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The Impact of Immersive VR verses Desktop VR Technologies on Learning Attainment and Sense of Presence

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THE IMPACT OF IMMERSIVE VR VERSES DESKTOP VR TECHNOLOGIES ON LEARNING ATTAINMENT AND SENSE OF PRESENCE

By

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ABSTRACT

The study examined the influence of immersive technologies and sense of presence on learning outcomes while comparing different media formats (Immersive Virtual Reality and Desktop Virtual Reality). The experiment was conducted on N=68 students that experienced a biology lesson about the human cellular system and its related processes. The current literature suggests that Immersive technologies can a powerful impact to learning, but it is crucial to identify when and how these impacts emerge. The current assumption is that presence and educational outcomes stem from the amount of engagement with the material, which is suggested to depend on the level of immersion. Currently, the question is whether technological immersion elicits this psychological state of presence and whether this feeling of presence has an influence on learning or not. Much of the literature relates to qualitative measurement techniques, such as motivational and emotional questionnaires. As well as a major issue relating to the methodology, such as sample size and inconsistency between groups. The study addressed this limitation by assessing learning outcomes quantitatively, and consistency of stimulus between experimental groups. We proposed that the largest learning gains may be seen in the iVR environment, since evidence suggest that designing active and embodied lessons with meaningful interactivity and manipulation of content may continue to induce significant influence in learning interventions. These findings may provide empirical evidence to help understand the influence of these variables on learning in iVR.

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Dr. Michael Granaas

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Introduction

Close your eyes and imagine students at a university or in a high school classroom walking into their general biology or anatomy class and on the desks are Virtual Reality (VR) headsets. After putting on the headset, students are immediately transported into a world where they see enlarged images of the microscopic organelles of a human cell revealing the many physiological and anatomical functions of the cell. Viewing enlarged microstructures is the kind of educational experience one can have using immersive virtual reality (iVR). Now imagine the same lesson delivered on a typical computer monitor, or simply reading a section out of the assigned textbook. Would the use of an immersive VR experience impact the acquisition and retention of the concepts differently when compared to a less-immersive VR experience?

Many have argued that the use of immersive VR in education encompasses affordances that are only seen in a fully immersive technology (Chen, 2006; Chen & Wan, 2008; Parong & Mayer, 2018; Mikropoulos, 2006; Mikropoulos & Strouboulis, 2004; Winn & Windschitl, 2000; Mulders, Buchner, & Kerres, 2020). These affordances include the ability to examine and manipulate microstructures and processes that are not possible in a real-world environment. They also include the ability to access and manipulate information in a fully stereoscopic 3D environment, an environment in which one is able to see the information represented in its true binocular spatial 3D form. The same experience shown on a desktop computer, which represents the same 3D information in a 2D form. Virtual environments (VE) provide the opportunity to explore and interact with microstructures and processes that would otherwise be inaccessible to the student, as well as visualize information in a 3D form (Chen, 2006; Milgram et al., 1994; Mulder, Buchner, & Kerres, 2020; Schneiderman et al., 2016; Slater et al., 1999). Interacting with VEs through iVR may allow learners to engage with content in a more intuitive and immersive way, potentially leading to deeper understanding and retention of the material (Milgram et al., 1994; Mulder, Buchner, & Kerres, 2020; Schneiderman et al., 2016; Slater et al., 1999).

Human Factors is the study of how people interact with technology and the environment, including the design of interfaces, displays, and controls (Dempsey, Mogalter & Hancock, 2000; Licht, Polzella & Boff, 1989; Schneiderman et al., 2016). In the case of iVR, Human Factors plays a critical role in ensuring that the iVR experience is optimized for learners to engage with content in an intuitive and immersive way. This involves considering factors such as user comfort, ease of navigation, and the design of the VE (Dempsey, Mogalter & Hancock, 2000; Licht, Polzella & Boff, 1989). Additionally, Human Factors considerations must also take into account the potential cognitive and ergonomic factors associated with the use of iVR, such as cognitive load, visual perception, and interaction design (Schneiderman et al., 2016). Thus, Human Factors research needs to be integrated with iVR developers and educators to ensure that the immersive educational experience is not only engaging but also safe and effective for learners (Dempsey, Mogalter & Hancock, 2000; Licht, Polzella & Boff, 1989; Schneiderman et al., 2016).

What is Immersive Technology?

For the purposes of this work discussion of immersive technologies will focus on computer-based virtual environments. In this context, immersive technologies refer to software and hardware systems that allow users to replace or expand physical environments to get more information than their physical surroundings can offer (Jensen & Konradsen, 2018; Mikropoulos, 2006; Milgrim et al., 1994). These technologies include virtual (VR), augmented (AR), and mixed reality (MR) (Dalgarno & Lee, 2010; Freina, 2015; Mikropoulos, 2006; Milgrim et al., 1994). Under some circumstances, immersive technologies can add a powerful benefit to learning (Jensen & Konradsen, 2018; Mikropoulos, 2006). Immersive technologies are sought after because of the belief that they have the power to astound and engage learners, both by helping educators present complex concepts more easily, resulting in a depth of understanding by the learner that other technologies cannot achieve (Freina, 2015; Mikropoulos, 2006; Milgram et al., 1994).

Immersion

Two attributes of iVR thought to contribute to education are immersion and presence. Immersion typically refers to the visual, auditory, and haptic devices that establish physical immersion in the scene that is changing in response to the users' actions, an objective characteristic of the media (Mikropoulos, 2006; Mikropoulos & Strouboulis, 2004; Slater et al., 1999). Witmer and Singer (1998) define immersion as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences." Witmer and Singer have also argued that immersion is a prerequisite for experiencing presence within a virtual environment.

Witmer & Singer's (1998) definition of immersion agrees with Slater, Linkakis, Usoh, & Kooper (1999) who described immersion as a physical characteristic of the medium itself for the different sensory modalities involved within the experience. With this idea in mind, immersiveness is innately related to the compatibility of the iVR device with human characteristics, such as quality of the iVR display and changing in response to the users' actions. From this perspective, immersion is intended to instill a sense of belief that one has left the real environment and is now "present" in the virtual world. This notion of being present in the virtual environment is a crucial aspect of the virtual environment (Chen, 2006; Milgram et al., 1994; Mulder, Buchner, & Kerres, 2020; Slater et al., 1999). The user then interprets cues to gather information while navigating the environment and controlling objects. Naturally in response, the corresponding sensory inputs are present in the virtual environments which results in the user becoming immersed within the experience (Mulder et al., 2020).

iVR is all about sensory immersion, where other less immersive technologies excel at delivering and embedding concepts and knowledge; iVR takes the learner out of the classroom and into an immersive experience. Milgram et al. (1994) suggest that iVR is the most immersive technology available, surpassing less immersive options such as desktop virtual reality (dVR), which, in turn, offers a more immersive experience than static images found in books.

Presence

Presence can be defined as a feeling of being in and of the virtual world, and the ignoring of physical world distractions, a subjective feeling (Dalgarno & Lee, 2010; Freina, 2015; Mikropoulos, 2006; Winn, 1993;1999; Witmer & Singer, 1998). High levels of immersion are associated with high levels of presence (Bulu, 2012; Parong & Mayer, 2019; Richards & Taylor, 2015). If you were to subjectively react to being immersed in a virtual environment (VE) such that your brain and nervous system behave in a manner consistent with that same situation in the real world, you would be experiencing presence (Dalgarno & Lee, 2010; Freina, 2015; Mikropoulos, 2006; Winn, 1993;1999; Witmer & Singer, 1998). In contrast with immersion, which is an objective property connected to the VR system itself (e.g., resolution, field of view, sound quality etc.), presence, instead, is a subjective experience happening inside the head of the iVR user.

Witmer and Singer (1998) report that both involvement and immersion are key in experiencing presence. Involvement relies on focusing one’s attention and energy on a coherent set of stimuli in the virtual environment (VE). For most people, high levels of involvement can be obtained in media other than a VE, such as movies and books. As users focus attention on the VE stimuli, they become more immersed in the VE experience, which leads to an increased sense of presence in the VE (Dalgarno & Lee, 2010; Freina, 2015; Witmer & Singer, 1998; 2005). The current evidence suggests that a VE that produces a greater level of immersion will produce a higher sense of presence (Mikropoulos, 2006; Mikropoulos & Strouboulis, 2004; Slater, 1999).

Sheridan (1992) indicates that validated questionnaires that examine both personal and technological factors of presence are the most common method of measuring this construct. The Presence Questionnaire (PQ), developed by Witmer and Singer (1998) is considered to be the “gold standard” for measuring presence. This questionnaire, and others, measure the degree to which individuals experience presence in a VE and the influence of contributing factors (Akyol & Garrison, 2011; Huang et al., 2020; Sarasso et al., 2022; Sheridan, 1992; Wilkinson et al., 2019; Witmer & Singer, 1998). Fidelity, involvement, realism of the VE, and sensory factors, can all affect how much presence is reported. In addition, individual differences, motivational traits, cognition, and the emotional state of the user may also influence one’s sense of presence (Parong & Mayer, 2018; Mikropoulos, 2006; Mulders, Buchner, & Kerres, 2020).

Moreover, with immersion being a “technology- related” aspect of VEs, presence is considered to be a psychological, perceptual, and cognitive effect of immersion. Meaning, presence is the psychological experience of being in the VE in which one is immersed. This sense of presence is another key characteristic for educational VEs. The sense of presence in virtual environments is believed by many to be an important factor for educational VEs, as it provides a psychological perception of being immersed which is thought to enhance the learning experience (Parong & Mayer, 2018; Mikropoulos, 2006; Witmer & Singer, 1998; Mulders et al., 2020). (See Appendix A to learn more about the history of iVR).

Types of Immersive Technology

According to Milgram et al. (1994), immersive technologies are “technologies that create the impression that one is participating in a realistic experience via the use of sensory stimuli, narrative, and symbolism (pg. 283).” Immersive technologies utilize various types of software and hardware resulting in a continuum with varying levels of interactivity and immersiveness (Dalgarno & Lee, 2010; Freina, 2015; Mikropoulos, 2006; Milgrim et al., 1994; Witmer & Singer, 1998). Milgram et al. also describes this experience of immersion as being on a continuing experience between the physical and virtual worlds, known as Milgram’s Reality-Virtuality Continuum (Milgram et al., 1994). This continuum reflects the transitional and immersive experience moving from the real world into the experience of a VE.

The immersion continuum is anchored at one end, by the real physical environment, which consists solely of real objects. At the other end of the continuum is a purely virtual environment, which consists of only virtual objects (Milgram et al., 1994). At the virtual end of the continuum, a person can interact within an artificial 3D environment using electronic devices. Within this continuum, any environment which consists of a blending of real and virtual objects is considered to be mixed reality. Mixed reality environments in which the real world is augmented with virtual content are called augmented reality, while those where most of the content is virtual but there is some awareness or inclusion of real-world objects are called augmented virtuality (Jensen & Konradsen, 2018; Milgram et al., 1994). Based on research carried out in the technology field, it is possible to distinguish among two categories of virtual reality: the immersive VR (iVR) and desktop VR (dVR) which can be achieved through various types of equipment with varying functions.

Immersive Virtual Reality (iVR)

Immersive virtual reality (iVR) refers to a computer-generated simulation delivered using a VR headset. The headset blocks out external visual stimuli and presents the VE stereoscopically. In the iVR VE, a person can interact within an artificial 3D environment using electronic devices, such as special goggles with a screen and possibly gloves fitted with sensors (Jensen & Konradsen, 2018; Milgram et al., 1994). Virtual Reality technologies often use high performance graphics engines to render moving near photo-realistic scenes in real-time and in three-dimensional perspective combined with associated surround-sound audio and tactile feedback to a user (Chen, 2006; Jensen & Konradsen; Milgram et al., 1994; Schneiderman et al., 2016). In this simulated artificial environment, the user can have a realistic-feeling and immersive experience. When fully immersed in a virtual environment, the overall goal is to create user experiences that feel real when interacting with the virtual environment (Milgram et al., 1994; Schneiderman et al., 2016).

Desktop Virtual Reality (dVR)

Desktop virtual reality (dVR) is a less-immersive form of VR in which you interact with an environment through a computer or gaming console using a less-immersive display (i.e., computer monitor or television). In dVR the user can control some characters or activities with a mouse and keyboard or game controller (Chen, 2006; Freina, 2015; Jensen & Konradsen, 2018;

Schneiderman et al., 2016). This technology also provides users with a computer-generated virtual environment The main affordances of dVR experiences are that users can keep control over the VE while being aware of what is going on around them: sounds, visuals, and haptics (Mulder et al., 2020). dVR is less immersive and interactive in comparison to iVR headsets (Mulder et al., 2020). Through dVR technology, participants can view the 360° content by moving or rotating the image on the device, on which the content is displayed, such as a desktop, smartphone, or tablet (Chen, 2006; Moro, Stromberga, Raikos, & Stirling, 2017; Schneiderman et al., 2016; Trindade & Fiolhais, 2002). In dVR, participants are external observers but still use various input devices, that allow them to interact with digital content on a physical display.

