the experience and pushed them. The student immersed in the experience would get distracted by the outside interaction and lose their focus. She also noticed in tight spaces, if people are not paying attention to their virtual boundaries or do not have a spotter in the real world, they tend to

accidentally collide with other users. This caused them to have to come out of the experience and re-orient themselves. Liz discussed distractions in the experiences themselves, “the more things calling your attention, you know, the more things you have to then focus on. So, you know, is that a distraction?” Liz is saying that too much information in an experience can cause a distraction or cognitive overload.

When designing the coral reef, I tried to make it as representative of real life as possible; however, before the pilot test, it was overwhelming for the participants who tested. There was too much to focus on and the participants did not know what to do. Their focus shifted from element to element.

In the post-interviews, several of the educators in the study discussed that an overwhelming amount of information could affect the user’s cognitive load to the point of exhaustion as well as the loss of retention. Sue stressed the importance of finding a balance in the amount of information and how it is curated.

Guided Focus

All the educators discussed how VR helps control distractions and focus their energy and mind on the content. Jessica stated, “(VR) is a great way to capture attention and really get somebody totally invested and totally motivated and excited to kind of see through the content as it unfolds.” Jessica is highlighting how immersing a student in VR eliminates the outside distractions and allows them to focus on the present moment as it happens around them.

In the post-interview, the use of subtle AR interactions was a draw for Liz when watching sporting events. She first noticed the use in an NFL game:

> *watching the NFL broadcast on TV with that was a specific augmented reality experience, where you see like the first and 10 lines being displayed, using the green screen and motion tracking technology.*

She thought this was an amazing way to incorporate the viewers into the game by giving them a direct connection to where the offense needed to go. She was engaged in the action. She went on to say, “when I'm watching football, I feel like if you know, like is anything I can do to make my experience better, right? Or more enhanced or more active as a participant.” By using AR, Liz added, “they just took this experience (televised NFL game) and they just enhanced the entire experience design by adding the layer of information to make us an active participant in this experience, it's collective.” Her statement highlights how adding an AR layer of information could be applied to education for a collective experience for students. This idea could help their engagement by focusing their attention on augmented content.

One of the features that almost all VR headset makers advertise is the ability to meditate in VR. Jen discussed her experiences and ability to focus with VR mediation:

> *it's visual, but that helps me tap into the somatic sensing (how the body expresses deeply painful experiences, applying mind-body healing to aid with trauma recovery) that you have that is connected to what you're seeing. And I think a lot of times it's difficult for people to get out of their head and into their body.*

She stressed the ability to quickly separate herself in VR from the physical space and find her “center” for meditation. Jen also talked about how meditating outside of VR can take a long time for her because she can get distracted by little details that catch her attention. Seeing cracks in the floor or random objects in the physical space stressed her out. In VR, if the space is designed correctly, she stated:

> *(VR) allows people to also go to the physiologically destress and kind of interrupt the stress response that you have because for in a nice way, kind of knocking you off your feet in from being quite quickly someplace else and someplace pleasant context.*

Several of the educators pointed out that during the coral reef experience, the water made them feel relaxed and they were able to focus and feel immersed in the space. As Kai stated, “I did feel

immersed under the seas, was paying attention to the other types of things." The feeling of relaxation was stated by several educators after they went through the coral reef experience. The educators discussed a range of emotions they had when they were in the VR experience and in the post-interview. In the next section, I will discuss the emotions that the educators felt in the coral reef VR experience and how those emotions can help their students.

Emotion Machine

In 2015, Chris Milk, a famous director and pioneer of creative 360-degree VR experiences, labeled VR as an "empathy machine" (Milk, 2015). He proclaimed that VR experiences have an innate ability to increase the participant's empathy for others in the experience. He believed it had the power to give the participants the perspective of another and in return, it would increase their empathy for that person's struggles. The educators agreed with some of Chris's statements. However, they suggested that the changes to the technology and the ability to make users feel more present in fully immersive experiences compared to the 360-degree video VR experiences are different. They discussed how there is more than just empathy that occurs in the experiences.

Creating Empathy

As Milk said in his talk, VR increases a person's empathy in an experience (Milk, 2015). Eric added, "I feel as though some of the best lessons in education are about empathy." Liz discussed that after one of her first immersive experiences, "Instant thing. I was like, oh my goodness, the empathy-building abilities are like incredible." The ability to engage students and have them see another's perspective in VR has a deeper impact than reading a book or watching a video. For example, Kim stated, "we've talked about empathy, the value of VR, kind of innately having an empathetic nature, so anything that you're trying to teach in education, that

would require understanding someone else's perspective, it's very good at." Kim is suggesting that VR helps participants embody someone else and experience "walking a mile in their shoes." Jen summed up empathy in VR experiences by saying, "it (VR) looks at the challenges people have about getting out of their own head and they start appreciating somebody else's perspective." Several educators agreed and discussed that the ability to engage a student's empathy for another person's experience can have a major impact on education.

In the post-interviews, several of the educators discussed experiencing the Sundance Ignite Festival's VR experience called *Tree*. I discussed this experience previously in the manuscript. The educators that experienced *Tree* discussed that when they entered the experience, they placed a tree seed into a pot of dirt. They then entered the VR experience and embodied the seed as it was pushing up through the ground. They then became a full-size tree in a rainforest. The educators discussed how they experienced what it is like to be in the rainforest looking over the other trees and hearing animals all around them. Shortly after getting used to the sensation of being a tree, Kim and Kai remembered that they started to hear sounds of chainsaws off in the distance and they smelled fire (the VR operator lit a match and blew it out in real life to simulate the smell). In the end, they recalled they were separated from the tree, and they saw the forest being destroyed.

