2023

An Experimental Mixed Methods Pilot Study for U.S. Army Infantry Soldiers - Higher Levels of Combined Immersion and Embodiment in Simulation-Based Training Capabilities Show Positive Effects on Emotional Impact and Relationships to Learning Outcomes

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AN EXPERIMENTAL MIXED METHODS PILOT STUDY FOR U.S. ARMY INFANTRY SOLDIERS - HIGHER LEVELS OF COMBINED IMMERSION AND EMBODIMENT IN SIMULATION-BASED TRAINING CAPABILITIES SHOW POSITIVE EFFECTS ON EMOTIONAL IMPACT AND RELATIONSHIPS TO LEARNING OUTCOMES

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A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the School of Modeling, Simulation, and Training
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Spring Term
2023

ABSTRACT

This pilot study examines the impact of combined immersion and embodiment on learning and emotional outcomes. The results are intended to better enable U.S. Army senior leaders to decide if dismounted infantry Soldiers would benefit from a more immersive simulation-based training capability. The experiment's between-subject design included a sample of 15 participants randomly assigned to one of three system configurations representing different levels of combined immersion and embodiment. The control group was a typical desktop, and the two experimental groups were a typical configuration of a Virtual Reality headset (VR) and a novel configuration using VR supported by an omnidirectional treadmill (ODT) for full body exploration and interaction. Unique from similar studies, this pilot study allows for an analysis of the Infinadeck ODT's impact on learning outcomes and the value of pairing tasks by type with various levels of immersion. Each condition accessed the same realistically modeled geospatial virtual environment (VE), the UCF Virtual Arboretum, and completed the same pre and post VE-interaction measurement instruments. These tests included complicated and complex information. Declarative information involved listing plants/communities native to central Florida (complicated tasks) while the situational awareness measurement required participants to draw a sketch map (complex task). The Kruskal-Wallis non-parametric statistical test showed no difference between conditions on learning outcomes. The non-parametric Spearman correlation statistical test showed many significant relationships between the system configuration and emotional outcomes. Graphical representations of the data combined with quantitative, qualitative, and correlational data suggest a larger sample size is required to increase power to answer this research question. This study found a strong trend which indicates learning outcomes are affected by task type and significant correlations between emotions important for learning outcomes increased with combined immersion and embodiment.

ACKNOWLEDGMENTS

First, I would like to thank my beautiful and loving wife, Jennifer, and our children for their support throughout this entire process.

Next, I would like to thank my Thesis Committee Chair, Dr. Maria C. R. Harrington, for her mentorship, expertise, and patience as I worked to complete this project. I would also like to thank my Thesis Committee Members, Dr. Charles E. Hughes and Dr. Bruce D. Caulkins, for their invaluable advice and feedback during this project.

Thirdly, I would like to thank the M3DVR Team, Mr. Matthew Hogan and Mr. Robert Oglesby, and the UCF Games and Interactive Media Maker Space Manager, Mr. Jordan Lipscomb. Without their assistance this project would not have been possible.

Finally, I would like to thank Colonel Gregory Pavlichko, Lieutenant Colonel Ryan Scott, and Mr. Ron Walck for their mentorship and assistance in enabling me to pursue this project.

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CHAPTER ONE: INTRODUCTION

> In order to enunciate anything we must have a premise. The most obvious is the last war. Further, the impressions we gained there were the most vivid we have ever experienced; burned on the tablets of our memories by the blistering flash of exploding shell, etched on our souls by the incisive patter of machinegun bullets, our own experiences become the foundation of our thoughts and, all unconscious of personal bias, we base our conceptions of the future on our experience of the past. (Patton, 1931, p. 79)

Adversaries of the United States (U.S.) are actively working to develop systems, technologies, and capabilities to degrade the U.S.' ability to project military power (Headquarters, Department of the Army (HQDA), 2021, p. 1). For instance, recent satellite imagery suggests that the Chinese military is testing its anti-aircraft carrier capability by including a "a full-scale outline of a "Ford-class" aircraft carrier currently being constructed for the US Navy" at one of its known ballistic missile test sites (Stapleton et al., 2021, para. 2). Aircraft carriers are very concrete representations of the U.S. military's power-projection capabilities. In response to such actions, the U.S. Army is actively transforming into the "Multi-Domain Army of 2035" (HQDA, 2021, p. 1). This transformation is informed by the Multi-Domain Operations, or MDO, operational concept which influences how the Army conducts operations, organizes itself, and modernizes (Feickert, 2022, pp. 1-2). For example, Army units are being/will be developed, equipped, and required to perform tasks not traditionally associated with Army operations such as sinking ships and/or neutralizing satellites (McEnany, 2022, pp. 1, 3, 8). Concerning modernization, the Army has identified six priorities which include modernization efforts involving networks, long range fires, air and missile defense, combat vehicles, aviation assets, and increased Soldier lethality (HQDA, 2021, p. 22).

A tool/capability currently in development that must be leveraged to enable MDO modernization priorities is the U.S. Army's Synthetic Training Environment (STE) capability. As the Army's primary training modernization effort, the STE will improve the existing training model by synchronizing "live, virtual, constructive and gaming training environments" (Rozman, 2020, pp. 1, 3). This combining of environments will enhance training by increasing training interoperability and accessibility (Rozman, 2020, p.1). The STE will provide realistic simulated real-world terrain which allows Soldiers to better understand terrain they may be required to conduct training or operations on (Rozman, 2020, p.1). The STE will operationalize the availability of simulated real-world terrain through One World Terrain (OWT). The OWT initiative/solution will deliver "3D global terrain capability and associated information services that support a fully accessible virtual representation of the physical Earth accessible through the Army network" (PEO STRI, n.d.c, para 2). OWT will support simulation-based training capabilities amongst other potential requirements from the Soldier/Squad to the Army Service Component Command level (PEO STRI, n.d.c, para 1.). The STE will enhance Soldier lethality by enabling training in a more realistic environment, providing training repetitions, and most importantly simulating combat (Rozman, 2020, p.1). From an MDO perspective, the STE is aligned against the increased Soldier lethality modernization priority (HQDA, 2021, p. 22; U.S. Army Professional Forum, 2020). The STE's development coinciding with the Army's MDO transformation provides a target of opportunity for the Army to improve simulation-based training requirements and capabilities for small unit dismounted infantry Soldiers.

Currently, there are virtual/simulation training systems in existence and under development which provide individual and collective training opportunities for dismounted infantry Soldiers, but room for improvement arguably exists. Although not an exhaustive list, existing systems/capabilities include the Engagement Skills Trainer II (EST II) and Virtual Battle Space 3 (VBS3) while systems/capabilities in development include the Soldier/Squad Virtual Trainer (S/SVT) and the STE-Information System (STE-IS) (Bohemia Interactive Simulations, 2017; PEO STRI, n.d.a; PEO STRI, n.d.b; United States Army Combined Arms Center (USA CAC), 2021, embedded slides). The EST II allows individual Soldiers and small units to conduct simulated weapons training in preparation for live fire exercises (United States Army Acquisition Support Center (USAASC), 2021). The system provides high fidelity weapon simulators (individual through crew-served weapons), allows for weapons qualification, and provides some collective training scenarios (USAASC, 2021). See Appendix A for more information about fidelity. EST II training occurs indoors "in a controlled environment" with up to 15 users engaging targets/scenarios projected on a screen via projector (USAASC, 2021, para. 1). For more information about the EST II and an image of Soldiers training with the system, please see https://peostri.army.mil/engagement-skills-trainer-est.

Small units, fire team to company-level, currently seeking collective-simulation-supported training will likely find VBS3 as the proposed solution. VBS3 gaming software resembles game series such as the commercially available Ghost Recon and ARMA (Bohemia Interactive Simulations, 2021). A VBS3 solution will most likely be supported by a desktop and mouse configuration with some unique peripherals such as a steering wheel and or joystick (Bohemia Interactive Simulations, 2021). To see an image of Soldiers training with VBS3, please see https://www.nationalguard.mil/Resources/Image-Gallery/News-

Images/igphoto/2002115810/. Tools such as, and similar to, VBS3 and EST II can be valuable training enablers for small unit training, but these current solutions may be lacking in their ability to generate immersion, presence, and embodiment which could result in missed learning opportunities (immersion, presence, and embodiment are discussed in detail in the following literature review section).

Elements of the STE under development include the STE-Information System (STE-IS) and the Soldier/Squad Virtual Trainer (S/SVT). The STE-IS capability is set to replace VBS3 apparently through the integration of the STE-IS' internal Training Simulation Software (TSS) and OWT capability (PEO STRI, n.d.d, description section; USA CAC, 2021, embedded slides). The S/SVT capability provides "four simulated military equipment (SME) training capabilities" (PEO STRI, n.d.b, expandable diagram). The capabilities include the Squad Immersive Virtual Trainer (SiVT), Weapons Skills Development (WSD), Joint Fires Training (JFT), and Use of Force (UoF) (PEO STRI, n.d.b, expandable diagram). The WSD, JFT, and UoF capabilities are essentially replacements for EST II and Call For Fire Trainer III (CFFT III) (PEO STRI, n.d.b, para. 1). The SiVT is a software solution which involves the use of the Integrated Visual Augmentation System (IVAS) which is derived from Microsoft Hololens headset technology produced by Microsoft (Bach, 2021; Rozman, 2020, pp. 4-5). For more information about the IVAS and images of Soldiers using the system, please see https://www.peosoldier.army.mil/Program-Offices/Project-Manager-Integrated-Visual-Augmentation-System/. Although the IVAS can support real-world operations, it can also support training through its organic Augmented Reality (AR) capability by adding virtual objects to the live training space to increase training complexity (Rozman, 2020, pp. 4-6). The SiVT will provide/provides this capability to IVAS users (Thompson, 2022). It is important to note that

Rozman (2020) lists using AR technology as one of the challenges the STE must overcome since scenarios will be encountered where “simulated terrain does not match the physical space on which it is overlaid” (p. 6). Additionally, AR technology may not be mature enough to meet Army training requirements which undoubtedly need functionality in daylight illuminated environments (Broll, 2022, p. 319; Stone, 2021). If the environment is too bright, AR presented images may be partially transparent or partially invisible since the IVAS is of an optical-see through design (Broll, 2022, p. 299). If AR technology cannot overcome these challenges, depending on the desired scenario, and the STE-IS produces a simple evolution of VBS3, immersion, presence, and embodiment may not be improved effectively potentially limiting Soldier learning/training outcomes.

A simulation-based training capability no longer listed as a current/legacy or future system by the Army is the Dismounted Soldier Training System (DSTS) (Bymer, 2012; USA CAC, 2021, embedded slides). In 2012, the system was described as the “first fully immersive virtual simulation training system for Soldiers” (Bymer, 2012, para. 2). The system included/required five work areas which in conjunction with one another through virtual reality placed up to a squad of Soldiers (approximately nine Soldiers) in a virtual environment to conduct combat-scenario training (Bymer, 2012, para. 7; Gregory, 2014, para. 3). It was a wearable system which included:

> a helmet complete with a mounted display, an integrated head tracker, stereo speakers and a microphone for voice and radio communications; a computer backpack for processing and display of the 3-D virtual environment; sensors for tracking body positions; and instrumented weapons for optics, sights and scope (Gregory, 2014, para. 5).

Individual/Soldier movement in the virtual environment was controlled by a combination of the Soldier physically turning to change their facing direction and a thumb stick located on the foregrip of the surrogate weapon to conduct movement (Bink et al., 2015, pp. 3, 5; Gregory, 2014, para. 5). The system required "1,500 square feet of space" to conduct training and although intended for squad training, multiple systems could be linked to train larger units such as platoons (Bink et al., 2015, p. 2; Gregory, 2014, para. 14). As of 2011 apparently over one hundred of the systems were scheduled to be distributed throughout the Army in 2012 (Gregory, 2014, para. 15). Currently, as of 03 March 2021, DSTS is not listed as a training capability on the U.S. Army's Combined Arms Center's website focused on the purpose of the TRADOC Proponent Office – Synthetic Training Environment (TPO-STE) (USA CAC, 2021, embedded slides). Although seemingly no longer a training option for dismounted infantry Soldiers, the DSTS was an immersive training capability (Bymer, 2012; USA CAC, 2021, embedded slides). For more information about DSTS and an image of a Soldier training with the system, please see https://www.army.mil/article/97582/virtual_training_puts_the_real_in_realistic_environment.

Current U.S. Army simulation-training tools for dismounted infantry Soldiers from the fire team to company-level (small units) may lack the capability to provide the immersion, presence, and embodiment required to best prepare Soldiers for future battlefields. The core of this pilot study is formed around the alternate hypothesis that more immersive systems, when aligned against appropriate tasks, better prepare Soldiers for future battlefields because they allow Soldiers to achieve greater learning outcomes than from less immersive systems. Future battlefields will be increasingly complex; enemies will be more capable and "attack US forces relentlessly by every means at hand" (Freedberg, 2018, para. 6; Rozman, 2020, p. 2). Frontline combat units, such as dismounted infantry Soldiers, will be required to navigate, communicate, and operate on battlefields affected by, and through the five domains (land, air, maritime, cyber, and space) (Army Futures Command Futures and Concepts Center, 2020, p. 13). A simulation-driven capability which enhances immersion, through technology, presence, and embodiment may better prepare small unit dismounted infantry Soldiers for future battlefields characterized by increased violence, degraded communications, and non-contiguous areas of operations (Freedberg, 2016; Rozman, 2020, p. 2). This capability may prepare them by providing a more immersive environment to refine their skills while experiencing and reacting to complex problems difficult to replicate in the real-world; the capability could allow Soldiers to learn more effectively the skills required to react to complex situational problems. If this capability gap is not filled, dismounted infantry Soldiers may be at a disadvantage on these future battlefields. As the STE continues to develop and the Army continues to transform into the Multi-Domain Army of 2035, the Army should consider the acquisition of technological solutions which enhance immersion, presence, and embodiment for small unit dismounted infantry Soldiers if they improve learning outcomes essential to understanding and reacting to complex situations. A technological solution which offers and combines immersive geospatial information about the terrain with full body and full motion integration is expected to increase learning outcomes due to the resulting increase in immersion, presence, and embodiment. Such a configuration may include a Virtual Reality (VR) headset coupled with an omnidirectional treadmill.

This pilot study's purpose is to examine the impact of combined immersion and embodiment on learning outcomes. The results of this examination should better enable U.S. Army senior leaders to decide if small unit dismounted infantry Soldiers from the fire team to the company level would benefit from a more immersive simulation-based training capability. Guiding this examination is the following research question. In the context of a realistically modeled outdoor VE, does technologically enhanced immersion-embodiment result in the achievement of more learning outcomes when conducting a situational awareness-focused task due to the technology's ability to affect more of the senses? This pilot study's alternate hypothesis is that conducting a situational awareness-focused task in a realistically modeled VE will result in increased learning outcomes if the VE is accessed through a more immersive technical configuration (see Figure 1: desktop < VR headset < VR headset supported by omnidirectional treadmill).

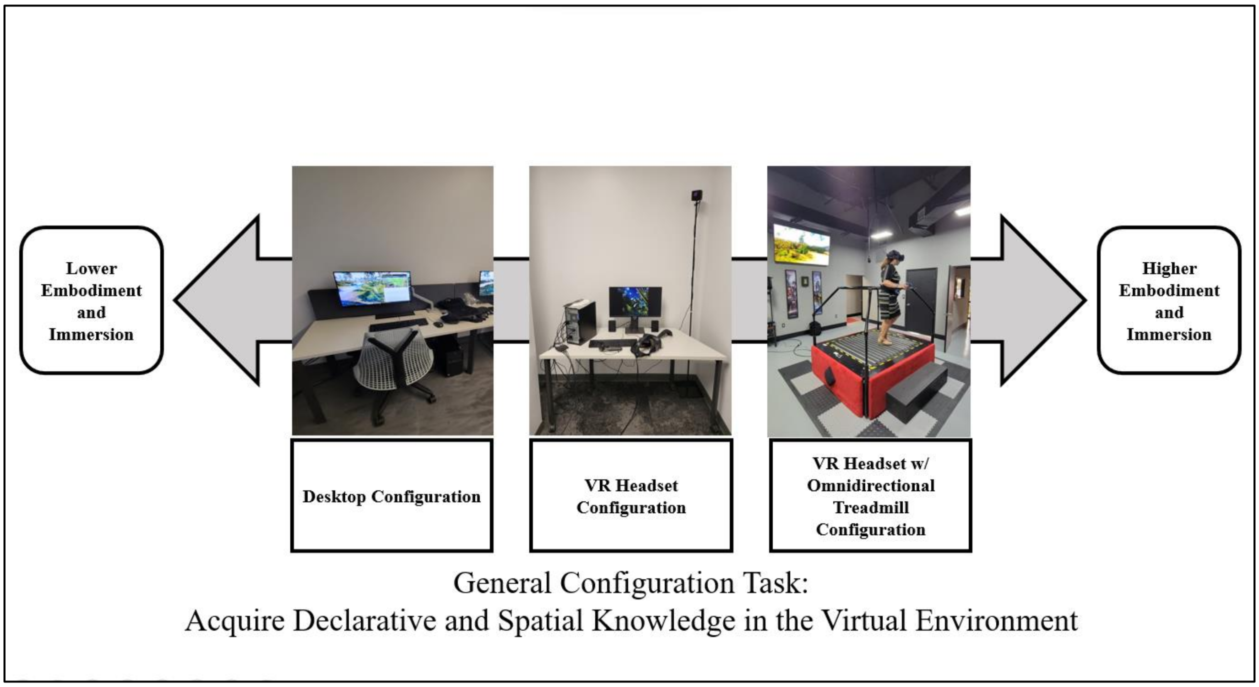


Figure 1: Conceptual Embodiment and Immersion Spectrum

Source: Author

The idea driving this alternate hypothesis is increased embodiment correlates to increased immersion resulting in increased learning (Makransky & Peterson, 2021, p. 949; Skulmowski & Rey, 2018). See Appendix A for more information about situational awareness and the following literature review and methodology sections for more information about embodiment and learning. For the purposes of this pilot study, the control condition is a VE accessed through a desktop configuration while the experimental conditions access the VE through the increasingly immersive Virtual Reality (VR) headset configuration and VR headset supported by an omnidirectional treadmill configuration. I intend for this work to contribute to the body of knowledge in several ways. First, it contributes by examining the impact of combined immersion and embodiment on learning outcomes by testing if more immersive technologies result in increased learning outcomes as compared to their less immersive counterparts. Next, by specifically selecting and analyzing complicated and complex tasks, this pilot study contributes by enabling a better understanding of which technological configuration best supports which type of task. Thirdly, it contributes to the body of knowledge focused on spatial knowledge acquisition. See Appendix A for more information about spatial knowledge acquisition.

To the best of my knowledge, this is the first study aimed at providing information to U.S. Army senior leaders based on complex geospatial and temporal learning outcomes influenced by hardware configuration alone. The unique innovation is to test and measure the new omnidirectional treadmill, the Infinadeck, to support the notion that tasks which are complex in nature are better supported by more immersive technological configurations. Thus, I examine the impact of combined immersion and embodiment on learning outcomes. The results of this examination should better enable U.S. Army senior leaders to decide if small unit dismounted infantry Soldiers would benefit from a more immersive simulation-based training capability. This study is important because the Soldier who achieves more learning outcomes in training will be better prepared to meet the complex demands of future battlefields.

This paper proceeds by first conducting a literature review which includes discussion of key terms and concepts, Army systems, and the relationship between technology, immersion, presence, embodiment, and learning. Following sections describe this pilot study's methodology, experiment, experimental findings, and conclusion.

CHAPTER TWO: LITERATURE REVIEW

This literature review's themes, topics, and organization emerged and evolved over time and in parallel with this pilot study's guiding hypothesis and supporting experiment (Tay et al., 2022). The review's development was a nonlinear process; it was not completely planned before all its various parts were identified and combined (Tay et al., 2022). However, a common thread throughout the review, excluding the terms and concepts section, is the comparing of various environments, created by technology and the real-world, which provide users different levels of immersion. This review's initial stages of development, like this pilot study's, began with a research emphasis on understanding the relationship between immersion, presence, immersive technologies such as AR and VR, and how these concepts and technologies supported training and learning for military forces. The next phase of research included the same previous concepts and technologies but broadened to examine their influence on learning in general rather than focusing solely on military interactions. Within these first two phases the idea of task-type analysis (complex vs. complicated) was identified and introduced as an analytical tool. Lastly, as the idea for this pilot study's experiment came into focus, the research emphasis shifted to studies examining spatial knowledge acquisition. The result of the development process outlined above has led to the current state of this literature review's organization.

The remainder of the literature review proceeds as follows. First, key terms and concepts are discussed to define the conceptual toolbox used to engage, analyze, and discuss the studies included throughout the review. It is worth noting these terms and concepts also informed the design of this pilot study's experiment, see the methodology section for details, while providing a lens to analyze and discuss experimental results. The next section is focused on the relationship between the key terms and concepts, technologies, and learning. The purpose of this section is to define how immersive technologies have influenced learning outcomes, and to highlight the multiple ways these technologies can be used to teach, train, and study the effectiveness of learning interventions. This section includes three sub-sections. The first emphasizes studies focused on military forces/topics. The next sub-section places emphasis on various studies best categorized as 'general learning' before concluding with studies focused on spatial knowledge acquisition. Each sub-section presents reviewed studies in accordance with the aggregate level of immersion created by their configurations from lowest to highest. For example, a study comparing the learning outcomes of groups who interacted with a desktop-powered VE and video presentation will be presented before a study comparing learning outcomes of groups who interacted with a VR-driven VE and the live environment. The aggregate level of immersion is determined subjectively by the researcher. Sub-section organization enables the researcher to speak directly to this pilot study's intended audience; Army senior leaders. These leaders would likely ask about findings from military related studies (military forces/topics sub-section), academia studies (general learning sub-section), and how and why this pilot study fits into the larger picture concerning immersion and learning (spatial knowledge acquisition sub-section). The final section of the literature review describes the research gap this pilot study seeks to address.

Key Terms and Concepts

Immersion, Presence, Realities, and U.S. Army Systems

To discuss the importance of immersion and presence these terms must be defined; these terms/concepts do not have clear and universally accepted definitions (Doerner et al., 2022, p. 17; Nilsson et al., 2016, p. 108; Slater, 2003, p. 1). Slater (2003) highlights that presence can be confused with immersion amongst other terms and calls for the academic community to agree on definitions for such terminology (pp. 1, 5).

For the purposes of this paper immersion can be understood from a technological perspective; immersion is achieved solely by "the technology used to produce the [Virtual Environment]" (Ragan, et al., 2010, p. 528; Stevens et al., 2015, p. 525). This paper defines immersion as "the objective level of fidelity of the sensory stimuli produced by a [Virtual Reality] system" (Ragan et al., 2010, p. 528; Stevens et al., 2015, p. 525). The impact of immersion on learning transfer remains uncertain with some researchers recommending more research (Steven, et al., 2015, pp. 525-526, 532). See Appendix A for more information about transfer.

Presence can be understood from a psychological perspective "as the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer & Singer, 1998, p. 225; Stevens et al., 2015, pp. 525-526). So, technological solutions create immersion and enable the feeling of presence; Slater (2003) explains "[p]resence is a human reaction to immersion" (p. 2). According to Dieker et al. (2014) a simulator can only be deemed effective if presence is achieved (p. 22). When presence is effectively achieved through immersive technologies, a suspension of disbelief can be willingly created in the user (Hayes et al., 2013, p. 22). Reaching this point is critical for learning outcomes if they are influenced by immersive features; if users do not suspend disbelief they will likely not be immersed in their experience (Dieker et al., 2014, p. 23; Hayes et al., 2013, p. 22). Hayes et al. (2013) explain that "[t]here is an inherent barrier to success in the simulation when a user finds it difficult to suspend disbelief and commit to achieving a constructed goal for a contrived scenario in a constructed environment" (p. 22). It is important to note presence can be experienced in an intense manner even though the user is aware they are in an artificial environment (Doerner et al., 2022, p. 7). Users who are knowingly placed in a VE through a VR-headset which depicts them standing near the edge of a skyscraper's roof present fear reactions such as accelerated breathing and heart rate and sweaty hands as they move closer to the roof's edge (Doerner et al., 2022, p. 7). In scenarios like this, it is easy to see that the immersive and presence producing features of the technological configuration have caused the user to suspend their disbelief even though they are fully aware they are not on top of a skyscraper (Hayes et al., 2013, p. 22). Similar to immersion, the impact of presence on learning transfer is also uncertain (Stevens et al., 2015, p. 526). Some studies have identified a positive relationship between learning and presence while others have not (Stevens et al., 2015, pp. 526, 532).

As the Army moves forward with its current training capabilities and the development of the STE, the importance of presence and immersion cannot be overlooked as it pertains to small unit dismounted infantry simulation-based training. Presence and immersion are inextricably linked, the achievement of immersion results in presence (Doerner & Steinicke, 2022, p. 51; Slater & Wilbur, 1997, p. 603). Existing simulation-based training solutions for small unit dismounted infantry training may be lacking in their ability to generate immersion and presence as typified by the common use of VBS3 and its desktop supported configuration and the EST II with its "controlled environment" projection screen supported configuration (Bohemia Interactive Simulations, 2021; USAASC, 2021, para. 1). While the STE is creating a solution for small unit dismounted infantry training which capitalizes on Augmented Reality (AR) and/or Mixed Reality (MR), and VBS3's replacement, a solution involving Virtual Reality (VR) appears to be lacking (Rozman, 2020, pp. 4-5; Stone, 2021; USA CAC, 2021, embedded slides).

AR and MR are related capabilities and involve virtual objects being placed in real environments through computer produced graphics/images (Harrington et al., 2019, p. 179; Milgram & Kishino, 1994, pp. 3-4; Stone, 2019). According to Stone (2019), "AR environments are integrated spatially with elements of, and contexts in the real world, endowing the end user with an enhanced real-time understanding of those elements and contexts" (AR section). For instance, an AR application could allow you to view a real-world body of water through your phone while the application digitally renders a historical ship into the water (Stone, 2019, AR section). Interaction with the ship-scene may occur by touching the ship on the phone screen (Stone, 2019, AR section). MR, although similar to AR, can include the user's real-world body as a way to interact with the VE. For example, while wearing some form of headset device which allows for digital augmentation of a real-world environment, a Soldier may operate a low-fidelity replica of a weapon system (Stone, 2019, MR section). However, even though the Soldier is standing in a "green screen" type room with a low-fidelity weapon replica, the Soldier sees and interacts with a detailed VE while operating a highly detailed version of the weapon due to the computer rendering graphics in the Soldier's headset (Stone, 2019, MR section). VR on the other hand involves a solely computer-generated world; a VR "environment is one in which the participant observer is totally immersed in, and able to interact with, a completely synthetic world" (Harrington et al., 2019, p. 179; Milgram & Kishino, 1994, p. 2). A 'way' a human may interact with a VR generated VE is through a VR headset and its accompanying controllers running an appropriate software application. This technical configuration would likely immerse the user in the VE by stimulating multiple senses such as vision, hearing, "proprioceptive (body position and movement)," and touch through haptic feedback from the controllers (Stone, 2019, MR section). Despite their differences, the realities discussed above are related because they “clearly share the common feature of juxtaposing "real" entities together with "virtual" ones” (Milgram & Kishino, 1994, pp. 3-4).

The previous list of AR, MR, and VR examples is not exhaustive. It is important to note they can be differentiated in multiple ways (Milgram & Kishino, 1994, p. 4; Stone, 2019). They can differ by the way they allow the user to interact with the environment and how the user is presented feedback or information from the environment (Stone, 2019). The nuances between them are important to understand because when these realities are used to achieve learning/training outcomes, the task and form of reality to be utilized must be deliberately paired to achieve the best/desired outcome (Mikropoulos & Natsis, 2011; Philbin et al., 1998; Stone, 2019).

Army training-system development without an emphasis on VR could result in lost training/learning opportunities due to the corresponding lack of presence inducing opportunities created by this immersive technology (Selzer et al., 2019, p. 9). With the proper software and scenario development support, an infantry fire team, squad, platoon, or company could train for nearly any situation in a VR enabled training environment. The degree of presence one experiences from immersion matters because more presence inducing technological configurations, when compared to desktop configurations, may lead to increased learning outcomes (Selzer et al., 2019, p. 13). Increased learning may result even when the supporting more immersive technologies range from the low-end of the market (cheap VR systems) to the high-end of the market (expensive VR systems) (Selzer et al., 2019, p. 13).

Complex vs. Complicated

Similar to immersion and presence, the terms ‘complex’ and ‘complicated’ must be defined before use to mitigate confusion concerning their meaning. These terms are often associated with systems and problems and have definitions which are not clearly distinguishable (Poli, 2013, section 1). During reviews of virtual technologies associated with learning outcomes, the term complex is sometimes associated with describing learning content or tasks (Bink et al., 2015; Champney et al., 2015; Dobrowolski et al., 2021; Hayes et al., 2013, p. 30; Mikropoulos & Natsis, 2011; Stevens, et al., 2015). Distinguishing between complex and complicated tasks is critical, because this distinction may unveil the true value of more immersive simulation-based training capabilities for small units of dismounted infantry Soldiers (Mikropoulos & Natsis, 2011).

For the purposes of this paper, the distinction between complex and complicated systems, or tasks, will be viewed as “a difference of type and not of degree” (Poli, 2013, section 2). Complicated systems or problems are those which when a specific input is introduced, a specific outcome is achieved (Poli, 2013; R. D. Walck, personal communication, 27 October 2016). Due to this characteristic, associated issues “can be addressed piece-by-piece” and “the relevant systems can be controlled and the problems they present admit permanent solutions” (Poli, 2013, section 1). For example, a watch can be understood as a complicated system (R. D. Walck, personal communication, 27 October 2016). If you build a watch in a particular manner with the appropriate parts, you will get a functioning watch. Although building a watch has many associated steps, which can cause it to be misunderstood as a complex system, it is complicated because interacting with its parts in a specific manner will result in a specific and predicted outcome (R. D. Walck, personal communication, 27 October 2016). Poli (2013) points out complicated systems can actually be understood as rare, and that they can “at least in principle – [be] fully understood and modeled” (section 2).

Conversely, approaching complex systems/problems in a piece-by-piece manner will not lead to a solution because their inputs are multiple, interact with one another, and “cannot be individually distinguished” (Poli, 2013, section 1). Small adjustments to, or interactions with these types of systems/problems may result in unproportionate outcomes (Poli, 2013, section 1). Complex problems/systems must be managed because they are ultimately unsolvable; “typically any intervention merges into new problems as a result of the interventions dealing with them; and the relevant systems cannot be controlled” (Poli, 2013, section 1). The best achievable outcome for interacting with a complex system/problem is the accomplishment of desirable influence (Poli, 2013, section 1). However, this influence will not last indefinitely and will likely only be temporary if even possible (Meadows, 2001, p. 59).

Meadows (2001) captures how to interact with complex systems/problems by stating “We can't control systems or figure them out. But we can dance with them!” (p. 59). For instance, a puppy can be understood as a complex system (R. D. Walck, personal communication, 27 October 2016). If the puppy’s owner tries to potty train the puppy, the puppy’s response to training is unpredictable and unknowable (R. D. Walck, personal communication, 27 October 2016). If the puppy urinates on the floor, and the owner reacts too sternly, the puppy may decide that urinating on the furniture or out of sight of the owner is a viable solution (an undesired and arguably unproportionate response). If the owner reacts too calmly, the puppy may decide that it is doing something right and continue to urinate in the house. The inputs provided to the puppy by the world and the interventions of the owner cannot be controlled in a manner that yields the definite result of the puppy being successfully potty trained. Additionally, the precise impact of tweaking an intervention is unknowable as well. The puppy’s training must be managed to get to the desired result with possible detours along the way (Poli, 2013).

Unlike complicated systems/problems, complex issues cannot be fully modeled (Poli, 2013, section 2). Models of complex systems/problems can be made, but once complete are no longer truly complex due to the inherent creative and everchanging nature of the modeled complex system; “even in principle – [models of complex systems/problems] are always incomplete and diverge over time” (Poli, 2013). Although somewhat counterintuitive, complex system/problems are generic because they are all around us and include all living, psychological, and social systems (Poli, 2013, section 3).