Virtual Environments in Education

Research on the effectiveness of immersive VR for education is mixed. In some cases, immersive VR seems to aid learning (Dalgarno & Lee, 2010; Kahlert, Camp, & Stiefelhagen, 2015; Klingenberg et al., 2020; Mikropoulos & Bellou, 2006; Ray & Deb, 2016). In other cases, immersive VR provides no benefit (Bailey et al., 2012; Makransky et al., 2019) or even impairs learning (Parong & Mayer, 2018; Makransky, Andreasen, Baceviciute, Mayer, 2020; Richards & Taylor, 2015).

Due to the recent increase in popularity of VR, the question of whether immersive VR has the potential to transform education and learning has been raised (Chen, 2006; Jensen & Konradsen, 2018; Moro et al., 2017; Mikropoulos & Natsis, 2011; Mikropoulos & Strouboulis, 2004; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). Current research demonstrates that HMDs do not cause learning to occur, but they can be used as a medium to access simulations in which learning may take place (Chen, 2006; Jensen & Konradsen, 2018; Mikropoulos &

Strouboulis, 2004). Because of this, the question is not whether HMDs are useful for education, but rather what type of VE is useful in aiding learning. iVR as an educational technology should not be widely accepted as a pedagogical learning tool until its effectiveness is demonstrated.

Some software developers are promoting iVR educational experiences without considering educational theories or principles, solely relying on the novelty and excitement of the technology to drive sales (Boivie et al., 2003; Ogunyemi and Lamas, 2014, p. 4; Saghafian et al., 2021). This lack of expertise in pedagogy and user experience design can lead to the development of VEs that fail to consider the needs of learners. As a result, learners may be presented with VEs that are engaging but fail to provide meaningful educational outcomes (Parong & Mayer, 2019). It is important for developers to collaborate with educators and human factors researchers to ensure that iVR educational experiences are designed to effectively support learning (Boivie et al., 2003; Ogunyemi and Lamas, 2014, p. 4; Saghafian et al., 2021).

Interest in the possible educational use of VR increased following the release of the first version of a consumer priced HMD, the Oculus Rift (Jensen & Konradsen, 2018). With the launch of a consumer-priced iVR system, the technology became more widely accessible for consumers and academic researchers (Richards & Taylor, 2015). A broader focus on the appropriate educational implementation of virtual reality technology is of crucial importance. This consideration is crucial because people are spending money on technology that may not work or technology that would work if used correctly. To facilitate our understanding of how to best use these tools it is critical to use reliable and valid measures of learning. Current research exploring the use of iVR in education frequently lacks reliable and valid measurement methods for establishing whether information is learned and retained (Chen, 2006; Radianti et al., 2020).

Virtual Learning Environments (VLE)/ Virtual Environments

A physical learning environment generally integrates course materials and resources such as libraries, and formal communication such as whiteboards and written assignments. Similarly, a 3D virtual learning environment (VLE) integrates a variety of tools supporting multiple functions such as information presentation, communication, collaboration, involvement, and learning. Wilson (1996) defines these 3D VLEs as computer-based environments that are relatively open systems, allowing interactions, and encounters with other participants and providing access to a wide range of resources. Numerous 3D VLES have been developed using platforms such as, Second Life, Open-Sim, Traveler, Croquet, Adobe Atmosphere (Chen, 2006; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017; Radianti et al., 2020). Regardless of the hype surrounding 3D VLEs, the successful development and implementation of this technology in the classroom is a slow process. However, defining and studying the main features that arise from the VRE characteristics is an important step in understanding the contribution of VLEs to learning.

Characteristics of 3D VLEs

3D VLEs elicit a unique set of features from a pedagogical point of view. Dalgarno and Lee (2010) identify three features of a 3D VLE that make them distinct from other forms of interactive media: three-dimensionality, smooth temporal changes, and interactivity. These characteristics distinguish 3D VLEs from other VLEs such as learning management systems (LMS). The 3-dimensional characteristic of VRE allows one to move freely within the environment, as well as view and manipulate objects within it (Dalgarno & Lee, 2010). Smooth temporal changes within 3D LVEs reflect the smooth motion of objects within the environment which allows for a realistic experience (Mikropoulos & Natsis, 2011; Moro et al., 2017). The interactivity characteristic in a 3D environment allows students to both access material independently and follow different paths through active learning and interaction with the material in the VLEs (Dalgarno & Lee, 2010). Because of this interactivity and actions consistent with the real world, the ideas learned within the 3D VE may be more readily recalled and applied within the physical environment. Research suggest that the role of these technological characteristic may assist in developing positive learning behavior, as well as enhancing the learning experience (Dalgarno & Lee, 2010; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017).

Chen (2016) explains that 3D virtual worlds typically share three important features: the illusion of 3D space, avatars that serve as visual representations of the user, and an interactive tool for users to communicate with one another. Also, in line with Dalgarno and Lee (2010), Chen suggests that the use of an avatar gives rise to an on-screen persona which can result in "user embodiment" within a VE. As well as encompassing many life-like actions, such as walking, running, and control using hand controls, joystick, or mouse. The technological characteristics and affordances of 3D VLEs described here do not directly cause learning, but can plausibly enhance certain learning tasks that may result in increased learning.

Dalgarno and Lee (2010) identified five potential educational benefits of VEs that are both measurable and hypothesized to be related to learning processes and outcomes.

> **Spatial Knowledge Representation.** This refers to the mental processes of encoding, storing, and retrieving information about the spatial relationship between objects and locations in the virtual environment, in which one forms mental maps or representations of spatial layouts (Dalgarno & Lee, 2010).

Experiential Learning. States that learning through experience, observation, and reflection allows engagement with the environment and the ability to reflect on the experience to gain insights, develop new skills, and deepen understanding (Dalgarno & Lee, 2010).

Engagement/ Embodiment. This describes the extent to which a person is actively involved in their environment and is responding to stimuli. It emphasizes the importance of sensory and motor experiences in shaping cognitive processes such as perception, attention, and memory (Dalgarno & Lee, 2010).

Contextual Learning. Emphasizes the importance of the context in which learning occurs. This focuses on the practical application of knowledge and skills in real-world situations (Dalgarno & Lee, 2010).

Collaborative Learning. Describes an approach to education where students work together to complete a task or project, with the aim of achieving a common goal. This involves active participation, open communication, and the sharing of ideas. This approach recognizes the value of social interactions, experiences, and skills that lead to a deeper understanding of the subject matter and the material (Dalgarno & Lee, 2010).

Presence, Immersion, and Education

Researchers in educational technology continue to question whether level of immersion and presence not only effect the user’s experience but whether there is an effect on learning (Chen & Wan, 2008; Mikropoulos & Strouboulis, 2004; Mikropoulos, 2006; Winn & Windschitl, 2000). Many researchers have argued that immersion and presence are critical features of VLEs that are distinguishable from other types of computer applications (Chen &

Wan, 2008; Mikropoulos & Strouboulis, 2004; Mikropoulos, 2006). The current assumption is that presence and improved educational outcomes stem from the amount of engagement with the material, which is thought to depend on the level of immersion (Mikropoulos, 2006; Winn & Windschitl, 2000). Many authors suggest that switching from moderate to higher immersion VEs increases motivation and engagement (Chen, 2006; Chen & Wan, 2008; Mikropoulos, 2006; Mikropoulos & Strouboulis, 2004; Winn & Windschitl, 2000), which is believed by some to benefit learning.

Mikropoulos (2006) and others (Chen, 2006; Chen & Wan, 2008; Mikropoulos & Strouboulis, 2004; Winn & Windschitl, 2000) suggests that the use of an avatar gives rise to an on-screen persona which can be described as “user embodiment” within a virtual environment as well as encompassed many life-like actions. The use of avatars is thought to enable realistic interactions within the 3D environment, allowing users to interact and act on the world. Mikropoulos et al. investigated the effect of presence on learning outcomes in educational VEs, through the use of an avatar by either a projection on a wall or through an HMD.

The goal of the Mikropoulos (2006) study was to investigate the sense of presence of middle school children within an educational VE. The VE used in the study was a representation of a two-story house located in the ancient city of Kassiopis, Greece, in which was occupied by avatars. The students could navigate the VE and complete tasks through the use of an avatar, which enabled a sense of embodiment and the ability to complete learning tasks. The results reflected that the existence of a personal avatar as the student’s representation in the HMD group enhanced both presence and learning outcomes compared to those in the wall projection group. They also reported that the students had a high sense of presence for both versions of the virtual environment. Overall, Mikropoulos concluded that the students reported a higher sense of presence and completed their learning tasks more easily and efficiently using the HMD (Mikropoulos, 2006).

Winn et al. (2000) sought to examine whether varying levels of immersion within a learning virtual environment can enable various types of concepts to develop. In this study, researchers used an educational simulation of tidal currents which allowed students to control the water speed, direction, and salinity with virtual instruments. Students interacted with the simulation using either HMD VR technology or a less-immersive desktop computer screen. Students visited these VEs on three separate occasions for training and testing. Upon completing the simulation and the tasks, students were asked to take an objective short-answer posttest to measure learning outcomes from the simulation (Winn et al., 2000; Winn & Windschitl, 2000). Results reflected an increase of both learning outcomes and presence for the students who interacted with the environment with an HMD. To increase learning outcomes, Winn et al. suggest that increasing a student's "presence" by utilizing an immersive VE rather than the traditional desk-top application (Winn et al., 2000; Winn & Windschitl, 2000). Mikropoulos (2006) and Winn et al. (2000), found that HMD immersion compared to a desktop system has an educational advantage only when the content to be learned is complex, 3D, and dynamic. Overall, it is important to give careful consideration to both immersion and presence levels, while also conducting additional research to better understand the influence of immersiveness on learning.

Researchers have defined how immersion is a crucial factor that can greatly impact a user's motivation and learning. Dede (2009) reports defining characteristics on how immersive presence enhances both motivation and learning outcomes. Dede suggests four types of immersion that learning depends on, **sensory immersion, actional immersion,** and **symbolic/narrative immersion**.

Sensory immersion is the technological ability to digitally replicate the experience of location inside a three-dimensional space. This type of immersion is supported by interfaces that utilize iVR headsets. As well as the incorporation of our sensory system through realistic stereoscopic sound, haptic technologies that apply forces, vibrations, and motions to the user, and the ability to touch virtual objects (Dede, 2009).

In **actional immersion**, the user is empowered in an experience that allows the participant to make novel actions (Dede, 2009). For example, in an immersive chemistry lab, actional immersion allows purposeful movement and actions with the material to reinforce what is being taught in the classroom. As well as the opportunity to discover new abilities as a result of the movement and actions. As a result, discovering these abilities allows one to be highly motivated and sharpens attention.

Symbolic immersion triggers powerful semantic association through the context of the environment, which is an important motivational and intellectual component of learning (Dede, 2009). Creating digital versions of situations within a VE from one's culture deepens the immersive experience by drawing on the participant's beliefs, emotions, and values about the real world. Dede suggests that the more a VE is based on designing with actional, symbolic, and sensory factors, the greater the belief that the student is present within VE.

The use of technology in an educational setting is not new. Technology such as digital learning tools like websites, online games, videos, or programs used to teach and support student learning and schoolwork have been extensively studied. This interest in educational technology has resulted in many studies examining the effectiveness of both iVR and dVR in education and training (Pantelidis, 2009).

Current Applications

Currently most, students learn about biological science, health science, physics, chemistry, and other academic subjects primarily through static images and the written word (Chen, 2006; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Mikropoulos & Strouboulis, 2004; Moro et al., 2017). Formats such as these do not completely encapsulate the complexities of microstructures, molecules, or cells, as they represent 3D material in a flat two-dimensional image. To improve student understanding and to enhance learning across all age groups, innovations need to be made in the teaching of microanatomical, biological sciences, and education in general (Bailey et al., 2012; Chen, 2006; Dalgarno & Lee, 2010; Jensen & Konradsen, 2018). In these circumstances, VLEs can more accurately illustrate some features and processes, as well as allowing for extreme close-up examination of an object, and observation and examination of areas and events unavailable by other means (Bailenson et al., 2016; Chen, 2006; Dede, 2009; Jensen & Konradsen, 2018; Moro et al., 2017).

When designing and implementing iVR or dVR in education, Bailenson and Cummings (2016) outline various affordances for 3D VLEs. Bailenson and Cummings suggest that iVR should be used in situations where it is most advantageous for the user, such as when the experience is otherwise impossible or expensive to complete. Bailenson and Cummings also suggest that VLEs have been utilized in the field of education for the following reasons:

- Access to situations that would otherwise be dangerous (Bailenson & Cummings, 2016)

- Situations where interaction is crucial in understanding (Bailenson & Cummings, 2016)
- Situations that can’t be experienced in real life (e.g., microscopic organelles, chemistry molecules) (Bailenson & Cummings, 2016)

Jensen and Konradsen (2018) as well as Chen (2016), express that although iVR is recognized as an impressive learning tool, there are still many issues that need further consideration. These include 1) identifying the appropriate theories or models to guide iVR’s development in education and investigate how iVR attributes can support learning, 2) establishing whether iVR’s use can improve students’ performance and 3) investigating ways to achieve more effective learning when using iVR technology. Chen’s research, along with others, has resulted in clearer insights on the theoretical framework and implementation for VR-based learning environments (Chen, 2006; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017).