The educators were able to recall the experience from six years prior and were able to express their sense of empathy for the tree and the forests being destroyed. After discussing that experience, Kim stated, "So I think one of the biggest effects of VR is that it creates empathy. Because you are embodying something like it's very hard for you not to get engaged and emotionally involved." Kim's words highlight how VR can evoke emotions by changing a participant's perspective. They each were able to recall the whole experience as if they just came

out of the experience and it was fresh on their minds. They all discussed the emotional effect of empathy from seeing the forest being destroyed by loggers. For instance, Kim stated, “the learning component of it is very similar to what I described with Tree in that the remembrance of the experience because it's so engaging, reinforces what you're supposed to learn.” Kim’s statement supports the idea that engagement in experiences increases memory of the story. In the following section, I will discuss how the educators described how emotional connections can increase learning in VR.

Emotional Connection

Successful storytelling uses emotion to draw the viewer into the narrative. James stated, “much of what we put in books, is to make an effort to arrive at an emotional connection to some kind of subject matter.” Mar et al. 2010 stated that “once one has finished reading, these emotions don't simply dissipate but may have an impact that lasts hours or days, long after closing the covers of the book, perhaps re-emerging whenever the book is brought to mind.” Educators in this study have stated VR can create a deeper emotional impact on the participant. Eric stated, “that's something that's something special, you know, when we can elicit an emotional reaction. So that was that was the moment that I realized I think this is for me.” What Eric is saying here is that when a VR experience can cause students to be emotionally connected to content, there is a powerful effect. Liz added, “it's the emotional connection because of that fully immersed experience and then seeing it firsthand, like the experience of it is so much different than just kind of like being told or any anything else.”

The emotional connections excited many of the educators when they thought about how VR could affect learning. James stated, “when the goal is to create an emotional and sensory

understanding of the subject matter, VR feels extremely well suited to delivering that type of content." Liz added that her students,

> *they get an understanding of contrast, perspective, scale relationships, connection, there's just so many more things that become something more emotional. And instantly, it's like yeah, it's like I can explain it I can show you a PowerPoint but that's not going to give you the same active experience as if you are fully immersed in an XR experience.*

Here, Liz is suggesting the depth of relationships that students can make with the content in virtual spaces through identifying the different elements. This connection can have more of an impact on the students. Several of the educators echoed this statement and talked about the student's ability to be immersed in the experience and how that helps drive their emotional connection. From that emotional connection, they feel present.

After ending their VR coral experience, the participants discussed the emotions they had after seeing the changes in the coral reef over the years. Jessica said, "I'm sufficiently saddened in reduction in biodiversity." James added,

> *That's very different from me, feeling emotionally attached to something, taking pleasure in the beauty of it. I'm not sensing or perceiving coral to be like, an arbitrarily beneficial aquatic life form. I'm like, it's that beautiful thing that I just enjoyed and like really was like looking at and it's gone.*

The feeling of loss and sadness was repeated by most of the participants. James went on to add "I think that that emotional connection to the intellectual fact of that loss is powerful and important. Well, that's something that it does. That's something that you don't get through other means." James is expressing how VR can help participants feel connected to a space. When that space experiences loss, the participants feel that loss too. In the case of the coral reefs, there was less life in the second experience, and he is highlighting how he felt that loss of life in that space. Morgan expressed her loss, "It was depressing. It was awesome to see how it used to look but it was very depressing to see how it looks now and you hear about it, but to see it is very different."

Morgan adds that she was excited to see the beauty of the coral reef in the 1980s but felt sadness in the loss of life in the 2020 coral reef. She discussed how she had more of a connection to the story and understood the loss more through the experience than by someone telling her about what happened to the coral reef.

A couple educators brought a positive emotional connection to the experience. Sue discussed, “I loved, I loved how it allowed me to experience the ocean, without the fear and phobia I have of the ocean. Because I have a really extreme fear of going underwater, especially in the ocean.” Eric added,

> *I was always scared ever since I was a little kid of the ocean. So being able to feel at peace in that same environment, is a, I feel a really beautiful thing and it shows even more potential behind VR.*

Several of the educators discussed that having this experience alleviated their fears. As Liz stated, “instantly I was like, oh, no, this is something I can trust. I can be calm here. I can enjoy this like, and then that carried, and that trust was never broken so that's good.” Liz highlights that the experience allowed her to explore the space safely. She alluded to how she was allowed to experience the coral reef in a way that being in the real coral reef could not allow her to do.

Some added that being in a safe immersive space allowed them to see the space and connect to it better than they could have in real life. Jen added, “I felt I felt immersed in it. And I'm someone who has a fantasy about going snorkeling and scuba diving, but a tremendous fear of sharks and probably never will actually do it.” For Liz, she discussed how the sensory experiences of VR allowed for her to connect at a deeper level to the experience. She stated,

> *it's a sensory experience, the sensory experience is what is probably the biggest draw for me. And the, the impact for potential for use cases like to, like help people and like I just said, like, the value add that it provides is so much higher when people can experience it through multiple senses… The more active you are in a, in an experience, the more senses are engaged, the*

> *more emotional it's going to become. And so the more you get to remember it, the more impact it's going to have on you.*

The increase in sensory and emotional connections to the reef and other VR experiences was an exciting point for the educators to remember the content and the space easier. They believed creating experiences that engage user's emotions heightened interest in the topic.