Learning content, or tasks, can be understood as complicated or complex systems/problems. In the context of dismounted infantry training, assembling and disassembling an M4 rifle can be understood as a complicated task. Assembling the weapon in a specific manner with specific parts will result in a known outcome: a functioning rifle. Although variables surrounding assembly/disassembly can be altered, such as the weather, the task of assembling and disassembling the rifle remains complicated. On the other hand, a complex training task for dismounted infantry could involve the execution of an offensive operation against a free-thinking opposing force, sometime referred to as force-on-force training. If the opposing force is ‘allowed’ to truly be free-thinking, the task of attacking it is complex because the opposing forces’ actions and reactions cannot be fully known to, or predicted by the attacker. Additionally, this task is complex because the leader in charge of the attack can never be fully certain that a subordinate will interpret and execute an order as envisioned by the leader. Thus, the actions of friendly and, to a more significant degree, enemy forces cannot ever be fully predicted causing a task as straightforward as attack to become complex before considering other variables.

Distinguishing between complicated and complex learning content and tasks is important when evaluating the performance of virtual systems regarding learning outcomes because this distinction may significantly impact evaluation results. Due to the inherent nature of complicated and complex systems/problems, it is safe to assume different methods of learning are beneficial when interacting with each type (R. D. Walck, personal communication, 27 October 2016). It must be noted that Mikropoulos' and Natsis' (2011) review of empirical research spanning a decade concerning educational virtual environments found "that immersion compared to a desktop system has a great advantage only when the content to be learned is complex, 3D and dynamic…" (p. 774).

So, studies comparing learning outcomes resulting from a 'less-immersive versus more-immersive technical configuration' model may need to be cast aside if complex content/tasks are not involved. Otherwise, studies comparing these configurations and claiming no difference between learning outcomes may be clouding the true value of more immersive simulation-based training capabilities. The experiment used in this pilot study involves a situational awareness-focused task to ensure the participant-group-conditions are evaluated through an adequate task; a complex task rather than a complicated one.

Technology, Immersion, Presence, Embodiment, and Learning

Studies have suggested and demonstrated that virtual media, and its associated degree of immersion, can affect learning outcomes (Champney et al., 2015; Dong et al., 2022; Harrington, 2011; Hayes et al., 2013; Knerr, 2006; Lackey et al., 2014; Reitz & Richards, 2013; Selzer et al., 2019). These studies employ technology ranging from the low-end of immersive capabilities such as desktop computer enabled solutions through high-end immersive capabilities powered by leading commercial VR systems stimulated by virtual environments/worlds (Selzer et al., 2019, p. 13; Wehden et al., 2021, p. 6). For the purposes of this paper, desktop configurations (e.g., monitor, mouse, keyboard) are viewed as sitting on the low-end of the immersion spectrum with leading commercial VR systems and accompanying peripherals (e.g., omnidirectional treadmills (ODTs)) sitting towards the high-end of the spectrum. The live environment represents the highest degree of immersion possible on the spectrum because “the Real environment represents the highest degree of Presence possible, with many signals and redundancy gains” (Harrington, 2011, p. 184). The discriminator used to determine whether a system is less immersive or more immersive involves the number of senses affected combined with the degree of interaction fidelity produced by the technological configuration.

A desktop configuration typically affects vision and hearing while a VR headset affects vision, hearing, proprioception, and equilibrioception to a limited degree by allowing the user to turn their head and body to observe the VE. A VR headset supported by an ODT is more immersive than the previously mentioned configurations because it affects vision, hearing, proprioception, and equilibrioception to a greater extent by allowing users to turn their heads and bodies, and, depending on the version of ODT, ‘walk’ naturally to navigate in the VE. To expand on the previous point, a contributing factor causing a desktop configuration to be less immersive when compared to a VR system is interaction fidelity (Bowman et al., 2012, pp. 3, 9; Stevens et al., 2015, p. 529). Bowman et al. (2012) defines interaction fidelity as “the degree to which user actions in a system match their real-world counterparts” (p. 3). Although both conditions stimulate the user’s vision, the VR system is more immersive because it provides visual feedback supported by feedback from the vestibular system, a system which informs equilibrioception, while conducting movement and/or changing direction in the VE (Ruddle et al., 1999, p. 158; Stevens et al., 2015, p. 529; The Balance of Evolution, n.d.). On the other hand, the desktop configuration is less immersive because it provides visual feedback from movements which correspond to keyboard and mouse inputs executed by the user's hands (Ruddle et al., 1999, p. 158; Stevens et al., 2015, p. 529).

Therefore, the VR system is more immersive than the desktop configuration due to its user-interface's ability to increase interaction fidelity; put simply, turning one's head to observe the world is more realistic than moving a mouse to observe the world (Bowman et al., 2012, pp. 3, 9; Stevens et al., 2015, p. 529). When analyzed in total, the studies discussed in the following sub-sections suggest the trend and, in some cases, find an increase in immersion, with its corresponding interaction fidelity and presence, results in an increase in learning outcomes (Dobrowolski et al., 2021; Harrington, 2011, p. 184; Selzer et al., 2019, p. 13).

The degree of interaction fidelity provided by a technological configuration is important because it can directly affect learning (Makransky & Peterson, 2021, p. 949). From a learning perspective, interaction fidelity supports theories of embodied cognition/learning (EC) (Makransky & Peterson, 2021, p. 949; Skulmowski & Rey, 2018). These theories imply "that there is a connection between motor and visual processes; and the more explicit the connection the better the learning, suggesting that embodiment is important for learning" (Makransky & Peterson, 2021, p. 949). For instance, physically performing certain tasks, such as throwing a ball, will result in more learning than simply reading about them. Embodiment is effective for the enhancement of procedural knowledge, but it may also improve factual and conceptual knowledge acquisition by strengthening "neural pathways during factual/conceptual learning" (Makransky & Peterson, 2021, p. 949). EC developments can be observed through "enhanced transfer performance" (Makransky & Peterson, 2021, p. 949). For instance, studies have demonstrated that children can improve reading comprehension, an EC related task, when they physically perform or enact the stories they are reading (Skulmowski & Rey, 2018, p. 2). Therefore, when interaction fidelity is maximized through the effective alignment of more immersive technologies and appropriate tasks, whose "physical activities are meaningful for the learning outcome," increased learning gains can be achieved (Makransky & Peterson, 2021, p. 949). Assuming relevant physical activity enhances learning, it is easy to imagine a squad of infantry Soldiers learning more by conducting a complex task (e.g., squad attack) in a more immersive environment powered by VR technology as opposed to a less immersive environment driven by a desktop configuration.

It is worth mentioning another potential benefit of technological configurations which enhance learning through embodiment is the indirect learning which can be achieved by observers through mimicry (Hayes et al., 2013, p. 29). While describing the TLE TeachLivE™ system, a "Mixed Reality classroom simulator," which allows teachers to train in a highly immersive and embodying VE with virtual human-controlled students, Hayes et al. (2013) explain mimicry enables learning for observers of the system's user (p. 21, 29). Essentially, while one teacher is in the VE, other teachers observe their interaction (Hayes et al., 2013, p. 29). These observers become engaged, in a manner "similar to watching a movie or actual game play," while watching the system user, and express emotional responses to the user's actions and behaviors (Hayes et al., 2013, p. 29). Learning from this situation occurs because observers who later become users change their behavior in the VE based on watching others' VE interactions (Hayes et al., 2013, p. 29). As a learning approach, mimicry is gaining support from the medical community.

> This approach is gaining in validity as neuroscientists reveal the existence and function of mirror neurons whereby in the process of watching another's actions neural connections are formed based on what the actor does, what the observer predicts the outcome to be, and the actual outcomes. (Hayes et al. 2013, p. 29)

In an appropriate setting supported by the proper technological affordances, it is easy to imagine Soldiers learning from other Soldiers while observing them perform military actions in a more immersive and embodying simulation-based training capability. Since the TLE TeachLivE™ system capitalizes on mimicry while preparing teachers for the complex task of interacting with groups of students with various backgrounds, disabilities, behaviors, and motivations, it seems this form of learning could generalize to other subject matter (Dieker et al., 2014, pp. 25, 29; Hayes et al. 2013, p. 21). It is unclear if learning through mimicry is effective while watching someone else perform actions in a low immersive and low embodying system such as a desktop configuration; VBS3 in the context of military training. However, mimicry appears to be an indirect learning opportunity provided by learning situations where embodiment is high for the actual user/trainee (Hayes et al. 2013, p. 29). For more information about TLE TeachLivE™ see https://www.ucf.edu/research/research-project/teachlive/. The remainder of the literature review evaluates the impact of technologically induced immersion and embodiment on learning outcomes by analyzing the relationship between technological configurations, the level of combined immersion and embodiment achieved through these configurations, and the nature of the task performed (complex vs. complicated).

Military Forces/Topics Emphasis

Studies evaluating virtually driven training against more traditional classroom instruction/training have yielded results favorable to adopting more immersive technologies for training/learning outcomes. Lackey et al. (2014) compared Virtual World (VW) enabled training to traditional classroom training and their effects in relation to learning outcomes through battle drill training (p. 1). The experimental condition group was trained via a VW-enabled solution (desktop configuration – computer simulation with Soldier avatars controlled via third-person perspective) and the control condition group was trained using traditional methods (classroom instruction – lecture and presentation) (Lackey et al., 2014, pp. 5-6). Once each respective training phase was complete, each group participated in a live/real-world assessment to determine performance outcomes (Lackey et al., 2014, p. 6). VW-based training was found to be suitable for the training of room clearing tasks (a dismounted infantry collective task) (Lackey et al., 2014, pp. 9-10). Room clearing is undoubtedly a complex task due to multiple variables at play during execution such as shooting engagements at extremely close range. During the final assessment, if a group "passed" then they were complete (Lackey et al., 2014, pp. 6-7). If they did not pass their first iteration of the final assessment, they conducted a second iteration. Three quarters (6/8) of the traditionally trained groups passed their first iteration while only half (4/8) of the VW trained groups passed theirs (Lackey et al., 2014, pp. 6-7). However, during the second assessment iteration, the VW trained groups achieved 100% training completion (8/8 teams passed) while the traditionally trained group did not (7/8 teams passed); so, the VW group reached training completion first (Lackey et al., 2014, pp. 6-7, 9-10). Group results indicate that both groups learned the training material; it is important to keep in mind that successful training can be equated to learning.

Regarding the VW group's ability to successfully complete the training first, the authors provide a key inference. They explain the repetitions provided by VW-training may enable Soldiers to identify and correct mistakes quickly (Lackey et al., 2014, p. 10). This inference suggests VW, or virtually driven, training may increase Soldier skills/readiness, or learning, faster than traditional means (Lackey et al., 2014, p. 10).

Another angle to view the speed with which the groups completed the training involves participant mental workloads and interaction fidelity (Lackey et al., 2014, p. 10). Concerning mental workload, the authors explain the VW condition "reported higher mental demand compared to participants in the Live group although the level of mental demand in the VW group was still relatively low" (Lackey et al., 2014, p. 10). This finding is logical since the VW condition involved an interactive training tool while the control condition's training was more passive in nature (Lackey et al., 2014, p. 10). But, if traditional methods of instruction are how Soldiers in this study are conditioned to receive information, feasibly this is why the control condition performed better during the initial assessment phase (Lackey et al., 2014, p. 10). Perhaps the additional requirement of learning the computer simulation's control scheme to engage the training material led to a slightly slower learning progression by the VW group (Lackey et al., 2014, p. 10).

Regarding interaction fidelity, although not explicitly stated, it seems logical to assume groups who did not pass their first assessment iteration were provided an opportunity to 're-train' using their respective condition's training configuration/materials. Assuming this was the case, it makes sense the VW condition would learn more effectively following their initial final assessment run. At this point, the VW group would be more comfortable with the control features of their desktop configuration possibly reducing mental workload allowing more mental capacity to focus on learning the training material (Merriënboer & Bruin, 2014, p. 26). A more detailed discussion about mental resources and learning can be found in this document's methodology section. Since the VW group's training configuration was more immersive with a higher level of interaction fidelity than the control condition's, due to the ability to control avatars in a VE, perhaps this training method better aligned with EC learning theories even if only at a marginal level (Makransky & Peterson, 2021, p. 949; Skulmowski & Rey, 2017, pp. 1-2; Skulmowski & Rey, 2018, pp. 1-2). Both conditions were after all training for a live assessment of the room clearing task which requires physical movement and coordination between multiple team members for successful execution. Consequently, one can infer the VW configuration enabled learning more effectively during the second iteration due to its increased interaction fidelity which allowed Soldiers to maneuver avatars in a VE in a manner more consistent with EC learning theory than the control condition (Skulmowski & Rey, 2017, pp. 1-2). Of note, if this experiment progressed as assumed, this sequence of training supports Harrington's (2011) notion that a virtual-live-virtual training rotation is the optimal training sequence (p. 184). Both methods of instruction, or training configurations, enabled Soldiers to learn. But Soldiers in the VW, or more immersive, group successfully completed training first albeit at a slower rate than the control condition. This study provides evidence that more immersive technologies can achieve increased learning outcomes in comparison to less immersive training options when tasks are complex in nature and require the synchronization of physical movement.

In a similar study, Champney et al. (2015) sought to determine the value of AR to support complex training/learning activities through the wearable Augmented Immersive Team Trainer (AITT) system (pp. 251-252). This study does not directly compare the AITT system to another training system, but it highlights the system's novelty in that it allows for training to occur outdoors in real-world training environments unlike other virtual training systems (Champney et al., 2015, p. 252). So, this study lends the AITT to indirect comparisons with other virtual systems such as desktop configurations which use a program like VBS3 (Champney et al., 2015, p. 252). This experiment included Subject Matter Experts (SMEs) conducting Call for Fire (CFF) tasks with the AITT equipment (Champney et al., 2015, pp. 254-255). CFF tasks involve an observer requesting fire support from artillery units positioned away from the frontlines of the battlefield. A CFF mission in the real-world is complex in nature, but it can quickly become a complex task during training depending on the variables involved in the training scenario or exercise. The SMEs each conducted three CFF missions against computer-generated/simulated enemy elements displayed on real-world terrain before providing feedback on the AITT system (Champney et al., 2015, p. 255). Typical classroom instruction "requires far-transfer: applying knowledge learned in the classroom situation to a far different outdoor context" (Champney et al., 2015, p. 253). Ideally, using this system would allow users the ability to simply walk outside their classrooms to practice CFF tasks rather than waiting to go to a geographically and temporally distant field exercise (Champney et al., 2015, p. 253).

This study measured presence and immersion amongst other variables and concluded that its findings support previous research which claims AR, an immersive virtual solution, can enable learning environments focused on the development of complex skill sets (Champney et al., 2015, p. 259). Although this study did not directly compare the AITT against another virtual training system such as a desktop configuration running VBS3, it is easy to see how the AITT could increase learning gains compared to these types of systems (Champney et al., 2015, p. 252). If two groups were asked to complete CFF tasks, where one used the AITT while the other used a desktop configuration, it is easy to imagine the AITT group learning more. The AITT group would likely learn more due to the increased immersion, presence, and embodiment or interaction fidelity provided by the AITT. The AITT user could use the system in conjunction with their real-world equipment and CFF tools in a real-world training environment. Viewed through a lens shaped by EC learning theory, the ability to physically enact the CFF process, rather than simply using a mouse and keyboard to complete the actions, would likely result in higher learning gains (Skulmowski & Rey, 2018, p. 2). Despite relying on subjective measures, (e.g., questionnaires) to generate evidence, this study demonstrates how, and suggests more immersive training configurations could lead to increased learning outcomes (Champney et al., 2015, pp. 253-254).

An additional aspect this study highlights is the significance of interaction fidelity when designing a virtual system for training purposes. The need for users to switch between the virtual and real-world to use real-world tools in support of the simulated scenario caused frustration (Champney et al., 2015, p. 260). Frustration appears to have resulted due to low interaction fidelity regarding the participants' ability to transition between observing battlefield targets and referencing their real-world CFF related tools (Champney et al., 2015, p. 260). A more immersive configuration, such as one that utilizes VR, could allow users to operate in realistic digital terrain and reference digital versions of the CFF related tools they would carry on their person in the real-world. To enhance learning through more immersive technologies, developers of simulation-based training configurations must clearly understand the tasks they are supporting to ensure low immersion, caused by low interaction fidelity, does not detract from the desired learning outcomes.

Studies have also assessed learning/training outcomes through experiments which involve training with simulation-based capabilities combined with the execution of live training events. Knerr's (2006) conference paper discusses the U.S. Army's testing of a prototype "dismounted Soldier simulation system" called the Virtual Integrated MOUT (Military Operations on Urbanized Terrain) Training System (V-IMTS) (pp. 21-3-21-6). The experiment collected data through questionnaires focused on the system's capability as a simulator as well as its training effectiveness (Knerr, 2006, p. 21-5). The system enabled squad training (9 Soldiers) through a combination of "[t]hree Soldier Visualization Station Immersive (SVSI) simulators and six SVS Desktop (SVSD) simulators" (Knerr, 2006, p. 21-4). Squad leadership, the squad leader and two team leaders, used the SVSI while the remaining squad members used the SVSD to conduct training missions (Knerr, 2006, p. 21-4).

The two systems are "functionally similar" but differ in how they allow Soldiers to interact with the VE. Soldiers using the SVSI interact with the VE while standing with a simulated weapon in hand, by observing the environment on a projection screen located to their front which is "approximately 10 feet wide by 7.5 feet high," and by controlling movement in the VE "via a thumb switch located on the weapon" (Knerr, 2006, p. 21-4). Soldiers assigned to the SVSD interacted with the VE through a less immersive technical configuration involving the use of a personal computer on a table supported by a joystick for movement and weapon actions (Knerr, 2006, p. 21-4). The two systems were connected allowing all squad members to conduct training, through their avatars, as a squad in the same VE (Knerr, 2006, p. 21-4). The squad and its supporting simulators were located in a 40-foot by 40-foot square shelter with squad internal communication conducted through voice while the squad leader was provided with a radio to communicate with the platoon leader (Knerr, 2006, pp. 21-3 - 21-4).

The experiment's design called for three squads (27 Soldiers) to conduct a live training mission followed by at least six virtual/simulation-based training missions prior to execution of a final live training mission in a 48-hour period (Knerr, 2006, p. 21-5). Although not directly stated, it seems the intent of this design was to allow Soldiers to assess how much they improved between the two live training missions due to the training provided by the V-IMTS. Despite the experiment's design, only one squad completed the experiment within the established design parameters, but all squads conducted two live training missions and at least two virtual/simulation-based training missions (Knerr, 2006, p. 21-5). Training scenarios focused on "Cordon and Search a Building and Attack/Assault a Building" missions (Knerr, 2006, p. 21-5). Questionnaires were completed following the final live training mission (Knerr, 2006, p. 21-5).

Although the author highlights the unexpected "lack of a significant difference in rated training effectiveness between the Soldiers trained in the SVSD and the leaders trained in the SVSI," the data demonstrates Soldier improvement (Knerr, 2006, pp. 21-5 - 21-6). The overall average rating for the eleven assessed tasks was 1.8 where a 2.0 on the rating scale indicated moderate improvement (Knerr, 2006, p. 21-5). It is safe to assume enhanced improvement in this study can be equated to enhanced learning and training proficiency. The author acknowledges the SVSI and SVSD assigned Soldiers "were performing and learning different learning tasks" (Knerr, 2006, p. 21-5). However, the author also states the lack of significant difference between the two groups may warrant an investigation into whether the increased cost of a more immersive simulation-based training capability is worth the cost when compared to a desktop computer (Knerr, 2006, p. 21-5).

An interesting result of the V-IMTS training effectiveness findings is that the two highest rated task improvements by the VSMI users were "[c]ontrol assault movement" and "[a]ssess tactical situation” (Knerr, 2006, p. 21-5 - 21-6). These ratings are interesting because each of the tasks are arguably complex in nature. It is also worth noting the “[c]ontrol assault movement” task was the only task which “approached significance” when analyzing the differences between VSMI and VSMD user ratings (Knerr, 2006, p. 21-5). Perhaps this task approached significance because it was complex in nature suggesting the more immersive configuration was better suited for enhancing training/learning.

Another experiment which focused on assessing training/learning outcomes through simulation-based capabilities combined with the execution of live training events involved DSTS and the Small Unit Virtual Immersion System (VIRTSIM) (Bink et al., 2015, p. 21; Reitz & Richards, 2013, p. 4). In 2012 these “two immersive dismounted infantry simulations" were examined in detail during the U.S. Joint Forces Command’s warfighting experiment Bold Quest 2012 at Fort Benning Georgia (Bink et al., 2015, p. 21; Reitz & Richards, 2013). This experiment was held “in conjunction with the Army Expeditionary Warrior Experiment… and focused on immersive training effectiveness for the small unit and small unit leaders” (Bink et al., 2015, p. 21). A core element of the experiment included the comparing of VE training against live-environment training and determining “the impact of virtual training on live performance” (Bink et al., 2015, p. 21). The event involving DSTS and VIRTSIM included four squads of dismounted infantry Soldiers: “two U.S. Army, one U.S. Marine Corps and one Canadian Army” (Reitz & Richards, 2013, p. 2). Although VIRTSIM’s and DSTS’s VEs were created by VBS2 (Virtual Battlespace 2) software, VIRTSIM differs from DSTS due to the way in which the user moves within the VE (Reitz & Richards, 2013, p. 4). Whereas DSTS relies on a switch on the surrogate weapon, VIRTSIM employs “motion-capture technology” to allow “naturalistic movement within a certain volume of space with the trainee pivoting to continue forward within the environment" (Bink et al., 2015, pp. 1, 21; Reitz & Richards, 2013, p. 4). VIRTSIM's wearable equipment which includes a surrogate weapon and virtual reality headset, essentially allows users to walk through the VE (City of Plano Texas, 2012). VIRTSIM takes an open space, such as a basketball court-sized area, and places a detailed VE in the physical open space (City of Plano Texas, 2012). This allows the physical basketball court-space to house a virtual representation of locations such as the inside of a school or office building for users to conduct training (City of Plano Texas, 2012). An additional VIRTSIM capability worth noting is that it can produce pain when users are injured in the VE (Ungerleider, 2012). When 'shot' in the VE, a user will receive an electric shock from "two muscle stimulators attached to the triceps" (Ungerleider, 2012). For more information about VIRTSIM and an image of a team training with the system, see https://www.fastcompany.com/3000383/virtual-training-world-law-enforcement-inflicts-real-pain.

It is worth noting Bink et al.'s (2015) report (which was sponsored by the U.S. Army) focused solely on the performance of U.S. Army squads and their usage of DSTS (pp. i, 21). The purpose of the report "was to document the training capabilities of DSTS at this point in time" (Bink et al., 2015, p. i). On the other hand, the conference paper by Reitz and Richards (2013) analyzed data provided by all four participating squads and the DSTS and VIRTSIM simulation systems (pp. 4-5). The purpose of the conference paper was to inform military decision-makers on how to best balance "live and virtual training capabilities" in regard to enhancing "situational understanding and small unit readiness" (Reitz & Richards, 2013, p. 1).

The Bold Quest 2012 experiment involving DSTS and VIRTSIM occurred over a five-week period. The study began with the four participating squads (one control and three experimental) receiving Advanced Situational Awareness Training (ASAT) followed by the execution of three live training missions (Reitz & Richards, 2013, p. 3). The live-training-mission scenarios were “Area Reconnaissance (AR), Cordon and Search (C&S), and Attack (AT)” (Reitz & Richards, 2013, p. 4). The ASAT and live training missions were conducted to create a “solid experimental basis for assessment of squad performance changes across three 96-hour use case scenarios" (Reitz & Richards, 2013, p. 4). Each of the three four-day case scenarios involved one control and two experimental squads, focused on one specific mission scenario, and included three days of training with each group’s respectively assigned condition (DSTS, VIRTSIM, or live) (Reitz & Richards, 2013, p. 4). The fourth day of the case scenario was a live “force-on-force field assessment event” (Reitz & Richards, 2013, p. 4). The control group trained for their respective mission in a live environment while the experimental groups trained in VEs using DSTS or VIRTSIM (Reitz & Richards, 2013, p. 4).

The report by the Bink et al. (2015) research team focused on training outcomes and only collected information from U.S. Army squads where the experimental group used DSTS (p. 21). These parameters led to analysis of only one four-day case scenario focused on Area Reconnaissance (Bink, 2015, p. 29). Data collection utilized questionnaires focused on “DSTS Performance Capabilities,” “After Action Review Capabilities,” decision making, training preparation, and operational realism (Bink et al., 2015, pp. 22-23). Thus, data analysis relied on subjective Soldier perceptions regarding the questionnaire topics.

Key findings by the Bink et al. (2015) report do not shine a positive light on DSTS as a training capability when compared to live training. The capability questionnaire, which sought to determine the similarity, accuracy, and difficulty associated with performing real-world tasks in the VE such as traversing stairs, resulted in negative perceptions regarding DSTS’s potential training capability (Bink et al., 2015, p. 25). The authors highlight this sample of participants had a shorter amount of time with the system, and this group conducted less missions than groups in previous studies which provided more positive ratings concerning system capabilities (Bink et al., 2015, p. 25). In terms of decision-making, DSTS was determined to provide "opportunities and capabilities equal to but no better than live training" (Bink et al., 2015, p. 26). However, the value of this result may be limited since responses from both participant groups indicate that neither environment truly enhanced decision-making skills (Bink et al., 2015, p. 26). Lastly, the "training preparation" and "operational realism" questionnaires provide the most interesting and arguably controversial findings. First, Soldiers who trained in the live environment felt better "prepared to execute the final live mission than were Soldiers training in DSTS" (Bink et al., 2015, p. 26). Next, the operational realism questionnaire, which focuses on scenario sufficiency in terms of providing environmental cues to drive training requirements, found the live environment to provide more realism, or "functional verisimilitude," than the virtual in terms of executing infantry tasks (Bink et al., 2015, pp. 27, L-2).

The training preparation and operational realism-related findings are interesting and arguably controversial because they lead to questions regarding the experiment's overall purpose and value. It must be pointed out that the final live mission was conducted on the exact same terrain the live condition group was provided for training; the Mckenna MOUT (Military Operations on Urbanized Terrain) site (Bink et al., 2015, p. 21). Although the MOUT site was modeled in the VE for the VE group, the outcome seems apparent that VE users would feel less prepared for a live mission they trained for virtually when compared to a group who trained on the same ground in a live environment. A more valuable study could have allowed the VE group to train with a model of the site, taking advantage of VR's inherent capabilities, while the live group trained at a location that was not used for the final live-assessment mission. This type of design would have capitalized on the value of VR and prevented the results of the live condition's performance and perceptions from becoming questionable. This logic is not farfetched, Armies do not allow potential enemies to train on the ground they may be required to fight them on.

The research team's findings are controversial because they seem so obvious. Of course, the live group felt more comfortable executing a live mission on the same ground they trained on than a group who did not have access to this same terrain. Additionally, it seems obvious that the realism provided by the real-world training area, supported by U.S. Army training capabilities such as live role players for the opposing forces, would be deemed more operationally realistic than a VE (Bink, 2015, p. 23). The study's findings are questionable, from my perspective, due to the research design. Anyone who has spent any time in or around the Army knows that live training will always be the preferred and best method of training especially when properly resourced. Due to this perspective, one must question why a study would focus on comparing live and virtual training in a "head-to-head" fashion (Bink et al., 2015, p. 21). It is worth noting the authors did highlight that an additional purpose of Bold Quest 2012 was evaluating "the impact of virtual training on live performance" (Bink et al., 2015, p. 21). If the research teams would have focused their efforts on determining this impact, perhaps this study would invite less questions regarding its overall purpose, design, and value of its findings.

While Bink et al.'s (2015) research focused solely on training outcomes involving DSTS during Bold Quest 2012, Reitz' and Richards' (2013) focused on assessing "the quality of training transfer from virtual training capabilities to live mission execution" (p. 1). Reitz and Richards (2013) evaluated data regarding how training capabilities influenced "situational awareness (SA), situational understanding (SU) and small unit readiness" (p. 2). The Situational

Awareness Rating Tool (SART) was utilized to measure situational awareness (Reitz & Richards, 2013, p. 1, 6). The tool includes Likert-style questions which gauge the supply and demand of attention resources and situational understanding (Reitz & Richards, 2013, p. 1, 6). This survey was administered to individual Soldiers to determine levels of situational awareness achieved by participating squads supporting this portion of the study's "between-subject design for squads" (Reitz & Richards, 2013, p. 8). Evidence provided by the SART highlighted that no matter the experimental condition (VIRTSIM or DSTS), the treatment/virtual groups/squads achieved the same level of situational awareness as the control/live group/squad (Reitz & Richards, 2013, pp. 1, 8). Identified differences in situational awareness levels were concluded to be related to the type of mission executed rather than the employed training capability (Reitz & Richards, 2013, pp. 1, 8). This outcome indicates VIRTSIM and DSTS performed as well as the live environment in terms of providing environmental information or signals for squads to achieve situational awareness during their missions. It is important to note the training missions can easily be viewed as complex tasks due to the likely various variables affecting each session.

Another focus area for the research team was "inter- and intra-squad communications" due to this form of communication's importance to the achievement of situational awareness at the individual and squad level (Reitz & Richards, 2013, pp. 1, 6, 8). These communications are critical for situational awareness, since situational awareness involves perceiving and understanding the current environment to forecast potential future situations, because they allow units to quickly consider information gathered by the collective (Reitz & Richards, 2013, pp. 3, 8). Data was collected by reviewing recorded communications from the live and virtual environments and relied on counting successful and unsuccessful instances of the squad leader "pulling" or being "pushed" information (Reitz & Richards, 2013, pp. 8-9). Findings from this data, similar to situational awareness analysis, demonstrated that the experimental groups achieved increases similar to the live condition regarding squad communications (Reitz & Richards, 2013, pp. 1, 9-10).

Prior to concluding their paper, the authors noted the overall performance of the squads involved in the study. Although the experimental groups did not improve mission performance in a statistically significant manner, they "were able to maintain their performance in increasingly challenging live missions at a level on par with those who experienced live training" (Reitz & Richards, 2013, p. 10). The authors appear to make this point to suggest that the acquisition of these types of systems at large could lead to similar results across the Army (Reitz & Richards, 2013, p. 10). Additionally, they highlight that as these types of systems improve, they will likely become a part of future training requirements due to their ability to offset resource constraints (Reitz & Richards, 2013, p. 10).

The research conducted by Reitz and Richards (2013) indicates that virtual systems can match learning outputs produced by live training in certain conditions. Their conference paper supports the alternate hypothesis of this pilot study by suggesting immersive technologies can lead to learning gains. If immersive technologies allow Soldiers to refine communications skills while providing VEs which allow for the achievement of small unit situational awareness and understanding, at least on par with live training during complex tasks, this technology should be desirable to the U.S. Army. It is common knowledge that live training is resource intensive, expensive, and desired, but the acquisition of a more immersive simulation-based training capability for small unit dismounted infantry Soldiers could provide another valuable option for training focused on complex problems. Resourced properly, this capability could potentially increase learning/training gains by simply providing Soldiers a resource to get more training repetitions. After all, "[s]imulations allow individuals to have repeated trials involving high stakes situations without risk of loss of valuable resources (e.g. money, time, and people)" (Hayes et al., 2013, p. 21). If senior leaders decide to adopt a new more-immersive system, and possibly its supporting training protocol, it could better prepare Soldiers to get the most out of live training opportunities (Reitz & Richards, 2013, p. 1). Developers of this hypothetical new supporting training protocol should consider requiring a virtual-live-virtual training sequence as recommended by Harrington (2011) to best cement learning/training outcomes (p. 184). However, the purpose of this paper is not to argue for a replacement of live training. This pilot study's purpose is to examine the impact of combined immersion and embodiment on learning outcomes. The results of this examination should better enable U.S. Army senior leaders to decide if small unit dismounted infantry Soldiers from the fire team to the company level would benefit from a more immersive simulation-based training capability.

Blending military and general learning topics, the Hughes et al. (2005) article describes "two extreme experiences that are equally demanding" in terms of cases utilizing immersive MR technologies for public education and military training purposes (p. 24). The article's purpose was to capture how an interdisciplinary team of researchers developed educational and military related applications through their knowledge of MR methods and technologies (Hughes et al., 2005, p. 24). Although not discussed in this review, the article also describes an "iterative MR production pipeline" developed by the interdisciplinary team (Hughes et al., 2005, p. 27). The motivation guiding this article is the idea effective MR experiences are more than the sum of more immersive technologies because the affective impact caused by an experience "is needed to leave a lasting impression of the experience with users" (Hughes et al., 2005, p. 24). For example, the 'story' provided by the MR experience must be interesting to the user (Hughes et al., 2005, p. 24). Implemented properly with a technological configuration, a story can increase the pleasure associated with a learning experience resulting in higher engagement (Hayes et al., 2013). To further emphasize this point, the authors state “[t]he ultimate criterion for judging an application’s success is not a functional requirement, but the human impact measured by affective evaluation” (Hughes et al., 2005, p. 24). The first extreme experience involved public-education-focused work with the Orlando Science Center while the second experience involved a military training emphasis with the U.S. Army’s Research Development and Engineering Command (Hughes et al., 2005, pp. 24-25). This article did not directly compare technological configurations with various levels of immersion and embodiment features, but the cases allow for indirect comparisons involving typically used configurations.