Pedagogical Theories

Research into the impact of iVR on learning outcomes focused on both K-12 and higher education is often limited, focusing on the student experience rather than meaningful educational outcomes. The primary supporting argument for iVR in education compared to conventional methods, is based on providing new learning opportunities for concepts and relationships that are not easily grasped or visualized by students in the absence of technology. (Mayer, 2003; Parong & Mayer, 2018; Salzman, Dede, & Chen, 1999; Trindade & Almeida, 2002; Winn, 1999; Leman, Williams, & Gu, 2012). Researchers are still unsure of what kind of tasks or academic concepts are well suited to benefit from iVR (Bailenson et al., 2012; Leman, Williams, & Gu, 2012; Mayer, 2003; Parong & Mayer, 2018; Salzman et al., 1999; Trindade & Almeida, 2002; Winn, 1999).

Pedagogy refers to the learning theory that enables the fulfillment of educational goals and research pertaining to learning outcomes and retention (Chen, 2006; Mayer, 2001; 2003; 2005; Moro et al., 2017; Parong & Mayer, 2018; Trindade & Almeida, 2002). There seems to be widespread lack of consideration in the VR educational literature of pedagogical frameworks or concepts that influence learning. The research is often focused on the technology itself and less on the pedagogical affordance of virtual environments for learning and education (Chen, 2006; Jensen & Konradsen, 2018; Madden et al., 2018; Moro et al., 2017; Winn, 1999).

Virtual reality technology has demonstrated it has unique capabilities. However, it is important to effectively establish when and how VR can be implemented to assist in the learning process (Chen, 2006; Jensen & Konradsen, 2018; Moro et al., 2017). Chen and others emphasize the need for careful consideration of the learning goals, target audience, and technical feasibility of iVR implementation before incorporating it into a VE (Chen, 2006; Jensen & Konradsen, 2018; Mayer, 2001; Mayer, 2003; Mayer, 2005). This approach can ensure that iVR is utilized in a way that maximizes its potential to support learning and enhances the educational experience (Chen, 2006; Jensen & Konradsen, 2018; Mayer, 2001; Mayer, 2003; Mayer, 2005; Moro et al., 2017; Parong & Mayer, 2018).

Pedagogical Theories for Technology

In the last two decades pedagogical theories have been adapted or created to address changes in available education technology (Mayer, 2001; Mayer, 2003; Mayer, 2005; Parong and Mayer, 2018). Pedagogical theories of interest for the present research include Mayer’s (2001) Cognitive Theory of Multimedia Learning (CTML) and Mayer’s (2003) Cognitive Load Theory

(CLT). Research suggests that the successful implementation of pedagogical learning theories, such as Mayer's CTML and CLT emphasizes not only the importance of learning through active engagement and by doing, but that the type or authenticity of that experience is important in learning outcomes, retention, and even learner motivation (Mayer, 2001; Mayer, 2003; Mayer, 2005; Parong and Mayer, 2018). Through this active engagement and interactivity mediated by iVR, one may be able to promote meaningful learning outcomes by mimicking these physical and cognitive processes within a VE.

Multimedia Learning

Mayer's CTML was developed to enable the development of meaningful learning interventions incorporating electronic media such as animated and narrated pictures or videos. The principle known as the "multimedia principle" is described as learning more deeply from words and pictures than from words alone (Mayer, 2001). However, simply adding words to pictures or pictures to words is not necessarily an effective way to achieve multimedia learning. Mayer's CTML presents the idea that the brain does not interpret a multimedia presentation of words, pictures, and auditory information in a mutually exclusive fashion; rather, these elements are selected and organized dynamically, to produce logical mental constructs. Mayer also discusses the role of three memory stores within the theory's three supporting principles: sensory, working, and long-term memory.

Mayer (2001) proposes that the CTML is likely to create meaningful learning experiences if the content is developed with principles from cognitive science. Mayer (2001) not only describes the structural characteristics of working memory but also the processes which are necessary for meaningful learning. This occurs when learners actively engage in cognitive processes during learning so they can generate coherent mental representations of the information, which involves the processes of selecting, organizing, and integrating the relevant information. The theory is built on the following three principles:

The Dual Channel Principle. States that our brains process information across two separate channels- auditory and visual. In this part of the process, information from the two channels is integrated to enhance learning (Mayer, 2001). After the processing of the auditory and visual channels, information is then transferred into sensory memory where the brain selects which information to process first via working memory.

The Limited Capacity Principle. States that the auditory and visual channels have limited capacity. One should limit the information presented to avoid overwhelming learners with information (Mayer, 2001).

The Active Processing Principle. Recognized that learning is an active process of filtering, selecting, organizing, and integrating information based upon prior knowledge (Mayer, 2001). At this point, the information is then incorporated into a mental framework or model of the information via active process (Mayer, 2001). For learning to occur, the brain must transfer information from the sensory memory to working memory to create mental models of the information learned. The information can then be integrated with prior knowledge, as well as applied to new concepts. By testing learning retention and the creation of a long-term memory, active processing enables learning to create mental models and knowledge constructs (Mayer, 2001).

Overall, Mayer's CTML operates under the assumption that humans can only process a finite amount of information in a channel at one time, while simultaneously processing incoming information by actively creating mental representations. From a Human Factors perspective, these principles are crucial considerations in the design of iVR educational experiences. As VEs often present complex and detailed visual and auditory information, researchers and designers must carefully consider how to present this information in a way that leverages the separate channels of visual and auditory processing. These principles are particularly important for iVR experiences, as they offer unique opportunities for immersion and interactivity that can be leveraged to support active engagement and information processing within the VE. Schneiderman et al. (2016) and others have discussed the application of these principles in the design of effective virtual environments, highlighting their relevance for human factors research and the design of iVR educational experiences (Frederick et al., 2022; Pascal & Romme, 2013; Ragusa, 2010).

Two studies looked specifically at Mayer's CTML to predict learning outcomes for students using HDMs (Kahlert et al., 2015; Trindade et al., 2002). In a study examining science learning in virtual environments, Trindade et al. (2002), sought to examine whether 3D VLEs are more useful for students compared on the traits of higher comprehension and spatial reasoning. In this work, they analyzed the effects of learning retention through a virtual reality experience encompassing the contents of both physics and chemistry in both high school and college aged students (Trindade et al., 2002). They hypothesize that since both physics and chemistry utilize 3D objects, students will be able to visualize and mentally manipulate objects aiding in students learning by taking the form of images and mental constructs (Trindade et al., 2002). Unlike traditional education methods, iVR allows students to view microscopic structures as well as other structures not seen in the physical environment.

Trindade et al. (2002), created a computer-based virtual environment (Virtual World) in which students were enabled to study phases of matter, transition, and atomic orbitals, as a supplement to the associated lecture material. They found after the students participated in the Virtual Water experience, their responses to questions in general were more complete, accurate, and reflected a deeper conceptual understanding than previous responses provided by the same students. Results indicated that the 3D virtual environments may assist students in spatial learning and allow for better conceptual learning. However, this study lacked comparison to a control group, dVR, or other immersive formats, lacking the necessary criteria to examine whether immersiveness is necessary.

Kahlert et al. (2015) also examined Mayer's CTML for learning outcomes, using a virtual juggling task in an HMD. To examine the learning of a psychomotor skill, they conducted a study with nine participants who had prior juggling experience. The goal of the virtual experience was to teach a basic juggling pattern where users had to take a virtual training course to learn the skill. Similar to Trindade et al. (2002), this study did not utilize a control group or a comparison to dVR or other immersive formats. Overall, Kahlert et al. (2015), showed that motor skills can be transferred from a virtual environment to the real world even if certain aspects are simplified within the virtual environment.

Cognitive Load Theory

Cognitive Load Theory (Mayer, 2003) is often ignored when designing or researching virtual environments for learning. According to cognitive load theory, short-term or working memory has a limited capacity and can only handle so much information effectively at one time. Mayer's CLT presents two forms of cognitive load that are suggested to have an effect on the learner's ability to successfully process the information to be learned. Intrinsic load is defined as the to-be-learned information and task. While extraneous load is unnecessary information or activities, such as noise or stimuli, which is suggested to inhibit learning and negatively impede the learner outcomes.

Like Mayer’s (2001) model of CTML, the CLT (2003) argues that one should present educational content clearly, by minimizing unnecessary information to the learner to avoid cognitive overload, which may occur when excessive or irrelevant information is portrayed via words or images. A unique implication of the CLT model is the need to minimize extraneous information that is unnecessary for the learner. One of the main findings from CLT research is that highly interactive and perceptually rich learning environments can be disadvantageous to learning due to the high extraneous load imposed on the user, of which may be present in iVR.

The underlying assumption for Mayer’s CTL often involves the construction of knowledge structures and is suggested to include two important principles for the successful implementation of information to the learner (Mayer, 2001; Mayer, 2003; Mayer, 2005). First, the presented material should have a coherent structure and second the message should provide guidance to the learner for how to build the structure. For example, if the iVR experience lacks a coherent structure, such as being a collection of isolated facts, the learner’s knowledge construction with the material will be ineffectual (Klingenberg et al., 2020; Pascal & Romme, 2013; Salzmann et al., 1999; Winn, 1999).

The principles of CLT are highly relevant to the design of effective iVR educational experiences from a Human Factors perspective. As such, Human Factors researchers and designers must consider the potential extraneous load imposed by iVR environments and enable experiences that optimize cognitive load for learners. Because our brains need a certain level of cognitive stimulation to maintain attention and engagement in a task, being cognitively unstimulated can also pose a threat to learning as much as being overloaded with information.

taking a Human Factors approach and applying the principles of CLT, developers can ensure that the learning experience is optimized for the learner's cognitive capacity (Dempsey, Mogalter & Hancock, 2000; Frederick et al., 2022; Licht, Polzella & Boff, 1989; Pascal & Romme, 2013; Ragusa, 2010; Schneiderman et al., 2016).

iVR technology, when combined with pedagogical theory and intervention, has shown improved both knowledge in classrooms and training programs (Chen, 2016; Klingenberg et al., 2020). Future research should focus on which pedagogical theories, learning situations, and educational subjects that can result in successful learning outcomes within a virtual environment. As well as enhancing our understanding of the affordances and underlying principles that may help revolutionize iVR and education. This and future research should also strive to identify barriers and uncover ways of minimizing them. As technology evolves, research should seek to discover new affordances that will expand the list of pedagogical strategies consistent with learning attainment and retention for various subjects and concepts.

Current Limitations

While there are strong claims about the value and effectiveness of iVR in education, there are also critical issues pertaining to the methodology and usefulness of the research being reported. Researchers and educators still wonder what high quality pedagogy in iVR will look like (Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017; Stranger-Johannessen, 2018). Much of the educational iVR research relates to the use of iVR in medical education (Freina et al., 2015) including basic information delivery as well as more advanced simulations aimed at training surgeons (Bric, Lumbard, Frelich, & Gould, 2016) or exploring public health (Ma, Jain, & Anderson, 2014). As well as technical and vocational training aimed towards manufacturing, heavy machinery, and aviation (Bracq, 2019; Maricic et al., 2019).

Immersive virtual reality (iVR) simulations and training for education have been found to increase affective outcomes towards learning compared to traditional media, but the effects on learning are still being investigated (Dede, 2006; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017). Currently, the literature reflects that student tend to respond favorably to iVR, but learning beyond other methods may not be occurring (Bric et al., 2016; Chen, 2016; Mikropoulos & Natsis, 2011; Moro et al., 2017). To clearly see the effects of iVR in education, one needs to understand both when and how it is useful.

Many have noted the reoccurring issue of monitor-based desktop VR being confused with immersive headset-based VR in the literature, largely due monitor-based VR frequently being discussed simply as VR in the 1990s and early 2000s (Eng-Kiat Koh., 1996). This issue has resulted in differences in both language and confusion about which type of technology is used in the research. It has also led to multiple definitions of VR, which subsequently overlap in key areas. When we use the term "VR" now, it most often refers to computer generated imagery and head mounted displays specifically designed to bring those sights and sounds to us in a way that is fully immersive. Creating consistency of language within the literature moving forward may assist in resolving this ambiguity that stems from VR research.

Another methodological issue stems from the treatment of research reports and summary reports reporting non-significant findings as demonstrating VR as the superior media compared to less immersive conditions (Kozhevnikov, Gurlitt, & Kozhevnikov, 2013; Madden et al., 2018; Moro et al., 2017; Stranger-Johannessen, 2018). While research that reflects iVR as the inferior and non-beneficial media within the study, are often ignored (Chen et al., 2020; Makransky & Terkildsen, 2019). For example, research completed by Moro et al. (2017) compared science learning within iVR, dVR, and a 2D video lesson. The reported results suggested no clear benefit of iVR instruction when compared to the learning outcomes compared to interventions. However, the researchers commented on their findings, calling them encouraging and promising, despite that iVR performed at an inferior level to the other interventions.

This issue was also evident in a study completed by Madden et al. (2018), who compared iVR to dVR for teaching astronomy principles pertaining to phases of the moon. The researchers reported iVR as being the superior method, even though the study demonstrated that there were non-significant differences between the two interventions. Findings such as these claim that the use of HMDs in iVR is more effective than non-immersive methods, even when the evidence is consistent with iVR being no more or even less effective. This willingness to ignore or misreport results within the iVR literature has contributed to the ambiguity and confusion surrounding iVR and education.