Several educators believe understanding the effect of emotion in these immersive experiences is incomplete. Kai raised the concern:

> *I think one of the other concerns and this gets one of the reasons we're still in this economy, the psychology and potential negative effects is, we don't yet know how processing these in what type of impact the way people process information, what's the long-term effects are, we know that presence is more engaging. And that consequence, it tends to have a greater impact on people's attitudes, emotional experiences, and responses.*

Her insight is impactful because she states that presence is engaging, but because the widespread use of VR is still relatively new, we do not know the long-term effects of participant's memory. In the post-interview, she went on to discuss a study:

> *They, there's been very little research done on this to some extent, but they did, for example, do one study about young children who swam with whales in virtual reality. And then when they asked them several months later, they believe that they had actually swam with whales.*

Jessica referenced a study by Segovia & Bailenson (2009), where they studied false memory formation. They both wonder if realistic experiences could negatively affect a student's memory. This highlights that there is more that needs to be studied in this realm.

Summary

In this chapter, the educators agreed that the best way students can learn is through being present in a space and understanding the relationships of that space. The more they can, as Chris said, "suspend disbelief," the more present they feel in that virtual space. The educators talked about how navigating their spatial relationship with the real world and VR is initially difficult.

As they acclimated to the virtual space, they felt free to move through the space. This feeling of presence in VR opens the ability for the participants to explore and move through the virtual space to analyze the events unfolding around them. The educators suggested this was more effective than other educational media.

These spatial relationships not only make the user feel more present, but it could also help them remember the space better. According to the educators, when a participant is present in the space and can interact with the objects, they can see the impact of their actions. This understanding of their impact helps participants become more thoughtful about the information and ask different types of questions. As several educators stated, it inspires students to engage with the content and the virtual space more. The educators also talked about their personal experiences of learning better through spatial experiences, such as the coral reef experience. The educators discussed how VR could be more than just an empathy machine. The educators suggested that VR experiences have the capability to invoke a much wider range of emotions than any other media can. When a student looks at an image or watches a video, if something is unsettling in that scene, they can look away and detach themselves from it. In VR, they cannot look away and detach themselves from the image, because they are surrounded by it. They are in that moment as if it is happening in real life. The educators agreed that there is deeper learning occurring because of VR. VR could duplicate real life in many ways and what it does well is create opportunities for students to engage with experiences that evoke an emotional connection. We still need to study the effects of XR on emotions and how this could positively and negatively affect people in the future. In the following chapter, I will present the summary and discussion of the themes, as well as recommendations, and the opportunities for future research.

Chapter 6

Discussion

It has been close to a decade since I was first introduced to the possibilities of XR technologies in the educational space. Over the years, I have read numerous articles from industry professionals touting the need for XR to be in educational spaces. What I noticed in their articles was a lack of foundational research to support their statements as well as how their participants made meaning of the VR experience. This inspired me to design a research project that would capture how educators made meaning of VR experiences. For this study, I was excited to see how educators perceive the use of XR in their professional lives and explore their thoughts about XR in education.

I believe starting the interviews with their personal experiences established rapport and trust, which led to having robust and in-depth conversations. For all the educators, their first XR experience was varied. Each of them was exposed to XR in different ways. Some started with AR, others tried MR simulations, and a couple started with VR. The educators expressed varying levels of excitement as they discussed the different XR technologies and experiences they tried. They each discussed how that first exposure to XR shaped their perception of the use of XR in education.

As my mentor and I discussed the data from this study, we imagined the possibilities of being in the trenches of the Western Front during World War I. We talked about the ability to hold onto a DNA strand and dissect it to see its different components. Every XR scenario we thought about for education got both of us excited about the possibilities. We both agreed that many educators do not know the capabilities that XR can bring to their classrooms. The idea that XR educational technologies can create powerful learning opportunities for educators and

students became our focal point. My goal for this research project was to share the passion, excitement, and meanings that the educators interviewed in this study had about using XR in education. Additionally, I wanted to describe these findings to educators and students. In the next section, I will summarize the major findings and why they are significant.

Summary of Findings

Design

One of the key findings of this study centered on how the educators talked about VR design. Design was important for the educators because it covered several different aspects of VR that make it innovative and immersive for students. Sue was able to articulate that the use of XR in education can change the way content is shown, stating "I think is incredibly innovative for education." From their interviews, I was able to group their discussions into three main educational design areas: (1) experiential learning; (2) skilled-based learning; and (3) personalized learning.

The educators talked about the importance of experiential learning in the design of VR experiences. For example, James stated, "the thing that nothing else will do." James' statement is important because it shows why XR technologies stand out in education. No other technology has been able to "transport" a student to another place or time in history like XR can. The ability for XR technologies to instantly change the classroom setting that students interact with introduces new ways for students to experiment with content.

Several of the educators discussed how XR introduces new ways for students to learn by "walking through" the content, such as a battlefield in Europe or a crowd waiting to hear Martin Luther King Jr. speak. The ability to "be there" and see history unfold changes how field trips can be experienced. Through these virtual field trips, the educators discussed how XR can have a

deeper impact on student's learning rather than reading a book. This finding is important because it demonstrates how multimedia learning theory is applied to XR. In addition, it shows students' ability to learn through spatial relationships.