The public education focused MR experience, “MR Sea Creatures,” sought to enhance the museum’s dinosaur exhibit hall (Hughes et al., 2005, p. 25). This experience was powered by an MR portal, positioned in the exhibit hall, which included a spherical screen and projector for image presentation (Hughes et al., 2005, p. 25; Hughes et al., 2007, pp. 5, 15). Through this portal the user could observe the dinosaur exhibit in its typical real-world state and an AR or MR state as provided by the screen and projector (Hughes et al., 2005, p. 25). The experience begins with a virtual guide moving onto the screen and describing the exhibit to the user (Hughes et al., 2005, p. 25). Once the virtual agent completes their introduction, the exhibit hall begins to fill with water causing the dinosaur bones and fossils to come to life (Hughes et al., 2005, p. 25). Once fully flooded, the users can observe the exhibit hall in its underwater state teeming with prehistoric life through the MR portal from their personal perspective as if looking through a window (Hughes et al., 2005, pp. 25-26). The MR portal is also equipped with controls which allow users to pilot a small virtual submarine through the environment and a screen which allowed users to view the environment from the submarine's perspective (Hughes et al., 2005, p. 25). The experience's end begins as the water in the museum hall starts receding and the museum begins returning to its typical real-world state (Hughes et al., 2005, p. 25). But at a certain point in this process a Tylosaurus jumps out of the water and grabs a Pterodactyl from the sky with its jaws and moves back to the ocean floor with the flying creature in its mouth (Hughes et al., 2005, p. 25). Once complete with the MR portal and users begin to walk the real-world exhibit, they will find a real-world fossil of the Tylosaurus with a Pterodactyl in its mouth (Hughes et al., 2005, p. 25). This linking of the MR experience back to the real-world experience, in the museum hall, "is intended to permanently bind the experience to the visitor's mind" (Hughes et al., 2005, pp. 25-26). The authors explain this type of learning experience's purpose, a "free-learning education experience," is to generate positive feelings towards the experience by inspiring curiosity, creating a positive attitude, and generating engagement which allows the experience to be placed in long-term memory (Hughes et al., 2005, p. 26). For more information about, and images of the MR Sea Creatures experience see http://e2i.ist.ucf.edu/project/58.

To measure the affective impact of the experience a survey was provided to users of the MR Sea Creatures portal over a three-week period (Hughes et al., 2005, p. 26). The survey included Likert-style questions which ranged from "Strongly Agree" to "Strongly Disagree" (Hughes et al., 2005, p. 26). The questions were focused on a user's experience in terms of learning, entertainment, desire to return to the exhibit, and desire to explore other similar exhibits (Hughes et al., 2005, p. 26). Concerning learning, approximately 80% of users agreed the experience helped them learn more about the Cretaceous period (Hughes et al., 2005, p. 26). Additionally, over 98% of users said this type of experience encouraged them to spend more time in the exhibit (Hughes et al., 2005, p. 26). Lastly, over 80% of users said this experience encouraged them to return to the exhibit in the future (Hughes et al., 2005, p. 26). Each of these responses can be reduced to factors which contribute to learning such as engagement and curiosity (Hayes et al., 2013, p. 26). See Appendix A for more information about engagement.

The addition of the MR portal to the typical museum hall allows for an indirect comparison of the typical real-world exhibit with no MR portal and the real-world exhibit with the MR portal regarding immersive features and learning outcomes. The exhibit with the MR portal can be understood as a more immersive technological configuration while the typical real-world exhibit can be understood as the less immersive configuration. Although the survey provides subjective information, it suggests the more immersive exhibit positively impacted feelings towards learning, engagement, and curiosity (Hughes et al., 2005, p. 26). These feelings are easily recognized as factors which can contribute to increased learning outcomes. It is logical to assume if users are more interested in, and engaged by learning content presented by a technological configuration, they will learn more (Hayes et al., 2013, pp. 21, 26). This case suggests the more immersive configuration would result in higher learning outcomes due to its positive impact on factors which contribute to learning.

The military focused experience involved the "MR MOUT" training simulation. This experience combined real-world objects with virtual objects to create an urban environment for dismounted Soldiers to train (Hughes et al., 2005, p. 27). The user interacts with the environment wearing a see-through head mounted display which allows the virtual enhancement of real-world objects and the placement of solely virtual objects in the environment (Hughes et al., 2005, p. 27). For example, a blue sky is added to the indoor environment where the urban facades are located and potential enemy avatars are added inside of buildings which can be seen through windows using bluescreen technology (Hughes et al., 2005, p. 27). The resulting environment is highly immersive and embodying, "[t]he trainee can move around the courtyard and hide behind objects with real and virtual players popping out from portals to engage in close-combat battle" (Hughes et al., 2005, p. 27). This simulation is unique in that it allows users and virtual characters to occupy the same terrain (Hughes et al., 2005, p. 27). Also of note, the real-world environment can change in response to user actions (Hughes et al., 2005, p. 27). For example, using their physically carried weapon simulator, users can shoot lights out which cause visual and audio feedback such as real-world lights going out and glass breaking sounds (Hughes et al., 2005, p. 27). The authors highlight the importance of the MR MOUT simulation trainer's audio capability in terms of providing an immersive experience which synchronizes audio in a spatial and temporal manner (Hughes et al., 2005, p. 27). They explain it "is especially important in military training, where sensory overload prepares the soldier for the real battlefield" (Hughes et al., 2005, p. 27). For images of the MR MOUT system see https://www.researchgate.net/figure/US-Army-MR-MOUT-facility-at-RDECOM-displaying-multiple-real-virtual-or-augmented_fig3_237324303.

Similar to the former experience, the MR MOUT experience allows for an indirect comparison of technological configurations when VBS3 and its common desktop configuration is viewed as the typical or control condition. However, it is important to note no survey or study type data was presented in this article regarding MR MOUT, but the authors note the Army Research Institute was conducting affective surveys like those used during the MR Sea Creature experience. Compared to VBS3, the MR MOUT experience is highly immersive and embodying. Instead of controlling a Soldier's actions via mouse and keyboard, such as instructing an avatar to hide behind cover and fire its weapon at enemies, the MR MOUT experience allows Soldiers to physically perform these actions in a realistic spatial environment. From a senses affected and EC shaped perspective, the MR MOUT experience should easily lead to higher learning outcomes if appropriate tasks are paired with the system. It would be interesting to see how two teams of Soldiers performed on a real-world assessment with one group being trained on VBS3 and the other being trained with the MR MOUT training simulation. Since urban combat is complex in nature, I would expect the MR MOUT simulation to lead to more highly trained Soldiers due to its ability to generate higher levels of immersion, presence, and embodiment for users.

The two cases discussed in this article highlight how immersive technological configurations can be applied to a range of various settings and subject matter. Each technological configuration increased the level of immersion associated with its related experience (e.g., dinosaur museum exhibit, urban combat environment) while appearing to positively influence affective factors which contribute to learning and/or embodied cognition. This article and its cases suggest more immersive technologies can positively influence learning outcomes when compared to less immersive systems.

General Learning Emphasis

Unlike the experiments described by Bink et al. (2015) and Reitz and Richards (2013), the research design by Dobrowolski et al. (2021) did not introduce bias into its findings by allowing a condition to train with the same real-world tool/environment used in their final assessment. This study compared the performance of two groups executing a complex task where one of the groups was trained in a VR environment (interactive) while the other was trained in a text-and-video environment (non-interactive) (Dobrowolski et al., 2021, p. 1). The purpose of the study was to determine the value of VR as a complex-skill training tool (Dobrowolski et al., 2021, p. 1). The VE was presented to the VR condition through a Sony HMZ-T3 VR headset while interaction occurred through "custom-made data gloves" (Dobrowolski et al., 2021, p. 5). The VE was modeled to replicate the real-world task's environment and associated task-objects to allow participants to virtually perform the task before execution of the real-world final assessment (Dobrowolski et al., 2021, p. 4). The text-and-video condition was trained through a training video presented on a laptop screen accompanied by a paper brochure which generally provided the same information in the video (Dobrowolski et al., 2021, p. 4). The complex skill, or task, involved the participants placing/matching shape cut-out objects with their corresponding slots in a specific amount of time while simultaneously monitoring another situation to keep a status level within acceptable levels (e.g., not letting the status get too hot or too cold) (Dobrowolski et al., 2021, p. 3). The task can be understood as "a sensorimotor workstation task" (Dobrowolski et al., 2021, p. 1).

This study's findings support the notion that more immersive training solutions are better suited for the learning of complex/dynamic tasks than less immersive or non-interactive training solutions (Mikropoulos & Natsis, 2011, p. 774). The VR condition outperformed the text/video condition, and the variable age (young and old) was not found to influence the learning outcomes of those who trained in the VR condition (Dobrowolski et al., 2021, p. 7). Real-world task performance was measured through accuracy, the placing of objects correctly within a time limit, and the number of timeouts earned by not successfully maintaining the "too hot or too cold" status (Dobrowolski et al., 2021, p. 4). The final assessment's outcomes demonstrated "a successful transfer of skills between virtual reality and the real world" (Dobrowolski et al., 2021, p. 1). The finding regarding age as a neutral variable concerning learning outcomes associated with VR is important because it suggests that younger and older adults serving in the Army could benefit from more immersive training technologies. The study clearly indicates that more immersive simulation-based training capabilities can lead to enhanced learning/training outcomes when the associated task is complex in nature. Perhaps more immersive technologies such as VR are suitable for complex tasks, when paired appropriately, because they support approaches to learning consistent with characteristics of embodied cognition by capitalizing on gesturing and enactment to support learning gains (Skulmowski & Rey, 2018, pp. 1-2, 8). In this case, it seems allowing the participant to enact or physically practice the task in VR allowed them to learn the task more thoroughly by engaging more of the participant's senses.

Another approach to achieving learning outcomes using immersive technological configurations involves the cave automatic virtual environment (CAVE) (Choy et al., 2021, p. 36; Cruz-Neira et al., 1992). Choy et al. (2021) highlight that the air cargo industry's growth is raising the demand for more educated manpower (p. 35). Site visits have been identified as an effective method to "stimulate students' interest in learning the basic logistics operations during their studies" (Choy et al., 2021, p. 35). However, site visits are an unfeasible method for teaching air cargo logistics due to the safety concerns which arise in this high tempo working environment, and the general difficulty associated with learning by observing the execution of real-world terminal operations (Choy et al., 2021, p. 36). Due to these conditions, this field "is one of the possible areas to adopt immersive VR in teaching and learning due to its complex operational procedures" (Choy et al., 2021, p. 37). The article's purpose is to create/design an "air cargo logistics system" which benefits from the CAVE system's ability to produce an immersive and educational VR environment through the application of the "ADDIE" model to inform the associated instructional design (Choy et al., 2021, pp. 36-38).

The CAVE system creates a virtual environment which allows a single user, or multiple users, to interact with a VE (Choy et al., 2021, p. 41). Users step into a "cube-like space," whose walls are projection screens, wearing VR glasses to view the projected virtual object or environment in three-dimensions and interact with these virtual objects/environments in a realistic manner (Choy et al., 2021, p. 36; Computerphile, 2014). The CAVE system enables interaction with the VE by detecting user "movement and motion" (Choy et al., 2021, p. 36). The system allows for limited natural walking and appears to rely on a handheld controller to traverse further distances in a VE such as a city environment or air cargo terminal (Choy et al., 2021, p. 40; Computerphile, 2014). Assuming the typical classroom environment is employed to teach air cargo logistics, the use of the CAVE system for educational purposes dramatically enhances the level of technological immersion for students (Choy et al., 2021, p. 36). Viewed from this perspective, this article indirectly compares a more immersive system against a less immersive system for educating students.

The authors propose their air-logistics-cargo system design by explaining the system through each of the "ADDIE" model's phases (analysis, design, development, implementation, and evaluation) (Choy et al., 2021, p. 38). The model describes basic teaching processes and can be used to increase educational performance (Choy et al., 2021, p. 37). Each phase-description outlines how the air logistics cargo system should be developed. Since this article's goal is the design of a system, it seems an associated traditional study did not occur. However, although not explicitly stated, the development of the proposed design seems to have corresponded with the design's operationalization through a form of pilot study to collect user feedback (Choy et al., 2021, p. 40). The article presents user feedback collected from reflective essays focused on "the challenges and advantages of using VR in learning logistics operations" and questionnaires regarding "system usage experience" (Choy et al., 2021, pp. 38, 41-42).

User feedback provided an overall positive response concerning the use of the CAVE system, the "immersive VR system" or "imseCAVE," as an educational medium for the study of air cargo logistics operations (Choy et al., 2021, pp. 41-42). Choy et al. (2021) noted that users could "learn actively" by using the system despite never actually physically visiting a terminal (Choy et al., 2021, pp. 42-43). By using the CAVE system, students "were able to learn the operations and draw the process flow based on the operation sequence they experienced" (Choy et al., 2021, p. 43). Additionally, most students were found to support the notion that the CAVE system would be beneficial to their learning experience while stimulating their level of interest (Choy et al., 2021, p. 43). The authors appear to view their VR system, with its ability to create an immersive VE which provides sensory experience, as a capable learning medium for teaching students about air cargo logistics operations without disrupting real-world terminal operations (Choy et al., 2021, pp. 37, 44).

Although this article's findings were derived from subjective sources, it suggests more immersive simulation-based training capabilities can lead to learning gains when aligned against a proper task. The authors state that air cargo operations are "complex" in nature, so developing an immersive training tool which allows training just short of training in the live environment supports the idea that more immersive systems are best suited for teaching complex tasks (Choy et al., 2021, p. 37). Describing air cargo operations as complex appears to be consistent with the definition used in this paper due to the multiple variables, such as the value and perishability of goods, which affect and influence operations (Choy et al., 2021, p. 37). It seems the air cargo industry's ideal location for training would be the live environment; the real-world terminals used for shipping cargo (Choy et al., 2021, pp. 35-36). But, although the live environment is the best training environment for its employees, it is not always feasible for various reasons (e.g., safety, disruption of operations) (Choy et al., 2021, p. 36). The Army appears to share a similar training problem. Ideally, it would conduct the majority of its training in a highly realistic and live environment, but this is not always an option for various reasons (e.g., training area availability, differing Soldier training proficiencies) (United States Department of the Army (USDA), 2021, p. 4-3). However, if the limited findings by Choy et al. (2021) can generalize outside of air cargo operations, these findings can be viewed as evidence supporting the idea that dismounted infantry Soldiers would learn more from more immersive simulation-based training capabilities. If students can learn more about the processes required to succeed in the fast-moving air cargo logistics industry through an immersive VE, perhaps Soldiers can do the same in preparation for complex battlefields (Choy et al., 2021, p. 43). Small unit dismounted infantry Soldiers operate in environments full of complex and dangerous tasks and this article suggests more immersive training capabilities can better prepare Soldiers for these challenges.

Furthermore, this article makes several additional points worth mentioning. First, it identifies a gap concerning the development of current immersive technological systems for educational purposes (Choy et al., 2021, p. 45). More specifically, it highlights how these "existing VR systems are developed based on practical experience without a systematic instruction design framework" (Choy et al., 2021, p. 45). If rigor is not applied to the educational materials supporting these systems, it is easy to questions their ability to inform learning gains. This pilot study does not address the instructional design consideration which would support a theoretically new system for Soldiers but acknowledges this as an important feature of the system's development. The responsibility of developing the training scenario experienced in the

VE produced by the immersive technological system would currently fall to the Army leader planning and executing the training event.

Next, Choy et al. (2021) points out the CAVE system's ability to enable collaboration as an important feature which supports learning (p. 42). For a theoretically new and more immersive system to support small unit dismounted infantry Soldiers, the ability to collaborate/interact in the VE is of critical importance. If the system is highly immersive and realistic on an individual Soldier level but does not adequately support small unit communications, the achieved learning gains may not be worth the investment. Wickens and Hollands (2000) drive this point home while emphasizing the importance of communications for group performance (p. 234). They state clearly, "[t]he design of effective systems for information display and control with the single operator is a necessary but not sufficient condition for effective human performance" (Wickens & Hollands, 2000, p. 234). The ability to communicate effectively is key to achieving successful small unit performance (Wickens & Hollands, 2000, p. 234).

The findings from the Makransky et al. (2019) study sheds light on the importance of task and technology selection when evaluating the impact of more immersive technologies on learning outcomes. Motivation for the study was provided by the lack of evidence supporting the notion that simply increasing immersion, specifically through devices such as VR headsets, will lead to more "student motivation and learning" (Makransky et al., 2019, p. 225). Despite this lack of evidence, this idea is leading to businesses and schools "investing significant resources in adapting standard educational tools that have traditionally been used on a desktop computer to immersive VR" (Makransky et al., 2019, p. 225). During this adaptation, in this quickly growing sector, "instructional design decisions are often" being guided by perspectives shaped by practicality or economic concerns since evidence-based arguments are lacking (Makransky et al., 2019, p. 225). This study's primary objective was to "assess the influence of the role of immersive technologies on learning outcomes" (Makransky et al., 2019, p. 225). A second objective included examining if Richard E. Mayer's (one of the study's authors) multimedia learning principles "generalize to immersive VR" (Makransky et al., 2019, p. 225). The third objective was the use of "cognitive neuroscience methodologies" to determine real-time levels of cognitive processing during the experimental interventions (Makransky et al., 2019, p. 225).

To pursue experimental objectives the study "employed a 2 x 2 mixed design" with approximately half of the 52 participants being placed in a group which would receive text and narration (T + N condition) during their interaction with the learning simulation while the other group only received text (T condition) (Makransky et al., 2019, p. 227). Both conditions interacted with the low immersion configuration (desktop) and the high immersion configuration (VR headset) (Makransky et al., 2019, p. 227). But each condition was counterbalanced so half of the respective condition interacted with the VR headset configuration first while the other half interacted with the desktop configuration first (Makransky et al., 2019, p. 227). Learning outcomes were assessed using two tests (knowledge and transfer tests) issued together three times (Makransky et al., 2019, pp. 228-230). The design/protocol essentially included a pre-test and two post-tests. The steps for a participant were as follows: preparation, questionnaire section A (pre-tests), simulation interaction 1 (VR or desktop), questionnaire section B (post-tests 1), simulation interaction 2 (VR or desktop), and questionnaire section C (post-tests 2) (Makransky et al., 2019, pp. 228-229, 231).

The simulation interaction was stimulated by software which provided participants a virtual lab environment to "develop an understanding of mammalian transient protein expression" (Makransky et al., 2019, p. 228). The desktop configuration was provided a "high-end laptop computer" to run the software; the environment was viewed on a monitor and interacted with through a wireless mouse (Makransky et al., 2019, p. 230). The VR headset configuration was provided "a Samsung Galaxy S6 phone, and stereoscopically displayed through a Samsung GearVR" headset (Makransky et al., 2019, p. 230). The VR headset configuration enabled VE interaction by having the participant aim the dot-cursor in the center of their visual display, via head movement, at an item and physically using "the touch pad on the right side of the [headset] to emulate the left-click function of a wireless mouse" (Makransky et al., 2019, p. 230). This aim-and-click functionality of the VR headset configuration basically allowed it to perform as the wireless mouse in the desktop configuration (Makransky et al., 2019, p. 230). The virtual lab environment software was originally designed for a desktop configuration and ported to support the VR headset configuration (Makransky et al., 2019, pp. 225, 227). The virtual lab environments only differed in functionality as it pertained to each configuration's respective VE interaction method and the presentation of text and narration or just text based on the participant's assigned condition (T + N or T condition) (Makransky et al., 2019, p. 228). After a brief introduction to the VE's tools, participants were introduced to and led through their lesson by a virtual agent which served "as an AI instructor" (Makransky et al., 2019, p. 228). This agent was the source of information for text and narration as it led the participant through "the essential material, such as lab procedures and lab equipment" (Makransky et al., 2019, p. 228). When narration was involved, the agent spoke, when textual information was involved, it was provided as on-screen text (Makransky et al., 2019, pp. 225, 230).

Tasks in the virtual lab environment involved participants receiving information and feedback, answering questions on a virtual tablet, and "doing interactive lab procedures such as mixing specific compounds with a serological pipette and discarding the used pipette tip after use" (Makransky et al., 2019, p. 228). The multiple-choice questions presented in the VE on the virtual tablet served as progress gates requiring participants to answer them correctly before progressing (Makransky et al., 2019, p. 228). It is not clear if the tasks involved were of a complicated or complex nature, but participants were tested on "conceptual and procedural knowledge" (knowledge test) and their ability to apply what they learned to a realistic situation (transfer test) (Makransky et al., 2019, pp. 229-230). Both tests included ten multiple-choice questions (Makransky et al., 2019, p. 229).

This study's most important empirical contribution was that although participants "felt a greater sense of presence" while using the VR configuration, they learned less than when using the desktop configuration (Makransky et al., 2019, p. 233). One potential reason offered by the researchers for this outcome was supported by the use of the EEG (electroencephalogram) during VE interactions to collect a "brain-based measure of workload" (Makransky et al., 2019, p. 234). Users of the VR headset configuration were found to be "more overloaded during learning later in the session" when compared to desktop configuration users (Makransky et al., 2019, p. 234). EEG evidence/findings were interpreted as suggesting the VE provided by the VR headset configuration may have been too stimulating for users (Makransky et al., 2019, p. 234). It is worth noting the EEG also revealed that the lesson provided to participants was overly difficult for all participants in the study (Makransky et al., 2019, p. 234). Additionally, a second empirical finding was that no significant impact on participant "learning or self-report ratings" occurred when narration was combined with textual information in the VE (Makransky et al., 2019, p.

234). Thus, the T + N condition was found to learn the same as the T condition from a statistical standpoint (Makransky et al., 2019, p. 233).

The primary finding from this study highlights the importance of task selection when developing technological configurations for learning outcomes. The article clearly states that the VE software was ported from the desktop version to support the VR configuration, and that this adaptation did not optimize “the specific advantages of immersive VR” (Makransky et al., 2019, p. 235). By not taking advantage of a VR headset’s capabilities when porting the software, the study essentially achieved what it set out to do; it examined how simply adapting educational content designed for less-immersive systems to more-immersive systems impacts learning outcomes (Makransky et al., 2019, p. 225). This study supports the claim that merely adapting desktop-based educational material to a VR setting does not automatically increase learning outcomes (Makransky et al., 2019, p. 225, 236). Additionally, the researchers also explained that increased immersion can likely increase learning outcomes when the “goal is to teach specific performance skills in realistic settings” to experienced personnel, and when content is developed specifically for VR considering its “unique advantages” (Makransky et al., 2019, p. 235). Comments such as these suggest that more immersive simulation-based training capabilities can lead to learning gains when leveraged properly. This study highlights the importance of task and technology selection by providing evidence that simply increasing immersion for the sake of immersion does not positively affect learning outcomes. However, a closer look at the technological configurations used in this study makes it easy to question how much ‘more’ immersive the VR headset configuration was compared to the desktop configuration.

The difference in the levels of immersion provided by the desktop and VR configurations is questionable due to the change in number of senses affected and the level of interaction fidelity produced by the VR configuration itself. The researchers explain that the VR headset used in this study was a limitation due to the aim-and-click functionality required to control interaction with virtual lab items (Makransky et al., 2019, pp. 234-235). Participants “were given a situation in which they were supposed to be active; but they were not given the tools to do so” (Makransky et al., 2019, p. 235). It is easy to imagine a virtual lab setting in VR which allows a participant to control their virtual hands, through physical controllers, and pick up and interact with typical laboratory equipment. However, the VR configuration in this study did not allow participants to interact with the VE in this manner.

In terms of senses affected, the use of the headset seems to have only increased immersion involving vision by providing the participant the ability to look around the lab with a three-dimensional field of view tethered to their head movement (Makransky et al., 2019, p. 230). Perhaps the increased presence reported by participants simply equated to them feeling ‘more’ in the lab due to the ability to view the lab in VR instead of on a flat computer screen (Makransky et al., 2019, p. 232). Immersion could have also possibly been improved through hearing depending on the quality of sound provided by the VR headset in comparison to the desktop configuration. From a senses-affected perspective, the VR headset configuration did not drastically change the level of immersion for participants.

In terms of interaction fidelity, the two configurations appear to have been very similar. Both configurations required the participant to move a cursor and click a button to interact with the VE. Neither configuration’s method of interaction with the VE appears to have enhanced interaction fidelity or supported EC learning theories (Makransky & Peterson, 2021, p. 949). If the VR configuration could have interacted with objects in the VE using their hands through controllers while moving their arms, interaction fidelity could have been enhanced adding to increased immersion. Like senses affected, interaction fidelity was not drastically, or at all, increased by the use of the VR headset configuration suggesting that immersion was only marginally different between the two configurations. Moreover, it is reasonable to question if cognitive load was increased in users of the VR configuration due to the “new and not very intuitive” user interface required for VE interaction rather than an increase in signals provided by the environment or the novelty of VR (Makransky et al., 2019, p. 234). It is fair to assume participants were more acquainted with using a desktop configuration than a VR configuration (Makransky et al., 2019, p. 234).

The quantity and type of senses affected and lack of change in interaction fidelity between the two configurations could support an argument that the VR configuration was not more immersive than the desktop configuration. If evidence for this outcome were identified, it would not be surprising that the supposedly ‘more’ immersive configuration did not increase learning outcomes. It would not be surprising because it would not be capitalizing on the strengths of VR which support EC learning theories (Makransky & Peterson, 2021, p. 949). The VR configuration in this study could then be viewed as an awkward replacement for a desktop computer rather than a ‘more’ immersive technological configuration which enhances learning through increased interaction fidelity.

Although this study did not provide evidence that increased immersion automatically leads to increased learning outcomes, it indirectly highlights the importance of task and technological configuration selection and pairing. The views provided by the researchers on the potential for more immersive technologies such as VR for learning/training outcomes combined with some of the questions their study’s design invites increases the relevance of this pilot study (Makransky et al., 2019, p. 235). This pilot study remains relevant because it examines the impact of immersion on learning outcomes when a task is deliberately chosen to amplify the impact of more immersive and interaction fidelity-producing technological configurations.

The achievement of successful learning outcomes through virtual technologies has also been demonstrated by studies using realistic VWs modeled after real-world locations. Selzer et al.'s (2019) study involved a "virtual representation of the wetland of Villa del Mar, Buenos Aires" while Harrington's (2011) study used a virtual representation of the Trillium Trail, a wildflower reserve, located in Pennsylvania (p. 10; pp. 176-178). The Villa del Mar study examined the value of using low-end VR systems for educational purposes in a classroom environment (Selzer et al., 2019, pp. 9-10). The study was accomplished by comparing the utility of low-end VR systems against a desktop configuration (control condition), and a high-end VR enabled configuration (Selzer et al., 2019, pp. 9-10). The control and experimental groups interacted solely with the VW through their respective technological configurations (Selzer et al., 2019). The Trillium Trail study "compared learning activity in situ of a real environment (Real) and a desktop virtual reality (Virtual) environment, built with video game technology, for discovery-based learning" (Harrington, 2011, p. 175). Participants visited both the real Trillium Trail (control condition) and the virtual Trillium Trail (experimental condition) in the form of a class field trip (Harrington, 2011, p. 175). One group visited the virtual representation first followed by the real-world trail while the other visited the real-world trail first followed by the virtual version (Harrington, 2011, p. 179).

Both studies support the notion that increased immersion leads to increased learning outcomes, and measured learning outcomes using a pretest/survey and posttest/survey concept (Harrington, 2011, p. 179; Selzer et al., 2019, p. 11). A key finding from Selzer et al.'s (2019) work highlights that virtual presence, or presence, and learning outcomes share a positive relationship; they each increased together (Selzer et al., 2019, p. 13). Harrington's (2011) study led to similar results finding the real environment (most immersive and presence producing) as the "superior learning environment" (Harrington, 2011, p. 185). It is worth noting for in-curriculum material, the learning gains were identical in both conditions, but the real-world condition learned more because the real environment produces more signals which provide more out of curriculum information to learn overall (Harrington, 2011, pp. 180-183). However, this study also highlights presence, albeit less, was achieved by the VE and "the Virtual shows value for carefully targeted learning objectives of in-curriculum material, especially when the real environment is not available" (Harrington, 2011, p. 185). The author explains presence "may be important in the Virtual" setting and suggests that a more immersive configuration would have increased learning outcomes (Harrington, 2011, p. 184). A key finding offered by this study is the combination of real and virtual worlds leads to significant learning transfer, and that transfer from the real-world to the virtual is stronger than transfer from the virtual to the real (Harrington, 2011, p. 184; Stevens et al., 2015, p. 524). This finding leads to the suggestion that VW training should be provided following real-world training to reinforce lessons learned with the ideal training/learning model following a VW, real-world, VW rotation to attain the best results (Harrington, 2011, p. 184; Stevens et al., 2015, p. 524). This sequence allows the virtual to prime participants for their activity in the real-world and reinforce lessons learned while in the real-world after their interaction (Harrington, 2011, p. 184). Each of these studies strongly suggest and demonstrate how virtual and immersive environments and technologies can lead to the increased achievement of learning/training outcomes.

Although not directly researching the impact of immersion on learning outcomes, Wehden et al.'s (2021) study compared different immersive technologies and measured presence. The purpose of this study was to determine the influence of VR technology and omnidirectional treadmills (ODT) on gaming experiences (Wehden et al., 2021, p. 7). The technology used in this study was distributed through its three supporting experimental conditions: desktop computer with a keyboard and mouse, VR headset and its supporting controllers (HTC VIVE), and VR headset (HTC VIVE) paired with an ODT (Virtuix Omni) (Wehden et al., 2021, p. 8). The Virtuix Omni simulates movement/walking by requiring users to slide their feet across a disc shaped base in a walking motion while physically restricting their movement to the center of the disc; users can rotate their bodies 360 degrees to change the direction they are facing (Hejtmanek et al., 2020, p. 481; Omni by Virtuix, 2022; Wehden et al., 2021, p. 10). Once introduced to the study and familiarized with their respective technological configuration, participants completed tasks in the VW (Wehden et al., 2021, pp. 9-11). A key finding of this study was that presence was increased, among other variables, receiving significantly higher values when participants used a VR configuration in comparison to a desktop configuration (Wehden et al., 2021, pp. 8, 11). Lastly, findings indicated the only significant difference between each VR enabled configuration, to include presence, was the amount of physical exertion by the ODT users (Wehden et al., 2021, pp. 8, 11). As a reminder, this study's focus was on how immersive technologies impact gaming experiences rather than learning outcomes (Wehden et al., 2021, p. 7). However, although the authors did "not find extensive additional benefits of using" ODTs to support VR gaming, the Army may desire the increased physical exertion caused by ODTs as well as their potential to increase presence and learning outcomes (Wehden et al., 2021, p. 13). Of note, Slater and Wilbur (1997) support Wehden et al.'s (2021) findings by citing a previous study which explains walking techniques for transportation, such as walking in place, used in a virtual environment can increase presence more than "using a pointing device" (p. 7).

Spatial Knowledge Acquisition Emphasis

While not directly evaluating learning gains through a comparison of different levels of technological immersion, the study by König et al. (2021) effectively did just that. The study was designed to determine "whether and how spatial learning in a virtual environment is influenced by different sources for spatial knowledge acquisition" (König et al., 2021, p. 2). The 'different sources' of information in the study were the two different presentation mediums of the VE. One participant group experienced the VE "directly" through an immersive VR-headset configuration while the other group experienced it "indirectly" through "an interactive city map" (König et al., 2021, pp. 2, 17-18). So, the VE was the same for both groups, but their method of experiencing it was different. The VE was modeled after a "typical European small village" and is relatively large compared to other studies' environments evaluating spatial knowledge acquisition; the fictional island town included over 200 buildings and "would cover about 216,000 m^2 in real-world measure" (König et al., 2021, p. 3).