Another methodological issue stems from the failure of comparing iVR to other learning formats. As seen in research completed by Allcoat et at. (2021) who found no differences between dVR and iVR, although they looked at iVR in isolation, rather than comparing it to dVR. The lack of consideration of both confounding and ignoring meaningful comparisons conditions are common in the current research (Allcoat et al., 2021).

Another major issue related to VR for education is the lack of consideration for the implementation method and more for the media. To successfully demonstrate the value of iVR, more research needs to focus on the method of how this information is being presented, and less on the media itself. Currently, a substantial amount of the literature fails to mention the use of a theoretical approach underlying the intervention (Radiant et al., 2020). Considering the potential of using VR technology in the educational process, it is necessary to develop a methodology for implementing this technology in education, with particular emphasis on the requirements and needs of the learner (Bric et al., 2016; Chen, 2016). Thus, a major issue in the application of VR in the field of education is the lack of development of an appropriate methodology for the effective implementation of iVR into the classroom to increase the efficiency of the educational process.

Current research targeting the use of VR in education often fails to use reliable and valid measurement methods for the objective measurement of knowledge learned and retained (Christopoulos, Kajasilta, Salakoski, & Laakso, 2020). In the research, many are using student self-reports about feelings towards the technology and subjective self-ratings of learning, rather than using objective measures of learning (Bric et al., 2016; Christopoulos et al., 2020; Chen, 2016; Mikropoulos & Natsis, 2011; Moro et al., 2017). Some even label these qualitative self-reports as true measures of learning (Christopoulos et al., 2020). As mentioned previously, Mayer (2005) acknowledges that the use of declarative knowledge retention tests as the only instrument to infer learning outcomes can be considered a limitation. The current research aimed to address not only declarative knowledge but learned spatial knowledge as well. The addition of a realistic measure of spatial knowledge was used to assess the relative position between objects, and properties of spatial relationships in which declarative knowledge does not capture (Mayer, 2005).

Much of the current literature lacks quality methodology, and much of the research fails to integrate or consider pedagogical theories in the testing of iVR as an educational tool. Fortunately, these limitations and challenges can be addressed by integrating pedagogical and cognitive approaches. As technology evolves, research should seek the affordances that will expand the list of pedagogical strategies consistent with learning attainment and retention for various types of academics and concepts.

Summary of Hypotheses

Despite literature claiming a broad support for the positive impact of iVR in education, empirical research on the effectiveness of using iVR with HMDs for educational outcomes is mixed. One explanation for this outcome is that iVR creates cognitive load, which impairs learning performance. Mayer (2003) suggests using a direct measure of cognitive load to examine this claim. This study was conducted to explore the use of iVR with HMDs to further investigate and compare its effectiveness when compared to a desktop monitor-based VE (dVR) with respect to learning performance through consistency of educational interventions among experimental groups. The proposed VR interventions are both passive experiences, so that iVR and dVR differences are minimal.

The current study makes use of an objective knowledge test consisting of both retention and transfer questions, which much of the current research lacks. Support for this testing approach stems from Mayer (2001), who notes that retention is an important aspect of STEM related learning, the CTML contends that deeper learning occurs when concepts are representing spatially, through visualizing relationships, analyzing static and dynamic systems of objects, observing how objects behave in their environment, and recognizing the relationship between the two.

We also looked at the impact of cognitive load on learning outcomes as well as exploring whether Presence affects learning outcomes. Previous studies have argued that a learner's level of engagement and sense of Presence in a learning environment can influence their ability to acquire and retain new knowledge and skills (Dalgarno & Lee, 2010; Freina, 2015; Mikropoulos, 2006; Winn et., 2000; Winn & Windschitl, 2000; Witmer & Singer, 1998; 2005). While this idea has gained some support, it has seldom been demonstrated in existing literature (Akyol & Garrison, 2011; Huang et al., 2020; Sarasso et al., 2022; Wilkinson et al., 2019).

Prior studies on virtual education and Presence have used global Presence scores without exploring the individual subscales of the Presence Questionnaire (PQ). While unlikely, it is possible that only certain aspects of Presence impact learning. Therefore, this study will examine total subjective PQ and its subscales to measure each participant's sense of Presence and investigate their effects on spatial and declarative learning.

This research aims to contribute to our understanding of the appropriate educational applications for Head-Mounted Displays (HMDs), as well as identify specific skill areas where HMDs can be beneficial. In this study, we utilized a VLE designed to teach students about the processes and microstructures involved in the human circulatory system by providing a guided tour through the bloodstream.

Research Questions

1. Does learning in a virtual learning environment (VLE) with immersive virtual reality (iVR) differ from learning with desktop virtual reality (dVR)?

2. Does sense of presence correlate with learning outcomes?

Research Hypotheses

H1: There will be a difference between the iVR condition and the dVR condition on learning outcomes for declarative and spatial knowledge.

H2: There will be a difference between the iVR condition and dVR condition on sense of presence.

H3: Presence will impact learning outcomes.

Methods

Participants

The participants for this study were sixty-eight undergraduate students from the University of South Dakota, located in the United States. Their ages ranged from 18 to 29 years old, with most being between 18 and 24. Participants were recruited using SONA.

Apparatus

Common Computer Hardware: The computer used in this study is an HP computer with a i7-7700 processor CPU @ 3.60, NVDIA GeForce RTX 2060 graphics card, 16 GB of RAM, with a 24' Full HD (1920 x 1080 x 60 HZ) monitor and Windows 10 operating system.

Desktop VR (dVR) Hardware. In the dVR condition, the 24" PC monitor described in Computer Hardware was used. The PC monitor was connected via HMDI, which supported 1920 x 1080 at 60 HZ. A desktop mouse and Bose QuietComfort 25 headphones with noise-cancelling were also used. In this condition, participants controlled the 360-degree view by either clicking the pan button in the upper left corner of the display with the mouse or using the WASD keys. Since using a 24" monitor represents a typical educational implementation, matching the visual angle of the HMD to the PC monitor was not done for making the comparison to iVR.

Immersive VR (iVR) Hardware. In this condition, participants used the HTC Vive, an immersive Head Mounted Display (HMD). The computer was connected to the HMD via HMDI. The HMD features a resolution of 1080 x 1200 pixels per eye with a refresh rate of 90 Hz, a 110-degree field of view, and real-time tracking of head position and controllers. The participants also used two wireless HTC Vive hand controllers that were connected to the HTC Vive via Bluetooth, allowing the user to interact with the virtual environment and receive haptic feedback for certain interactions. Participants were occasionally presented with a close-up view of a part of the blood stream or cell, and they could physically touch, move, and rotate these objects (e.g., a close-up of a white blood cell or a mitochondrion) using the two HTC Vive controllers.

Software: "The Body VR, A Journey Inside a Cell (The Body VR, 2016)," is a 12-minute educational experience for Biology, available on the Steam website. Previous research on educational technology has used similar VR simulations (Krassmann et al., 2020; Parong & Mayer, 2018). In the virtual environment, the participant had a full 360-degree view and was microscopically "shrunk" to travel through the bloodstream of the human circulatory system. The subject virtually traveled through the bloodstream and discovered how blood cells work to spread oxygen throughout the body. As the participants moved through different areas of the body, 3D diagrams of the cells and components discussed appeared in the front of the subject with bright labels.

Measures

Knowledge Test: Based on the content presented in "The Body VR, a Journey Inside the Cell", the researchers created a pre-test consisting of 8, four option multiple choice questions (See Appendix B). Items were scored as correct or incorrect, resulting in a total score between 0 and 8. The pre-test was designed to assess participants' prior knowledge of the basic Biology concepts and procedural information involved in the lesson.

A post-test consisting of fourteen questions: seven of which assessed declarative knowledge and seven that assessed spatial knowledge were developed. No items were duplicated from pre-test to post-test (See Appendix C). All of the declarative questions and four of the spatial questions were four option multiple choice, with 1 point given for each correct answer. The remaining three spatial questions were fill-in the blank responses, with 1 point given for each correct answer. Thus, the total score ranged from 0 to 14. The post-test score was used as a measure of learning.

Demographic Questionnaire: This instrument was used to measure the participant's level of experience in gaming, and their current usage of both dVR and iVR systems (See Appendix D).

NASA-TLX: This instrument was used to measure the participants level of cognitive load. The NASA Task Load Index (TLX) assesses workload on five, 20-point scales (Hart & Staveland, 1987) each representing a dimension of cognitive workload (See Appendix E). The five dimensions are: Mental Demand, Temporal Demand, Performance, Effort, and Frustration. The internal consistency of the instrument was evaluated using Cronbach's alpha, yielding a value of 0.81 (Hart & Staveland, 1988).

Presence Questionnaire (PQ): Sense of presence was measured using Version 3.0 of the Presence questionnaire developed by Witmer & Singer (2005). The PTQ assesses five dimensions of presence. It consists of 19, 7-point numeric response items (See Appendix F). Except for the Self-Evaluation of Performance factor, these subscales corresponded to those identified in a cluster analysis of data from an earlier version of the questionnaire (Witmer, Jerome, & Singer., 2005). The internal consistency of the instrument was evaluated by Witmer, Jerome, & Singer (2005) using Cronbach's alpha, with a value of 0.84 (Witmer, Jerome, & Singer., 2005). The subscales are:

Realism (7 items). Witmer and Singer (1998) define this factor as the perceived connectedness and continuity of the stimuli being presented. This factor addresses how involving were the visual aspects of the VE, and how involved the participants became. In general, the more consistent the information conveyed by a VE is with that learned through real-world experience, the greater the experience of presence (Witmer et al., 2005; Witmer & Singer, 1998).

Possibility to Act (4 items). Witmer and Singer (1998) defined this factor as the perceived control of the events in the VE and the responsiveness of the VE to user-initiated actions. In general, the more control a person has over the task environment or in interacting with the VE, the greater the experience of presence (Witmer et al., 2005; Witmer & Singer, 1998; Sheridan, 1992).

Quality of Interface (3 items). Witmer and Singer (1998) defined this factor as the perceived quality of the visual and control interfaces. These items address whether control devices or display devices interfere or distract from task performance, and the extent to which the participants felt able to concentrate on the tasks. When a person acts in an environment, the consequences of that action should be appropriately apparent to the user. Noticeable delays between the action and the result are expected to diminish the sense of presence in a VE (Held & Durlach, 1992) (Witmer et al., 2005; Witmer & Singer 1998).

Possibility to Examine (3 items). Witmer and Singer (1998) defined this factor as the perceived ability to actively search the VE. In which users can modify their view- point to change what they see, or to reposition their head, or to search the environment haptically, they should experience more presence.

Self-Evaluation of Performance (2 items). Witmer and Singer (1998) Defines this as the perceived task performance when interacting with the virtual environment.

Procedure

Upon arrival at the research facility, participants were greeted and asked to complete informed consent (See Appendix G). The researcher then introduced the participant to the nature of the research.

Following the general introduction, the researcher asked the participant to complete the Demographic questionnaire and administered the knowledge pre-test to assess the pre-intervention level of knowledge about the human cellular system. Participants were given 15 minutes to complete the instruments and asked to complete the instruments to the best of their ability. Following completion, the researcher randomly assigned individuals to either the iVR or the dVR condition. Participants were provided instruction based on their assigned treatment condition.

In the Immersive VR (iVR) condition, the participant took a narrated biological tour while wearing an immersive virtual reality headset. Participants were first instructed about the nature of their virtual experience and how to use the controllers. The researcher then assisted the participant in putting on and adjusting the HMD, for comfort and safety. By preventing the participant from walking into walls, the researcher ensured that the participant was able to be fully engaged in the VE without any physical harm. The participant was then prompted to start by standing in the middle of the room and to begin their experience when they were ready. The participant was able to move around the research room throughout the 12-min lesson.

In the Desktop VR (dVR) condition, the participant took the narrated biological tour displayed on a conventional desktop computer screen. Participants were first instructed about the nature of their desktop experience at a computer workstation. The researcher then instructed the participant about the mouse and headphone controls. The participant was able to use the mouse to change the view of the experience by clicking and holding the wheel icon in the upper left corner of the presented screen. The researcher then prompted the participant to put on their headphones and begin their experience when they were ready.

In both conditions, participants were not allowed to navigate the virtual environment (play, pause, fast forward or rewind), beyond rotating for a 360-degree viewing experience, ensuring that both groups experienced the same pace of information presentation and visuals, with the only difference being the media format. Thus, both formats had the same duration (12 min). Following completion of the 12-minute learning experience, the researcher administered the post-knowledge, NASA-TLX, and presence instruments. Upon the completion of the experimental protocol, the participant was debriefed, thanked, and compensated for their time and the experiment ended.

Results

Microsoft Excel was used to log and tabulate the data. Descriptive and inferential statistics were computed using the R statistical programming language (Version: 4.1.3).

Data Screening.

Sixty-eight participants were randomly assigned to either the iVR or dVR conditions and completed the study. One participant was excluded from analysis for scoring above 6 on the pre-test. Two participants obtained negative learning scores, and their data were also excluded from analysis.