Skill-based learning was the second way educators discussed VR design. As many educators stated, the ability to practice skill-based procedures as many times as they want in a virtual simulation can improve the students' understanding. The use of skill-based learning introduces the ability to design experiences that scaffold learning so that the student's cognitive load is balanced. The use of skill-based learning also helps students in professional fields such as architecture, to see their designs built in virtual spaces and experience what it is like to walk around inside of them. As Kim states, "a student would not be able to do that until they entered the workforce and had one of their designs physically built." The ability to spatially experience a design that a student has created is an exciting way to learn and inspire creativity.

The third way that the educators discussed design in education was through personalized learning. Liz stated, "let's wrap the education and experience around them versus the opposite." Liz's words are important because XR gives educators the opportunity to personalize learning for every student. She believes the students will each experience the information differently as they interact and explore the content in XR spaces. This was evident as each educator experienced the coral reef experience. They all explored and asked questions about the reefs in their own way and were drawn to different aspects of the reef and the experience. In the end, they all came to the same conclusion that something needs to be done to replenish the reefs. But, they all got there in their own ways. Multimedia theory is implicated here: by increasing students' ability to not only build a mental representation of content in their mind, but also build a virtual representation of content in a virtual space with the combination of video, audio, and through an immersive

environment like traditional game-based scenarios (Mayer, 2002). This is important because this will increase the student's presence and decrease their cognitive load in the VR experience.

In addition to being able to engage students with different educational designs, the educators also discussed how storytelling is an integral part of incorporating XR into the classroom. All the educators discussed how they have experienced 360-degree videos in VR. They were initially impressed with the ability to be completely immersed in the story and look all around the environment. However, this new version of storytelling was intriguing for them because as Liz stated, "what I love about that is just that it breaks out of the rectangles." This method of storytelling was different because the participant could see the whole environment of the story. They are not limited to looking through a window into the story's environment. The ability to look around a jail cell in the 360-degree video VR experience *Solitary Confinement*, as Kai discussed, has a different effect on the participant in the story. I say this because the participant has a deeper sense of spatial relationships when they are standing in a jail cell. The scale and the weight of the virtual space creates an emotional response in participants when they start mentally comparing it to the physical space.

The educators believed that a unique feature of VR storytelling was the designs that allowed the participants to explore freely and interact with the virtual space. As Ben stated, "sort of the endless possibility scenario that it poses." In this statement, Ben is referring to being able to move in a virtual space with six degrees of freedom. The freedom to move through and interact with the virtual space introduces new ways to tell stories. The new dimension of storytelling, as Chris states, "feels like something intense, like a major point of difference." Chris' statement highlights how the ability to design spaces that engage students' imagination in new ways shows how exciting learning in XR can be.

This excitement can also be carried over to the possibilities of how XR can be designed to be accessible for all students. When XR experiences are accessibly designed, several educators pointed out that XR can enhance engagement for all learners. As Kim suggested, “I've seen people who were legally blind put on a VR headset and have like a really great experience.” The ability to heighten senses and create experiences that are accessible to all users is an opportunity that most educators in the study talked about.

The first facet of accessibility that many educators talked about was the use of different senses in XR experiences. XR is defined as the integration of digital assets in different spaces to enhance the environment. The educators discussed the ability to add audio and physical interactions with digital assets to heighten the experience for participants. The ability to get haptic feedback from touching an object can also enhance the experience for all.

The second facet of accessibility that the educators discussed was mobility in VR. They talked about the ability to move through virtual environments and how many VR experiences address mobility in different ways. The ability to switch between seated experiences and standing is one way that Chris discussed being able to address mobility. Jessica talked about how movement, in either instance, can be done by using the joystick to float through the virtual space. The participant can teleport from place to place, as well as physically move around the space. She also discussed that new technologies coming to the market that allow for the user to physically move using a treadmill for walking or using a wheelchair.

Presence in XR

Presence in XR was a dominant theme in the pilot study and the dissertation study. Discussions of presence dominated both the pre- and post-interviews along with the think-aloud in the VR experience. All the educators discussed the importance of presence in XR education

because it helped students feel connected to the virtual space, increase memory retention, and to create an emotional connection with the content.

Several of the educators' first introduction to XR was a 360-degree video VR experience. They all agreed that the experience was a great introduction to the potential of VR. All the educators wanted to do more in these experiences. They stated that they wanted to move around and explore more of the environment and be more active. Through this activity, they felt that students would develop connections to the environment and to the story that was unfolding around them. These connections would help the students increase their understanding of the material.

The educators all agreed that the ability to create XR experiences with realistic environments and avatars heightened student engagement. Many stated that it also increased the student's ability to relate content from the virtual space to the content in the physical space easier. The educators discussed how the use of photogrammetry and 3D modeling software can create realistic assets. Because of this, VR experiences are looking more like real life. Many of the educators felt that the ability of students to easily recognize and identify realistic components in a VR experience also lowers the cognitive load of the student and increases their focus and presence. This is important because it helps students relate to the content and increases their mental capacity to store the information in long-term memory.

Many of the educators discussed how XR evoked empathy from them. Several said that it was more than just empathy they felt in XR experiences. The educators felt when XR engages a student's range of emotions, it can enhance learning, decrease cognitive load, and increase the student's memory. This is important for students to feel connected to the material, as Eric said, that connection helped increase his understanding of the material and retain it in his memory.