The study included two participant groups which were separated in terms of the technological configuration they were assigned to for interaction with the VE. Although not explicitly stated, the study appears to have been of a between-subject design. The VR-headset group utilized an HTC VIVE headset with an accompanying controller to view and move through the VE (König et al., 2021, p. 7). Participants rotated their bodies on a swivel chair to change their physical perspective/direction in the VE and the controller's touchpad to move forward (König et al., 2021, p. 7). Using this configuration participants essentially walked through the VE; the researchers deemed this method of interaction as experiencing the "primary environment" since it "would allow an experience more similar to the direct experience of a natural environment" (König et al., 2021, p. 7).

The interactive-map group engaged the VE through a desktop configuration and viewed the VE, which "resembled a traditional city map with a north-up orientation and a bird's-eye view," on computer screens using a mouse for interaction (König et al., 2021, p. 4). The map was interactive because it allowed participants to view pictures of some of the buildings in the VE from street level (König et al., 2021, p. 4). When participants hovered over a building, an onscreen selectable indicator would appear and once clicked the software would provide the user a picture of the side of the building the indicator appeared on (König et al., 2021, p. 4). The pictures provided were taken in the same VE the VR-headset group experienced when moving/walking through the town (König et al., 2021, p. 4).

The experiment included four phases: introduction, exploration, testing, and questionnaire. Both groups conducted all phases three times in a ten-day period (König et al., 2021, p. 3). Participants freely explored their respective VE for 30 minutes during each exploration-phase iteration and once complete immediately entered the testing phase (König et al., 2021, pp. 3, 6). The testing phase included three tasks and two-time conditions for each task where one allowed the participant to choose an answer in three seconds and another which allowed an unlimited amount of time (König et al., 2021, pp. 5, 6). The order of the six task blocks presented to participants "was randomized across subjects" (König et al., 2021, p. 6). Following testing, participants filled out a questionnaire to enable the researchers to better understand spatial strategies employed by participants (König et al., 2021, p. 8).

To determine how spatial learning was impacted by different information sources, König et al. (2021) evaluated and compared the accuracy results of the two groups following the third testing phase using “a logistic regression analysis” (pp. 3, 8). The testing phase included an absolute orientation, relative orientation, and pointing task (König et al., 2021, p. 5). It is important to note that each question supporting each task included two possible choices for the participant; one correct option and one incorrect option (König et al., 2021, p. 5). The tasks were performed by presenting participants with a picture of a building or the “prime stimulus” for a set amount of time and then presenting participants with the two answer options on two computer screens (König et al., 2021, pp. 5-6). The absolute orientation task required participants to decide which picture of a building with a compass needle overlaid accurately depicted the building’s orientation to the north (König et al., 2021, p. 5). The relative orientation task required participants to select the building with the same orientation as another building (König et al., 2021, p. 5). Lastly, the pointing task required participants to accurately select the picture of the building with an overlaid compass needle pointing correctly to another building in the town (König et al., 2021, p. 5). The influence of multiple factors (e.g., “how long a building was looked at” or familiarity as determined by eye gaze behavior or clicks) were analyzed when comparing group task accuracy (König et al., 2021, p. 10).

Despite several findings affirming that, and demonstrating how the source of spatial information impacts spatial knowledge acquisition, two results stand out. First, the VR-headset group, which interacted with the VE in a more immersive manner, achieved “higher accuracy for judging straight-line directions between buildings” than the interactive map group (König et al., 2021, p. 16). Next, the interactive map group achieved “higher accuracy in tasks testing cardinal directions and building-to-building orientation” when compared to the VR-headset group (König et al., 2021, p. 16). These results stand out because they highlight how different types of knowledge can be gained by different presentations of the same information. The researchers point out that the VR-headset group may have performed better during the judgement direction task due to a required switch in perspective by the interactive map group during testing to answer these types of questions (König et al., 2021, pp. 16-17). This task required the map group to change their perspective from a "bird's-eye perspective of the map" to an "ego perspective" used by the VR-headset group during exploration (König et al., 2021, pp. 16-17). The researchers also point out that the VR-headset group likely performed worse than the map group during the other two tasks due to a requirement for them to switch their perspective to a "bird's-eye" view to answer these types of questions (König et al., 2021, pp. 16-17). This study's results clearly demonstrate that the source or medium providing information can affect spatial knowledge acquisition or learning in regard to the task evaluated.

While this study did not directly assess the impact of technological immersion on learning gains, it demonstrates how the presentation of the same information can be impacted through different technological configurations and mediums. The more immersive VR-headset group clearly acquired certain information more effectively than the other group and vice versa. Perhaps judging the distance between locations is more of a complex task than the other two tasks in this study, so it requires more interaction fidelity to be more accurate. The article points out that real-world spatial navigation is a complex task and that immersive VR exploration "results resemble the results after knowledge acquisition in the real world more than those after map learning" (König et al., 2021, pp. 16, 19). Furthermore, the researchers explain that better performance in the judgement direction task likely resulted due to the "action-relevant information" provided by the VR-headset experience which is consistent with EC theories (König et al., 2021, pp. 16, 19). Spatial navigation in the real-world "is a multimodal activity that requires the embodied interaction of the navigator with the environment" (König et al., 2021, p.

19). This activity relies on information provided by “visual, motor, kinesthetic, and vestibular changes” through the senses (König et al., 2021, p. 19). Thus, it stands to reason a more immersive technological configuration which increases interaction fidelity or embodiment results in better learning for specific tasks such as judgement direction required for spatial navigation. Supporting this notion, König et al. (2021) suggests a more immersive VR-supported environment which supports free-space movement and closes the distance between a lab environment and the real-world could increase spatial learning outcomes (p. 19).

This article provides evidence that a more immersive technological configuration can lead to improved learning gains when an appropriate task is aligned with it. When the act of spatial navigation and the communication of spatial knowledge acquisition are viewed as complex tasks, it supports this pilot study’s alternate hypothesis that increased technological immersion can lead to increased learning outcomes. It is not hard to imagine a small unit of dismounted infantry Soldiers training in a VE using a VR-headset supported by an ODT configuration referencing a virtual two-dimensional map of the virtual terrain they are standing on in the VE. This setup would allow the Soldiers to achieve the best of both worlds in terms of gaining spatial knowledge short of conducting the training in the real-world on the actual terrain (König et al., 2021). If the VE was modeled after a real-world environment, like the ones OWT will provide, it is easy to assume these Soldiers would learn more than Soldiers training with VBS3 using a desktop configuration due to the increase in sensory inputs provided by the more immersive configuration.

Dong et al. (2022) evaluated learning outcomes between a live and immersive Virtual Reality (iVR) condition. The focus of the study was determining if “wayfinding behavior and spatial knowledge acquisition” are the same between the two conditions (Dong et al., 2022, p.

226). The study's experimental environment involved the third and fourth floors of a campus office building (Dong et al., 2022, p. 229). Both conditions were assigned a set of nine tasks which involved wayfinding tasks in the environment and tasks associated with spatial knowledge acquisition (Dong et al., 2022, p. 231). Wayfinding tasks in the environment included a sequential set of subtasks that generally involved searching for a specific room or location as quickly as possible (Dong et al., 2022, p. 231). Spatial knowledge acquisition tasks involved distance and direction estimates, a questionnaire, an interview about cognitive processes during the performance of wayfinding tasks, and, of note, the drawing of a sketch map of the floors used in the study (Dong et al., 2022, pp. 230-231).

The tasks involved do not immediately appear to have been complex in nature, however, an argument could be made that the sketch map task was. The sketch map task could be deemed complex since the creation of a map for evaluation forces the participant to recall their actions during wayfinding and consider how to best communicate those actions so another individual can understand them. The consideration of the human's unknown response when reviewing the produced map becomes the variable which may cause the task to become complex in nature.

To effectively compare "human wayfinding behavior and spatial knowledge acquisition," Dong et al. (2022) developed a framework (p. 232). The framework captured wayfinding performance through the tasks previously mentioned to include "eye-tracking experiments" (Dong et al., 2022, p. 232). For instance, wayfinding task performance was determined through "wayfinding time and the number of wrong decisions metrics" (Dong et al., 2022, p. 232). Spatial knowledge acquisition was evaluated through a lens shaped by cognitive maps (Dong et al., 2022, p. 233). The authors justify their measurement methods of spatial knowledge acquisition, distance and direction estimates and sketch mapping, by explaining the importance of cognitive maps (Dong et al., 2022, p. 233). They explain “[c]ognitive maps represent the most advanced level of spatial representation and integrated knowledge about the environment” (Dong et al., 2022, p. 233). For the sketch mapping task, participants were provided templates of the building floors to complete; the accuracy of the drawn routes was the only factor considered when evaluating the correctness of the sketch maps (Dong et al., 2022, pp. 233-234).

Participants assigned to the live condition performed their respective tasks in the ‘real’ building while those assigned to the iVR condition interacted with a VE modeled after the ‘real’ building space. The live condition was not completely untethered while performing their wayfinding tasks, their mobile eye-tracking devices were connected to a laptop as they moved (Dong et al., 2022, p. 241). The iVR condition was provided with an HTC VIVE VR headset, which was connected to and supported by a computer, and moved through the VE using body rotation and a handheld joystick (Dong et al., 2022, pp. 229, 242). The research team decided not to use a “locomotion method [such as an ODT] to simulate movement in iVR” because the VE was not a one-to-one match with the real-world environment (Dong et al., 2022, pp. 229, 242).

Despite the conditional differences between groups, the authors’ hypothesis appears to have been supported. Dong et al. (2022) hypothesized that both conditions, iVR and live, “would exhibit the same wayfinding behavior and obtain equivalent spatial knowledge” (p. 227). Key findings from this study demonstrate how immersive technological configurations can lead to learning gains similar to, or better than those achieved in a real-world environment. One difference between the conditions was the accuracy of distance estimations; the iVR condition was more accurate than the live condition (Dong et al., 2022, p. 241). Although subtle, this can be interpreted as the iVR condition learning ‘more’ than the live condition. The authors suggest the iVR condition may have learned ‘more’ simply because the live environment provided too many signals, or was more immersive, making it easier for participants to become distracted (Dong et al., 2022, p. 241). They note the VE was “substantially simplified” when compared to the real building (Dong et al., 2022, p. 241). The number of signals appears to have affected behaviors between the conditions during the free viewing and wayfinding tasks (Dong et al., 2022, p. 241). The iVR condition reportedly focused on landmark identification while the live condition was “distracted by other objects in the environment, such as wall murals (irrelevant information)” (Dong et al., 2022, p. 241). Landmarks in the VE were therefore likely more salient than in the real environment due to less competition (Dong et al., 2022, p. 241). Perhaps immersive technologies and their accompanying VEs can aid learning outcomes when compared to a live environment due to their ability to be built or scaled back to meet specific learning/training objectives.

In terms of similarities between the two conditions, wayfinding performance was determined to be, in general, equivalent between the groups. Even though it was reasonable to expect poorer wayfinding performance by the iVR group due to their lack of iVR wayfinding experience, the group performed “with similar efficiency and effectiveness to that of participants in the [live condition] as they became familiar with the iVR setup” (Dong et al., 2022, p. 241). This finding demonstrates that an immersive technical configuration, VR-supported in this case, can lead to learning outcomes similar to those achieved in the real-world. Additionally, although the wayfinding tasks cannot immediately be identified as complex, it seems the interaction fidelity provided by the iVR configuration enhanced the iVR group’s ability to keep pace with the live condition (Dong et al., 2022, p. 241).

Next, arguably the most interesting finding from the Dong et al. (2022) study involved direction knowledge and the sketch mapping task. No differences were determined between the two groups regarding "spatial direction estimation" and the results of the sketch mapping task were similar between the two conditions (Dong et al., 2022, p. 242). The outcome of the sketch mapping task is indicative of the two conditions processing "direction and structural information in a similar way" (Dong et al., 2022, p. 242). These findings are arguably the most interesting because they lead the authors to claim this study provides "preliminary evidence that spatial knowledge and cognitive maps developed in iVR" may be transferable to the real-world (Dong et al., 2022, p. 242). These findings provide evidence for the claim that more immersive technological configurations can lead to learning outcomes comparable to those gained in the real-world, and that these gains are transferable to the real-world. It is easy to imagine how the Army could benefit from a simulation-based training capability that capitalizes on this phenomenon. If small unit dismounted infantry Soldiers trained in a realistically modeled VE pushed by OWT, via an immersive VR and ODT supported setup, they would undoubtedly be more prepared for actual combat operations by learning the "lay of the land" before ever stepping foot on the ground. This type of learning is invaluable because it could lead to one less variable Soldiers must consider during combat.

It is also worth noting Dong et al. (2022) stated to test the ecological validity of iVR, "experiments in larger outdoor areas…will be needed" (p. 242). This pilot study's experimental environment, the Virtual UCF Arboretum, is a large (247 acres) outdoor area (University of Central Florida, n.d.b). Its use supports this recommended requirement to a limited degree since the experimental environment is modeled after the 'real' UCF Arboretum which is not involved in the experiment.

Waller et al.'s (1998) study, although dated, remains relevant because it evaluated the transfer of spatial knowledge acquired through six different training conditions which exposed participants to varying levels of immersion prior to a real-world final assessment. The goal of the study was to clarify the value of immersion to training with fidelity (interface and environmental) as the guiding concept (Waller et al., 1998, pp. 129-132). The researchers note VEs can undoubtedly enable spatial knowledge training, but it is important to understand the technical variables which can be sacrificed while still achieving training outcomes (Waller et al., 1998, p. 130). Understanding these variables is important "[b]ecause the effectiveness of VEs always hinges on a tradeoff between economic and technological variables" (Waller et al., 1998, p. 130).

To evaluate the different variables which affect spatial knowledge acquisition in VEs, learning transfer was assessed using a real-world "14-foot X 18-foot maze" with adjustable walls and a multiple-choice test (Waller et al., 1998, pp. 133, 137). The maze included four large stuffed animals and a corresponding cardboard number; these objects served as "prominent landmarks" (Waller et al., 1998, p. 133). Prior to the final assessments, participants conducted preparatory tasks (such as walking blindfolded) and were then randomly assigned to one of six training conditions (Waller et al., 1998, pp. 134-136). The conditions were: blind (no access to maze for training), real (trained one minute using the real-world maze room), map (trained one minute using a map of the maze), VR-Desk (trained for two minutes using VE of maze on desktop configuration), VR-Immersive (trained for two minutes using VE of maze with VR headset supported by joystick for movement), and VR-Long Immersive (same as previous condition but allowed to train for five minutes) (Waller et al., 1998, pp. 135-136). The same VE was provided to each of the 'VR' conditions; it was a replica of the real maze room presented using grayscale colors (Waller et al., 1998, pp. 135-136). After each of the six training iterations, where conditions trained in accordance with their assigned time limits, participants were "blindfolded and escorted to the beginning of the real-world maze" (Waller et al., 1998, p. 136). So, participants trained using their assigned configuration six times and attempted the maze blindfolded six times. Once at the maze, participants were tasked "to touch each stuffed animal in order, as quickly as possible, while minimizing the number of times that they hit the walls of the maze" (Waller et al., 1998, p. 136). During the first training iteration for all but the blind condition, participants were provided information regarding the correct path (Waller et al., 1998, pp. 135-136). Participant scores for the "blindfolded walkthrough task" were based on completion time and the number of times they 'bumped' into the walls (Waller et al., 1998, p. 136).

Following the sixth maze exposure iteration, participants were given a distraction task so the maze could be reconfigured (Waller et al., 1998, p. 136). Once adjusted, participants were issued the "integration task" which required them to go from stuffed-animal one to three as quickly as possible (Waller et al., 1998, p. 136). However, two of the three route options were made unavailable between the two stuffed animals during the maze's reconfiguration; "both the most familiar and the most direct path were blocked" (Waller et al., 1998, p. 136). This maze alteration, once recognized, forced participants to "rely on their mental representation of the maze and integrate the piece-meal knowledge they had acquired to that point" (Waller et al., 1998, p. 136). The researchers recorded completion time, wall bumps, and all attempted routes (Waller et al., 1998, pp. 136-137). The integration task can be understood as complex because it was a situational awareness task. The task required participants to assess the current environment and apply information learned about the environment to determine their future action (Gawron, 2019, p. 135). Following the integration task, participants completed the multiple-choice (true or false) test which presented map depictions of the maze to determine knowledge regarding survey and route knowledge (Waller et al., 1998, p. 137). Results were determined using several statistical methods, but the basis of analysis was “a two-tailed alpha level of 0.05” (Waller et al., 1998, p. 137). The six condition groups of 20 participants were analyzed from a between-subjects and within-subjects perspective depending on the variable under analysis (Waller et al., 1998, pp. 138-140).

This study resulted in three key findings. First, although all conditions became increasingly faster at completing the blindfolded maze task, the real and VR Long-Immersive groups were the fastest during the fifth and sixth iterations (Waller et al., 1998, pp. 138-140). Although not to a statistically significant degree, the VR Long-Immersive condition outperformed the real condition during the two final iterations, and these conditions’ progress “cannot be attributed to the learning of the environment” while blindfolded because the blind condition’s performance remained “significantly worse” (Waller et al., 1998, pp. 139-140). As a result, the most immersive technological configuration performed as well as, or learned as much as, the real condition in terms of learning route knowledge (Waller et al., 1998, p. 141). It is important to note, although the integration task can be understood as complex in nature, the Waller et al. (1998) article does not appear to provide performance results based on direct comparisons of the condition groups for this task (pp. 140-141). The task’s results were combined with multiple-choice test results to analyze mental representation differences (p. 140).

Despite the researchers stating interface fidelity, essentially interaction fidelity, does not affect “the acquisition of route knowledge” much, it seems plausible the increased interaction fidelity caused by the VR headset led to increased performance (Waller et al., 1998, p. 142). For the sake of perspective, the VR-headset used in the Waller et al. (1998) study had a 60-degree horizontal field of view, while today’s commercially available HTC VIVE Flow and Pro 2 headsets can achieve between a 100 and 120-degree horizontal field of view (VIVE, n.d.; p. 131). People with normal vision have approximately a 180-degree horizontal field of view (Mazuryk & Gervautz, 1999, p. 16). From a vision-centric perspective, today's headsets are clearly more immersive than the one used by Waller et al. (1998). This pilot study's experiment incorporates modern headsets. The more immersive headsets should allow for more sensitive measures between conditions.

The next key finding involves participant mental representation differences, or cognitive map differences, determined by the multiple-choice test (Waller et al., 1998, p. 140). These results were presented by condition and by gender (male, female) (Waller et al., 1998, p. 140). The map conditions for both genders resulted in the highest scores on the test with all VR conditions performing worse than the map and real condition (Waller et al., 1998, p. 140). These results are key because, like the König et al. (2021) study, they highlight the importance of task pairing with the task training method/configuration. The multiple-choice questions presented by Waller et al. (1998) seem to rely heavily on survey-type knowledge which appears to be learned more effectively from exocentric views with maps than through egocentric views and direct spatial exploration (König et al., 2021 p. 17; p. 137). To optimize small unit dismounted infantry performance with support from OWT, the U.S. Army may benefit from replacing VBS3's commonly used desktop configuration with a more immersive simulation-based training capability.

Lastly, gender was found to be a significant factor affecting performance (Waller et al., 1998, pp. 141-142). Concerning the blindfold task, men, on average, outperformed women "in all nonblind experimental groups" (Waller et al., 1998, p. 141). During the blindfold task, overall group average-maze-exposure times ranged from less than 100 seconds to more than 400 seconds with each group improving their average time from their first to their sixth interaction (Waller et al., 1998, p. 138). During the sixth and final maze interaction the blind group was slowest at nearly 300 seconds while the VR-Long immersive was the fastest at less than 100 seconds (Waller et al., 1998, p. 138). Women in VE conditions “performed significantly worse than men in the VE conditions” during the blindfold task (Waller et al., 1998, p. 141). Similar results were discovered regarding spatial representation measures (Waller et al., 1998, p. 141). However, men and women who trained in the real condition performed similarly indicating gender was not the primary factor affecting spatial knowledge acquisition (Waller et al., 1998, p. 142). The researchers provide several reasons why gender may have affected the performance of VE-trained participants such as men being more experienced with video games (Waller et al., 1998, p. 142). The results concerning gender led to the recommendation that future studies should control for gender (Waller et al., 1998, p. 142). This is significant because this pilot study’s results may not have been generalizable to the target population if a significant proportion of participants were male or female; especially since the sample size was small at 15 participants. However, although this pilot study did not control for gender during recruitment, it seems the results should generalize to the target population because a third of participants identified as female with two of these participants being randomly assigned to two of the condition groups (VR and VR supported by ODT). The active-duty Army in 2020 was composed of 84.5% male Soldiers and 15.5% female Soldiers, so, with condition groups of five, each gender is represented in each condition group in a manner which closely resembles the active-duty proportion of male to female Soldiers (Military OneSource, n.d.).

Waller et al. (1998) also highlighted interesting points which are relevant to this pilot study. They explain the development of a mental representation of an environment is a process which progresses in phases (Waller et al., 1998, p. 132). The first phase is familiarization where an individual simply learns key locations within the environment (Waller et al., 1998, p. 132). Next, after familiarization, the individual develops route knowledge which links key locations together via routes (Waller et al., 1998, p. 132). The final phase of understanding an environment involves the development of a "survey representation" which is map like in nature; the researchers point out not everyone will achieve this level of understanding (Waller et al., 1998, p. 132). This mental representation results in a deep understanding of the environment independent of route knowledge and enables "spatial inferences and can allow people access to spatial information regardless of orientation" (Waller et al., 1998, p. 132). Regarding the final phase, Waller et al. (1998) explain the development of spatial knowledge requires "conscious effort" (p. 132). To motivate this type of effort in support of the sketch map task, this pilot study's experimental instructions inform participants they will be required to communicate geospatial information or 'what they found' to another person.

Furthermore, Waller et al. (1998) explain the development of survey knowledge in VEs is "confounded" due to two factors (p. 132). First, as previously mentioned, VR-headsets have a lesser field of view as compared to the real-world and this limitation can negatively affect real-world spatial knowledge acquisition (Waller et al., 1998, p. 132). Next, they explain using VEs for survey knowledge development is impacted because the act draws from cognitive resources since "wearing a headset and navigating by looking or by mouse movement are not natural activities" (Waller et al., 1998, p. 132). Essentially the participant must allocate some mental capacity to understanding the technological configuration they are using rather than allocating all mental resources to spatial knowledge acquisition (Merriënboer & Bruin, 2014, p. 26; Waller et al., 1998, p. 132). These two issues are relevant because they could easily influence the results of this pilot study. However, this pilot study seeks to mitigate their impact by using VR-headsets with a larger field of view, and recruiting participants who have experience with using VR-headsets. The availability of cognitive resources is important for spatial knowledge acquisition and learning in general; please see the methodology section for a detailed description of how this pilot study's experiment is understood to affect learning while accounting for mental resources. Despite these concerns, the Waller et al. (1998) study demonstrates with the proper time allotted, more immersive configurations can enable learning, specifically with tasks involving route knowledge, to a degree similar to real-world training environments (Waller et al., 1998, p. 141).

Hejtmanek et al.'s (2020) study incorporated an ODT to determine what extent spatial knowledge acquired from a VE transfers to the real-world. This study assessed spatial learning outcomes by comparing three navigation conditions: real-world, VR with ODT support, and desktop (mouse and keyboard) (Hejtmanek et al., 2020, p. 479). The ODT which supported this study was the Cyberith Virtualizer; it replicates movement by allowing the user to rotate their body 360 degrees while freely moving their head, and walking by sliding their feet over the treadmill base (Hejtmanek et al., 2020, pp. 481, 485). The study's VE, accessed via the desktop and VR configuration, was modeled after the real-world "campus building environment" used by the real-world condition and for the final learning assessment of all conditions (Hejtmanek et al., 2020, pp. 479, 482). Prior to the final assessment in the real-world environment, participants were provided the opportunity to 'learn' the building in their assigned technical configuration by completing tasks requiring the identification of specific locations (Hejtmanek et al., 2020, p. 483). Learning transfer was assessed by measuring time and accuracy; measures were described as "path length, visitation errors, and pointing errors" (Hejtmanek et al., 2020, p. 479). The VR-trained condition outperformed the desktop-trained condition overall while the real-world trained condition performed best (Hejtmanek et al., 2020, pp. 483-484). This performance outcome supports the notion that a more immersive training environment, with the real-world being the most immersive, increases learning outcomes due to more multisensory cues being affected (Harrington, 2011, p. 184; Hejtmanek et al., 2020, pp. 498-499).

It is worth noting in this study, like the Bold Quest 2012 experiment, the real-world condition trained in the same real-world environment used for the final assessment to determine learning gains (Bink et al., 2015, p. 21; Hejtmanek et al., 2020, pp. 482-483). Allowing the real-world condition to train in the same real-world environment used for the final assessment could have easily introduced bias into the study's results. The real-world condition could have performed better because they were familiar with the real-world environment due to their training in the real-world environment. The authors, noting this study's environment involved a medium-sized office building, speculated that "if participants had to navigate longer distances, such as would be required for a park or city" the VR configuration could have potentially achieved more significant learning outcomes when compared to the desktop configuration. Despite the introduced bias and concern over the use of a small area for experimental testing, this study demonstrates that an increase in immersion can result in increased learning outcomes.

The studies described in this section demonstrate how multiple immersive technological configurations have been studied and compared in terms of immersion, presence, embodiment, task type, and learning with an emphasis on several broad topics (military, general learning/academia, spatial knowledge acquisition). Although no single study provides overwhelming evidence in favor of using more immersive simulation-based training capabilities to achieve learning gains, observed collectively they provide evidence for the claim enhanced learning gains are possible under the proper circumstances. A key aspect of "the proper circumstances" is the appropriate alignment of technological configurations and tasks. When studies included immersive configurations and appropriate tasks, with a degree of complexity where physical activity was meaningful for learning and supported by interaction fidelity, only comparable real-world or live environment conditions appear to have performed routinely on par or better (Makransky & Peterson, 2021, p. 949). Since learning outcomes can be positively affected by more immersive technologies, this literature review clearly emphasizes more research regarding the relationship between immersive technologies and learning outcomes is warranted and that a research gap remains.

Research Gap

A quick review of the literature reveals a research gap and sheds light on why the Army may want to fill this gap due to the influence of increased immersion, and the corresponding presence, on learning outcomes. As the Army develops the STE and transforms into the MDO Army of 2035, it becomes apparent it may be missing a more immersive and presence producing simulation-based training capability for dismounted infantry Soldiers from the fire team to company level (Rozman, 2020, pp. 4-5; Stone, 2021). The Army's current and common solution for these Soldiers, a desktop configuration running VBS3 software, could be enhanced through technological improvements which would most likely correlate positively with increased learning gains. These learning gains could lead to higher quality live training events by allowing Soldiers to achieve a higher degree of training proficiency before the execution of live training events. However, this more immersive simulation-based training capability is missing from the Army's current training toolbox and does not appear to be currently under development as part of the STE initiative.

As discussed in the introduction, the Army is not without simulation-based training capabilities for small unit dismounted infantry Soldiers due to existing and future capabilities such as the EST II, VBS3, and the currently under development S/SVT and STE-IS. Despite their strengths, these capabilities are not without their limitations. As described repeatedly in the literature, VBS3's primarily desktop-enabled configuration is viewed as the least immersive common technological configuration. If VBS3's replacement is a simple evolution of the current system, the level of immersion will likely not change. Although the EST II supports some collective training, such as "judgmental escalation-of-force exercises," it is difficult to imagine its indoor "controlled environment" weapons ranges, supported by projectors and projection screens, inducing a feeling of presence amongst users (USAASC, 2021, para. 1). Perhaps this capability is best for training complicated tasks such as weapons familiarization and basic rifle marksmanship.

Although immersive in nature, systems capitalizing on AR, such as the SiVT, still face challenges which can dramatically reduce immersion and presence. First, AR technology struggles to provide realistic images in a daylight environment; the Army will likely require this technology to provide training opportunities in outdoor settings (Broll, 2022, pp. 299, 319; Stone, 2021). Sunlight may cause AR presented images to appear somewhat transparent or partially invisible (Broll, 2022, pp. 299, 319). If Soldiers cannot see the virtual objects in their training environment as they would expect to see them in a real-world situation, their feeling of immersion and presence will undoubtedly be reduced. Next, AR training technology still relies on, and is limited to a certain degree by real-world access to real-world training resources (e.g. training areas) (Rozman, 2020, p. 6). For instance, if a unit is trying to train for a unique environment, and the available real-world training area does not possess similar characteristics, training will likely be degraded due to a corresponding lack of similarity with the desired environment (Rozman, 2020, p. 6). It is easy to imagine Soldiers in the deserts of Fort Bliss having a challenging time training for pacific island jungles even with state-of-the-art AR equipment. Furthermore, if an adequate real-world training area does exist, it may simply be unavailable for a plethora of reasons which could include another unit reserving the land first. Resourced properly, an immersive VR-driven capability could allow small units to simply suit up and enter a realistic tropical environment, or any other environment, habitat, or biome on the planet, in a day or night setting no matter where they are stationed. So, theoretically "VR, in contrast to AR, has no limitations: neither in content nor in physics (in a VR you can define your own physics!)" (Doerner et al., 2022, p. 23). VR training solutions may be more mature than their AR counterparts; in recent years "VR has experienced a boom" when compared to AR technologies, including the Microsoft Hololens, in terms of market success (Doerner et al., 2022, p. 26). The Army's current and future capabilities do and will allow small unit dismounted infantry Soldiers to train for the complex battlefields of the future, but the Army could potentially benefit from acquiring a more immersive simulation-driven capability for this audience. The hypothesized benefit of this capability lies in its potential to affect the achievement of increased learning outcomes in a manner consistent with EC learning theories which result in better trained and prepared Soldiers.

Key findings from the literature review point out why the Army should desire more information about a more immersive simulation-based training capability for its small unit dismounted infantry Soldiers: the potential for increased learning outcomes. The reviewed studies examined and compared multiple technological configurations and learning environments in various ways. These studies involved traditional classroom and live environments as well as desktop, VW, CAVE, AR, and VR configurations with some including the integration of ODTs. These studies share the common thread of suggesting or finding that increased immersion leads to increased learning outcomes in certain circumstances. The notion of increased presence, which results from immersion, leading to increased learning outcomes is supported with strong evidence by Harrington (2011) who found the real environment as the most effective learning environment (pp. 184-185; Slater, 2003, p. 2; Slater & Wilbur, 1997, p. 603). This idea was further supported by studies such as Selzer et al.'s (2019) who found a positive correlation between increased immersion, and the corresponding "virtual presence" or presence, and learning outcomes (p. 13). Despite these findings in the literature and the apparent lack of a more immersive simulation-based training capability in the Army's training toolbox for small unit dismounted infantry Soldiers, this pilot study's goal of informing U.S. Army senior leaders does not appear to be approached in an oversaturated manner in the existing literature.

This pilot study's purpose, to examine the impact of combined immersion and embodiment on learning outcomes, is approached in research. However, the intention of these studies' results do not appear to be geared towards enabling U.S. Army senior leaders to make decisions about simulation-based training capabilities. As an Army simulation operations professional, I am "in the business of protecting assets by training practitioners in simulators" so I am highly interested in informing senior leaders about their capabilities and potential capabilities (Hayes et al., 2013, p. 21). This study seeks to bridge this research gap by reviewing existing literature and highlighting relevant points, and conducting an experiment to generate evidence concerning the guiding hypothesis. This study's results expand the body of knowledge focused on determining the impact of increased immersion on learning outcomes, the most beneficial alignment of immersive technologies and task types, and spatial knowledge acquisition. For instance, this study expands on knowledge generated by studies such as Stevens et al.'s (2015) which examined "prior research comparing the effect on human performance between [head mounted displays] and traditional screen-based visual systems in virtual training" (p. 532). If this study's findings are overlooked, dismounted infantry Soldiers from the fire team to company level may not achieve the highest degree of readiness possible when preparing for the complex battlefields of the future.

Additionally, I would like to point out the purpose of this study is not to argue VR environments are more immersive than AR and live environments since they take place in the real-world; the prevailing educational environment (Harrington, 2011, p. 185). Rather, this study seeks to examine whether a more immersive training capability can be a valuable addition to the Army's existing simulation-based training toolbox. Moreover, this study acknowledges that financial decisions must be made when considering the acquisition of new training capabilities. Rather than ponder over whether a particular configuration is affordable or 'worth it,' this study seeks to provide and inform decision makers who control fiscal resources with evidence grounded in the achievement of learning outcomes.