Table 1. Demographic characteristics

Treatment	Immersive VR *N=35*	Desktop VR *N=30*	All *N=65*
Age			
18-24	N = 35 (100%)	N = 28 (93.3%)	N = 63 (96.92%)
25-34	N = 0 (0%)	N = 2 (6.6%)	N = 2 (3.1%)
Gender			
Female	N = 20 (57.1%)	N = 16 (53.3%)	N = 36 (55.4%)
Male	N = 15 (42.9%)	N = 14 (46.7%)	N = 29 (44.6%)

The remaining 65 participants included 36 female participants (55.4%) and 29 male participants (44.6%) with n = 35 assigned to the iVR condition and n = 30 assigned to the dVR condition. All participants reported having normal or corrected-to-normal vision. The modal age group of the participants was 18-24 years old (N = 63) with two participants in the 25-29 age group (See Table 1). Additional demographic information was collected for exploratory purposes (See Appendix H).

Mean pretest scores were similar for both groups, iVR condition (*M* = 4.0, *SD* = 1.08) and dVR (*M* = 4.23, *SD* =0.97). Mean pre-test scores for declarative and spatial knowledge were similar for both groups (See Table 2).

Table 2. Pre and Post Learning by Condition

Condition	Pre-Test (2 Spatial and 6 Declarative	Post-Test (7 Spatial and 7 Declarative)
iVR (N=35)		
Spatial	M = 1.06 (.76)	M = 4.37 (1.6)
Declarative	M = 2.94 (1.0)	M = 4.4 (1.2)
Total	M = 4 (1.08)	M = 8.8 (2.23)
dVR (N=30)		
Spatial	M = 1.2 (.55)	M = 3.93 (1.2)
Declarative	M = 3.03 (.93)	M = 4.5 (1.2)
Total	M = 4.23 (0.97)	M = 8.43 (1.81)

Research Question 1

To determine if there was a difference between iVR and dVR on learning outcomes the total correct post-test scores were computed for each type of learning outcome, declarative and spatial. These learning scores were analyzed using a 2(media type) by 2(learning type) mixed ANOVA. Media type (iVR or dVR) was a between subjects factor while learning type (declarative or spatial) was a within subject factor.

The interaction for type of learning and media type was not statistically significant ($F_{(1,63)} = 1.729$, $p = .19$). Neither the main effect for media type nor type of learning was statistically significant($F_{(1,63)} = 0.44$, $p = 0.51$, and, ($F_{(1,63)} = 3.5645$, $p = .06$ respectively). (Complete statistical report in Appendix I). To further examine this near-significant effect, a post-hoc simple main effect test was conducted to examine spatial learning across the two media types ($t_{(61.8)} = -1.2532$ $p = 0.2149$) and was found not to be significant.

A secondary post-hoc paired samples t-test was conducted to examine the media type of dVR and the two types of learning, declarative and spatial. The results of this analysis showed differences for the two types of learning for the dVR media type but did not meet the predetermined significance level ($t_{(29)}$ = 2.0364 p = 0.05093; 95% confidence interval -.00145 to 1.1356).

Research Question 1a

To test the differences in cognitive load across media type conditions, a NASA-TLX score assessing cognitive load was computed for each participant and analyzed using a Welch's Independent samples t-test. The test found no difference between the iVR and the dVR groups ($t_{(57.886)}$ = 0.89114, p = 0.3765) in reported cognitive load (M_{iVR} = 29.69, SD = 14.18; M_{dVR} = 33.1, SD = 16.37; 95% confidence interval -4.255 to 11.084) (See Appendix J for complete statistical report). Mean subscale scores for the NASA-TLX were similar for both groups (See Appendix K for complete table).

Research Question 2

To determine if there was a difference between iVR and dVR on sense of presence, scores were computed using the scoring rubric for the PQ3.0 instrument (Witmer, Jerome, & Singer., 2005). Resulting in a total Presence score for each participant. The scores were analyzed using a Welch's Independent t-test and found that there was no difference between the iVR group and the dVR group ($t_{(58)}$ = -0.44621, p = 0.6571) on overall sense of presence (M_{iVR} = 105.8, SD = 13.44; M_{dVR} = 104.2, SD = 15.2; 95% confidence interval -8.776 to 5.576.

Research Question 2a

An exploratory analysis was conducted to examine the five presence subscales individually. These sub-scale factors are Realism, Possibility to Act, Quality of Interface, Possibility to Examine, and Self-Evaluation of Performance. To test for media type differences on each of the subscales, a Welch's Independent t-test was used to analyze scores on each subscale and found no statistically significant differences were found for any of the subscales (all p's > 0.32) (See Appendix K for complete statistical report.)

Research Question 3

Although presence has shown no impact on learning outcomes in prior research of this type it is still widely reported as an important aspect of learning in virtual environments (Bailenson et al, 2012; Won, Flora, & Armel., 2012; Makransky et al., 2019; Chen & Wan, 2008; Chen, 2006; Kahlert et al, 2016). To examine whether Presence impacts learning outcomes, a regression analysis was used to predict total learning from sense of presence. A scatterplot suggested that the relation between learning outcome and presence score was positive and reasonably linear. The correlation between presence score and learning outcomes was computed and was not statistically significant $r_{(63)} = 0.058$, $p = 0.053$).

An exploratory regression to predict each type of learning from total presence was also conducted. Two response variables were used to examine learning, spatial and declarative. A correlation was computed between spatial learning and each participant's presence score, and was statistically significant, $r_{(63)} = 0.069$, $p = 0.034$. The correlation computed between declarative learning and each participants presence score, and was not statistically significant, $r_{(63)} = 0.0091$, $p = 0.45$.

A scatterplot revealed two univariate outliers (See Appendix L for scatterplot). Because there were no a-priori criteria for removal of outliers, an exploratory analysis was conducted to examine the impact of Presence on total learning and spatial learning after removing the two identified outliers. The correlation computed between presence scores and total learning outcomes was not statistically significant $r_{(61)} = 0.0095$, $p = 0.45$. The correlation computed for presence predicting spatial learning, was also not statistically significant, $r_{(61)} = 0.023$, $p = 0.23$.

Discussion

The first research question addressed whether there was a difference between iVR and dVR on two types of learning outcomes, spatial and declarative. Previous research suggests that one of the key advantages of virtual reality environments is that they allow for the creation of highly controlled and immersive experiences (Dalgarno & Lee, 2010; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017). This can enable users to engage in realistic simulations of real-world environments, which can be particularly useful for spatial learning tasks that involve navigating and orienting oneself in a new environment (Dalgarno & Lee, 2010; Jensen & Konradsen, 2018; Krassmann et al., 2020; Mikropoulos & Natsis, 2011; Moro et al., 2017; Parong & Mayer, 2018).

The results of the analysis of learning outcomes showed no statistical difference in performance across the two media types (e.g., iVR and dVR). There were small differences in the main effect for learning outcome that did not reach the pre-determined significance level. The pattern of means suggested no difference across media conditions for declarative knowledge. However, a possible deficit in spatial learning for the dVR condition was noted. A non-significant post-hoc t-test suggests that this apparent deficit could be an artifact of the small sample size.

There were no differences across media type for cognitive load or experienced presence consistent with the failure to find media related learning differences. Those potentially important factors are not directly influenced by media type.

This finding suggests the type of media used is not necessarily the primary factor influencing learning outcomes, but rather the quality of instruction and the design of the learning materials (Mayer, 2020) may be the primary influence. The “The Body VR, A Journey Inside a Cell (The Body VR, 2016)” educational VLE used in the study was not necessarily designed with the principles from Mayer’s CTML and CLT (Mayer, 2001; Mayer, 2003; Mayer, 2005), specifically, the limited capacity principle, in mind. The animations and narrations in the VLE may have enhanced extraneous auditory and visual input (Mayer, 2001; Mayer, 2003; Mayer, 2005). Meaning, the educational VLE may have created an excessive amount of additional mental load for the learner, which can result in a lack of available cognitive resources needed to effectively understand the core material being taught in the lesson.

In line with Mayer’s CLT (2003), cognitive load between the conditions was tested and the results of this analysis suggested that there were no significant differences in cognitive workload, across media conditions indicating that media type does not independently impact cognitive load. In research that compares iVR to dVR it is common to use non-equivalent teaching materials confounding media with method (Allcoat et al., 2021; Kahlert et al., 2015; Trindade et al., 2002). Mayer's CTML (2001) proposes that the method of instruction and the media used to deliver that instruction are two separate factors that can impact learning. In this case, the effectiveness of the instructional method may be confounded by the media used to deliver it in this study.

The media verses method confound suggests that the type of material being learned and the way it is presented can have a significant effect on cognitive load and that the design of the materials and the way they are presented need to be considered when creating educational virtual experiences, regardless of whether they are accessed via a desktop or a head-mounted display (Parong and Mayer, 2018; Schneiderman et al., 2016). It is worth noting that cognitive load is a complex phenomenon and can be influenced by many factors, such as individual differences, task characteristics, and the context in which learning occurs (Mayer, 2001; 2003; 2005; Parong and Mayer, 2018; Schneiderman et al., 2016). It is worth noting that cognitive load is a complex phenomenon that can be influenced by many factors, such as individual differences, task characteristics, and the context in which learning occurs (Mayer, 2001; 2003; 2005; Parong and Mayer, 2018; Schneiderman et al., 2016). Therefore, future research should continue to investigate the effects of cognitive load and media conditions on learning outcomes, using larger sample sizes and more rigorous manipulations of the independent variables.

This study focused on a particular learning context and utilized a specific measure of learning outcomes. Thus, the results of this study may not be generalizable to other learning contexts (e.g., Chemistry, History) or different measures of learning outcomes. It would also be important to examine the media and learning types outside of the laboratory, to see if the results found in this study can generalize to a real-world setting. Future research should explore the effects of educational VLEs on different learning contexts and using a variety of measures.

The second research question addressed if there were differences between iVR and dVR on the sense of presence or on any of the subscales of the Presence Questionnaire (PQ). Current research suggests that the higher the sense of presence, the more engaged and involved the participant feels in the experience (Bailey et., 2012; Dede, 2009). Higher presence is said to be found when participants feel immersed and engaged in the material in the experience. It is believed that this engagement leads to better learning outcomes (Mikropoulos, 2006; Mulders et al., 2020; Parong & Mayer, 2018). However, the relationship between presence and learning has mixed results in the literature (Polcar & Harejsi, 2015; Makransky, Terkildsen, Mayer, 2019).

On both overall sense of presence and its subscales, this study found that there were no significant differences between reported sense of presence across media types. The subscales of Realism, Possibility to Act, Quality of Interface, Possibility to Examine, and Self-Evaluation of Performance do not differ significantly across media conditions in this study. The current findings are not in line with existing literature, which in some cases have found a positive effect of type of immersive technology on sense of presence (Dalgarno & Lee, 2010; Kahlert, Camp, & Stiefelhagen, 2015; Klingenberg et al., 2020; Mikropoulos & Bellou, 2006; Ray & Deb, 2016). One reason could be related to the design of the education VLE itself, in which the VLE may not have been immersive enough to induce a strong sense of presence in participants. Alternatively, the sense of presence may have been affected by factors such as the short duration of the learning experience and the low level of interactivity in the VLE.

The impact of a small sample size could be another possible contributing factor to the lack of observed differences in presence across media conditions. In order to understand the role of presence in learning, if any, the influence of intervening variables should also be considered, as suggested by previous research (Chen, 2006; Chen & Wan, 2008; Kahlert et al, 2016; Makransky et al., 2019). Finally, it is also possible that the order in which participants completed the PQ 3.0 instrument influenced the results, as it was the last instrument to be completed and their memory of the experience may have degraded.

A planned analysis was conducted to examine whether presence impacts total learning. Although presence has previously shown no impact on learning outcomes in prior research of this type, it is still widely reported as an important aspect of learning in virtual environments (Bailenson et al, 2012; Chen, 2006; Chen & Wan, 2008; Kahlert et al, 2016; Makransky et al., 2019; Won, Flora, & Armel, 2012). The results of this analysis showed that presence scores and total learning were not correlated.

The findings of the exploratory analysis suggest that the participants who had a higher presence score, or a higher sense of immersion and engagement in the VLE, also tended to have increased levels of spatial learning. This finding is consistent with the widely held belief about the importance of presence in virtual environments for learning and performance (Bailenson et al, 2012; Chen, 2006; Chen & Wan, 2008; Kahlert et al, 2016; Makransky et al., 2019; Slater, 1999). The positive relation between sense of presence and spatial learning suggests that perhaps individuals who have a higher sense of immersion and engagement in an educational VLE also tend to perform better on tasks related to spatial learning (Kahlert, Camp, & Stiefelhagen, 2015; Klingenberg et al., 2020; Mikropoulos & Bellou, 2006; Ray & Deb, 2016). One possible explanation for this relationship is that a higher sense of presence leads to a greater sense of engagement and motivation, which in turn leads to more effective learning (Dalgarno & Lee, 2010; Kahlert, Camp, & Stiefelhagen, 2015; Klingenberg et al., 2020; Mikropoulos & Bellou, 2006; Ray & Deb, 2016).

Another possible explanation for the relation between presence and spatial learning is that a higher sense of presence leads to a greater sense of embodiment and a more realistic perception of the virtual environment, which in turn enhances spatial learning and performance (Chen, 2006; Chen et al., 2020; Dalgarno and Lee, 2010). An educational VLE that can create a high sense of presence may be more effective in facilitating spatial learning tasks that involve movement, such as navigating through a VLE, which may be difficult to replicate in traditional classroom settings (Chen, 2006; Dalgarno & Lee, 2010; Mulder, Buchner, & Kerres, 2020) or in a dVR format. Future studies could also explore how different factors, such as the design of the educational VLE or the task being performed, may impact the relationship between presence and spatial learning.