When an experience has an emotional dimension, the educators remembered the experience more. Eric talked about remembering an event that happened to him when he was eight years old. He attributes the spatial experience to these memories. However, from the smile on his face, and the excitement he had while talking about the experience, there was also a heightened emotional connection to the memory of the story.

Several educators discussed when XR experiences keep the participant's cognitive load balanced, they can cognitively process and recall content easier. Here, cognitive load theory is implicated because according to Sweller (2011), to process complex environments that students interact with, they store these interactions in their long-term memory. The ability of students to interact with XR spaces and repetition in the interactions makes it easier for them to store information (Sweller, 2011).

They also spoke about the ability of VR to fully immerse students into a space and eliminate distractions. The educators stated that this increases the student's ability to interact and develop connections with the content easier which increases memory recall later. As Mayer (1997) stated, multimedia learning occurs when a learner builds a mental representation from words and pictures that have been presented. The educators discussed that with the use of realistic environments and assets in VR, the students can draw more of a connection to prior experiences and develop an increased mental representation of the experience in the future.

The implications for this idea of presence in XR are that the students can explore and feel safe in the virtual space. When students are present in the XR environment, the technology can create an emotional connection to the content that increases the student's relationship with the material. In addition, presence in VR can lower a student's cognitive load and increase their memory retention.

Future of XR in Education

The educators all agreed that the future of XR in education is transformative because of the potential to change how educators teach and students learn. As James stated, “it (VR) changed my whole internal set of expectations and understanding of my own limitations, just because it opened a door that I didn't think was openable.” From the discussions with the educators, the intersection of design and presence will be integral to the future of XR. Chris stated that the cost of XR technology is decreasing while the capabilities are increasing. The more people are exposed to the capabilities of XR, such as feeling present in a virtual environment or walking around the inside of a heart, the more doors will open for educators. Several of the educators added that the integration of XR technologies into everyday life will be seamless. Ben talked about how Apple has started to design hardware that is not as bulky and intrusive to wear as previous VR HMDs. The ability to view AR content as a person walks down the street is already happening through their cell phones (Chatzopoulos et al., 2017). Chris pointed out that once the XR technology becomes a necessity, like our phones, to our everyday use, it will change how we interact with spaces. This is key because the more that people are exposed to XR, the more they will be able to explore information in new and exciting ways.

As several of the educators discussed, the easier it is for students to access the content and interact with it, the greater the learning experiences could be, especially regarding media literacy. To paraphrase Kai, students have been introduced to media literacy from an early age by watching television shows and movies, they understand what the beginning of a time flashback looks like, the screen gets wavey, and the scene changes. Kai’s words are important for the future of XR because content creators will need to educate new participants about new media

literacies, such as what it looks like for a time-lapse where the time and the space rapidly change. Designing stories in XR that have consistent literacy for students' cognitive load is necessary.

As stated earlier in the manuscript, the use of XR needs to be accessible to all users. The opportunities XR introduces to all users cannot be ignored. The creation of software and hardware that engages all users is a necessity for XR to be fully integrated into education. There has already been research that shows the impact that XR has on students with varying abilities (Valakou et al., 2023) With the increase of immersion of XR in education, as Kevin said, "we cannot leave anyone behind."

Lastly, with the integration of realistic avatars and environments, there is the introduction of ethical issues. The use of XR to spread false information can affect people differently than other media (Aliman & Kester, 2020). With the introduction of deep fake videos over the last ten years, the ability to integrate realistic avatars into XR experiences and spread false information is a possibility today (Blankenship, 2021). The ability to take a photogrammetry scan of a prominent figure and create realistic XR experiences of that person is a real scenario (Mirsky & Lee, 2021). As the educators have stated in this manuscript, the ability to feel present in an XR experience is heightened by the realism of the environment. Could this have the same effect on people believing realistic avatars?

As educators, we still have much work to do when it comes to understanding the long-term effect of XR technologies on students learning. I believe that currently, XR technology is introducing educational opportunities that I could only dream of when I started teaching over 20 years ago. I believe XR will be integrated into education in ways that we have not thought of yet. As this happens, we need to be optimistically cautious and consistently ask ourselves: (1) Is it

accessible? and (2) Is it ethical? Only after we can answer yes to both of those questions consistently, will XR become fully immersed in education.

Limitations

This study contributes to understanding how educators make sense of learning in VR. But, as with all studies, there were limitations. I will elaborate on three limitations of this study: (1) the participant pool, (2) the design of the VR experience, and (3) long-term study on memory and retention of information.

First, the pool of educators was not racially diverse. I believe this was a limitation because it did not establish the opportunity to represent and engage in meaningful discussions about the diverse population of students that XR could affect. I realize the size of the educator's pool, 13 people, and the diversity of regions represented, were both limited. Though small, the goal of this study was not to prove generalizations of XR in education but, rather how educators make sense of learning in XR. As Karp (1996) asserted, "One does not need huge sample sizes to discover underlying and repeating forms of social life that, once described, offer new levels of insight for people" (p. 202). This small study highlights this assertion and as Bogdan and Biklen (2007) state, "enlarging the conception of the phenomena under study" (p. 36).

In the pilot study, the five participants from the local university helped me understand how they made sense of learning in VR and that inspired me to expand my dissertation. Due to travel and availability, I was only able to add an additional eight participants from four new colleges and universities for the doctoral study. Given the opportunity for future study, I would expand out of this region and add another 20-30 participants from at least 10-15 different colleges and universities to increase the diversity, range of knowledge, and regions represented in the U.S. and internationally.