CHAPTER THREE: METHODOLOGY

Overview and Purpose

The purpose of this pilot study's experiment is to evaluate learning outcomes when participants are subjected to a situational awareness-based task in different technically determined levels of immersion. The experiment's guiding logic has three key components/assumptions. First, learning outcomes are enhanced when more of the senses are affected through a more immersive environment where interaction-fidelity features are deliberately incorporated against specific learning objectives (Makransky & Petersen, 2021, p. 949). Second, a situational awareness-based task is complex in nature and required to demonstrate the value of more immersive technological configurations (Mikropoulos & Natsis, 2011, p. 774). Thirdly, if this study's participants (UCF students) can achieve more learning gains through more immersive technological configurations, this study's target population (dismounted infantry Soldiers) will also be able to learn more from these same types of configurations.

The experiment outlined and discussed in the following sections operationalizes the purpose of this study by providing participants with a situational awareness-focused task in a realistically modelled outdoor VE (see Table 1 for research design overview). Participants are randomly assigned, without replacement, to one of three conditions which include increasingly immersive technological configurations. The purpose of random assignment is to equate the condition groups to minimize the impact of "known and unknown" extraneous variables thus strengthening the study's internal validity (Christensen et al., 2020, pp. 104, 133-134). This study's most significant independent variable (IV), method of access to the VE, is isolated by providing each of the three conditions the same VE for the execution of experimental tasks.

Isolation of this IV mitigates the influence of confounding extraneous variables (Christensen et al., 2020, pp. 115-118). For instance, if each condition was provided a different model of the UCF Arboretum, the desktop condition could potentially receive a more detailed model which enables better learning gains than a VR model with lower fidelity. In this case, the degree of immersion caused by each condition's respective technological configuration, their method of access to the VE, would no longer be the primary cause of learning differences between groups.

The control condition's associated desktop condition is intended to replicate the Army's current and typical use of VBS3 as a simulation-based training capability for small unit dismounted infantry Soldiers. The two experimental conditions, VR headset and VR headset supported by ODT, represent increasingly immersive environments as compared to the control condition. The UCF Virtual Arboretum can be viewed as a replication of the Army's OWT capability since it is a realistically modelled geospatial outdoor VE. Experimental tasks test declarative (factual) and spatial knowledge acquired through interaction with the VE. The evidence generated should better enable U.S. Army senior leaders to decide if small unit dismounted infantry Soldiers would benefit from a more immersive simulation-based training capability from a perspective shaped by the impact of combined immersion and embodiment on learning outcomes.

Research Question

R1: In the context of a realistically modeled outdoor VE, does technologically enhanced immersion result in the achievement of more learning outcomes when conducting a situational awareness-focused task due to the technology's ability to affect more of the senses?

Hypotheses

Conducting a situational awareness-focused task in a realistically modeled virtual environment will result in increased learning outcomes if the VE is accessed through a more immersive technical configuration (desktop < VR headset < VR headset supported by omnidirectional treadmill). The experimental condition users (VR headset and VR headset supported by ODT) will learn the names of more of the thirty-five flowers, ten habitats, and recall more accurately the location of the flowers, habitats, and objects spread throughout the VE such as park benches. The increased immersion, which corresponds to an increase in human senses affected and interaction fidelity, will lead to increased learning outcomes for the experimental groups when compared to the control group (desktop configuration). Although the content of this experiment is not directly Army focused, the results will be beneficial because they provide evidence as to whether increased immersion and embodiment are a cause for increased learning outcomes. However, this experiment likely relates directly to Army interests by studying if more immersive technological configurations can increase learning regarding the execution of complex tasks, and cause individuals to learn more information about a physical space. If so, future experiments could study whether spatial information gained from realistically modeled outdoor VEs transfers to actionable spatial knowledge which increases a small-dismounted infantry unit's operational performance in the modeled real-world environment.

- Null Hypothesis: H_0 – Desktop-Enabled Learning Environment Test Scores = Virtual Reality Headset-Enabled Learning Environment Test Scores = Virtual Reality Headset and Omnidirectional Treadmill-Enabled Learning Environment Test Scores. (All mean ranks are equal)
- Alternative Hypothesis: H_1: Not all mean ranks are equal, at least one is different.

Table 1:
Research Design Overview

Design Overview

Between Subject Design All Conditions (*N* = 15)			
Group 1: (*n* = 5) Participants (Random Assignment)	Pre-Survey and Pre-Test	Control Condition (Desktop Condition). Represents no intervention to normal way of learning/training.	Post-Test and Post-Survey
Group 2: (*n* = 5) Participants (Random Assignment)	Pre-Survey and Pre-Test	Experimental Condition 1 (VR Headset Condition) Represents more immersive intervention compared to normal way of learning/training.	Post-Test and Post-Survey
Group 3: (*n* = 5) Participants (Random Assignment)	Pre-Survey and Pre-Test	Experimental Condition 2 (VR Headset with ODT Support Condition) Represents most immersive intervention compared to normal way of learning/training.	Post-Test and Post-Survey

Study Environment

- UCF Institutional Review Board Approved (see Appendix B)
- Study Real-World Execution Locations (Laboratory-type Settings)
  - Games and Interactive Media Maker Space, UCF Downtown Campus, Communication and Media Building (Desktop and VR condition)
  - M3DVR, Office Suite, Winter Park, Florida (VR supported by ODT condition)
- Virtual Environment – The Virtual UCF Arboretum
  - Same Environment for all Three Participant Conditions
  - For more information about the Virtual UCF Arboretum: https://the-harrington-lab.itch.io/the-virtual-ucf-arboretum
- Participant Recruitment Process

- Mass Email Outreach

Study Equipment

- Technical Configurations and Key Supporting Equipment
  - Control Group: Desktop Configuration (see Figure 2)
    - Monitor: HP Z24n G2 (24 inch)
    - Computer Model: HP Z2 Tower G4 Workstation
    - Operating System: Windows 10 Enterprise 64-bit (10.0, Build 19043) (19041.vb_release.191206-1406)
    - Processor: Intel(R) Core(TM) i7-8700 CPU @ 3.20GHz (12 CPUs), ~3.2GHz
    - Motherboard: HP 8455, KBC Version 07.D2.00
    - RAM: 16 GB
    - Graphics Card: NVIDIA GeForce RTX 2080
    - Common Keyboard and Mouse
    - Headphones: XIBERIA V20: https://www.amazon.eg/-/en/XIBERIA-V20-BACKLIGHT-GAMING-HEADSET/dp/B0922XXR94

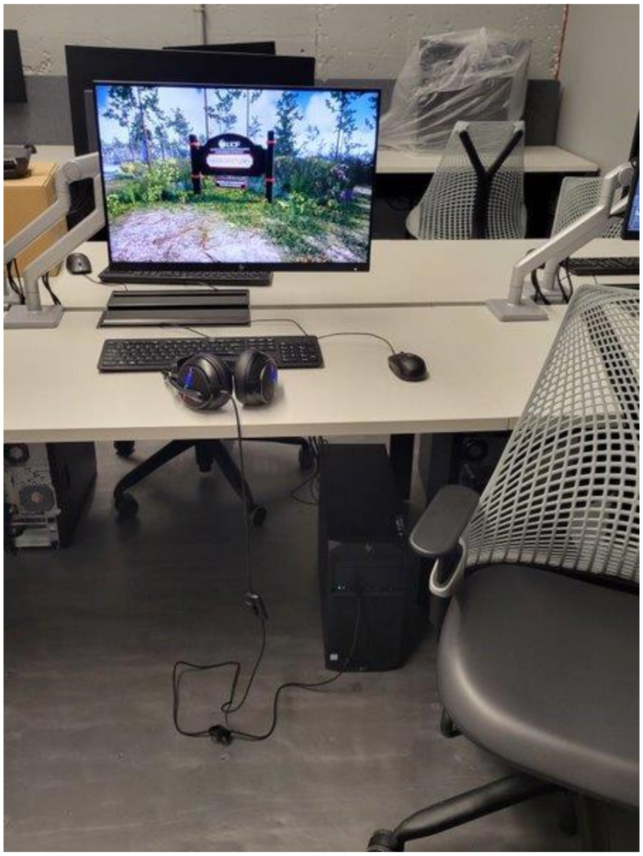


Figure 2: Desktop Configuration

Source: Author

- Experimental Group 1: VR Headset Configuration (see Figure 3)
  - HTC VIVE Virtual Reality System: Amazon.com: HTC Vive Virtual Reality System : Video Games
  - Computer Model: HP EliteDesk 800 G4 WKS TWR
  - Operating System: Microsoft Windows 10 Enterprise 64-bit (10.0.19044, Build 19044)
  - Processor: Intel(R) Core(TM) i7-8700K CPU @ 3.70 GHz, 3696 Mhz, 6 Core(s), 12 Logical Processors
  - Motherboard: HP 83E0, KBC Version 07.D1.00

- RAM: 32 GB
- Graphics Card: NVIDIA GeForce RTX 2080
- Headphones: E-Circuit: E-Circuit Round Over-Ear Headphones, 48 in. | Dollar Tree

Figure 3: VR-headset Configuration

Source: Author

- Experimental Group 2: VR Headset with ODT Support (see Figure 4)
    - Virtual Reality System: HTC VIVE Pro 2 Headset, three Valve Index 2.0 IR Base Stations, one HTC VIVE 2.0 Tracker, one HTC VIVE Controller (2018), two HTC VIVE 2.0 Tracker BT dongles: VIVE Pro 2 - The Best VR Headset in the Metaverse | United States
    - Infinadeck Omnidirectional Treadmill: https://www.infinadeck.com/

- Computer Model: Custom Tower
- Operating System: Microsoft Windows 10.0.19045 - 64 bit
- Processor: 12^{th} Gen. Inter Core i9-12900k, 3187 Mhz, 16 Cores, 24 Logical Processors
- RAM: 64 GB
- Graphics Card: NVIDIA GeForce RTX 3090

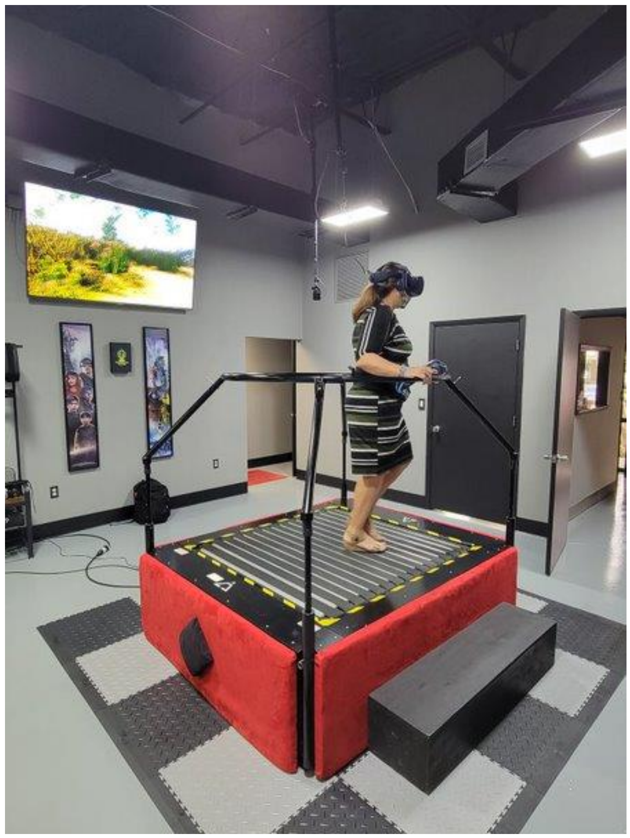


Figure 4: VR-headset supported by ODT Configuration

Source: Author

Variables

<u>Independent Variables</u>

- Technical Configurations for VE Interaction

Dependent Variables

- Learning Outcomes
    - Pre-Test and Post-Test Scores
- Survey Responses
    - Pre-Survey and Post-Survey Responses

Design, Measurement Instruments, and Data Collection

This experiment is of a between-subjects, pre-test-post-test control group design; specifically, it includes a control group and two experimental groups. A mixed methods data collection approach collects information through a pre-survey, pre-test, post-survey, and post-test. Group testing results are compared to measure learning gains. The surveys collect nominal, ordinal, and interval scale data, using a 7-point Likert scale, as well as qualitative information. The survey includes questions regarding demographics, attitudes, motivation, and perceived knowledge. Qualitative information is collected through open-ended questions. The purpose of survey data is to provide context for the researcher to make inferences while evaluating the quantitative data provided by pre-test and post-test scores. See Appendix C for measurement instruments.

The pre-tests and post-tests collect/generate ratio scale data through questions with defined correct answers in standardized evaluation grading rubrics. The pre-test asks participants to list the names of flowers and natural communities which reside within central Florida. The pre-test creates baseline data for participants' declarative knowledge regarding flowers and natural communities in central Florida. Following the intervention with the VE, the post-test repeats the pre-test by requesting participants to list the names of flowers and natural communities/habitats which reside within central Florida. Additionally, the post-test requires participants to draw a sketch map for "someone unfamiliar" with the VE to follow and find the flowers and habitats they discovered/listed in task one of the post-tests (Billinghurst & Weghorst, 1995, p. 42). Prior to entering the VE, participants are instructed to "explore it as fully as they" can and that they will be required to communicate geospatial information or 'what they found' to another person; they are not informed of the method of communication (Billinghurst & Weghorst, 1995, p. 42). This method of instruction is consistent with the Billinghurst and Weghorst (1995) and Dong et al. (2022) studies which do not appear to have informed participants of the requirement to produce a map after their experimental interventions. This technique enhances the internal validity of this experiment in two ways. First, it minimizes the impact of the testing effect in the sense that participants do not know what is explicitly on the post-test (Christensen et al., 2020, pp. 117-118). Next, these instructions ensure the experimental task is complex in nature by being a situational awareness-based task. Complexity is a result of the participant needing to consider the communication of their experience to an unknown individual who his unfamiliar with the VE. The logic behind adding the sketch mapping task to the post-test is to provide participants with a complex task to better accentuate the impact of technologically enhanced immersion and interaction fidelity on learning outcomes (Mikropoulos & Natsis, 2011, p. 774). Higher scores on the sketch mapping task are interpreted as a participant developing a 'better' cognitive map indicating they learned more.

Billinghurst and Weghorst (1995) validated sketch mapping as a legitimate measurement instrument for the reproduction of mental maps (Dong et al., 2022, p. 233). Dong et al. (2022) incorporated this technique in an experiment focused on comparing "how wayfinding behavior and spatial knowledge acquisition in [immersive] VR differ from those in real-world environments (REs)" (p. 226). With sketch mapping, participants must be aware of the object they are currently observing and its location and proximity to other items in the VE while trying to recall and develop a mental map they can successfully communicate to another individual. The accumulation of these somewhat simple tasks involves multiple variables which cannot be assembled to create a predictable outcome. Participants are provided with a nearly blank sheet of paper and pen/pencil and asked to produce their sketch maps by hand. Sketch maps are scored according to "relative object positioning" and distance and "object classes" (Billinghurst & Weghorst, 1995, p. 42). Relative object positioning allows for map scoring by evaluating the general proximity of an object in relation to another object on the map (Billinghurst & Weghorst, 1995, p. 42). For example, if flowers and other manmade objects such as benches are drawn "positioned to the right or left, above or below, or clockwise or counterclockwise" in an accurate manner in relation to other items, the map will receive points (Billinghurst & Weghorst, 1995, p. 42). Object classes involves the number of unique items articulated on the map (Billinghurst & Weghorst, 1995, p. 42). For instance, trail intersections, bodies of water, named groups of trees, signs, and benches will be counted and scored as separate objects (Billinghurst & Weghorst, 1995, p. 42). More object classes placed on a map result in a higher score. Thus, art skills are not important for this task, just the ability to accurately depict objects in relation to one another. Although sketch mapping is not as complex as leading Soldiers in a combat environment, it adds to the complexity of this experiment's task.

Due to the importance of immersion, presence, and embodiment to this study's findings, the "Single-Item Measure of Presence in VR" question is provided to participants in the post-survey to define the reliability and validity of the data (question 7) (Bouchard et al., 2004, p. 59). Answers to this question should indicate participants felt 'present' in the VE, otherwise it could be assumed the technical configurations in this study were not immersive. The study's internal validity would be significantly at risk if participants in the experimental conditions did not feel present in the VE. The question “To which extent do you feel present in the virtual environment, as if you were really there?” has been tested and determined to be an effective measure of presence (Bouchard et al., 2004, p. 59; Selzer et al., 2019, p. 11).

Learning outcomes are determined by comparing each condition’s pre-test and post-test results. Despite the small sample, the research design is using random assignment to improve internal validity (Christensen et al., 2020, pp. 104, 132). To increase the external validity, the experimental task is focused in a way that does not require specialized knowledge, allowing findings to generalize to adults in general, and the sample is pulled from a population similar to the Army population (Military OneSource, n.d.; Today’s Military, 2022; UNIVSTATS, 2022). The focus of this experiment is on the achievement of general learning outcomes and how they are affected by various degrees of immersion when aligned against an appropriate task.

Population

This study’s ideal population sample is adults, over eighteen years of age (18+), who could theoretically serve on active duty in the U.S. Army. Although the U.S. Army has additional requirements for entry, the only immediate discriminator for this study in terms of identifying an individual who could potentially serve in the Army is age; participants must be at least eighteen years old. Due to convenience and access to adults, this study recruited from the University of Central Florida’s (UCF) student body through mass emails ($N \approx 70{,}000$) (UCF, n.d.a). Mass emails are an efficient and cost-effective means of recruitment because they enable the notification of many students in a short amount of time for essentially no financial cost. The source of participants was a subset of the UCF student body; students and faculty in the GaIM (Games and Interactive Media) program and Modeling and Simulation graduate program were notified of the study. Other students in other programs may have received the recruitment email/message because recipients were encouraged to forward the email/message to other UCF students.

The UCF student body supports this study's external validity because it is composed of many individuals who could serve in the Army. The age requirement to enlist in the Army is 17-35 years old (17 with parental consent); the enlisted population accounts for the majority of Soldiers in the Army (Military OneSource, n.d.; Today's Military, 2022). In 2020, approximately 80%, or ≈ 388,000 of the Army's active-duty Soldiers were enlisted with an average age of 27 years old (Military OneSource, n.d.). A rifle or dismounted/light infantry company, the largest dismounted infantry small unit, consists of approximately 100 enlisted Soldiers in squads alone (USDA, 2016, pp. 1-13, 1-54). UCF's student population (graduate and undergraduate) includes approximately 69,000 students between the ages of 18 and 39 years old (UNIVSTATS, 2022). This study's findings should generalize to dismounted infantry Soldiers in the Army due to UCF's large number of students who could potentially serve in the Army due to their age. Random assignment to condition groups assists in controlling the influence of extraneous variables by increasing the probability that the groups are equated and representative of the target population (Christensen et al., 2020, pp. 104, 133-134).

Due to logistical and resource constraints, such as time to complete the study and access to specialized equipment such as an ODT, this study recruited a sample of 15 participants (N = 15) with each of the three condition groups receiving five randomly assigned participants. The recruitment email requested participants who are UCF students, are at least 18 years of age, speak English, have normal vision and hearing, can walk without assistance, have virtual reality headset experience, have experience using a treadmill for walking or running, and who are not susceptible to VR, cyber, or motion sickness. These factors are important because a participant who does not meet these criteria could lessen the experiment's internal validity. For example, if an individual who is susceptible to VR/cyber sickness is assigned to one of the VR supported conditions, they may be unable to complete the study, or even if they can finish the task, their focus could be drawn to the feeling of sickness rather than the task at hand (Makransky & Petersen, 2021, p. 952). This scenario would threaten the internal validity of the experiment because the participant's learning outcomes could be heavily influenced by VR/cyber sickness rather than the level of immersion associated with their assigned condition.

Procedure

This study recruited participants via mass email which specified participant requirements and desired attributes. Participants confirmed their intent to participate by emailing the researcher. Once the participants were identified, the researcher randomly assigned them, without replacement, to a condition (desktop, VR headset, or VR headset with ODT support), and sent an email to each participant containing their confirmed date, time, and location information. Once this email was sent to participants and participation was confirmed, all emails were deleted by the researcher to protect the identity of participants. The experiment's expected duration for each participant is a maximum of 95 minutes total depending on participant preference (see Table 2 for experiment duration summary). The study was conducted at multiple sites due to the physical location of condition supporting equipment. The desktop and VR headset condition groups participated at the Games and Interactive Media Maker Space located on the UCF Downtown Campus in the Communication and Media Building. The VR headset supported by ODT condition participated at the M3DVR Office Suite located in Winter Park, Florida. Both environments can be considered as a laboratory setting; they both allowed for limited environmental controls. Since the study required multiple sites, the study was conducted over several days. Specific days for experiment execution were coordinated for with the Games and Interactive Media Maker Space staff. One day was scheduled for the desktop-configuration participants and one day was scheduled for the VR headset-condition group. The researcher worked with participants on an individual basis to determine feasible participation dates and times if the originally scheduled dates were unfeasible. An additional day was coordinated for with the M3DVR staff for the VR headset supported by ODT condition group. Each condition group executed the experiment on a separate day to mitigate procedural errors by the researcher. Due to equipment constraints, participants in the VR headset and VR headset supported by ODT condition received individual report times. In these conditions, only one participant was able to interact with the VE at a time due to the availability of one VR headset and one VR headset supported by ODT. The researcher was physically present at each study site on each scheduled day/iteration for each condition group.

Table 2:
Estimated Experiment Duration Summary

Duration Estimation

Time Duration	**Activities**
15 minutes	consent, instruction, pre-survey, and pre-test
60 minutes maximum	interaction with virtual environment
20 minutes	post-test and post-survey
95 minutes total	experiment session complete

When participants reported to their assigned session, they were greeted by the researcher. The researcher led participants through the consent process; all participants were required to verbally consent. It is important to note that participants were informed that they could withdraw their consent at any time. To protect participant identities, identification numbers (ID#s) were issued to participants onsite in order of arrival; participant names were not linked to ID#s. Participant names were not recorded on any documents at either of the experimental sites. ID#s were written on each set of experiment supporting documents by the researcher. The use of ID#s enables the organization of study materials by condition while protecting participant identities.

Once consent was confirmed, participants received instruction regarding their experimental tasks. Following this instruction, participants were issued their pre-survey and pre-test. Following the initial survey and test, participants were instructed to begin interacting with the VE. Participants were encouraged to ask the researcher questions about how to interact with the VE through their respective technological configuration as necessary. Participants were given up to 60 minutes in the VE and informed they could leave the VE at any time. The researcher requested participants spend at least 30 minutes in the VE.

Once participants completed their interaction with the VE, they were provided the post-test. Once the post-test was complete, participants received the post-survey. Upon completion of each participants' respective participation, participants were thanked by the researcher and given a $20 Starbucks gift card as compensation.

Learning Facilitation Experiment of Declarative and Spatial Knowledge Acquisition

This pilot study's experiment enables learning when viewed from a perspective shaped by information processing, cognitive resource, and embodied cognition/learning theories (Merriënboer & Bruin, 2014, p. 26; Skulmowski & Rey, 2018, p. 1). Regarding cognitive resource theory, the experiment's learning model recognizes that humans have limited working memory resources which can generally maintain "7 ± 2 elements" or thoughts, and that humans may extend processing power through the chunking of information; see Figure 5 (Merriënboer &

Bruin, 2014, pp. 25-26; Miller, 1956, p. 93; Wickens & Hollands, 2000, pp. 250-251). Chunking enables bits of information to be stored together due to their associations in long-term memory allowing the elements present in working memory to contain more information (Miller, 1956, p. 93; Wickens & Hollands, 2000, pp. 250-251). For instance, someone new to a neighborhood may initially require five elements to remember five separate streets, but overtime and once learned, these five streets may be stored and recalled as a single element or road network once chunked together (Miller, 1956, pp. 93-95; Wickens & Hollands, 2000, pp. 250-251). Hence, elements available for consideration in working memory can be expanded to include more information since working memory is essentially "a fixed number of chunks" whose sizes can be increased to contain "more information than before" (Miller, 1956, p. 93). It is worth noting working memory is also short in duration; information "not rehearsed is lost within 30 [seconds]" (Merriënboer & Bruin, 2014, p. 26).

Learning occurs when information is processed and stored in long-term memory (Merriënboer & Bruin, 2014, p. 26). The availability of more working memory resources during an activity enables learning due to more resources being available for "genuine learning" (Merriënboer & Bruin, 2014, p. 26). Concerning information processing and embodied cognition/learning theory, the experiment's learning model acknowledges a link between the body and the environment through interaction (König et al., 2021, p. 1). While interacting, the body perceives the environment through its sensory register and develops a multisensory representation or mental model of the external environment (König et al., 2021, p. 1; Merriënboer & Bruin, 2014, p. 26; Skulmowski & Rey, 2018, pp. 1-2).

The mental model of the external environment contains the cognitive map which represents "the most advanced level of spatial representation and integrated knowledge about the environment” (Barsalou, 1999, pp. 582-583; Darken et al., 1998, p. 102; Dong et al., 2022, p. 233; Golledge, 2005, p. 329). As a result, the mental model includes spatial information about the environment as well as declarative information perceived in the environment. This process is important to this pilot study because the experiment involves sensing the environment, constructing a mental model of the environment based on sensory inputs, and then referring to that mental model, which includes the cognitive map, to transfer and demonstrate knowledge gains.

Figure 5 provides a visual representation of this experiment’s learning process. The VE is introduced to participants through one of the respective technical configurations. These configurations provide varying sensory cues in differing quantities and degrees of fidelity which are received through the participant’s sensory register for processing. As sensory cues are received and passed from the sensory register to working memory, mental model construction begins (Merriënboer & Bruin, 2014, p. 25). The model is developed and refined as information is transferred to long-term memory, or learned, from working memory (Golledge, 2005, p. 330; Merriënboer & Bruin, 2014, pp. 25-26). Experiment participants are aware they should explore the VE and be prepared to communicate geospatial information to an unknown individual following their interaction. These tasks should cause participants to knowingly construct a detailed mental model of their experience in the VE.

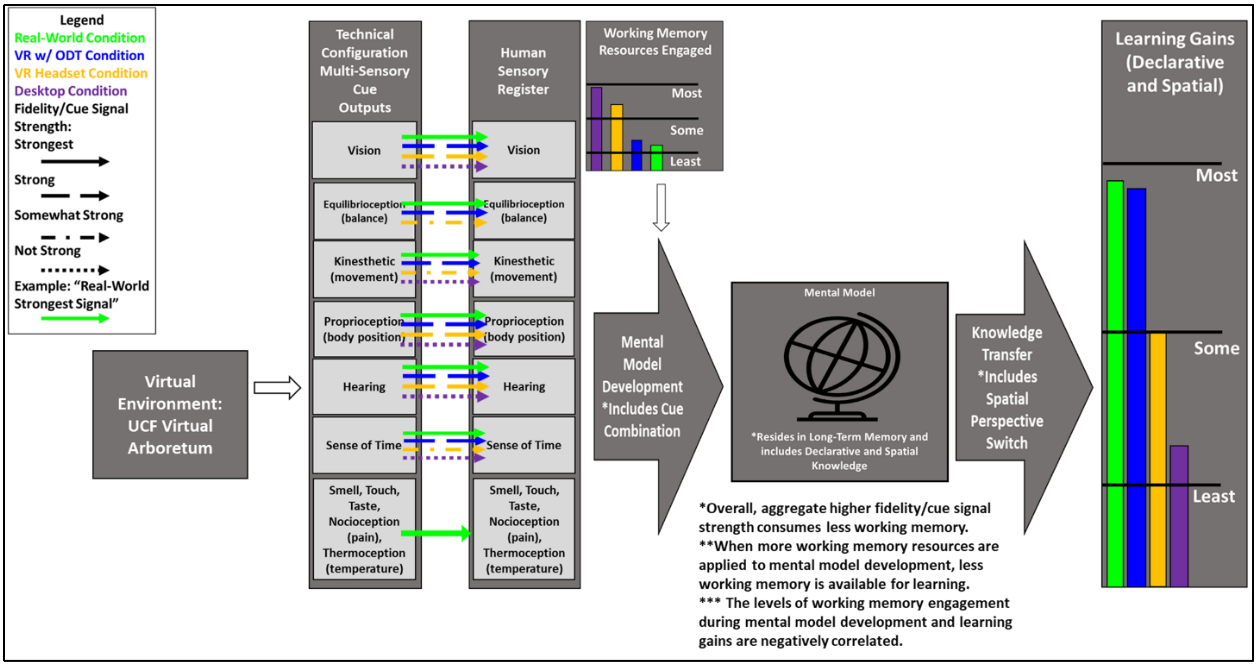


Figure 5: Experiment Learning Facilitation Model: Declarative and Spatial Knowledge Acquisition

Source: Author

Sensory cues/information provided by bodily movement "which are essential for spatial cognition" include visual, equilibrioception (balance), kinesthetic (movement) and motor changes (Ismail et al., 2022; König et al., 2021, p. 1; The Balance of Evolution, n.d.). Individually, each of these cues can inform spatial cognition (MICHAELHE, 2016). However, when multiple cues are presented together, these cues become redundant and inform the development of a more detailed cognitive map/mental model; the cues are combined (Chen et al., 2017, p. 108; MICHAELHE, 2016). So, the presence of more cues which contribute to spatial cognition results in the reception of a more salient signal representative of the external environment (M. C. R. Harrington, personal communication, June 6, 2022). The experiment's technical configurations provide these cues from an ego or first-person perspective since the VE is experienced as a three-dimensional space (König et al., 2021, pp. 16-17). The experiment's learning model assumes cognitive map construction in the real-world establishes the baseline for cognitive map development since it is the most cue producing and experienced environment by participants (Harrington, 2011, p. 184). Due to this viewpoint, it is reasonable to assume the level of mental effort required to generate a cognitive map is negatively correlated to a VE experience's level of fidelity when compared to the real-world (Waller et al., 1998, pp. 130, 133, 141). In other words, a more realistic interaction with the VE enables more "genuine learning" because less mental resources will be allocated to the mental model's development (Merriënboer & Bruin, 2014, p. 26). For example, if someone walks through a realistic three-dimensional environment using a laptop and mouse configuration knowing they must communicate geospatial information to someone following the interaction, they will need to apply mental effort to place themselves in the environment. The mental effort required to place themself in the environment and understand its scale to provide accurate distances between locations drains working memory resources. In the real-world or a highly immersive VR environment, the environmental scale is provided in high fidelity draining less working memory resources. Evidence indicates that spatial knowledge acquisition in VEs can resemble spatial knowledge acquisition in the real-world when more immersive configurations are used to access a VE (Dong et al., 2022, p. 242; König et al., 2021, p. 1).

This experiment's guiding logic is straightforward. The more the VE experience replicates the real-world in terms of fidelity, hence its degree of immersion, the more mental capacity the participant has available for learning (Merriënboer & Bruin, 2014, p. 26). More capacity for learning is available because the participant does not have to mentally create/imagine the missing cues required to develop a more detailed mental model/cognitive map. In support of this idea, studies have indicated distance estimation in VEs improves when user presence is higher (Doerner & Steinicke, 2022, p. 57). Thus, the quality of the mental model/cognitive map is significant. If it has holes due to a lack of redundant sensory-cue inputs required for spatial cognition, such as balance or movement information, the participant must deliberately fill these holes resulting in the use of more mental resources resulting in the learning of less information.

This pilot study's experiment exposes sensory-cue holes in cognitive maps by requiring participants to produce a sketch map; a task which involves a shift in perspective (König et al., 2021, pp. 16-17). Since the VE is experienced from a first person - egocentric - perspective, participants will need to change their perspective to a birds-eye view - exocentric - to communicate the survey knowledge required to produce the sketch map (Dong et al., 2022, p. 242; König et al., 2021, pp. 16-17). This switch in perspective should increase the difficulty associated with communicating geospatial information by adding an additional step further highlighting the quality of the participant's cognitive map (König et al., 2021, pp. 16-17). Evidence suggests that egocentric spatial explorers gain some survey knowledge during exploration (König et al., 2021, p. 17). So, this experiment's learning model assumes participant-learning gains will be a direct reflection of the impact of immersion on learning gains. If this study's alternate hypothesis is correct, the more immersive environment will enable more learning by requiring fewer mental resources during mental model/cognitive map construction.