A secondary analysis of presence and spatial learning was completed after the removal of two outliers, with unusually low total presence scores. After the removal of these outliers the correlations computed for both total and spatial learning with presence were found not to be significant. It is possible that the outliers may have distorted and artificially inflated the correlation coefficients.

A correlation computed between presence and declarative learning was found not to be significant. This is in line with previous research, which fails to find an association between presence and learning (Chen, 2016; Dalgarno & Lee, 2010; Jensen & Konradsen, 2018; Mikropoulos & Natsis, 2011; Moro et al., 2017). However, there are some points worth discussing regarding the non-significant results of this analysis. First, the instruments used to assess presence and declarative learning may have limitations. Similarly, the measure used to assess declarative learning may not have captured all aspects of declarative learning.

Furthermore, the lack of a significant relationship between iVR, presence and learning outcomes in this study may not be as straightforward as previously thought. There may be other factors that moderate the relationship between iVR, presence, and learning, such as the type of task, the duration of the exposure, individual characteristics of the user, and the design of the educational VLE (Chen, 2006; Milgram et al., 1994; Mulder, Buchner, & Kerres, 2020; Slater et al., 1999; Witmer & Singer, 1998). This may also suggest that presence may not be a strong predictor of learning outcomes or that the relationship between presence and learning is complex. Research should also focus on how presence influences motivation and engagement in the learning process. Research on iVR and learning should also be studied in different learning contexts and using different measures of learning outcomes. Therefore, more research is needed to understand the underlying mechanisms that drive this relationship.

In conclusion, the present study provides insights into the relationship between presence elicited by iVR and learning outcomes, but also highlights the complexity of this relationship. Future research should aim to address some of the limitations of this study, such as using more sensitive measures of presence, larger sample sizes, and more varied educational VEs and learning types. Comparing the effects of iVR and dVR could provide insights into the unique features of each technology and how they relate to the experience of presence and learning in a VLE. Finally, exploring the influence of iVR with different learning types, such as collaborative or self-directed learning, on presence and learning outcomes could help to develop approaches to iVR-based education. Overall, continued research in this area could inform the design and implementation of iVR-based educational interventions to optimize learning outcomes.

Finally, future research should also focus on understanding the relationship between iVR and learning in different contexts, such as education, training, and performance, as well as education at all levels, such as higher education. By doing so, we may be able to gain a deeper understanding of the mechanisms underlying the relationship between presence and learning and how best to use iVR to promote learning outcomes. It is also important for future research to investigate the role of Human Factors in the relationship between iVR, presence and learning outcomes. This includes understanding individual differences, such as personality traits, cognitive, and perceptual abilities, special consideration for the design of the VLE, in relation to its influence on iVR, presence, and learning outcomes.

Overall, the results of this study contribute to the growing body of research on the importance of VEs in iVR for learning outcomes and have important implications for the design and use of VEs in educational contexts.

References

Akyol, Z. & Garrison, D.R. (2011), Understanding cognitive presence in an online and blended community of inquiry: Assessing outcomes and processes for deep approaches to learning. *British Journal of Educational Technology*, 42: 233-250. https://doi.org/10.1111/j.1467-8535.2009.01029.

Allcoat, D., Hatchard, T., Muhlenen, A., Watson, D., Azmat, F, & Stanfield, K. (2021). Education in the digital age: Learning experience in virtual and mixed realities. *Journal of Educational Computing Research.*

Bailenson, B., Won, A., Flora, J., & Armel, K. C. (2012). Presence and memory: immersive virtual reality effects on cued recall. *Proceedings of the International Society for Presence Research Annual Conference.* October 24–26, 2012; Philadelphia, Pennsylvania, USA. Available at: https://vhil.stanford.edu/mm/2012/bailey-ispr-presence-memory.pdf

Boivie I., Åborg C., Persson J., Löfberg M. (2003). Why usability gets lost or usability in in-house software development. *Interacting With Computers*. 15, 623–639. 10.1016/S0953-5438(03)00055-9

Bouchard, R., Renaud., P., Courtnoyer., LG. (2004) UQO Cyberpsychology Lab: Congress of the Society Quebec for Research in Psychology (SQRP), Trois- Rivieres, 1-3.

Bracq, M., Michinov, E., Arnaldi, B., Caillaud, B., Gibaud, B., Gouranton, V., & Jannin, P. (2019). Learning procedural skills with a virtual reality simulator: An acceptability study. *Nurse Education Today, 79*, 153-160.

Bric, J. D., Lumbard, D. C., Frelich, M. J., & Gould, J. C. (2016). Current state of virtual reality simulation in robotic surgery training: a review. *Surgical Endoscopy*, 30(6), 2169–2178. https://doi.org/10.1007/s00464-015-4517-y

Bulu, S.T. (2012). Place presence, social presence, co-presence, and satisfaction in virtual worlds. *Computers & Education, 58*(1), 154-161. Elsevier Ltd. Retrieved March 10, 2023 from https://www.learntechlib.org/p/50698/.

Chen, C. J. (2006). The design, development and evaluation of a virtual reality based learning environment. *Australasian Journal of Educational Technology*, 22(1).

Chen, J. C., Huang, Y., Lin, K. Y., Chang, Y. S., Lin, H. C., Lin, C. Y., & Hsiao, H. S. (2020). Developing a hands-on activity using virtual reality to help students learn by doing. *Journal of Computer Assisted Learning*, 36(1), 46–60. https://doi org.usd.idm.oclc.org/10.1111/jcal.12389

Chen, C. J., & Wan, M. F. (2008). Guiding exploration through three-dimensional virtual environments: A cognitive load reduction approach. *Journal of Interactive Learning Research*, 19(4), 579-596.

Christopoulos, A., Kajasilta, H., Salakoski, T., & Laakso, M. (2020). Limits and Virtues of Educational Technology in Elementary School Mathematics. *Journal of Educational Technology Systems, 49*, 59 - 81.

Cipresso, Pietro, Giglioli, I., Raya, M., & Giuseppe, R. (2018). The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature. *Frontiers in Psychology, 9*, 2086.

Cummings, J.J., & Bailenson, J.N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*. 19:2, 272-309, doi:10.1080/15213269.2015.1015740

Dalgarno, B., & Lee, M.J. (2010). What are the learning affordances of 3-D virtual environments? *Br. J. Educ. Technol., 41*, 10-32.

Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science (American Association for the Advancement of Science), 323*(5910), 66-69.

Dempsey, Patrick G., Wogalter, Michael S., & Hancock, Peter A. (2000). What's in a name? Using terms from definitions to examine the fundamental foundation of human factors and ergonomics science. *Theoretical Issues in Ergonomics Science*, 1(1), 3-10.

Eng-Kiat Koh. (1996). WAVEVISIONS: A desktop virtual reality software, *Computers & Graphics*, 20, (1), 69-75, https://doi.org/10.1016/0097-8493(95)00094-1.

Frederick, C. M., Sonnenfeld, N., Lum, H. C., Amato-Henderson, S., Smith, T. J., & Steelman, K. S. (2022). Exploring the Future of Human Factors Education; Online Learning, MOOCs, Next Generation Standards, and the Technological Skills We Need to Impart. *Proceedings of the Human Factors and Ergonomics Society*, 60(). https://doi.org/10.1177/1541931213601097

Freina, L., & Ott, M. (2015). A literature review on Immersive Virtual Reality in education: State of the art and perspectives. *eLearning & Software for Education*, 1.

Hart, S.G., & Staveland, L.E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Advances in psychology, 52*, 139-183.

Held, R., & Durlach, N. (1992). Telepresence. Presence: Teleoperators and Virtual Environments, 1 (1), 109–112.

Huang, C. L., Luo, Y. F., Yang, S. C., Lu, C. M., & Chen, A.-S. (2020). Influence of Students' Learning Style, Sense of Presence, and Cognitive Load on Learning Outcomes in an Immersive Virtual Reality Learning Environment. *Journal of Educational Computing Research*, 58(3), 596–615.

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies,* 23(4), 1515-1529. doi:http://dx.doi.org.usd.idm.oclc.org/10.1007/s10639-017-9676-0

Kahlert, T., Camp, F.V., & Stiefelhagen, R. (2015). Learning to Juggle in an Interactive Virtual Reality Environment. HCI. International 2015, Los Angeles, CA, USA, August 2-7, 2015 Cham: Springer International Publishing*, 2015 Communications in Computer and Information Science,* 528: 196-201

Kalawsky R. S. (1993). *The science of virtual reality and virtual environments : a technical scientific and engineering reference on virtual environments*. Addison-Wesley. Retrieved March 10 2023 from http://books.google.com/books?id=n-BQAAAAMAAJ.

Keshner, E.A., Weiss, P.T., & Raban, D. et al. (2019). Tracking the evolution of virtual reality applications to rehabilitation as a field of study. J *NeuroEngineering Rehabilitation 16,* 76. https://doi.org/10.1186/s12984-019-0552-6

Klingenberg, S., Jørgensen, M.L.M., Dandanell, G., Skriver, K., Mottelson, A. & Makransky, G. (2020). Investigating the effect of teaching as a generative learning strategy when learning through desktop and immersive VR: A media and methods experiment. *British. Journal of Educational Techno*logy, 51: 2115-2138. https://doi-org.usd.idm.oclc.org/10.1111/bjet.13029.

Kozhevnikov, M., Gurlitt, J., & Kozhevnikov, M. (2013). Learning relative motion concepts in immersive and non-immersive virtual environments. *Journal of Science Education and Technology, 22*, 952–962.

Krassmann, Aliane & Mazzuco, Alex & Melo, Miguel & Bessa, Maximino & Bercht, Magda. (2020). Usability and Sense of Presence in Virtual Worlds for Distance Education: A Case Study with Virtual Reality Experts. 155-162. 10.5220/0009350401550162.

Leman, F., Gu, N., Williams, A. (2012)."Constructivist Learning Theory in Virtual Design Studios." *Computational Design Methods and Technologies: Applications in CAD, CAM and CAE Education*. 10.4018/978-1-61350-180-1.ch009.

Licht, D. M., Polzella, D. J., & Boff, K. (1989). Human Factors, Ergonomics, and Human Factors Engineering: An Analysis of Definitions. CSERIAC-89-01. Wright Patterson AFB, Dayton, OH: CSERIAC

Ma, M., Jain, L. C., & Anderson, P. (2014). Future trends of virtual, augmented reality, and games for health. In M. Ma, L. C. Jain, & P. Anderson (Eds.), *Virtual, Augmented Reality and Serious Games for Healthcare 1* (Vol. 68, pp. 1-6). (Intelligent Systems Reference Library; Vol. 68). Springer Verlag. https://doi.org/10.1007/978-3-642-54816-1_1

Madden, J. H., Won, A. S., Schuldt, J. P., Kim, B., Pandita, S., Sun, Y., Stone, T.J., & Holmes, N. G. (2018). Virtual reality as a teaching tool for moon phases and beyond. In *2018 Physics Education Research Conference*.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning Instruction.* 60, 225–236. doi: 10.1016/j.learninstruc.2017.12.007

Makransky, G., Andreasen, N. K, Baceviciute S., & Mayer R. M. (2020). Immersive Virtual Reality Increases Liking but Not Learning with a Science Simulation and Generative Learning Strategies Promote Learning in Immersive Virtual Reality. *Journal of Educational Psychology*. DOI: 10.1037/edu0000473

Maricic, S., Radolovic, D., Veljovic, I., & Raguz, R. (2019). VR 3D Education for Vocational Training. *MATEC Web Conference*. 299 03006 Vol. 299 DOI: 10.1051/matecconf/201929903006

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press

Mayer, R. E. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38, 43–52.

Mayer, R. E. (2005). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31–48). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.004

Mikropoulos, T. A. (2006). Presence: a unique characteristic in educational virtual environments. *Virtual Reality*, 10(3), 197–206.

Mikropoulos, T. A., & Bellou, J. (2006). The unique features of educational virtual environments. In P. Isaias, M. McPherson, & F. Banister (Eds.), *Proceedings e-society 2006,*

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780.

Mikropoulos, T. A., & Strouboulis, V. (2004). Factors that influence presence in educational virtual environments. *CyberPsychology & Behavior*, 7(5), 582–591.

Milgrim, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented reality: A class of displays on the reality-virtuality continuum. *SPIE: Telemanipulator and Telepresence Technologies* (pp. 282-292). Retrieved from http://etclab.mie.utoronto.ca/publication/1994/Milgram_Takemura_SPIE1994.pdf

Moro, C., Stromberga, Z., Anthansios, R., & Allan., S. (2017). "The effectiveness of virtual and augmented reality in health sciences and medical anatomy." *Anatomical Sciences Education* 10, 549-559.

Mulders, M., Buchner, J., & Kerres, M. (2020). A Framework for the Use of Immersive Virtual Reality in Learning Environments. *International Journal Of Emerging Technologies In Learning (IJET)*, 15(24), pp. 208-224. doi: http://dx.doi.org/10.3991/ijet.v15i24.16615

Ogunyemi, A., & Lamas, D., (2014). Interplay between human-computer interaction and software engineering. *2014 9th Iberian Conference on Information Systems and Technologies (CISTI)*, Barcelona, Spain, 2014, pp. 1-10, doi: 10.1109/CISTI.2014.6877024.