The VR experience design, itself, was a limitation. The VR experience was designed and built from scratch in Unreal Engine using components from the Epic Marketplace, models built in Blender, and photogrammetry scans from the Smithsonian. As stated earlier in the manuscript, the environment was designed for the participants to physically move around the space in six degrees of freedom.

I did not incorporate any active components to the environment that the educators could interact with. As Kim stated, “it would be nice to stick my hand in the seaweed and see it move.” The fish were designed to move away from the educators as they got close to them, but that was an indirect interaction and not one that they would notice without prompting. I believe there would have been a deeper conversation around interactivity in VR and how that increases presence and memory of the experience. Again, this was a limitation that could have yielded a conversation around a heightened sense of presence and discussions centered around the design of the experience.

In the pilot study, the educators could not virtually see their arms and hands in the experience when they held them out in front of them. This was a limitation because I feel it did not allow them to feel as present in the space as they could. I felt that part of feeling present in a space is being able to see your virtual appendages. This also limited how they were able to communicate with me in the space during the talk-aloud. If the educators wanted to ask a question about a particular piece of coral, they had to physically move closer and focus their vision on the coral itself. I believe this reduced their presence in the space because they had to figure out how to communicate with me through the technology. I feel this made the technology a distraction in the experience.

In the doctoral study, I added virtual hands to the experience so the educators could gauge their distance to objects in the environment easier. This modification was helpful because several educators discussed how it helped them feel more immersed. The technology was not a barrier for them, they were able to act as they would in the real space and point at what they were talking about during the think-aloud. Additionally, they used their digital hands to effectively gauge their distance from objects in the virtual environment. I would like to go back to the pilot study and see if this addition changes their perception of spatial relationships and presence in VR.

The last limitation I believe this study is it only had two semi-structured interview sessions. I believe that if I were able to schedule another interview a year later with the participants, I would gain more insight into what the educators remembered from the VR experience. This third interview, one year later, could give me insight into how they retain information from VR experiences. Next, I will discuss future research opportunities from this study.

Future Research

As I stated earlier in the manuscript, there is an opportunity to look at this doctoral data quantitatively and as a mixed methods study (Aguayo & Eames, 2023). The HMD was able to record the participants' cognitive load, and heart rate. This data could yield significant insight into how the educators perceived learning in VR by examining their heart rate as they were exploring the space. For instance, in the coral reef experience the educators participated in, one of the reef sharks swam over the educator's heads. I noticed a small increase in heart rate for most of the educators. In the post-interview with Kai, she stated she was excited because it reminded her of swimming with sharks when she went scuba diving previously. For the other

educators, why did their heart rate increase? Correlating the data from the HMD and semi-structured interviews could increase our understanding of how participants in VR interact with different environments.

The opportunity to also use the HMD to track the cognitive load of a student in a VR experience could yield quantitative data. The data could inform the students and educators if there is too much information. The experience could then be adjusted to reduce the amount of content the student is experiencing and retested. Conversely, it could be utilized to show if the student is not engaged with the content. This study would be significant in designing a VR experience to match students learning of all levels from elementary school to post-secondary. The same VR experience could change the VR experience based off the student's cognitive load.

After receiving the feedback from the educators from this study, I would like to incorporate more haptic feedback into the experience. In understanding haptic feedback better, I believe that a student's presence in the XR experience could be significantly increased. Students could also interact with digital objects like real objects. When Chris said that he accidentally grabbed onto his kitchen chair while in another coral reef experience, he felt like he was on the bow of that sunken ship and he said, "Woah, wait, this is real." This highlights how interactivity with haptic feedback could increase presence and I would like to explore this more.

In addition to using haptic feedback for interactivity, I would like to explore how haptic feedback could be used to create emotional connections in social VR experiences. The educators talked about the ability to feel connected to another person in VR through spatial relationships. What kind of emotional connection would you have if you were able to shake another person's hand or hug them in VR and feel it through haptic feedback? What kind of emotional reaction would the participants have?

Final Thoughts

In my venture to understand how XR is researched in education, I looked at the integration of educational technology in education. I noticed quantitative methodologies dominated the literature (Maas & Hughes, 2020). Several of the XR research studies procedures compared traditional classroom activities to recreating the same activities using XR technology (Alnagrat et al., 2022). Many of these studies analyzed the increase in learning through pre- and post-tests. For a select few of the studies, they did see a change in the results but most of the time, it was not significant, or the researchers found there was no change at all (Luo et al., 2024).

I feel these studies underestimate the educational potential of XR. As several of the educators stated throughout this study, XR is an innovative technology that can change how students learn. You cannot be innovative when the XR activity in a research study is compared to an identical traditional activity without XR. I believe those studies do not show the innovation capabilities of XR.

Earlier in my career I taught at a secondary school where all the administrators and teachers were excited to get a Smartboard in their classroom. Smartboards were essentially large tablets that allowed teachers to interact with their computers and write digitally on the board in front of the classroom. A month after the boards were installed, several of my colleagues, who were initially excited, were complaining that the boards did not improve their teaching. After asking them what they were doing differently with the boards, I discovered that the activities they did with their whiteboards were transferred to the Smartboard. No one showed them how to be innovative with the technology for their lessons. By the end of the school year, the Smartboards turned into expensive whiteboards. This same occurrence could happen to XR

technologies if there is not a support system in place that assists educators in exploring new ways to be innovative with the technology in their teaching.