Assessment Instrument(s)

The Kruskal-Wallis one-way analysis of variance by ranks test is utilized to determine how learning outcomes were affected by participants' randomly assigned conditions. Analysis with different statistical tests may be determined necessary in the future to evaluate stochastic dominance. The Kruskal-Wallis statistical tool allows for the comparing of three independent conditions with small sample sizes (e.g., $N = 15$) while determining if differences between conditions are statistically significant (Siegel & Castellan, 1988, pp. 206-215). This tool "tests the null hypothesis that the *k* samples come from the same population or from identical populations with the same median" (Siegel & Castellan, 1988, p. 206). SPSS (Statistical Package for the Social Sciences Statistics Base Grad Pack Version 29) software allows for a comparison of mean ranks or medians; the proper comparison is determined by the shape of the data distribution; in this study, mean ranks are compared (Laerd Statistics, n.d.a). The first phase of the test determines if samples or conditions are from different populations (Siegel & Castellan, 1988, pp. 206, 213). In this experiment, the samples are formed by the desktop, VR headset, and VR headset supported by ODT condition groups.

CHAPTER FOUR: DATA RESULTS

Due to this study's small sample size (*N* = 15), non-parametric statistics are employed to determine the significance of learning outcomes (Siegel & Castellan, 1988, pp. 2-3, 35). More specifically, this study utilizes SPSS software to facilitate the Kruskal-Wallis statistical test to analyze and compare test scores generated by each condition group. The Kruskal-Wallis test enables a determination as to whether statistically significant differences are present between each of the three condition groups' scores/learning outcomes. Descriptive statistics, correlation analysis, and other SPSS-powered tools are also used to analyze data; see Appendix D for the SPSS data table used to examine this experiment's results.

Overall Test Results

Before proceeding I would like to report findings associated with the "Single-Item Measure of Presence in VR" question presented to participants in the post-survey (question 7) and discussed in the methodology section (Bouchard et al., 2004, p. 59). Since the relationship between the condition groups' level of immersion-embodiment determined by system configuration and the associated feelings of presence are critical to this study's data reliability and validity, it must be mentioned prior to further data analysis. A non-parametric Spearman's rho correlation test was performed in SPSS to analyze this relationship (Laerd Statistics, n.d.b). The results of the analysis show a statistically significant and positive correlation between the feeling of presence and the level of condition groups' associated level of immersion-embodiment, $r_s(13) = .541$, $p = .037$. These results suggest participants felt more present in the VE as the level of immersion-embodiment was increased by each condition group's respective technological configuration. Through SPSS software, the Kruskal-Wallis test was applied to evaluate the null hypothesis. The Kruskal-Wallis test is appropriate to analyze this study's data because the sample size is small (N = 15), the DV is measured at the ratio/continuous level, the IV consists of multiple independent groups which are organized in a categorical manner, and observations were independent between the groups (Geert Van Den Berg, n.d.; Laerd Statistics, n.d.a; Siegel & Castellan, 1988, p. 35). Additionally, the Kruskal-Wallis is suitable to analyze mean ranks, rather than medians, because the shape of each groups' data distribution concerning test scores/learning outcomes is different or not normal; see Figures 6, 7, and 8 (Geert Van Den Berg, n.d.; Laerd Statistics, n.d.a).

- Null Hypothesis: H_0 – Desktop-Enabled Learning Environment Test Scores = Virtual Reality Headset-Enabled Learning Environment Test Scores = Virtual Reality Headset and Omnidirectional Treadmill-Enabled Learning Environment Test Scores. (All mean ranks are equal)
- Alternative Hypothesis: H_1: Not all mean ranks are equal, at least one is different.

The Kruskal-Wallis test is applied to compare the mean ranks of the test scores generated by condition groups (Geert Van Den Berg, n.d.; Laerd Statistics, n.d.a; Siegel & Castellan, 1988, pp. 206-216). The first set of scores compared is the percentage change from the pre-test to the post-test concerning the listing of plants and flowers native to central Florida (question 1). The second set of scores compared is the percentage change from the pre-test to the post-test concerning the listing of natural habitats/communities native to central Florida (question 2). Lastly, the third set of scores compared is the cumulative scores generated during the sketch map task (question 3, post-test only). See Appendix E for participant sketch maps and grading notes.

Concerning this study's guiding hypothesis, learning outcomes are defined by the percentage changes in scores from the pre-test to post-test for questions 1 and 2, and the scores for post-test question 3 as influenced by the technological configurations provided to each respective condition. However, since the research question is focused on the performance of a complex task, the sketch map task, only question 3's results speak directly to the research question.

Descriptive Statistics and Histograms

The data in Table 3 provides statistics for a comparison of the means between the three test questions by condition group while Tables 4-8 provide the results of the Kruskal-Wallis test as applied to the three questions by condition group.

Table 3:
Comparison of Means: Percentage Change in Scores for Questions 1 and 2 and Question 3 Score by Condition Group

Descriptive Statistics
Comparison

Condition Group		Q1. (List Plants) Score Percent Change	Q2. (List Communities) Score Percent Change	Q3. Draw Sketch Map Score
Desktop	N	5	5	5
	Mean	93.9117	76.6667	31.20
	Std. Deviation	6.82210	32.48931	14.601
	Std. Error of Mean	3.05093	14.52966	6.530
VR	N	5	5	5
	Mean	94.2857	29.6667	34.80
	Std. Deviation	7.82461	31.36700	19.344
	Std. Error of Mean	3.49927	14.02775	8.651
ODT	N	5	5	5
	Mean	89.9242	46.6667	47.20
	Std. Deviation	7.49770	46.24812	23.679
	Std. Error of Mean	3.35308	20.68279	10.590
Total	N	15	15	15
	Mean	92.7072	51.0000	37.73
	Std. Deviation	7.14324	39.97916	19.451
	Std. Error of Mean	1.84438	10.32258	5.022

Regarding the change in percentage for question 1 (list plants) from the pre-test to the post-test, Table 3 highlights that the differences between the condition groups are minimal concerning the mean, standard deviation, and standard error of mean. Question 2's results (list communities) appear to have more variation concerning the mean between the three groups with mean scores of ~76.7 (desktop), ~29.7 (VR), and ~46.7 (ODT). Question 3's results (draw sketch map) appear to also be varied. The mean scores for question 3 (draw sketch map) are ~31.2

(desktop), ~34.8 (VR), and ~47.2 (ODT) indicating participant scores rise in conjunction with the increased levels of immersion associated with each condition group's associated technological configuration. Below are histograms (Figures 6, 7, and 8) of each condition by test measurement to present a visual of this sparse dataset to complement the data in Table 3.

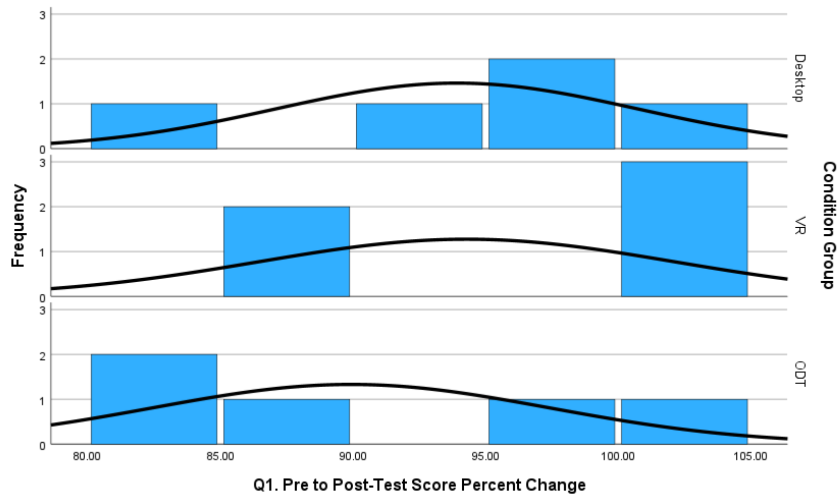


Figure 6: Data Distribution Shape: Q1. (List Plants/Flowers) Percentage Score Change from Pre-Test to Post-Test

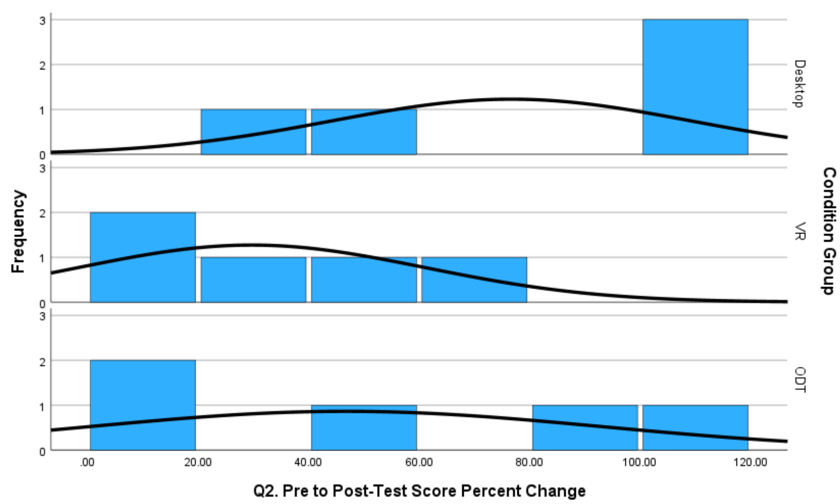


Figure 7: Data Distribution Shape: Q2. (List Habitats/Communities) Percentage Score Change from Pre-Test to Post-Test

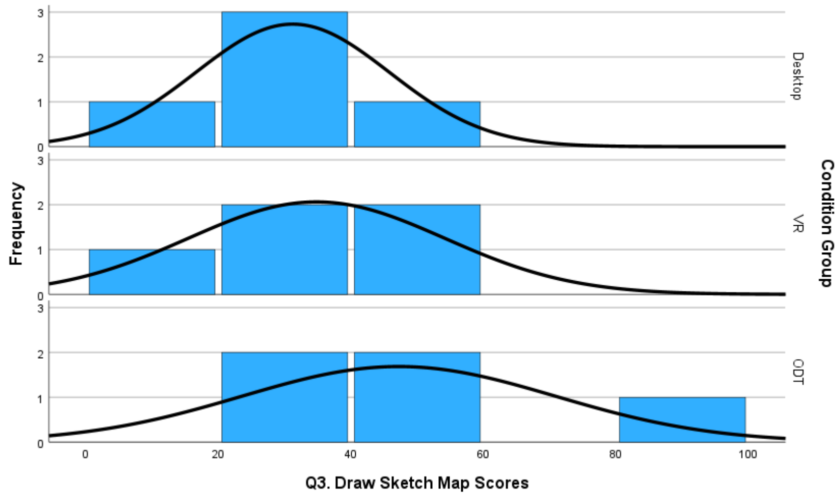


Figure 8: Data Distribution Shape: Q3. Draw Sketch Map Scores Post-Test

Learning by Condition Statistical Tests Data Results

The results of the Kruskal-Wallis test, data in Tables 4 and 5, shows no difference exists between the scores generated by each of the condition groups for each of the three questions. For questions 1, 2, and 3 the results are as follows: Q1: $H(2) = 1.332$, $p = .514$, Q2: $H(2) = 3.857$, $p = .145$, and Q3: $H(2) = 1.638$, $p = .441$ respectively.

Table 4:
Kruskal-Wallis Test Results: Percentage Change in Scores for Questions 1 (List Plants) and 2 (List Communities) and Question 3 (Draw Sketch Map) Score by Condition Group

Test Statistics[a,b]

	Q1. (List Plants) Score Percent Change	Q2. (List Communities) Score Percent Change	Q3. Draw Sketch Map Score
Kruskal-Wallis H	1.332	3.857	1.638
df	2	2	2
Asymp. Sig.	.514	.145	.441

a. Kruskal Wallis Test
b. Grouping Variable: Condition Group: Desktop, VR, ODT

Table 5:
Kruskal-Wallis Test Results: Mean Ranks by Condition Group for Questions 1, 2, and 3 (List Plants, List Communities, Draw Sketch Map) Score Percent Change for Q1 and Q2

Ranks

	Condition Group	N	Mean Rank
Q1. (List Plants) Score Percent Change	Desktop	5	8.00
	VR	5	9.60
	ODT	5	6.40
	Total	15	
Q2. (List Communities) Score Percent Change	Desktop	5	10.90
	VR	5	5.50
	ODT	5	7.60
	Total	15	
Q3. Draw Sketch Map Score	Desktop	5	6.30
	VR	5	7.80
	ODT	5	9.90
	Total	15	

Similar results are achieved if the Kruskal-Wallis test is run using post-test raw scores for questions 1 and 2 in terms of statistical significance as well; see Table 6. However, these results display a very strong trend for Q1: $H(2) = 5.798$, $p = .055$. A closer look at this trend through pairwise comparisons of the questions by condition group reveals the trend is between the desktop and VR conditions ($p = .051$, see Table 7) (stikpet, 2017). The desktop condition achieves higher scores on question 1 (list plants) with a mean rank of 11.60 versus the VR condition’s 4.90, see Table 8.

Table 6:
Kruskal-Wallis Test Results: Post-Test Questions 1 (List Plants) and 2 (List Communities) with Raw Scores

Test Statistics[a,b]

	Q1. (List Plants) Raw Score Post-Test	Q2. (List Communities) Raw Score Post-Test
Kruskal-Wallis H	5.798	2.042
df	2	2
Asymp. Sig.	.055	.360

a. Kruskal Wallis Test
b. Grouping Variable: Condition Group: Desktop, VR, ODT

Table 7:
Kruskal-Wallis Result: Pairwise Comparison of Condition Groups for Question 1(List Plants)

Pairwise Comparisons of Condition Groups for Question 1 (List Plants)

Condition Groups Compared	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
VR - ODT	-2.600	2.806	-.927	.354	1.000
VR - Desktop	6.700	2.806	2.388	.017	.051
ODT - Desktop	4.100	2.806	1.461	.144	.432

Each row tests the null hypothesis that the Sample 1 (condition group) and Sample 2 (condition group) distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 8:
Kruskal-Wallis Test Results: Mean Ranks by Condition Group for Questions 1 and 2 (List Plants, List Communities) Raw Score Post-Test

Ranks

	Condition Group	N	Mean Rank
Q1. (List Plants) Raw Score Post-Test	Desktop	5	11.60
	VR	5	4.90
	ODT	5	7.50
	Total	15	
Q2. (List Communities) Raw Score Post-Test	Desktop	5	9.30
	VR	5	5.70
	ODT	5	9.00
	Total	15	

Despite the results of the Kruskal-Wallis test, Siegel and Castellan (1988) explain the results of this type of test cannot be accepted at face value due to the small sample size involved (p. 210). Test results may indicate statistically significant results even when there is no significant difference and vice versa (Siegel and Castellan, 1988, p. 210). Specifically, "[f]ailure to reject H_0 does not imply that H_0 may be accepted and that there are no differences between the groups" (Siegel and Castellan, 1988, p. 210). The significance of this point is elaborated on in more detail in the discussion section.

Correlations Tests and Results

Using SPSS to analyze correlations between this study's multiple variables, such as condition groups and post-survey responses, resulted in several relationships worth mentioning. The following discussion is not an exhaustive list of all significant and/or interesting correlations; see Appendix F for a more detailed SPSS-generated correlations table. Unless otherwise stated, a 95% confidence level was applied to the following results.

The condition group variable showed significant positive correlations with post-survey questions: Q4: (imagination stimulation; $r_s(13) = .569$, $p = .027$), Q6: (feeling of immersion; $r_s(13) = .602$, $p = .018$), Q7: (feeling of presence; $r_s(13) = .541$, $p = .037$), and Q11: (interest to learn about natural communities now; $r_s(13) = .608$, $p = .016$). These correlations indicate as a technological system's combined immersive-embodied features increase, so do a participant's feeling of immersion, feeling of presence, stimulation of the imagination, and interest to learn more about natural communities/habitats. Thus, feelings of presence which coincide with a technological configuration's immersive features could positively influence someone's interest and motivation to learn more.

Next, it is also worth mentioning the feeling of immersion variable shares significant ($p < .05$) positive correlations with post-survey questions concerning variables or factors which can contribute to learning. First, when a 95% confidence level is applied, the feeling of immersion variable correlates to question Q1: (ease of learning; $r_s(13) = .599$, $p = .018$). Next, when a 99% confidence level is applied, the feeling of immersion variable correlates to questions Q2: (engagement during experience; $r_s(13) = .793$, $p = <.001$), Q4: (imagination stimulation; $r_s(13) = .694$, $p = .004$), and Q5: (curiosity stimulation; $r_s(13) = .759$, $p = .001$). These relationships suggest the level of immersion generated by a technological configuration could improve learning since feelings towards ease of learning, engagement, curiosity, and imagination increase together and can easily be understood as factors which contribute to learning (Hayes et al., 2013, p. 26).

CHAPTER FIVE: DISCUSSION

Even though the Kruskal-Wallis test suggested no statistically significant difference in the learning outcomes achieved by each of the condition groups, graphical representations of the data shown in the boxplots/box-and-whisker diagrams, Figures 9, 10, 11, and 12 combined with quantitative, qualitative, and correlational data suggest patterns worth noting. As previously mentioned, this pilot study's small sample size likely impacted the ability to locate a statistically significant difference between condition group learning outcomes. Due to this constraint, graphical representations of the data combined with quantitative, qualitative, and correlational data should be reviewed.

A simple way to see contextual comparisons of conditions is through boxplots comparing the raw score changes for post-test questions 1 (list plants/flowers) and 2 (list communities), post-test question 3's score (draw sketch map), and the raw total score changes from the pre-test to the post-test. Question 1 and 2's corresponding boxplots suggest there is a technological impact on learning outcomes associated with declarative knowledge or complicated tasks; see Figures 9 and 10.

The boxplots (Figures 9 and 10) tell a story which involves task type. First, it seems complicated tasks, such as learning declarative information, are better suited for low immersive and low embodied (desktop) or highly immersive and highly embodied (ODT) technological configurations. Concerning the same questions focused on learning declarative information, the study's VR condition group, or mid-immersive and mid-embodied condition, clearly performed the worst.

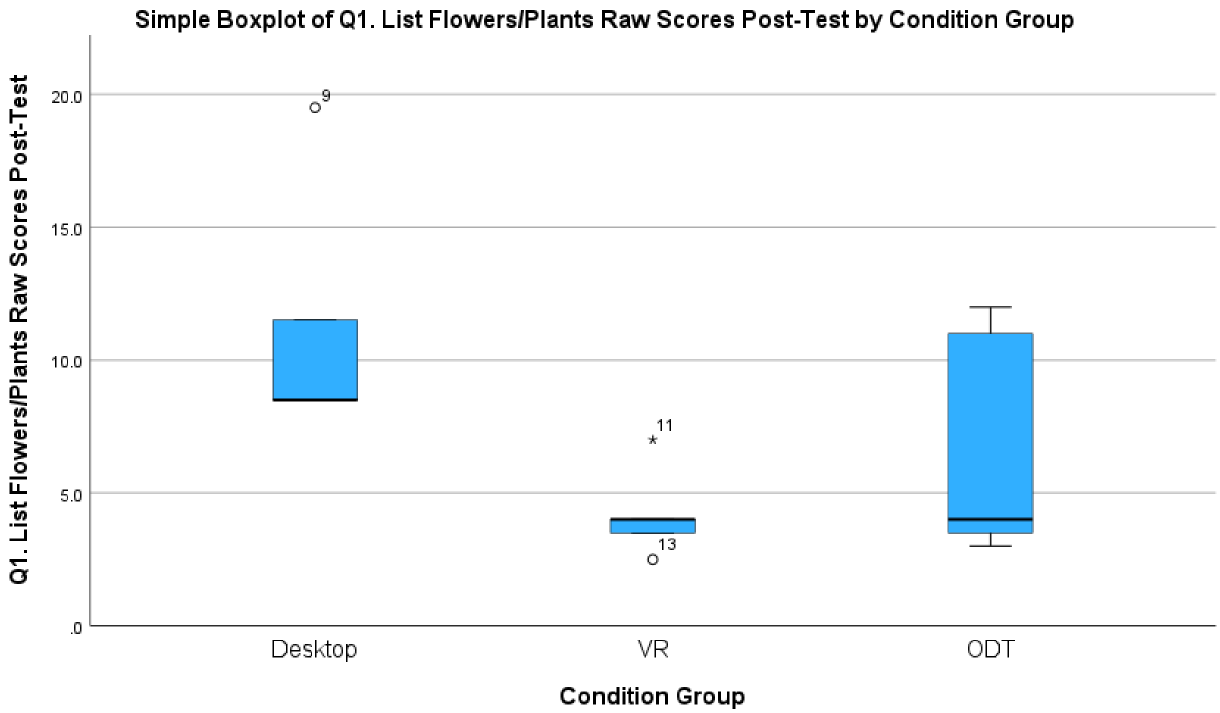


Figure 9: Boxplot of Post-Test Question 1 Raw Scores by Condition Group

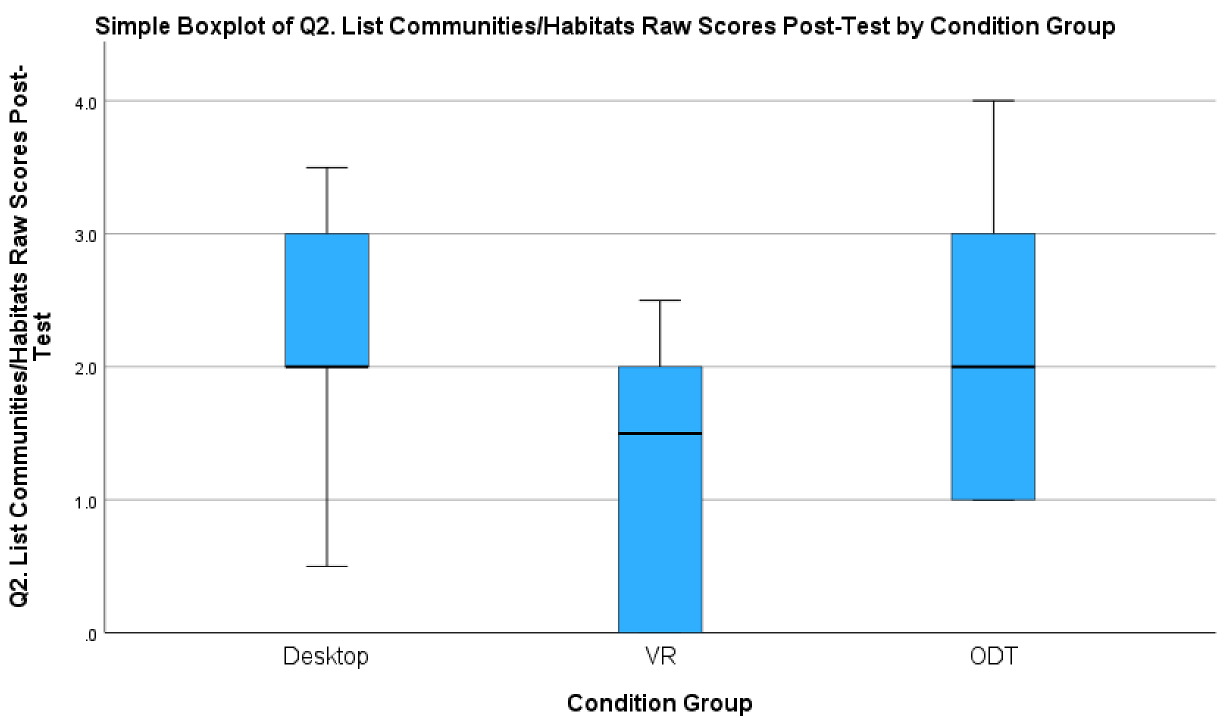


Figure 10: Boxplot of Post-Test Question 2 Raw Scores by Condition Group

One potential reason for the decreased performance by the VR group is offered by participant 14 of the VR condition. In response to post-survey question 14 (additional thoughts), this participant stated,

> …using the controllers definitely brought me out of the experience. I spent more time and effort using the tech than learning about the plants.

Perhaps the desktop condition performed better than the VR condition because college students are accustomed to using a desktop configuration and the resulting reduction in cognitive load associated with the user interface; I suspect this configuration has become natural for most people especially college students. Additionally, perhaps the ODT condition group's score variance skews higher than the VR group's because less mental effort was required to traverse the environment since they could walk naturally, reducing cognitive load. They did not have to learn the controllers to walk in the VE. Figures 9 and 10 suggest if a configuration is going to be used for declarative knowledge/complicated tasks, the information needs to be presented on a common system (desktop) or a system with higher interaction fidelity (ODT) to allow the participant to focus their mental resources on learning the information presented. As previously discussed, the difference between the desktop and VR condition groups' scores is approaching significance for question 1 (list plants) when question 1's post-test raw scores are compared by condition; see Tables 6-8 in the data results section. However, it seems the results presented in Figures 9 and 10 align with the Makransky et al. (2019) study which found lesser learning gains by the VR condition when compared against a desktop configuration (p. 233). Although, it is important to remember the VR system in the Makransky et al. (2019) study possessed low interaction fidelity due to its method of implementation.

On the other hand, it seems complex tasks, such as situational awareness-centric tasks, are better suited for more immersive systems with higher embodiment (VR and ODT); see Figure 11. This claim is further supported by the comparison of means presented in Table 3 which highlights how mean scores for post-test question 3 (draw sketch map) increased, ~31.2 (desktop), ~34.8 (VR), and ~47.2 (ODT), in conjunction with each condition group as the level of immersion and embodiment increased. Therefore, trends in the data suggest a configuration's level of immersion and embodiment and the type of task it is paired with matters because it can affect learning outcomes.

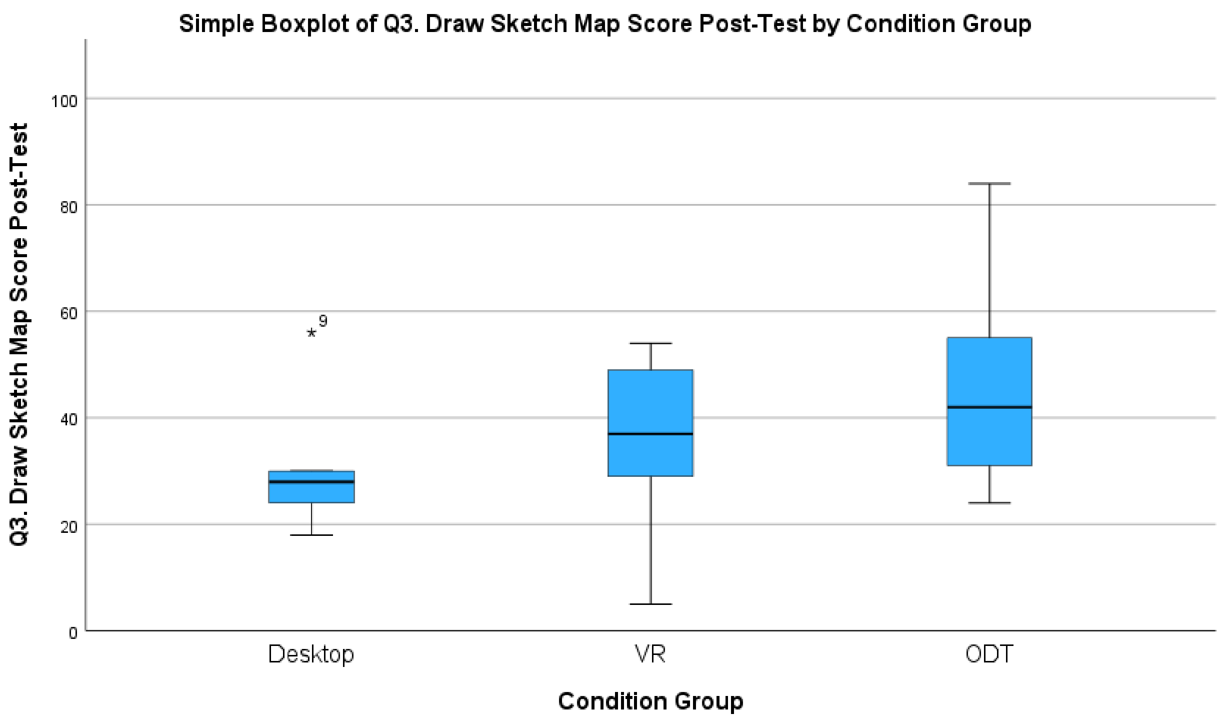


Figure 11: Boxplot of Question 3 Post-Test Scores by Condition Group

Furthermore, the boxplot presenting overall learning outcomes (see Figure 12) shows there is little to no difference in the central tendency between the condition groups' learning outcomes, but it also shows a different story in terms of the direction of variance. The desktop condition shows virtually no variance, the VR condition skews down, shows a tail below the mean score, and the ODT condition skews up, shows a tail above the mean score. Thus, the direction of variance suggests running this study with a larger sample size would clarify these results.

Figure 12: Boxplot of Pre-Test and Post-Test Total Raw Score Changes by Condition Group for Questions 1, 2, and 3

Figure 12's data distribution suggests overall test scores improve when participants interact with the VE in more immersive technological configurations. More importantly, Figure 12 suggests the answer to this pilot study's research question is potentially yes: In the context of a realistically modeled outdoor VE, does technologically enhanced immersion-embodiment result in the achievement of more learning outcomes when conducting a situational awareness-focused task due to the technology's ability to affect more of the senses? If this study incorporated a larger sample size for higher power, I would expect these differences to be increasingly evident.

Contribution to Body of Knowledge

This pilot study fits into existing literature by contributing to, and expanding the body of knowledge developed by studies which seek to determine the impact of combined immersion and embodiment on learning outcomes through various conditions. These studies include a wide range of condition group settings and can include variations from non-immersive configurations such as text and video to highly immersive configurations such as those offered by real-world training environments (Dobrowolski et al., 2021, p. 1; Waller et al., 1998, pp. 135-136). The focus of these studies can be categorized as military forces/topics, general learning, or spatial knowledge acquisition. Concerning the military focus, this pilot study contributes to the knowledge generated by studies similar to Reitz and Richards' (2013) who compared the performance of Soldiers training with different simulation-based training systems, DSTS and VIRTSIM, to those in a live training environment. These studies are related because each compared the performance of condition groups exposed to various levels of immersion while maintaining an interest towards their results' potential military application.

Regarding a general learning focus, this study contributes to the body of knowledge generated by studies like the Selzer et al. (2019) and Harrington (2011, 2012) studies who not only compared learning outcomes from groups exposed to different levels of immersion, but also featured realistically modeled VEs (pp. 9-10; pp. 175-178). Additionally, this pilot study adds to the knowledge base influenced by studies similar to the Makransky et al. (2019) study which found that the VR condition group learned less than the desktop condition group (p. 233). Although this pilot study found no statistically significant differences between learning outcomes across the condition groups, it did identify a strong trend of a difference between configurations, and statistically significant correlations of emotions by condition which show increased immersive features impact emotions related to positive learning outcomes; see Tables 6-8 and statistically significant correlations.

Next, this pilot study contributes to the body of knowledge shaped by studies focused on spatial knowledge acquisition. The König et al. (2021), Dong et al. (2022), Hejtmanek et al. (2020), and Waller et al. (1998) studies each evaluated learning outcomes or performance outcomes associated with spatial knowledge acquisition across various condition groups exposed to various levels of immersion. It is worth reiterating several points from each of these studies to highlight the similarities with this pilot study. The Dong et al. (2022) study compared a VR equipped condition group to a live condition group, and incorporated sketch mapping to aid in measuring performance (pp. 230-231). The Hejtmanek et al. (2020) study compared a VR supported by ODT condition group against a live and desktop configuration while the Waller et al. (1998) study utilized six condition groups with varying levels of immersive characteristics from a map trained group to a live trained group (p. 479; pp. 135-136). Lastly, this study contributes to the body of knowledge concerning spatial knowledge gains in VEs. Many studies use VEs which model fictional locations or indoor environments, such as a campus building, to study spatial knowledge acquisition (Billinghurst & Weghorst, 1995; Dong et al., 2022; Hejtmanek et al., 2020). Unlike these studies, this pilot study uses a VE modeled after a real-world outdoor environment, the Virtual UCF Arboretum, thus expanding the types of environments studied (The University of Central Florida (UCF), n.d.).

Although this pilot study shares many similarities with studies concerning different focuses, this pilot study is unique because it incorporated the Infinadeck ODT, a novel configuration, which allows for natural walking in any direction at various walking speeds, and explicitly analyzed the impact of immersion on learning outcomes by task type (complicated vs.

complex) (Infinadeck, n.d.). Other studies have incorporated ODTs, such as the Cyberith Virtualizer and the Virtuix Omni, however these configurations do not allow for natural walking. Rather they simulate walking by having users slide their feet across a surface to move through the VE (Hejtmanek et al., 2020, pp. 481, 485; Omni by Virtuix, 2022; Wehden et al., 2021, p. 10). The Infinadeck, on the other hand, “allows users to naturally walk in any direction” (Infinadeck, n.d.). Since the Infinadeck allows natural walking, it is clearly more immersive-embodied than other ODTs due to the higher interaction fidelity and embodied presence it provides.