Pantelidis, V., (2009). Reasons to Use Virtual Reality in Education and Training Courses and a Model to Determine When to Use Virtual Reality. *Themes in Science and Technology Education.* 2.

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Education Psychology*. 110, 785–797. doi: 10.1037/edu0000241

Pascal A., Thomas C., Romme A. G. L. (2013). Developing a human-centered and science-based approach to design: the knowledge management platform project. British J. Manag. 24, 264–280. 10.1111/j.1467-8551.2011. 00802.x

Polcar, J., & Horejsi, P. (2015). Knowledge acquisition and cyber sickness: a comparison of VR devices in virtual tours. *MM Science Journal*, (3) 613–616. https://doi.org/10.17973/MMSJ.2015_06_201516.

Saghafian, M., Sitompul, T. A., Laumann, K., Sundnes, K., & Lindell, R. (2021). Application of Human Factors in the Development Process of Immersive Visual Technologies: Challenges and Future Improvements. *Frontiers in Psychology*, 12, 634352. https://doi.org/10.3389/fpsyg.2021.634352

Sarasso, P., Ronga, I., Del Fante, E. et al. (2022). Physical but not virtual presence of others potentiates implicit and explicit learning. *Sci Rep* 12, 21205. https://doi.org/10.1038/s41598-022-25273-4

Salzman, M.C., Dede C., Loftin, R.B., & Chen, J. (1999) A model for understanding how virtual reality aids complex conceptual learning. *Presence* 8(3):293–316

Stranger-Johannessen E. (2018) Exploring Math Achievement Through Gamified Virtual Reality. In: Pammer-Schindler V., Pérez-Sanagustín M., Drachsler H., Elferink R., Scheffel M. (eds) Lifelong Technology-Enhanced Learning. EC-TEL 2018. *Lecture Notes in Computer Science*, vol 11082. Springer, Cham. https://doi.org/10.1007/978-3-319-98572-5_57

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers and Education, 147*, 103778.

Ragusa, A. T. (Ed.). (2010). *Interaction in Communication Technologies and Virtual Learning Environments: Human Factors: Human Factors*. IGI Global.

Richards, D., & Taylor, M. (2015). A comparison of learning gains when using a 2D simulation tool versus a 3D virtual world: An experiment to find the right representation involving the Marginal Value Theorem. *Computers & Education*, *86*, 157–171. https://doi.org/10.1016/j.compedu.2015.03.009

Schneiderman, B., Plaisant C., Cohen M., Jacobs, S., Elmqvist, N., & Diakopoulos, N. (2016). Designing the User Interface: Strategies for Effective Human-Computer Interaction (6th Edition ed.)

Sutherland, I.E. (1965). The Ultimate Display.

The Body VR. (2016). The Body VR: Journey inside a cell [Video Game]. New York, NY: The Body VR LLC. Steam

Trindade, J., Fiolhais, C., & Almeida, L. (2002). “Science Learning in Virtual Environments: a Descriptive Study.” *British Journal of Educational Technology* 33.4 (2002): 471–488. Web.

Wilkinson, M., Pugh, Z., Crowson, A., Feng, J., Mayhorn, C.B., and Gillan, D. (2019). Seeing in Slow Motion: Manipulating Arousal in Virtual Reality. *Proceedings of Human Factors & Ergonomics Society Annual Meeting*, 1649-1653. https://doi.org/10.1177/1071181319631512

Wilson, B.G. (1996). Constructivist Learning Environments: Case Studies in Instructional Design. *Educational Technology Research and Development*, 44(3), 99-101.

Winn, W. (1993). A conceptual basis for educational applications of virtual reality (Technical Report TR-93-9). Seattle, Washington: Human Interface Technology Laboratory, University of Washington. Retrieved from http://www.hitl.washington.edu/publications/r-93-9/

Winn, W. (1999). Learning in Virtual Environments: A Theoretical Framework and Considerations for Design. *Educational Media International*, 36(4), 271. Retrieved June 28, 2021 from https://www.learntechlib.org/p/89094/.

Winn W., & Windschitl, M. (2000) Learning science in virtual environments: the interplay of theory and experience. *Themes Education, 1*(4):373–389

Witmer, B.G. & Singer, M.J. (1998) Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence: *Teleoperators and Virtual Environments*, 7, 225-240. http://dx.doi.org/10.1162/105474698565686

Witmer, B.G., Jerome, J., & Singer, M.J.; The Factor Structure of the Presence Questionnaire. *Presence: Teleoperators and Virtual Environments* 2005; 14 (3): 298–312. doi: https://doi.org/10.1162/105474605323384654

UQO Cyberpsychology Lab. (2004b). Revised Presence Questionnaire 3.0. [Online] Retrieved From: http: //w3.uqo.ca/cyberpsy/docs/qaires/pres/PQ_va.pdf

APPENDIX A

Overview/ History of Virtual Reality (VR)

The idea of creating 3-D simulations and representations for leisure, learning, and gaming has been long contemplated. The stereoscope, which is of the earliest known 3D technologies created by humans, dates to the mid-1800s (Keshner et al., 2019). This technology was a handheld device that enabled people to look through a pair of lenses to view a photographic image (Cipresso et al., 2018; Keshner et al., 2019). Another form of this 3D technology was created by Morton Helig, who created a mechanical virtual display device, called the Sensorama (Cipresso et al., 2018). While experiencing the Sensorama, a person could view a 3D film with smell, vibration, and sound. In fact, one of the first documented used of a head-mounted display (HMD) was created in 1961 by Philco, which allowed remote viewing via a video camera (Cipresso et al., 2018; Kalawsky, 1993).

Other advancements occurred in 1965 when Ivan Sutherland, an American computer scientist and internet pioneer, presented his vision of the “Ultimate Display,” which is seen as seen as a fundamental and historical blueprint for immersive VR (iVR) (Cipresso et al, 2018; Kalawsky, 1993; Sutherland, 1965). Sutherland proposed a virtual world, which viewed through an HMD, which replicated reality so well that the user would not be able to distinguish virtual from actual reality, also allow the user to interact with objects. In the late 1960’s Thomas Furness, a military engineer, known as the grandfather of virtual reality, created the first flight simulator for the Air Force (Keshner et al., 2019). This revolution assisted in the advancement of VR because the military subsequently provided a lot of funding for producing better flight simulators for the training and safety of military personal. Virtual reality entered the mainstream of technology in the 1980s, because of being popularized by Jaron Lanier, one of the modern computer designers and interface pioneers in the field. Immersive technology was incorporated into military training, medical simulations, and education.

This continuum reflects the transitional and immersive experiment moving from the real world into the experience of iVR. The continuum begins with a real, physical environment and then moves to a non-immersive desk-top like display. The right immersive side of the continuum includes the technology of AR, which overlays a visual layer onto the physical world we see around us. Lastly, the model shifts to a full virtual experience, where a person can interact within an artificial 3-D environment using electronic devices (Shneiderman et al., 2016).

APPENDIX B

Knowledge Pre-Test Instrument

Indicate your preferred answer by marking an circling around your selected response. Try to answer all questions. In general, if you have some knowledge about a question, it is better to try to answer it. You will not be penalized for guessing.

1. What kinds of molecules pass through a cell membrane most easily?
   a. Water and Oxygen
   b. Sodium and Sugar
   c. Calcium and Potassium
   d. Sodium and Calcium

2. Out of the three different types of strands that makeup the cytoskeleton, which of the following is the smallest in diameter?
   a. Intermediate Filaments
   b. Microfilaments
   c. Microtubules
   d. Macrophage

3. Erythrocyte is another name for a __________
   a. White Blood cell
   b. Red blood cell
   c. Platelet
   d. Plasma

4. All the following is true regarding DNA except?
   a. DNA is also referred to deoxyribonucleic acid
   b. DNA is a molecule that carries our genetic code
   c. DNA contains instructions for protein synthesis in the process of translation.
   d. DNA contains instructions for protein synthesis in the process of transcription.

5. Which motor protein transports cargo such as ATP, by walking along microtubule tracks?

   a. Kinesin
   b. Actin
   c. Dynein
   d. Cytosine

6. The rough endoplasmic reticulum (RER) is a maze-like structure studded with ribosomes. What is the main function of this microstructure?

   a. Transmits instructions for protein synthesis in the process of transcription.
   b. Brings molecules into the nucleus.
   c. Maintains a vital role in protein synthesis by linking together amino acids, following the instructions received from the RNA.
   d. Functions as the control center of the cell containing most of the cells DNA.

7. Which of the following makes up 60% of the blood’s total volume?

   a. Erythrocytes
   b. Plasma
   c. Platelet
   d. Leukocyte

8. What are the mitochondria typically referred to as?

   a. Protein creators.
   b. The control center of the cell.
   c. The transcription center of the cell.
   d. The powerhouse of the cell

APPENDIX C

Knowledge Post-Test Instrument

Indicate your preferred answer by marking an circling around your selected response. Try to answer all questions. In general, if you have some knowledge about a question, it is better to try to answer it. You will not be penalized for guessing.

1. Which type of blood cell is likely to increase in quantities when the body is under attack from bacteria?
   - a. Leukocyte
   - b. Erythrocyte
   - c. Thrombocytes
   - d. Plasma

2. What is the function of receptor proteins on the outside of the cell membrane?
   - a. Protect against virus and bacteria
   - b. Maintains a vital role in protein synthesis by linking together amino acids, following the instructions received from the RNA.
   - c. Transfer information and nutrients to the cell.
   - d. The control center of the cell.

3. What is the main function of RBCs or erythrocytes?
   - a. Check for the presence of antibodies in the blood.
   - b. To transfer oxygen from our lungs to the vital parts of our body.
   - c. To stop bleeding at the site of a damaged blood vessel.
   - d. To link together amino acids

4. In the cytoskeleton, the Intermediate Filament is made up of what protein?
   - a. Dynein
   - b. ATP
   - c. Kinesin
   - d. Actin

5. Which of the following form the front line of our immune system?

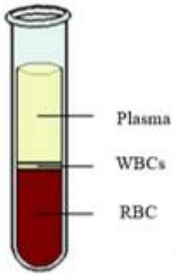
- a. Red Blood Cells (RBC) and White Blood Cells (WBC)
- b. Antibodies and White Blood Cells (WBC)
- c. Red Blood Cells (RBC) and Antibodies
- d. Antibodies and Platelets

6. From the rough endoplasmic reticulum (RER), the protein is transported in a vesicle made up of what membrane?

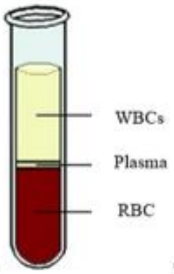
- a. Cytoplasm
- b. Aria Membrane
- c. Intermediate Filaments
- d. Microtubule

7. In reference to quantity, which most accurately represents the quantities of cells in our blood?

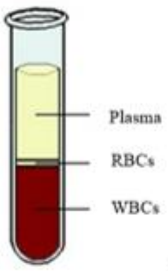
a.



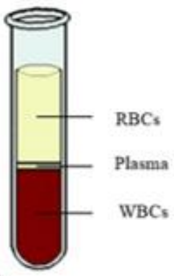
b.



c.



d.



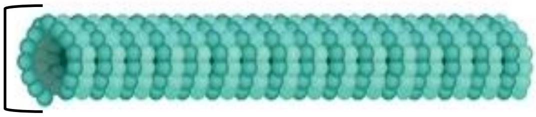
8. Which is the correct sequence of increasing organization?

- a**.** Molecule, cell, organelle, organ
- b. Organelle, tissue, cell, organ
- c. Organ, organism, tissue, cell
- d. Organelle, cells, tissues, organs

9. To the best of your ability, fill in the blanks in relation to the three different types of strands that makeup the cytoskeleton (Intermediate Filament, Microfilament, Microtubule).

10 nanometers

____



24 nanometers

____

7 nanometers

____

10. Which of the following are free-floating organelles?

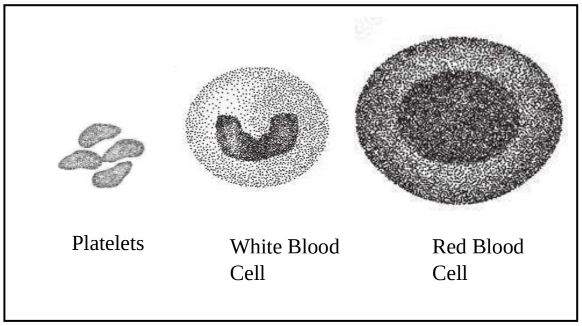
a. Ribosomes
b. Vesicles
c. Mitochondria
d. Nucleus

11. Which pathway correctly represents the flow of information in the cell?

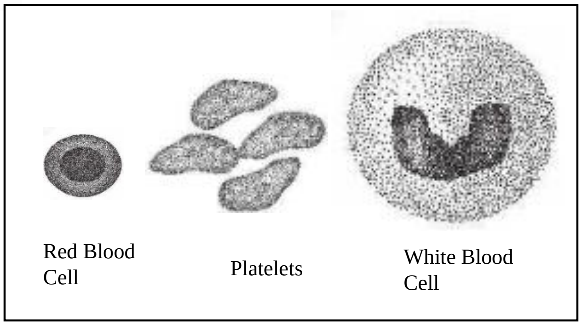
a. RNA → DNA → protein
b. DNA → RNA → protein
c. ER → DNA → RNA → protein
d. ER → DNA → Golgi → protein

12. In reference to size, which of the following illustrations most accurately represent the three types of cells that make up your blood?