XR has shown has also shown it has an emotional element to it. I believe that quantitative research is not going to capture those emotions at the same level that qualitative or mixed methods can. The ability to use interviews and participant observations in this study presented elevated engagement from the participants. I believe the educators were open and honest about their prior experiences and their passion for XR in education. I believe that future research needs to be done with qualitative or mixed methods to increase understanding of how to explore the emotional connections in XR.

In addition to being more cognizant of designing XR for accessibility, there are other ethical issues that I feel XR designers and researchers must address. I believe we need to be aware of the integration of deep fakes to misdirect students. As designers, educators, and researchers in educational XR, we need to be more cognizant of the messages of the XR experiences. With the rise of disinformation in media and news, I say this as a cautionary warning.

Finally, I would like to add that we have only begun to understand what XR can do for education and other professional fields. The educators were passionate and excited to talk about how they use XR in education. As a profession, I believe we are on the cusp of an educational shift in how we use educational technology in the classroom. I believe that XR technologies will be the leaders in this venture.

Appendix 1: Participant Descriptions

Name	Pronouns	Age	University	Description
Liz	She/Her	40-50	University 1 (Pilot)	Assistant Professor - Communications
Kim	She/Her	40-50	University 1 (Pilot)	Assistant Professor - Architecture
Kevin	He/Him	50-60	University 1 (Pilot)	Associate Professor - Communications
Kai	She/Her	50-60	University 1 (Pilot)	Ph.D. - Professor - Communications
Jen	She/Her	50-60	University 1 (Pilot)	Ph.D. - Professor – Public Health
Chris	He/Him	50-60	University 2	Director of XR Partner Development
James	He/Him	30-40	University 2	XR Professor, Center for Immersive Technologies
Jessica	She/Her	30-40	University 2	Ph.D., Research Scientist, School of Medicine
Eric	He/Him	30-40	University 3	Adjunct Professor - XR Podcaster
Sue	She/Her	40-50	University 4	Vice President of Strategic Initiatives
Ben	He/Him	30-40	University 5	Director of Creative Services
Morgan	She/Her	20-30	University 5	Libraries Coordinator
Jane	She/Her	20-30	University 5	IT Support Specialist

Appendix 2: Pre-Virtual Reality Experience Interview Questions

- Describe to me how make sense of extended reality?
- Describe your first extended reality experience?
    - Describe your first virtual reality experience?
- What did you think of the experience?
- What draws you to extended reality?
- What did you like the most about your favorite VR experience?
    - What made it engaging?
- Can you explain to me the difference between passive and active virtual reality?
- When did you know that this was a technology you wanted to use in the classroom?
- Have you created any virtual reality or XR projects?
    - What were they?
    - What was it designed for?
- Have your students created any virtual reality or XR projects?
- Describe the negatives of XR being used for education could be or are?
- Describe the benefits of XR, especially virtual reality be used for education could be?

Appendix 3: Post Virtual Reality Experience Interview Questions

- Describe your impression of the experience?
    - Realism
- What did you feel you learned from the experience?
- What did you like about the experience?
- What would you change about the experience?
    - Educationally?
    - Design?
- [How] was this experience different than your previous ones?
- How do you make sense of learning in XR?
- Describe potential negatives of VR/XR experience in education?
- What do you think XR means for education?
- What will the future of XR be?
- Any closing thoughts?

Appendix 4: Codes

1. Interactivity
2. Technology
3. Artificial Inteligence
4. Change
5. Emotion
6. Isolation
7. Social
8. Remote Learning
9. Tool
10. Resources
11. Immersion
12. Engaging
13. Holodeck
14. Empathy
15. Spatial
16. Presence
17. Learning
18. Creating
19. Accessibility
20. Financial Access
21. Sensory
22. Collaboration
23. Global
24. Adjustable
25. Resource
26. Training
27. Practical
28. Repetitive
29. Cognitive load
30. Data collection
31. Tenancies
32. Focus
33. Distractions
34. Audio
35. Realism
36. Low poly
37. Motion sickness
38. Exposure
39. Museums
40. Design
41. Movement
42. Story
43. Futuristic

Appendix 5: Threads

1. Social VR
2. Artificial Intelligence + XR
3. Story
4. Design
5. Movement
6. Realism
7. Motion Sickness
8. Training
9. Education
10. Design
11. Data Collection
12. Collaboration
13. Accessibility
14. Immersion
15. Emotion
16. Presence
17. Spatial Learning
18. Technology
19. Interactivity
20. Haptic Feedback
21. Engagement
22. Isolation
23. Future of XR

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Curriculum Vitae

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Education

2018-Present — Syracuse University – School of Education
Doctoral Student in Teaching and Curriculum

2011-2017 — Syracuse University – Newhouse School of Communications
Master of Art in Television, Radio, and Film

2001-2005 — Oswego State University
Master of Science in Technology Education

1998-2001 — Oswego State University
Bachelor of Science in Technology Education

1996-1998 — Villanova University
Majored in Computer Engineering

Professional Experience

2023 – Present — Assistant Professor at Syracuse University

- S.I. School of Public Communications - Visual Communications
  - VIS 337/600 - Motion Design for Production
  - VIS 447/647 - Motion Design
  - VIS 467/667 - Immersive Design
  - VIS 500 - Design and World Building
- XR Research Lab - Facilitator/Trainer

2015-2023 — Online Learning Analyst at Syracuse University

- High level support for university enterprise systems
- Design effective strategies for flipped, blended, and online learning environments
- Lead in workshops and trainings for different organizations on campus
- Design and produce content in Syracuse University Education Studio
- Facilitator of HP-EDUCAUSE Grant: *Future of the Classroom Project*
- Member of HP-EDUCAUSE Higher Education Board
- Facilitator of XR at SU group
  - Lead facilitator for XR in Research training

2021-2023 — Adjunct Professor for Visual and Performing Arts

- CAR 101 - Introduction to 3D Animation and Visual Effects
- CAR 201 – Intermediate 3D Animation and Visual Effects

2019-2023 Adjunct Professor for the School of Education

- IDE 552 - Digital and Media Production – A-synchronous online
    - Introduced students to developing pedagogy integrated with educational technology for teaching.