Another note worth mentioning involves the ODT group and VR group participants. Two VR group participants stated on post-survey question 14 (additional thoughts) that they felt sick or nauseous due to their VE interaction. However, one ODT group participant stated,

> [b]eing able to physical [*sic*] walk really helped, I tend to get motion sick after 10-15 mins of VR joystick movement.

This same participant spent 54 minutes in the ODT VE. Perhaps the higher interaction fidelity provided by the Infinadeck ODT could have lessened or prevented the VR/cyber sickness felt by the two VR group participants. In a future study, it would be interesting to compare a VR condition group against an ODT condition group to measure the impact of cyber/VR sickness.

This pilot study expands the knowledge base concerning the impact of combined immersion and embodiment system configurations on learning outcomes by specifically examining the type of task involved. It seems complex tasks (e.g., communicating geospatial information to an unknown person) are better suited to higher levels of combined immersive-embodied systems (VR and ODT) while complicated tasks (e.g., learning plant names/declarative information) are better suited for lower immersive and lower embodied (desktop) or high immersive and high embodied systems (ODT). This pilot study's findings support the notion that a task's type matters when selected for pairing with a technological configuration in pursuit of learning outcomes. Operationalized properly, these findings could save simulation-based training system developers and customers time and money by allowing them to bypass the incorporation of mundane complicated tasks into their training systems. More importantly, this information could lead to better trained Soldiers or system users by ensuring training systems are geared towards teaching appropriate tasks. Dieker et al. (2014) captures this point while describing the role of simulations in teacher education, "[i]f the ultimate target for the field of teacher education is to affect student learning outcomes through effective teacher preparation, the aim of evolving simulated environments should be directed toward specific performance targets" (p. 22). The remainder of this section focuses on this pilot study's limitations and offers recommendations to improve future iterations.

Pilot Study Limitations

Physically executing this pilot study shed light on its multiple limitations. Addressing these points during research design would lead to a higher quality and more efficient study if applied to future iterations.

- Since this pilot study's sample was a sample of convenience, due to only UCF students being included, future iterations of this study should cast a wider net when recruiting participants to improve the generalizability of findings. Additionally, the number of participants should be dramatically increased to enhance the statistical power of the overall study. As previously mentioned, this pilot study's small sample size likely clouded the statistical test's results (Siegel and Castellan, 1988, p. 210).

- The data collection process did not incorporate a think aloud protocol. Incorporating this technique would enable the collection of more fine grain data concerning participant affective states and feelings concerning their respective technical configurations. Although I was not recording observational data during the study's execution, it was obvious the experimental conditions 'talked to themselves' more often than the control condition. Perhaps the experimental conditions 'talked to themselves' more because they were more immersed and felt more alone despite being in the room with the researcher.
- A limited number of participants in each condition group had to restart their VE interactions due to various participant actions and un-forecasted technical difficulties. I do not believe these 'restarts' disrupted participant performance or test results. A procedure should be developed and standardized to address these types of occurrences.
- Although measures were taken to ensure participant VE-interactions were as similar as possible, the data windows provided by the VE with information such as plant names did not remain static once open in the VR-headset supported by ODT condition group. This group could open an informational window and continue walking with the window moving along with them while the other conditions had to stand and wait for these windows to fully open and load to read them. This occurrence should be resolved in future iterations of the experiment to mitigate a potential confounding variable.
- This pilot study includes a single hypothesis; I recommend future iterations of this study incorporate at least two. One should focus on the outcomes associated with

complex tasks while the other should focus on outcomes associated with complicated tasks. Organizing hypotheses in this manner would allow for more fine-grained analysis.

Future Experiment Improvements

Since this study's experiment was a pilot study, it was important to capture points of improvement during execution for incorporation into future iterations/expansions of this experiment. The following improvements fall into categories related to survey and test instruments, participant instruction, and the VE.

Survey and Test Instruments

- Incorporate a post-test section which allows participants to draw the plants they found in the VE to provide another means of identifying what they found rather than simply listing plant names.
- Incorporate a pre and post-test section which allows participants to pair the names of plants with plant pictures. The provided word-bank should include more plant names than plant pictures provided to enhance the accuracy of participant answers. The word-bank could also include the names of plants which are not native to central Florida or found in the VE.
- Incorporate a post-test section which allows participants to list facts they learned in the VE located in the educational story sections of the information windows which populate once a plant is clicked on in the VE.
- Add a question to the post-survey which asks participants about their sense of time in the VE. The question should ask if participants felt they were in the VE longer or

shorter than they thought. The answer to this question could shed light on a participant's level of engagement and/or immersion. Hayes et al. (2013) explain losing track of time can be associated with the concept of flow and suggest flow can result from high immersion (p. 26). See Appendix A for more information about flow.

- Add a question which asks participants about whether they felt like they were actually walking up and down hills/inclines in the VE. The answer to this question could provide evidence as to which technical configuration was the least/most immersive.

Participant Instruction and Supporting Protocol Design

- Incorporate a process to periodically inform participants how long they are in the VE. Throughout the experiment's execution, this question was asked multiple times. Providing these updates would allow participants to focus on their experimental tasks rather than preoccupy themselves with thinking about how long they were in the VE. I believe they asked this question because I requested they spend at least 30 minutes in the VE.
- Build a step into the experiment's execution which ensures the researcher checks test and survey documents before participants move to the next phase of the experiment. During the pilot study, one participant did not provide demographic information. Since I did not check the document once the participant was complete, I cannot be sure if this omission was intentional or a simple mistake.
- To the greatest extent possible, test participants independently of one another. Executing the experiment in this manner will eliminate the confounding variable of participants 'pacing' themselves based on what other participants are doing during the experiment. One set of participants conducted the experiment at the same time in

clear view of one another and completed their VE interactions after the same duration of time. Running these participants through the experiment independently would eliminate this situation entirely.

- This pilot study was designed to prevent participants from taking their own notes during VE interactions. To eliminate confusion, specify during participant instructions that there will be no note taking during the experiment's execution. However, on post-surveys, multiple participants (3/15) stated they would have liked to have been able to take their own notes.
- Incorporate a technical demonstration in the VE that is not at the same location as the participants' starting point upon entering the VE. This neutral location would eliminate any bias concerning which direction participants initially headed upon entering the VE.
- During participant instructions, highlight the purpose of the experiment is to evaluate learning gains and that it is fine if participants do not already know the material before starting the experiment. I suspect participants felt pressure during the pre-test if they were unfamiliar with the experiment's educational content. A contributing factor to the selection of the experiment's educational content was that I suspected it was not common knowledge.
- Add a Real-World and AR condition group which visit and interact with the actual UCF Arboretum instead of the VE. The incorporation of these condition groups would further solidify the evidence generated by this study since it would, by default, include more immersive condition groups and arguably the most immersive. By

comparing these five condition groups, it would become clear which technical configuration best compares to learning in the real-world environment.

- To allow for a more in-depth examination of learning outcomes, this study should add a longitudinal aspect concerning the testing of participants. For example, run the study as described in this document, but add a step where each participant retakes the same post-test 30-60 days following their initial VE interaction and post-test. I would expect this additional step to further accentuate the differences in learning outcomes achieved by each condition group. If more immersive configurations lead to more detailed memories due to their increased embodiment and interaction fidelity features and affective impact, these more detailed memories should lead to increased test scores.
- One VR participant stated on post-survey question 13 (what could have improved your learning experience) that wearing glasses made wearing the headset difficult. Perhaps this challenge should be acknowledged in the recruitment message to better enable people to decide whether or not they should volunteer to participate.
- Develop a story which provides information about why the participant is entering the VE. This story should provide some form of objective which increases the affective impact of their VE interaction (Hughes et al., 2005, p. 24). Perhaps the participant is helping someone complete a homework assignment before they run out of time by finding the specific location of flowers and plants. Written properly, this story could make the interaction more pleasurable and engaging for the participant (Hayes et al., 2013). Increased engagement by all participants could assist in emphasizing differences between learning outcomes across condition groups.

Virtual Environment

- Update the experimental design and supporting VE to record distance traveled by participants in each condition group. Once collected, this data could be reviewed to determine correlations between distance traveled and learning outcomes in each condition group.
- Update the VE to allow participants to click on and learn about wildlife in the VE such as the fish and birds. Participant 2 made this recommendation in post-survey question 13 (what could have improved your learning experience).
- Update the information windows which appear once an object is selected to include the option for the text information to be played aloud via an audio clip. Two participants inferred this as a desired feature in response to post-survey question 13 (what could have improved your learning experience). This feature supports the notion that people may learn more efficiently when multiple modalities are stimulated simultaneously (e.g., visual and audio stimulation so participants could look at the plants while hearing information about them) (Mayer, 2008, pp. 765-766).
- Several participants (4/15) stated or suggested in response to post-survey question 13 (what could have improved your learning experience) or question 14 (additional thoughts) that the text in informational windows was difficult to read because it was either too small and/or blurry. One participant recommended that users be able to move information windows closer to the user for easier viewing. This issue was only mentioned by participants in the VR or ODT condition group.

CHAPTER SIX: CONCLUSION

Although the results of the Kruskal-Wallis statistical test did not find learning outcomes between condition groups to be statistically different, these results do not mean that they are not. The results did display a very strong trend $H(2) = 5.798$, $p = .055$ for question 1 (list plants) when question 1's post-test raw scores are compared by condition. This trend lies between the desktop and VR conditions with the desktop condition achieving a higher mean rank concerning scores. The small sample size involved with this pilot study may have reduced the ability to detect a difference in a statistical test (Siegel and Castellan, 1988, p. 210). We must remain open to the fact with a larger sample, the distributions may become normal and tighter and show a significant difference. A larger sample would increase the statistical power and potentially result in a normal data distribution which permits the use of a parametric t-test of means needed to answer this question with confidence. Graphical representations of the data combined with quantitative, qualitative, and correlational data suggest a larger sample size would permit a more conclusive analysis and evaluation. This data indicates overall learning outcomes skew positively with increased immersion and embodiment (see Figure 12), learning outcomes are affected by the pairing of task type (complicated vs. complex) and various levels of immersion (see Figures 9, 10, and 11), and emotional factors which contribute to learning share a positive relationship with increased immersion and embodiment.

Concerning overall learning outcomes, the data distribution of total raw score changes from the pre-test to post-test for questions 1, 2, and 3 highlights the data's overall trend in variance; see Figure 12. The data or scores are skewed higher in accordance with configurations with increased immersion.

Visualizations of data distributions also indicate the pairing of task type and level of immersion-embodiment influence learning outcomes. Specifically, the boxplots depicted by Figures 9 and 10 suggest declarative knowledge or complicated tasks are better acquired or achieved by either the desktop condition (lowest level of immersion-embodiment) or the ODT condition (the highest level of immersion-embodiment). These figures suggest the VR condition is the worst for this type of task/knowledge. Additionally, post-test question 3's (draw sketch map) scores suggest more immersive technological configurations (VR and ODT) are more suitable for situational awareness or complex tasks; see Figure 11. Furthermore, although the score differences were not statistically significant, the mean scores per condition group are increasing in accordance with the increased immersion offered by each respective technological configuration concerning question 3 (draw sketch map); see Table 3. With higher power it would be interesting to see how the distributions compare by condition.

Five statistically significant correlations related to learning outcomes were found. There is a moderately strong positive correlation between presence and condition groups, $r_s(13) = .541$, $p = .037$. Put simply, the feeling of presence increases as the level of immersion produced by each condition's respective technological configuration increases. Next, there is a moderately strong correlation between the feeling of immersion and ease of learning, $r_s(13) = .599$, $p = .018$. Thirdly, there is a very strong positive correlation between level of immersion and curiosity stimulation, $r_s(13) = .759$, $p = .001$. Lastly, there is a very strong positive correlation between the feeling of immersion and engagement, $r_s(13) = .793$, $p = <.001$, as well as the feeling of immersion and imagination stimulation, $r_s(13) = .694$, $p = .004$. If more immersive configurations create elevated feelings of presence and immersion, and increased immersion positively influences factors which contribute to learning outcomes, it should be expected that more immersive configurations will lead to increased learning outcomes. These emotional reactions, that by themselves the Army should pay attention to as factors in learning and decision response to situations, could also activate episodic memory which could improve long-term memory retention (Cherry, 2022; Hughes et al., 2005, pp. 24-25; Patton, 1931, p. 79).

The results described should better enable U.S. Army senior leaders to decide if dismounted infantry Soldiers would benefit from a more immersive simulation-based training capability as the Army transforms into the Multi-Domain Army of 2035 supported by the development of the STE capability. These senior leaders should walk away from this study knowing the following points. First, the impact of immersion and embodiment appears to positively influence learning outcomes. Second, a technological configuration's associated level of immersion and a task's type matters because this pairing can affect learning outcomes. Complicated tasks appear to be best suited for low or highly immersive systems and complex tasks appear to be best suited for more immersive configurations. Lastly, increased immersion and embodiment shares a positive and statistically significant relationship with emotional factors which contribute to learning (i.e. ease of learning, curiosity and imagination stimulation, and engagement). The relationship between these variables could result in better memory retention or learning.

This pilot study expands the knowledge base focused on determining the impact of combined immersion and embodiment on learning outcomes. Concerning future work, I have two recommendations. First, I recommend running a larger iteration of this study with sufficient statistical power which adds a longitudinal repeated measures aspect to the post-test to measure long-term memory retention. Next, I recommend revising the pre and post-test instruments to measure complicated and complex learning tasks more precisely. Fielding a more immersive simulation-based training capability could lead to dismounted infantry Soldiers who are better prepared for the complex battlefields of the future; the data indicates technical configurations that enhance immersive-embodied experiences are positively correlated with emotions largely recognized to enhance long-term memory retention.

APPENDIX A: ADDITIONAL KEY TERMS

engagement: “a voluntary behavioral, emotional, and cognitive experience of presence, interest, and participation that results in pleasurable learning experiences” (Hayes et al., 2013, p. 26).

fidelity: “the degree to which the virtual environment is indistinguishable from the real environment or the degree of similarity between a simulator and the environment being simulated” (Stevens et al., 2015, p. 524).

flow: “a cognitive state where one is completely immersed in an activity—from painting and writing to prayer and surfboarding. It involves intense focus, creative engagement, and the loss of awareness of time and self” (Psychology Today, 2023, para. 1). Achieving flow can be enjoyable (Kahneman, 2013, pp. 40-41).

situational awareness: “is knowledge relevant to the task being performed” (Gawron, 2019, p. 135). Situational awareness includes three tiers: “Level 1, perception of the elements in the environment; Level 2, comprehension of the current situation; and Level 3, projection of future status” (Gawron, 2019, p. 135).

spatial knowledge acquisition: act of gathering information about the environment which enables the development “of a cognitive map of their surroundings” (Dong et al., 2022, p. 227). A “way” for humans to acquire spatial knowledge is direct wayfinding (Dong et al., 2022, p. 227).

transfer: “the application of knowledge, skills, and abilities acquired during training and applied to the environment in which they are normally used” (Stevens et al., 2015, p. 523).

APPENDIX B: IRB APPROVAL

UCF
UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

APPROVAL

June 3, 2022

Dear Fred Martin Jr:

On 6/3/2022, the IRB reviewed the following submission:

Type of Review:	Initial Study, Expedited Categories 4 and 7
Title:	Pilot Study: Improving Small Unit Dismounted Infantry Simulations Training
Investigator:	Fred Martin Jr
IRB ID:	STUDY00004289
Funding:	None
Grant ID:	None
IND, IDE, or HDE:	None
Documents Reviewed:	• HRP-502_Fred_Martin_Consent_Document_Adult5.31.22 (2).pdf, Category: Consent Form; • HRP-503_Protocol_Fred_Martin, Category: IRB Protocol; • IRB_Fred_Martin_Confirmation_Email.docx, Category: Recruitment Materials; • IRB_Fred_Martin_Recruitment_Email.docx, Category: Recruitment Materials; • IRB_Fred_Martin_Study_Script.docx, Category: Other; • IRB_Fred_Martin_Survey&Test_Instruments.docx, Category: Test Instruments;

The IRB approved the protocol on 6/3/2022. Use of the stamped, dated consent form is required.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. Guidance on submitting Modifications and a Continuing Review or Administrative Check-in is detailed in the manual. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Renea Carver
Designated Reviewer

APPENDIX C: MEASUREMENT INSTRUMENTS

ID Number:
Date:
Time:

Pre-Survey (Page 1)

1. **Age of adult participant**: _______________

2. **Gender: (M | F | Non-binary | Choose to self-describe)**: __________________
3. **What state or country are you from**? _________________________________

4. **How "interested" are you in learning about plants, flowers, and vegetation in general?**

1	2	3	4	5	6	7
Extremely Uninterested	Uninterested	Somewhat Uninterested	Undecided	Somewhat Interested	Interested	Extremely Interested

5. **How "interested" are you in learning about natural communities/habitats in general?**

1	2	3	4	5	6	7
Extremely Uninterested	Uninterested	Somewhat Uninterested	Undecided	Somewhat Interested	Interested	Extremely Interested

6. **How would you rate your level of knowledge about plants, flowers, vegetation, and natural communities/habitats native to central Florida?**

1	2	3	4	5	6	7
Not Knowledgeable	Far Below Average Knowledge	Below Average Knowledge	Average Knowledge	Above Average Knowledge	Far Above Average Knowledge	Extremely Knowledgeable

7. **Have you ever visited the UCF Arboretum?**
   - ☐ **yes**
   - ☐ **no**

8. **Have you ever visited/interacted with the UCF Virtual Arboretum through a computer or virtual reality device?**
   - ☐ **yes**
   - ☐ **no**

9. **Are you generally susceptible to virtual, cyber, or motion sickness?**
   - ☐ **yes**
   - ☐ **no**

ID Number:
Date:
Time:

Pre-Survey (Page 2)

10. How would you rate your ability to draw?

1	2	3	4	5	6	7
No Ability	Below Average Ability	Somewhat Below Average Ability	Average Ability	Somewhat Above Average Ability	Above Average Ability	Extreme Ability

11. How would you rank the following technological configurations in terms of their 'immersiveness'? (5 most immersive, 1 least immersive)
___Desktop with Mouse and Keyboard
___Virtual Reality Headset with Handheld Controllers
___Virtual Reality Headset with Handheld Controllers supported by an Omnidirectional Treadmill
___A well written novel
___A movie at a movie theater

12. Which of the following systems do you think you would learn 'more' with if the subject matter was as similar as possible between each of the systems? (5 most learning, 1 least learning)
___Desktop with Mouse and Keyboard
___Virtual Reality Headset with Handheld Controllers
___Virtual Reality Headset with Handheld Controllers supported by an Omnidirectional Treadmill
___A well written novel
___A movie at a movie theater

13. Do you think you would learn more from a more immersive technological configuration such as a Virtual Reality headset versus a desktop computer with software dedicated to the same topic? Why or why not?

14. Do you think you can learn to navigate a real-world space you have never visited by training with a software application? Why or why not?

ID Number:
Date:
Time:

Pre-Test

1. **Please list the names of all the plants and flowers you know that are native to central Florida:**

2. **Please list the names of all the natural communities/habitats you know that are native to central Florida:**

ID Number:
Date:
Time:

Post-Test (Page 1)

1. **Please list the names of all the plants and flowers you know that are native to central Florida:**

2. **Please list the names of all the natural communities/habitats you know that are native to central Florida:**

ID Number:
Date:
Time:

Post-Test (Page 2)

3. Below, hand draw/sketch a map for someone 'unfamiliar' with the Virtual UCF Arboretum that enables them to find the plants, flowers, and natural communities/habitats you listed in the previous questions. Be as detailed as you like.

ID Number:
Date:
Time:

Post-Survey (Page 1)

1. **How easy was it to "learn" in your experience?**

1	2	3	4	5	6	7
Not Easy At All	Difficult	Somewhat Difficult	Neutral	Somewhat Easy	Easy	Extremely Easy

2. **How "engaging" was your experience?**

1	2	3	4	5	6	7
Not Engaging At All	Not Engaging	Somewhat Not Engaging	Neutral	Somewhat Engaging	Engaging	Extremely Engaging

3. **How "realistic" was your experience?**

1	2	3	4	5	6	7
Not Realistic At All	Unrealistic	Somewhat Unrealistic	Neutral	Somewhat Realistic	Realistic	Extremely Realistic

4. **How much was your "imagination" stimulated?**

1	2	3	4	5	6	7
Not Stimulated At All	Not Stimulated	Somewhat Not Stimulated	Neutral	Somewhat Stimulated	Stimulated	Extremely Realistic

5. **How much was your "curiosity" stimulated?**

1	2	3	4	5	6	7
Not Stimulated At All	Not Stimulated	Somewhat Not Stimulated	Neutral	Somewhat Stimulated	Stimulated	Extremely Realistic

ID Number:
Date:
Time:

Post-Survey (Page 2)

6. **How strong was your feeling of "immersion"?**

1	2	3	4	5	6	7
Not Immersed At All	Not Immersed	Somewhat Not Immersed	Neutral	Somewhat Immersed	Immersed	Extremely Immersed

7. **To which extent do you feel present in the virtual environment, as if you were really there?**

1	2	3	4	5	6	7
Not Present At All	Not Present	Somewhat Not Present	Neutral	Somewhat Present	Present	Extremely Present

8. **How much do you want to visit the 'real' UCF Arboretum now?**

1	2	3	4	5	6	7
No Desire At All	No Desire	Somewhat No Desire	Neutral	Somewhat Desire	Desire	Extreme Desire

9. ***If you used a VR option, how important is the detail of the terrain for your learning?***

1	2	3	4	5	6	7
Not Important At All	Not Important	Somewhat Not Important	Neutral	Somewhat Important	Important	Extremely Important

10. **How "interested" are you in learning about plants, flowers, and vegetation now?**

1	2	3	4	5	6	7
Extremely Uninterested	Uninterested	Somewhat Uninterested	Undecided	Somewhat Interested	Interested	Extremely Interested

ID Number:
Date:
Time:

Post-Survey (Page 3)

11. **How "interested" are you in learning about natural communities/habitats now?**

1	2	3	4	5	6	7
Extremely Uninterested	Uninterested	Somewhat Uninterested	Undecided	Somewhat Interested	Interested	Extremely Interested

12. **How would you rate your level of knowledge about plants, flowers, vegetation, and natural communities/habitats native to central Florida now?**

1	2	3	4	5	6	7
Not Knowledgeable	Far Below Average Knowledge	Below Average Knowledge	Average Knowledge	Above Average Knowledge	Far Above Average Knowledge	Extremely Knowledgeable

13. **What could this experiment have done differently to increase your learning experience?**

14. **If you would like, please share any additional thoughts about your experience:**

Thank you for participating!

APPENDIX D: SPSS DATA TABLE

Thesis_SPSS_Data_Input_18JAN23.sav

	ID#	Condition1_5ODT6_10Desktop11_15VR	Minutes_in_VE_Ratio	Q1.Age_Ratio	Q2Gender0_male1_female2_nonbinary3_...	Q3.State_or_Country_Nominal	Q4.Interested_learning_plants_Interval
1	1	2	24	22	0	Florida	6
2	2	2	56	30	0	US	5
3	3	2	54	24	1	US	5
4	4	2	40	23	1	Florida	5
5	5	2	27	46	0	Iowa	2
6	6	0	21	37	0	Virginia	1
7	7	0	56	40	0	Florida	1
8	8	0	56	.	.	Null	5
9	9	0	60	25	1	Florida	5
10	10	0	37	39	0	Florida	3
11	11	1	55	36	0	Virginia	5
12	12	1	32	37	1	Florida	5
13	13	1	26	24	0	Florida	5
14	14	1	42	24	1	Virginia	5
15	15	1	33	25	0	Florida	3

Thesis_SPSS_Data_Input_18JAN23.sav

	Q5.Interested_learning_habitats_Interval	Q6.Rate_own_knowledge_Interval	Q7.Visited_the_real_0_no1_yes_nominal	Q8.Visited_the_Virtual_Arb_0_no_1_yes...	Q9.Motion_sickness_0_no_1_yes	Q10.Rate_ability_to_draw_Interverval
1	7	3	0	0	0	3
2	4	4	0	0	0	2
3	5	4	0	1	1	6
4	5	2	0	0	0	4
5	2	2	0	0	0	3
6	1	2	0	0	0	1
7	1	1	1	0	0	2
8	5	3	0	1	0	3
9	7	4	0	0	0	5
10	3	1	0	0	0	2
11	5	1	0	0	0	4
12	5	3	0	0	0	3
13	5	4	0	1	0	3
14	5	3	0	0	0	6
15	4	1	1	0	0	3

Thesis_SPSS_Data_Input_18JAN23.sav

	Q11.Rank_immersiveness_forced_rank_order	DesktopRank	VRRank	VROmniRank	NovelRank
1	.	3	4	5	2
2	.	3	4	5	1
3	.	3	4	5	2
4	.	1	2	3	5
5	.	2	5	5	2
6	.	1	4	5	2
7	.	3	4	5	1
8	.	2	4	5	1
9	.	2	3	5	4
10	.	3	4	5	1
11	.	3	4	5	1
12	.	2	4	5	1
13	.	3	4	3	2
14	.	1	4	5	2
15	.	4	5	3	1

Thesis_SPSS_Data_Input_18JAN23.sav

	MovieRank	Q12.Learn_more_from_forced_rank_order	DesktopRank_A	VRRank_A	VROmniRank_A	NovelRank_A
1	1	.	3	4	5	2
2	2	.	3	4	5	2
3	1	.	3	4	5	1
4	4	.	4	2	1	5
5	3	.	2	4	5	1
6	3	.	1	4	5	2
7	2	.	4	5	1	2
8	3	.	3	5	4	2
9	1	.	4	2	3	5
10	2	.	3	4	5	1
11	2	.	5	4	2	1
12	3	.	5	4	3	1
13	2	.	4	4	4	3
14	3	.	3	4	5	1
15	2	.	4	5	3	1

Thesis_SPSS_Data_Input_18JAN23.sav

	MovieRank_A	Q13.InterviewPreSurv	Q14.InterviewPreSurv	Q1.ListFlowersRatioPreTestScore	Q2.ListCommsRatioPreTestScore
1	1	.	.	.5	2.0
2	1	.	.	2.0	2.0
3	2	.	.	.5	.5
4	3	.	.	.5	1.0
5	3	.	.	.0	.0
6	3	.	.	1.5	.0
7	3	.	.	.0	1.0
8	1	.	.	.5	.0
9	1	.	.	.5	2.0
10	2	.	.	.5	.0
11	3	.	.	1.0	1.0
12	2	.	.	.0	.0
13	3	.	.	.0	.0
14	2	.	.	.5	.5
15	2	.	.	.0	1.5

Thesis_SPSS_Data_Input_18JAN23.sav

	Q1.ListFlowersRatioPostTestScore	Q2.ListCommsRatioPostTestScore	Q3.DrawSketchMapRatioPostTestScore	Q3a.ObjectClassRatioPostTestScore	Q3b.PositionRatioPostTestScore
1	4.0	2.0	42	20	22
2	12.0	4.0	84	43	41
3	11.0	3.0	55	29	26
4	3.0	1.0	31	16	15
5	3.5	1.0	24	12	12
6	8.5	.5	30	14	16
7	8.5	2.0	28	13	15
8	11.5	2.0	18	12	6
9	19.5	3.0	56	29	27
10	8.5	3.5	24	12	12
11	7.0	1.5	54	26	28
12	4.0	.0	37	19	18
13	2.5	.0	5	4	1
14	3.5	2.0	29	13	16
15	4.0	2.5	49	24	25

Thesis_SPSS_Data_Input_18JAN23.sav

	Q1.PercentChangeScore	Q2.PercentChangeScore	PreandPostTestPercentChangeScore	PreandPostTestRawChangeS...	Q1.RateLearnInterval
1	87.50	.00	42.79	45.50	7
2	83.33	50.00	96.00	96.00	7
3	95.45	83.33	67.55	68.00	6
4	83.33	.00	30.71	33.50	5
5	100.00	100.00	28.50	28.50	7
6	82.35	100.00	35.15	37.50	3
7	100.00	50.00	35.90	37.50	2
8	95.65	100.00	29.91	31.00	7
9	97.44	33.33	75.32	76.00	7
10	94.12	100.00	34.61	35.50	6
11	85.71	33.33	59.30	60.50	4
12	100.00	.00	41.00	41.00	3
13	100.00	.00	7.50	7.50	4
14	85.71	75.00	31.60	33.50	2
15	100.00	40.00	52.80	54.00	6

Thesis_SPSS_Data_Input_18JAN23.sav

	Q2.RateEngagingInterval	Q3.RateRealisticInterval	Q4.RateImaginationInterval	Q5.RateCuriosityInterval	Q6.RateFeelingOfImmersionInterval	Q7.RatePresentInterval
1	7	7	7	7	7	7
2	5	4	5	6	5	5
3	6	7	5	6	7	7
4	6	6	6	7	7	6
5	6	6	6	7	7	7
6	2	5	1	1	1	3
7	2	4	1	5	4	5
8	7	6	6	7	6	6
9	7	6	2	7	6	5
10	5	6	5	6	5	5
11	6	6	4	6	6	4
12	5	5	4	6	5	5
13	7	6	5	5	6	6
14	5	3	2	5	3	3
15	5	5	6	6	5	5

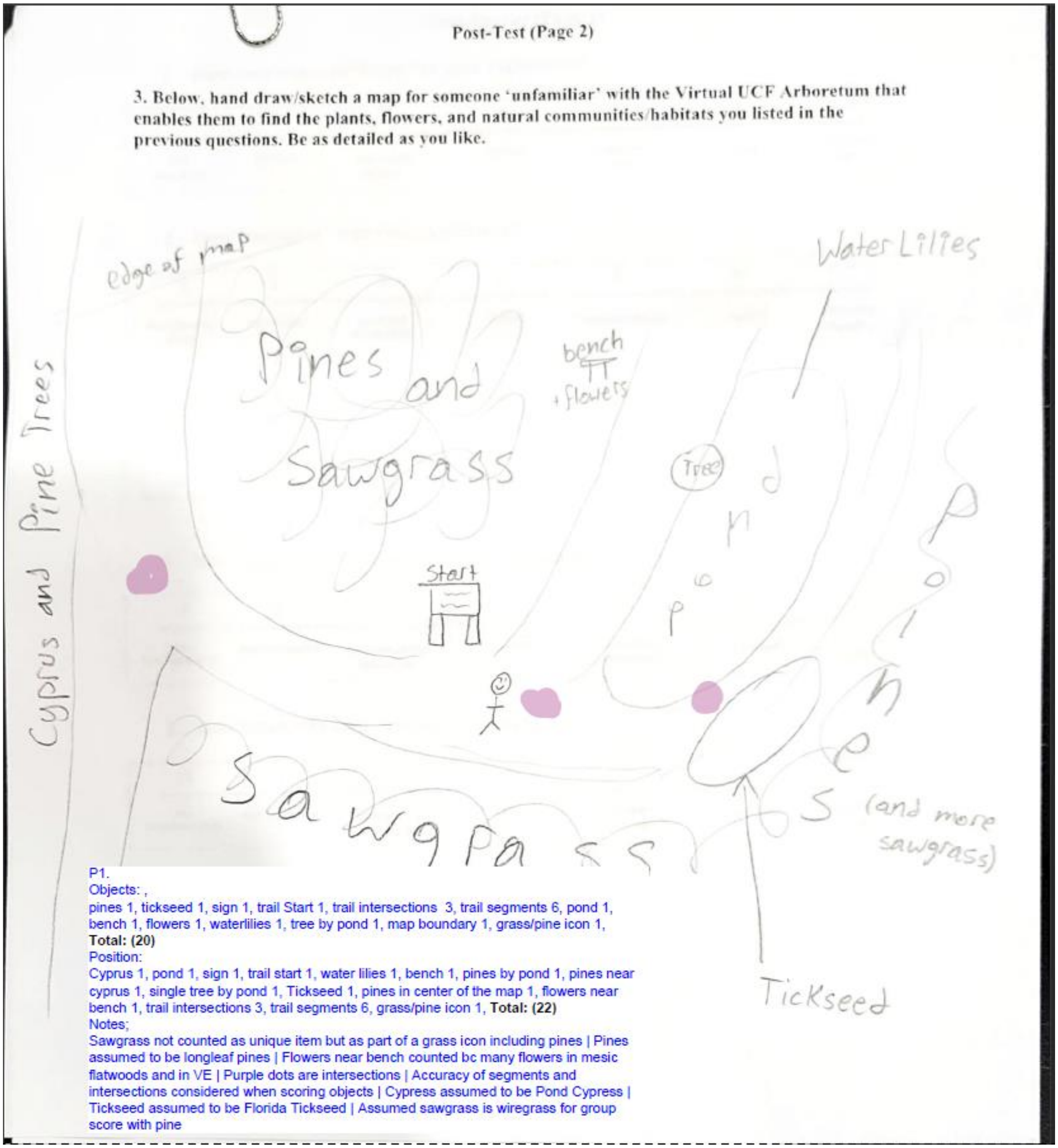
Thesis_SPSS_Data_Input_18JAN23.sav

	Q8.WantToVisitRealInterval	Q9.IfVRRateImportanceOfTerrainInterval	Q10.HowInterestedLearningPlantsNowInterval	Q11.HowInterestedLearningCommsNowInterval	Q12.RateKnowledgeNowInterval
1	7	6	7	7	4
2	6	6	7	6	5
3	6	7	6	5	5
4	5	6	5	6	3
5	2	5	2	2	4
6	1	.	1	1	3
7	5	.	2	2	2
8	6	.	6	5	4
9	7	.	5	3	5
10	5	.	4	4	3
11	7	7	5	5	2
12	5	3	5	5	4
13	5	5	5	5	3
14	5	5	5	5	4
15	7	6	6	6	3