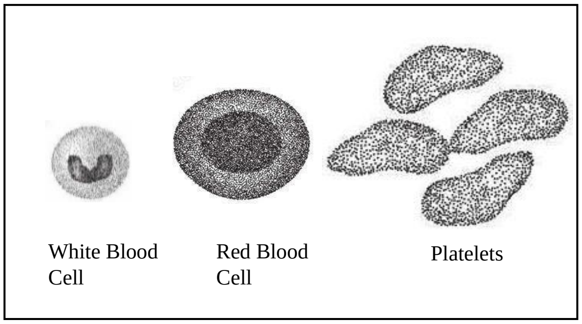
a.



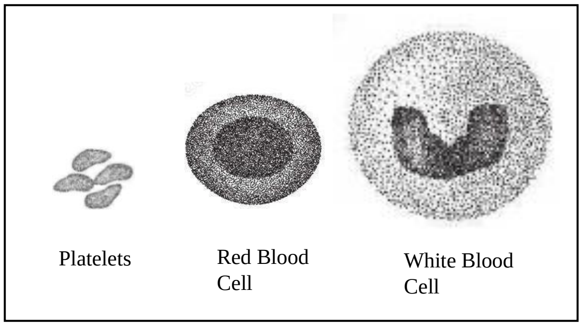
b.



c.



d.



APPENDIX D

Demographic Instrument

1. Are you male or female?

☐ Male
☐ Female
☐ Other

2. What is your age?

☐ 0-17
☐ 18-24
☐ 25-34
☐ 35-44
☐ 45-49
☐ 50+

3. Roughly how many hours do you spend playing video games each day (e.g. gaming consoles, mobile phones, computers, etc.)?

☐ 0 hours
☐ 1-2 hours
☐ 3-4 hours
☐ 5-6 hours
☐ More than 7 hours

4. In the past 30 days, which of the following devices have you used to play video games? (Please select all that apply.)

☐ Desktop/Laptop computer
☐ SmartPhone
☐ Tablet
☐ Nintendo Wii
☐ Nintendo Wii U
☐ Nintendo 3DS XL
☐ Sony PlayStation
☐ Sony PlayStation Vita
☐ Microsoft Xbox (Any Xbox Model)
☐ Virtual Reality System (HMD)
☐ I have not used any of these devices to play video games

APPENDIX E

NASA-TLX Questionnaire

Characterize your experience in the environment, by marking an **"X"** in the appropriate box of the 20- point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

Mental Demand: How mentally demanding was the task?

Very Low Very High

Temporal Demand: How hurried or rushed was the pace of the task?

Very Low Very High

Performance: How successful were you in accomplishing what you were asked to do?

Very Low Very High

Effort: How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low Very High

APPENDIX F

Presence Instrument

Characterize your experience in the environment, by marking an **"X"** in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL SOMEWHAT COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|__________|__________|__________|__________|__________|__________|__________|

NOT MODERATELY COMPLETELY
RESPONSIVE RESPONSIVE RESPONSIVE

3. How natural did your interactions with the environment seem?

|__________|__________|__________|__________|__________|__________|__________|

EXTREMELY BORDERLINE COMPLETELY
ARTIFICIAL NATURAL

4. How much did the visual aspects of the environment involve you?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL SOMEWHAT COMPLETELY

5. How natural was the mechanism which controlled movement through the environment?

|__________|__________|__________|__________|__________|__________|__________|

EXTREMELY BORDERLINE COMPLETELY

ARTIFICIAL NATURAL

6. How compelling was your sense of objects moving through space?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL   MODERATELY   VERY
                          COMPELLING   COMPELLING

7. How much did your experiences in the virtual environment seem consistent with your real-world experiences?

|__________|__________|__________|__________|__________|__________|__________|

NOT   MODERATELY   VERY
CONSISTENT   CONSISTENT   CONSISTENT

8. Were you able to anticipate what would happen next in response to the actions that you performed?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL   SOMEWHAT   COMPLETELY

9. How completely were you able to actively survey or search the environment using vision?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL   SOMEWHAT   COMPLETELY

10. How compelling was your sense of moving around inside the virtual environment?

|__________|__________|__________|__________|__________|__________|__________|

NOT   MODERATELY   VERY
COMPELLING   COMPELLING   COMPELLING

11. How closely were you able to examine objects?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL   PRETTY   VERY
                          CLOSELY   CLOSELY

12. How well could you examine objects from multiple viewpoints?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL	SOMEWHAT	EXTENSIVELY

13. How involved were you in the virtual environment experience?

|__________|__________|__________|__________|__________|__________|__________|

NOT INVOLVED	MILDLY INVOLVED	COMPLETELY ENGROSSED

14. How much delay did you experience between your actions and expected outcomes?

|__________|__________|__________|__________|__________|__________|__________|

NO DELAYS	MODERATE DELAYS	LONG DELAYS

15. How quickly did you adjust to the virtual environment experience?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL MINUTE	SOMEWHAT	LESS THAN ONE

16. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|__________|__________|__________|__________|__________|__________|__________|

NOT PROFICIENT	REASONABLY PROFICIENT	VERY PROFICIENT

17. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL INTERFERED PREVENTED
SOMEWHAT TASK PERFORMANCE

18. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL INTERFERED INTERFERED
SOMEWHAT GREATLY

19. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|__________|__________|__________|__________|__________|__________|__________|

NOT AT ALL SOMEWHAT COMPLETELY

APPENDIX G

Consent Form

UNIVERSITY OF SOUTH DAKOTA
Institutional Review Board
Informed Consent Statement

Title of Project: The Impact of Immersive VR (iVR) verse desktop VR (dVR) Technologies on Learning Attainment and Sense of Presence

Principal Investigator: Michael Granaas Ph.D., 205 South Dakota Union, Vermillion SD 57069 (605) 677-5351 michael.granaas@usd.edu

Other Investigators: Haley Hoffman, South Dakota Union, Vermillion, SD 57069

Purpose of the Study:

The purpose of this research study is to explore the relationship, if any, immersive technologies and learning attainment and individual's subjective sense of presence.

Procedures To Be Followed:

You will be asked to answer 12 questions across two questionnaires. You will then be asked to complete an immersive educational experience, either with a virtual reality (VR) headset or a desktop computer. In both immersive experiences, you will learn about biological concepts related to the human circulatory system and its processes. Completing the experience takes 12 minutes to complete. You will then be asked to answer an additional 36 questions on three questionnaires. Some of the questions will ask about your experience towards the technology based educational experience. You are free to skip any question(s) which you do not want to answer.

Risks:

There is some risk involved in participating in this study. The subjects assigned to use the VR group may experience discomfort in using the VR headset, especially if this is their first time. Nausea and headaches are common occurrences with virtual reality sickness. The room will be free of hazards that could harm the participant, such as chairs, wires, and desks. One participant will be in the room at a time. If you feel uncomfortable using the headset, please notify one of the researchers and you will be able to stop at any time.

Benefits:

You will receive 8 SONA credits for your participation. You may withdraw from the study at any time without losing the course points assigned by your instructor. If you choose not to participate in this research study, please consult your course instructor on other methods to earn course points or participate in a different study listed on SONA.

Duration:

It will approximately 1 hour to complete this study.

How will we protect your information?

We will protect the confidentiality of your research records by excluding information that may be personally identifiable. Any other information that can directly identify you will be stored separately from the data collected as part of the project. The records of this study will be kept confidential to the extent permitted by law. Any report published with the results of this study will remain confidential and will be disclosed only with your permission or as required by law. To protect your privacy, we will not include any information that could identify you. We will protect the confidentiality of the research data by keeping all documents under lock and key. It is possible that other people may need to see the information we collect about you. These people work for the University of South Dakota and other agencies as required by law or allowed by federal regulation

Statement of Confidentiality:

The questionnaire does not ask for any information that would identify who the responses belong to. Therefore, your responses are recorded confidentially. If this research is published, no information that would identify you will be included since your name is in not linked to your responses.

Right to Ask Questions:

The researchers conducting this study are Michael Granaas Ph.D. and Haley Hoffman. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Michael Granaas at 605 658-3700 during the day

If you have questions regarding your rights as a research subject, you may contact The University of South Dakota- Office of Human Subjects Protection at (605) 658-3743. You may also call this number with problems, complaints, or concerns about the research. Please call this number if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

Voluntary Participation

You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without losing any benefits to which you are otherwise entitled.

You do not have to answer any questions you do not want to answer.

You must be 18 years of age older to consent to participate in this research study.

Your Consent

Before agreeing to be part of the research, please be sure that you understand what the study is about. Keep this copy of this document for your records. If you have any questions about the study later, you can contact the study team using the information provided above.

APPENDIX H

Demographics Table

Factor	*Ivr N=35*	*Dvr N=30*	*All N=65*
Age			
18-24	N=35 (100%)	N=28 (93.3%)	N=63 (96.92%)
25-34	N=0 (0%)	N=2 (6.6%)	N=2 (3.1%)
Gender			
Female	N=20 (57.1%)	N=16 (53.3%)	N=36 (55.4%)
Male	N=15 (42.8%)	N=14 (46.6%)	N=29 (44.6%)
Gameplay Usage			
0 hours	N=9 (25.7%)	N=10 (46.6%)	N=10 (33.3%)
1-2 hours	N=17 (48.57%)	N=9 (30%)	N=9 (30%)
3-4 hours	N=7 (20.0%)	N=9 (30%)	N=9 (30%)
5-6 hours	N=2 (5.7%)	N=0 (0.0%)	N=0 (0.0%)
7+ hours	N=0 (0.0%)	N=2 (6.6%)	N=2 (6.6%)
Gameplay Device			
Desktop	N=19 (54.28%)	N=16 (53.3%)	N=35 (53.8%)
Phone	N=25 (71.42%)	N=20 (66.6%)	N=45 (69.2%)
Tablet	N=2 (5.71%)	N=3 (10%)	N=5 (7.6%)
PlayStation	N=6 (17.14%)	N=3 (10%)	N=9 (13.8%)
Xbox	N=2 (5.71%)	N=3 (10%)	N=5 (7.6%)
VR/HMD	N=0 (0.0%)	N=0 (0.0%)	N=0 (0.0%)
Other	N=0 (0.0%)	N=1 (3.3%)	N=1 (1.5%)
None	N=9 (25.71%)	N=10 (33.3%)	N=19 (29.2%)

APPENDIX I

ANOVA Table

Source	*SS*	*df*	*MS*	*F*	*p*
Between					
Media Format	0.462	1	0.462	.4448	0.5073
Error Between	65.38	63	1.0378		
Total Between	65.842	64			
Within					
Learning Type	9.638	1	9.638	3.5645	.0637
LT x MF	4.68	1	4.677	1.729	.1932
Error LT	170.34	63	2.704		
Total LT	184.658	65			

APPENDIX J

NASA-TLX Statistical Table

	T	Sig.	95% Confidence Interval of the Difference	
			Lower	Upper
NASA-TLX	0.89114	0.3765	-4.255345	11.083916

NASA-TLX Subscales Statistical Table

			95% Confidence Interval of the Difference	
Subscale	*t*	Sig. (p)	Lower	Upper
Mental Demand	0.67431	0.5031	-1.674240	3.369478
Temporal Demand	-0.1447	0.8854	-3.175823	2.747251
Performance	1.199	0.2359	-0.6857589	2.7238542
Effort	1.1599	0.2511	-1.015062	3.805538
Frustration	-0.39111	0.6972	-1.373252	2.039918

***NASA-TLX subscales were examined in an exploratory analysis to see if there is anything significant within each scale.**

APPENDIX K

NASA-TLX Subscale Means by Conditions

Condition		NASA-TLX Subscale Score
iVR (N=35)		
	Mental	M = 8.09 (4.18)
	Temporal	M = 7.11 (7)
	Performance	M = 4.71 (2.86)
	Effort	M = 6.37 (4.24)
	Frustration	M = 3.40 (3.11)
	Total	M = 29.69 (14.18)
dVR (N=30)		
	Mental	M = 8.93 (5.69)
	Temporal	M = 6.90 (4.87)
	Performance	M = 5.76 (3.83)
	Effort	M = 7.77 (5.29)
	Frustration	M = 3.73 (3.68)
	Total	M = 33.10 (16.37)

APPENDIX L

Presence Questionnaire Subscales Welch's Independent samples t-test

			95% Confidence Interval of the Difference	
PQ Factor	*t*	Sig. (p)	Lower	Upper
Realism	-0.40438	0.6873	-4.301667	2.854048
Possibility to Act	0.28434	0.7771	-2.066844	2.752558
Quality Interface	-0.049014	0.9611	-1.805116	1.719402
Possibility to Examine	-0.99377	0.3246	-2.4409353	0.8218877
Self-Evaluation of Performance	-0.72052	0.4746	-1.3888010	0.6554676

*** Presence Questionnaire (PQ) subscales were examined in an exploratory analysis to see if there is anything significant within each scale.**

APPENDIX M
Outlier Scatterplot

Figure 1. Outlier Scatterplot