2022 EDUCAUSE Learning Lab – XR in Research

- Lead facilitator
- Designed 4-week course to address research utilizing Extended Reality in education

2016-2018 Adjunct Professor for the Newhouse School of Communication

- VIS 467/667 - Motion Graphics
- TRF 400/600 - Visual Effects: VFX Assets
- TRF 400/600 - Visual Effects: VFX Composition

2014-2015 Itinerant Computer Education Specialist at CiTi in Oswego County

- Developed curriculum with educators to create interactive media
- Modeled effective strategies for flipped, blended, and hybrid learning
- Designed and implemented diverse lessons utilizing media

2013-2014 Technology Teacher at Oswego Buccaneer Jr/Sr High School

- Developed several curricula for Big Picture Learning School
    - 2D Animation, Video Editing, Cooking, and Robotics
- Learning Through Internship Coordinator

2001-2013 Technology Teacher at Cazenovia High School

- Developed several curricula for Communications Systems, Radio Broadcasting, Video Broadcasting, and Energy Systems
    - Taught Communications Systems, Tompkins Community College Radio Broadcasting, Video Broadcasting
- Advisor for Broadcast Communications Club
- Advisor for Annual Whiteout Benefit Concert
- Acquired donations from WTVH 5 and other local broadcasters to build the high school's television studio and editing classroom

2006-Present Freelance Work

- Training for animation and video production for schools
- General Manager and Media director for Oswego River Hawks Box Lacrosse
- Created motion graphics and promotional videos for Syracuse Silver Knights - Professional Indoor Soccer Team
- Produced and edited commercials for local businesses

Conference Presenter

2024 O'Reilly FOO Camp
- Invited by Meta VR Team
- Lightning Talk – VR is More Than Empathy

2023 HP HBCU Technology Conference
- Actions Thru Avatars
- Intersection of XR and AI in Education

2022 Virtual Reality as a Research Tool
- Yale/HP Hosted Virtual Presentation

2018 - 2023 EDUCAUSE Conference
- 2023 – Intersection of XR and AI in Education
- 2022 - XR in Research
- 2021 - Engaging Students with XR – Poster Session
- 2021 - Building an XR Center on Campus: Lessons from the Field – Panel
- 2020 - Draw All Learners In: The Power of Immersive Videos
- 2019 - HP, Yale, SU, and UNL Team Up on Blended Reality
- 2018 - Mixed Reality Technology Innovation Case Studies in Higher Ed.

2018 - 2021 Bb World Conference (Blackboard)
- 2021 – Beyond the Greenscreen – XR in Blackboard
- 2020 - Make Videos Students Will Watch
- 2018, 2019 - Pro Tips: How to Create Hollywood Content for Blackboard

2017 - 2020 Learning with Innovative Technology
- 2020 - It's Easy Going Green(screen)
- 2019 - Pro Tips: How to Create Hollywood Content for the Classroom
- 2018 - Creating Interactive Media
- 2017 - Creating Animated Classroom Media

2017 - 2018 University Business Tech Conference
- 2018 - Pro Tips: How to Create Hollywood Content for the Classroom
- 2017 - Multimedia Content Creation for Blended Learning & eLearning

2018 MSX Conference – Mediasite
- Pro Tips: How to Create Hollywood Content for the Classroom

2017 Sonic Foundry - Mediasite Webinar
- Pro Tips for Flipped Classroom Content Creation

2016 EdTech Teacher Conference
- Video Content in the Classroom

2016 Bring IT Together
- Creating Video Content with Mobile Devices
- Content Creation Through Multimedia

2016 - 2020 Adobe Design Achievement Awards
- Judge for ADAA Design Competition
- Mentor for 2016 ADAA Design Winners

Professional Affiliations

- EDUCAUSE XR Community
- EDUCAUSE/HP XR Community of Practice
- EDUCAUSE AI Community of Practice

Publications

- Webb, J. (2020). Technology in Practice: Pro Tips and Tools to Create Hollywood Content for Remote Instruction. *Community College Enterprise*, *26*(2), 105-109.
- Mangram, J., & Webb, J. (2020, October 22). *Fostering student creativity with green screen videos – The teaching professor*. The Teaching Professor. https://www.teachingprofessor.com/topics/teaching-strategies/teaching-with-technology/fostering-student-creativity-with-green-screen-videos/

Technical Skills

- Adobe Creative Cloud Suite
    - After Effect, Premeire Pro, Adobe Aero, Adobe Substance
- Virtual Reality Head Mounted Display Development
    - Meta (Oculus), HTC Vive, HP Reverb G2 Omnicept SDK
- 3D Modeling & Animation Software
    - Blender 3D, Maxon Cinema4D/Autodesk Maya
- XR Engine Editor
    - Unreal, Unity, A-Frame