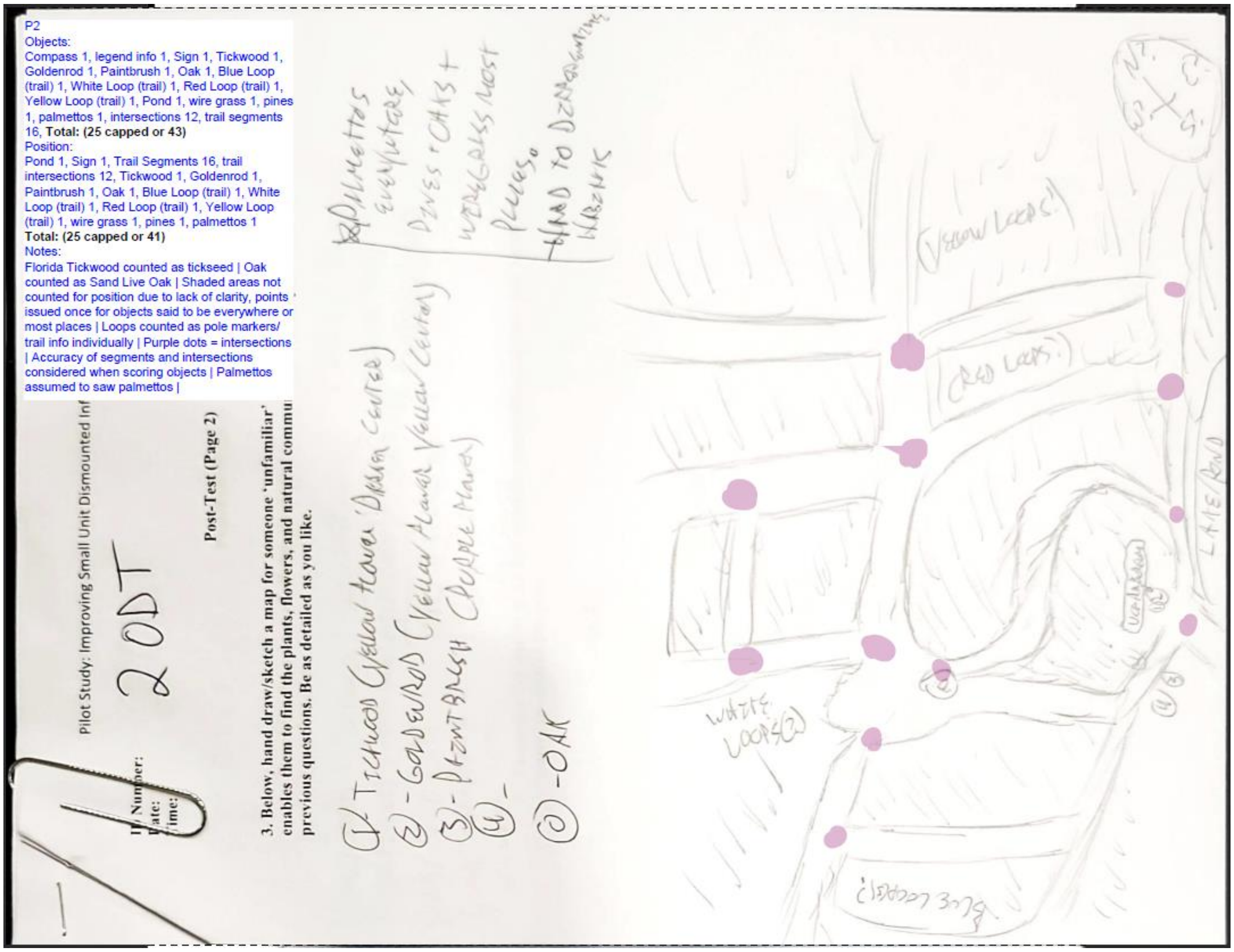
Thesis_SPSS_Data_Input_18JAN23.sav

	Q13.InterviewPostSurv	Q14.InterviewPostSurv
1	.	.
2	.	.
3	.	.
4	.	.
5	.	.
6	.	.
7	.	.
8	.	.
9	.	.
10	.	.
11	.	.
12	.	.
13	.	.
14	.	.
15	.	.

APPENDIX E: PARTICIPANT SKETCH MAPS WITH GRADING NOTES

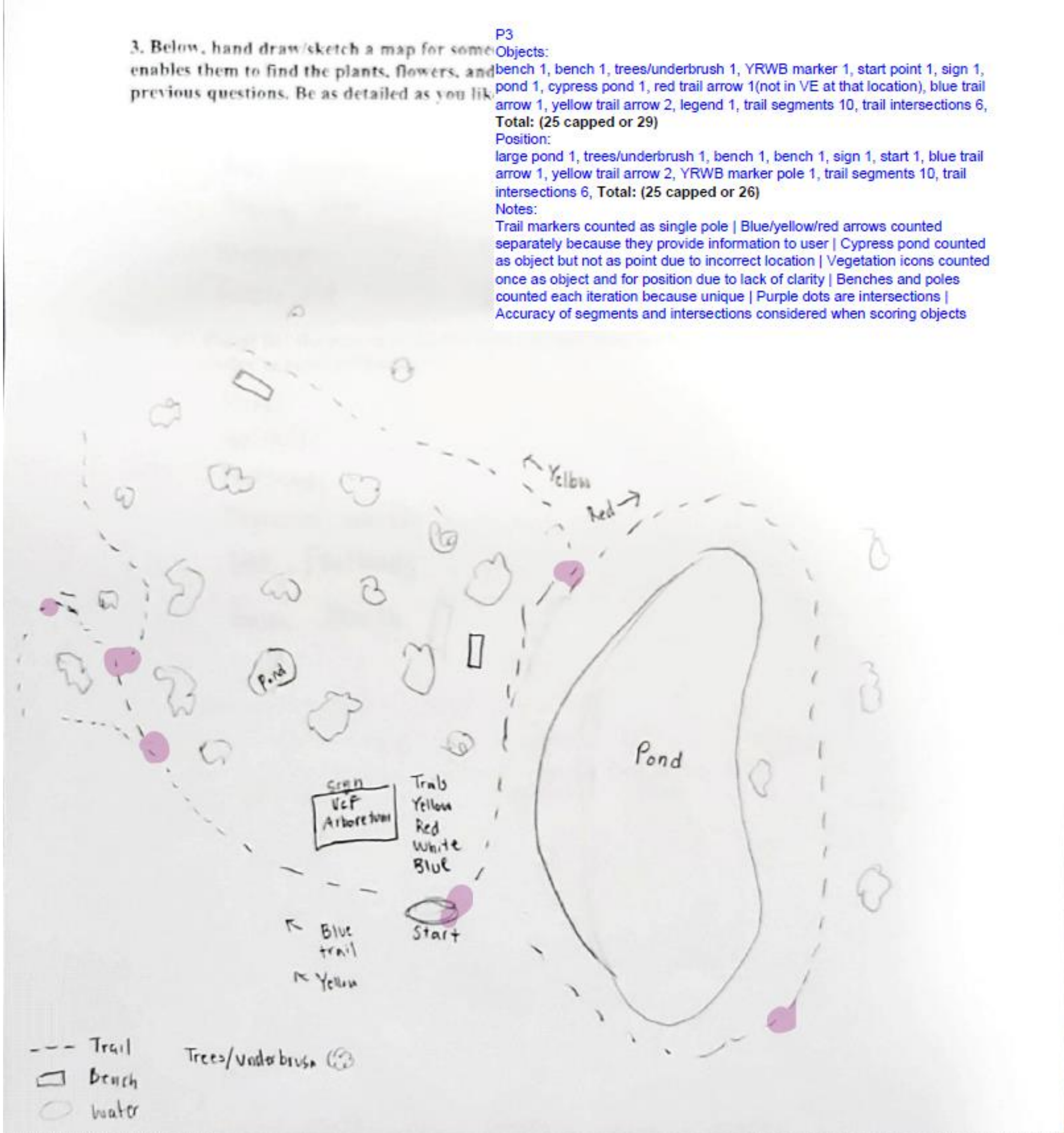


ODT Condition
Map Grading Resource: (Harrington et al., 2021)

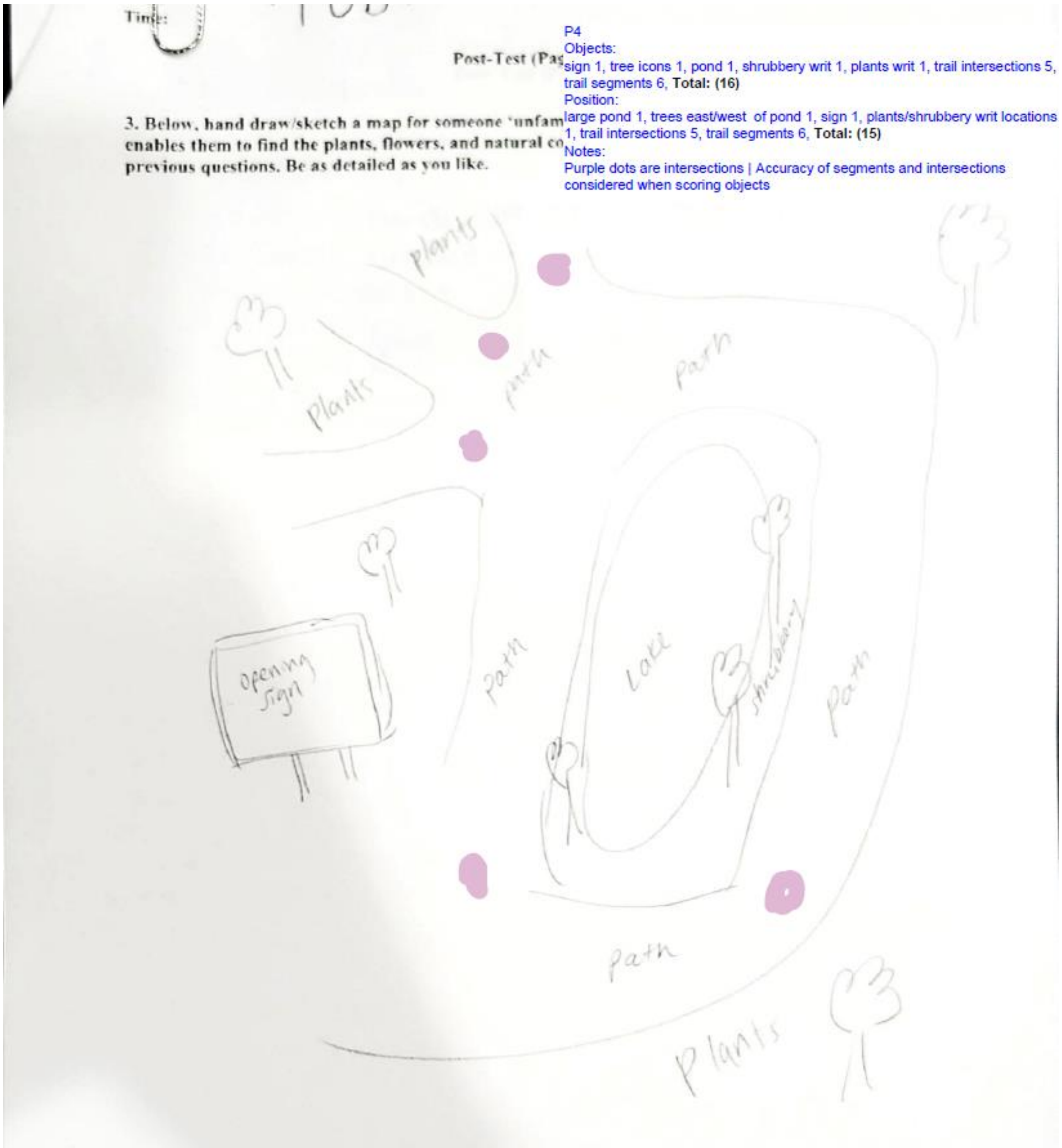


ODT Condition

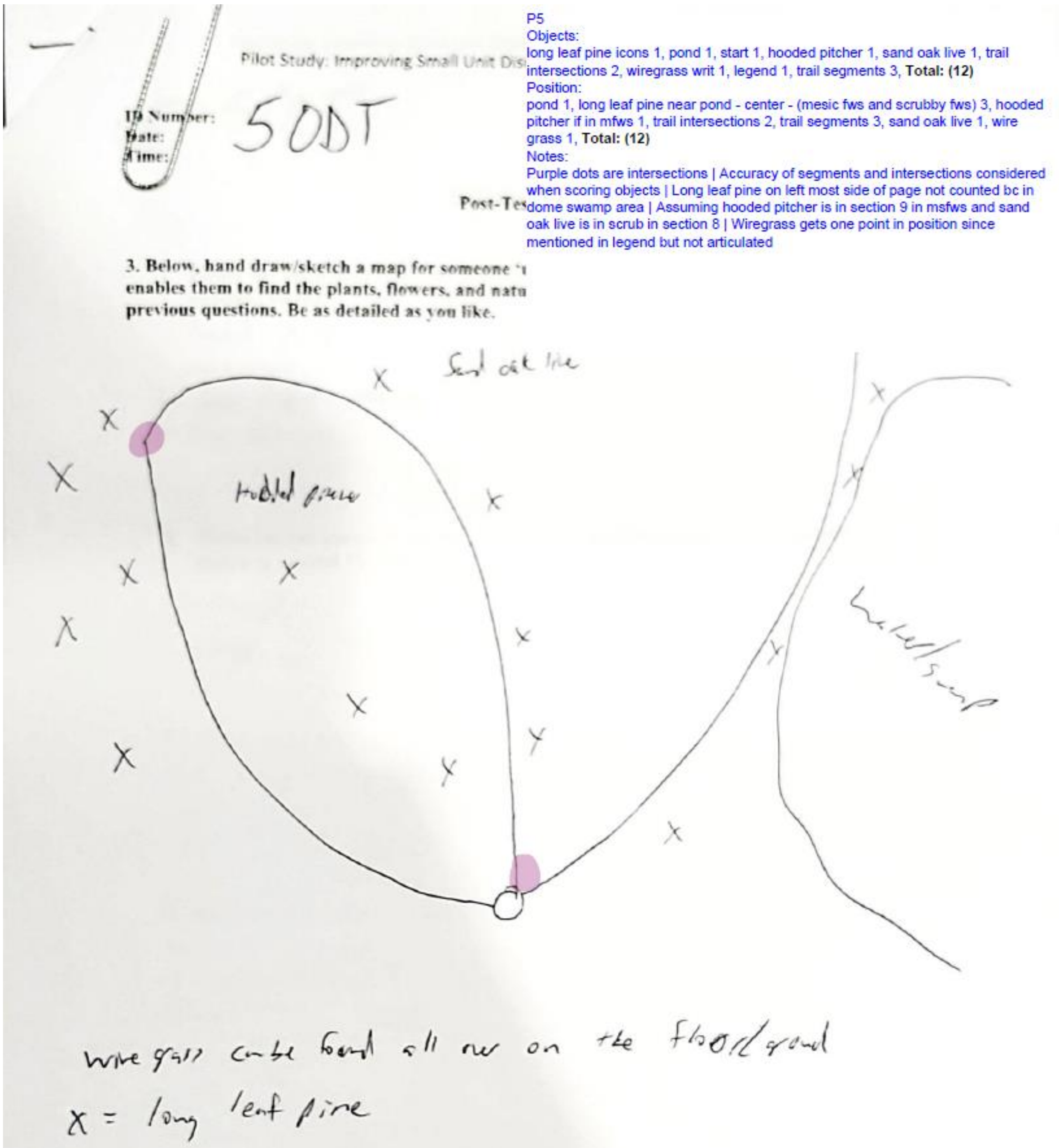
Map Grading Resource: (Harrington et al., 2021)



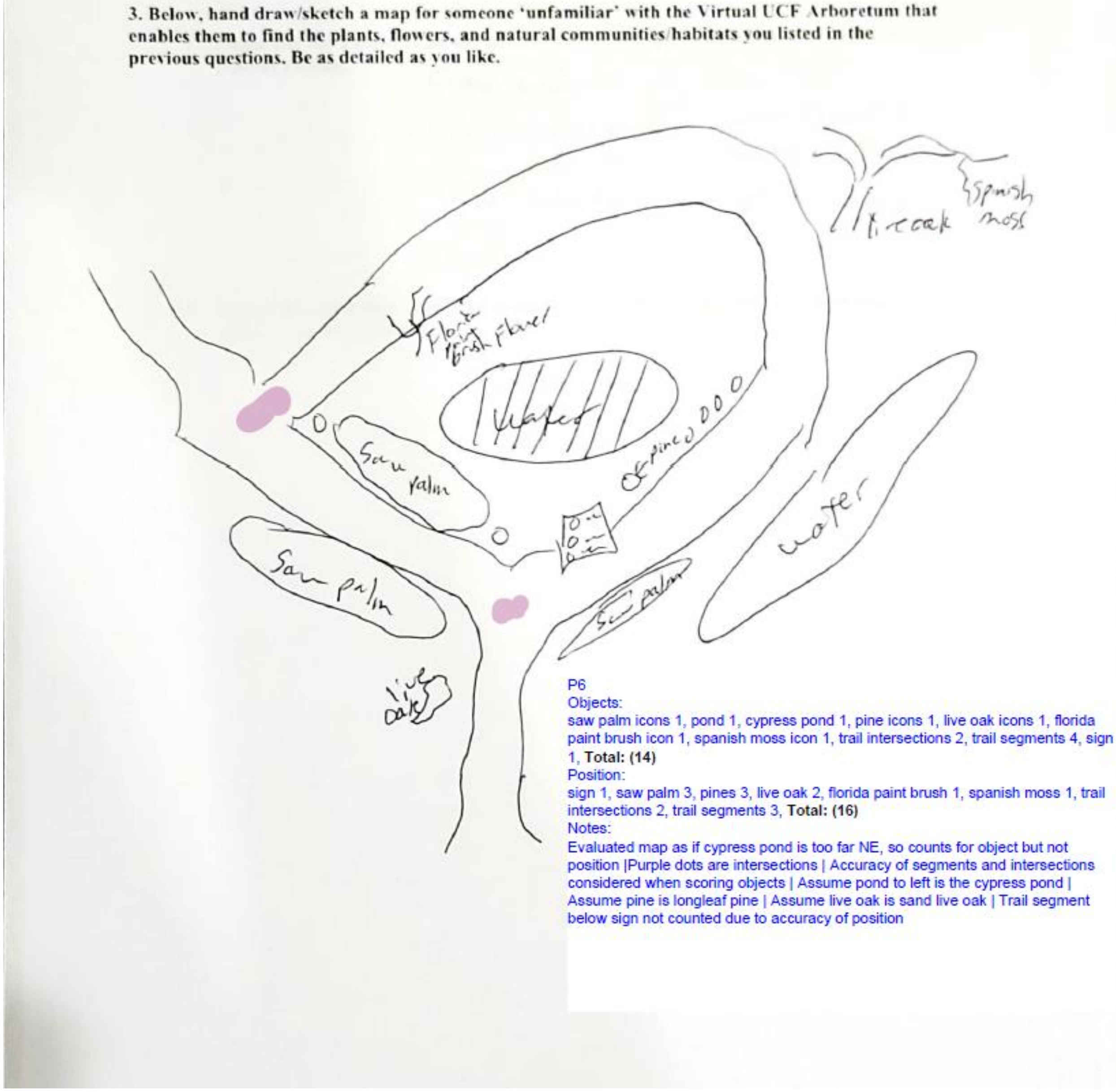
ODT Condition
Map Grading Resource: (Harrington et al., 2021)



ODT Condition
Map Grading Resource: (Harrington et al., 2021)

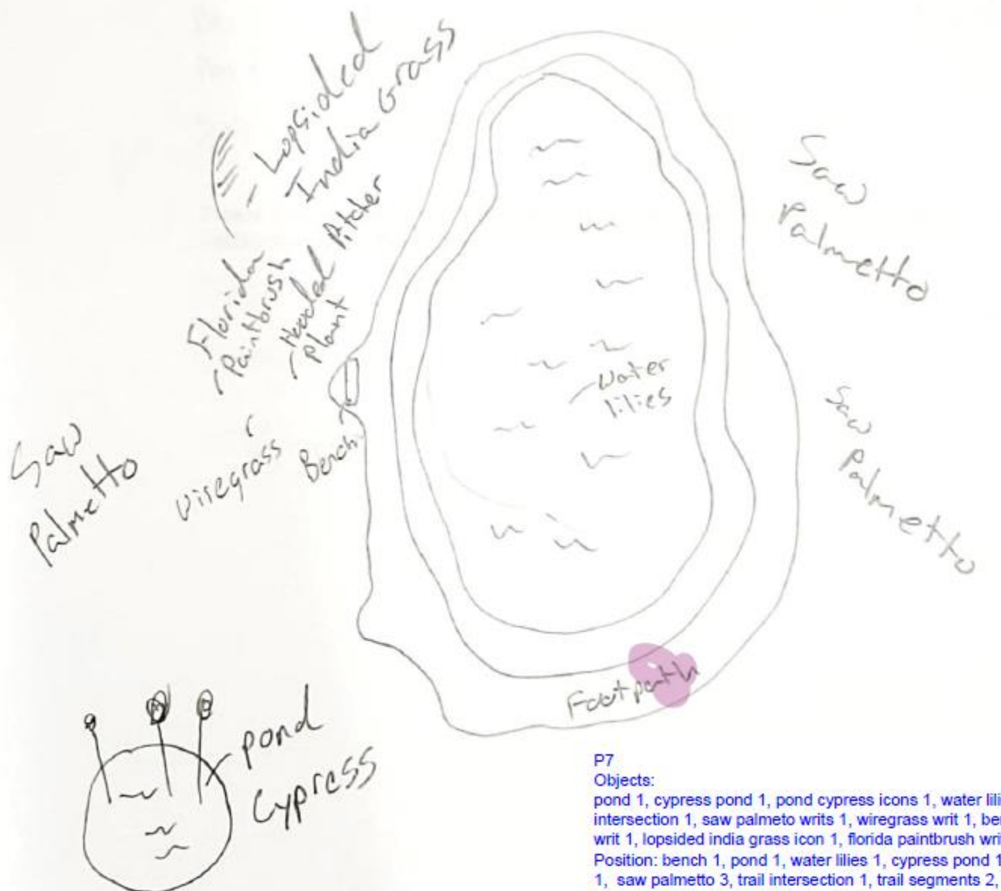


ODT Condition
Map Grading Resource: (Harrington et al., 2021)



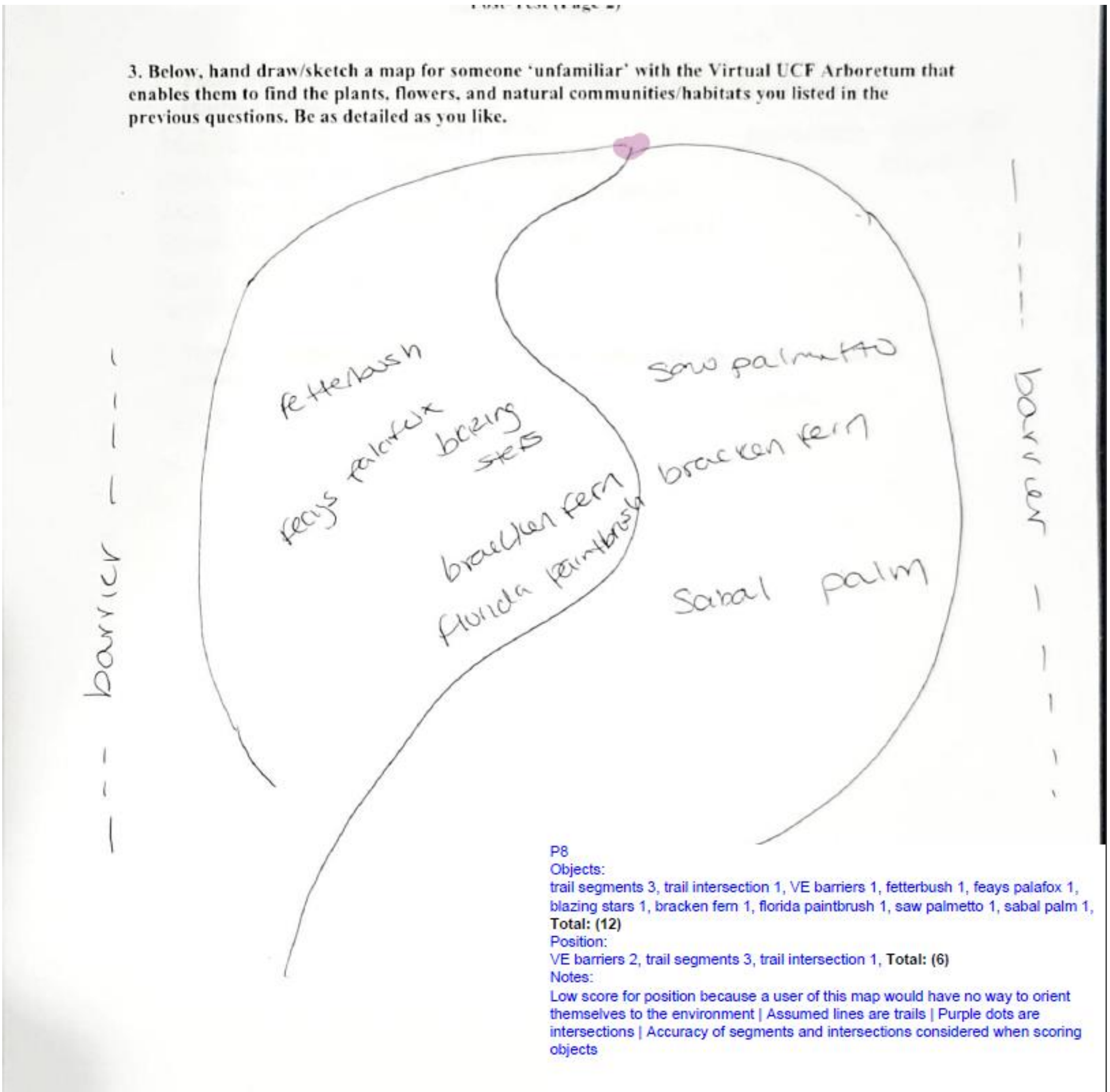
Desktop Condition
Map Grading Resource: (Harrington et al., 2021)

3. Below, hand draw/sketch a map for someone 'unfamiliar' with the Virtual UCF Arboretum that enables them to find the plants, flowers, and natural communities/habitats you listed in the previous questions. Be as detailed as you like.

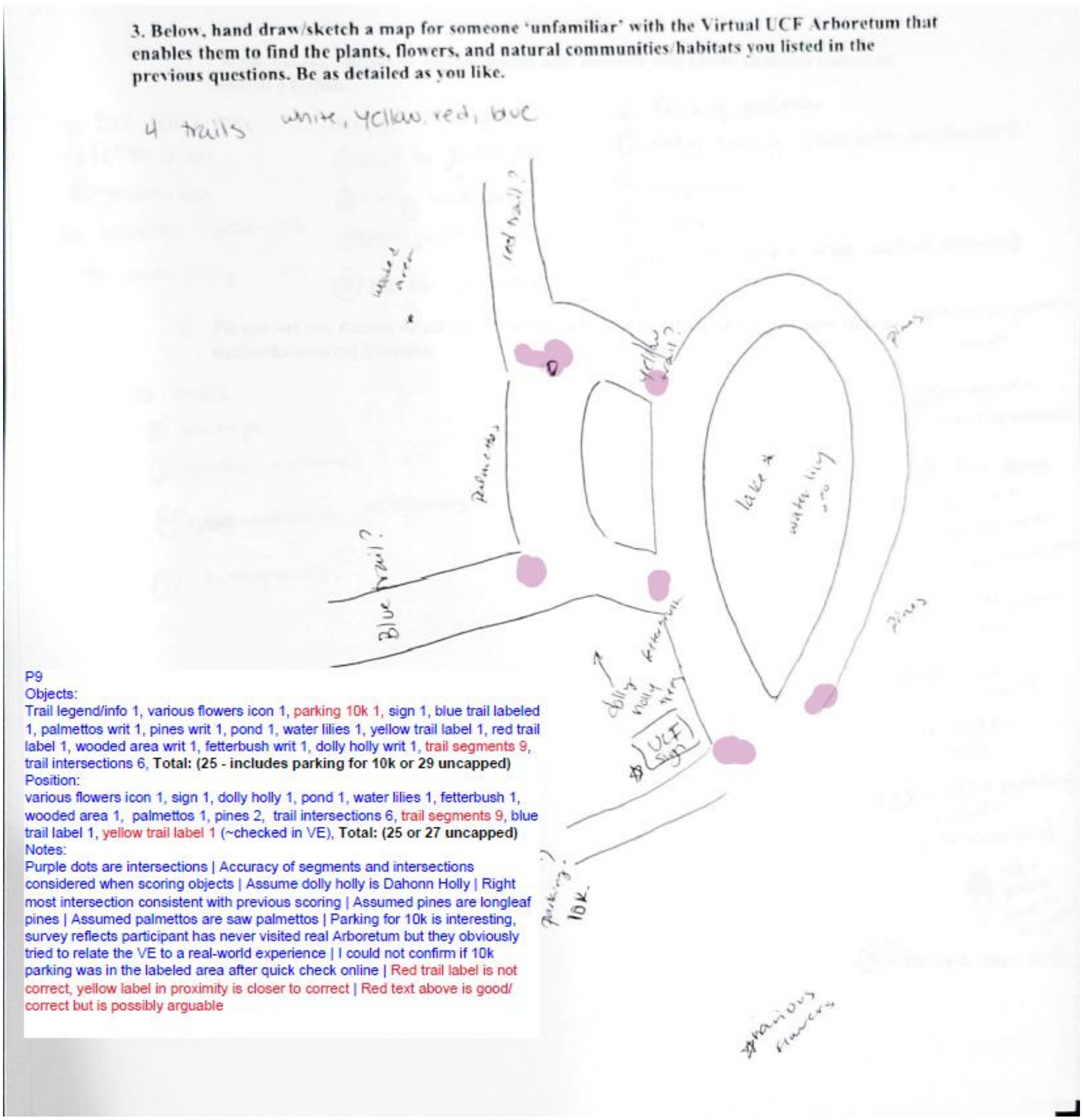


P7
Objects:
pond 1, cypress pond 1, pond cypress icons 1, water lilies 1, trail segment 2, trail intersection 1, saw palmeto writs 1, wiregrass writ 1, bench 1, hooded pitcher plant writ 1, lopsided india grass icon 1, florida paintbrush writ 1, **Total: (13)**
Position: bench 1, pond 1, water lilies 1, cypress pond 1, pond cypress tree icons 1, saw palmetto 3, trail intersection 1, trail segments 2, wiregrass 1, hooded pitcher plant 1, florida paintbrush 1, lopsided india grass 1, **Total: (15)**
Notes:
Used bench as map orientation point since no sign included | Purple dots are intersections | Accuracy of segments and intersections considered when scoring objects | Assume pond to left is the cypress pond | Trail intersection counted to remain consistent with other map evaluations |

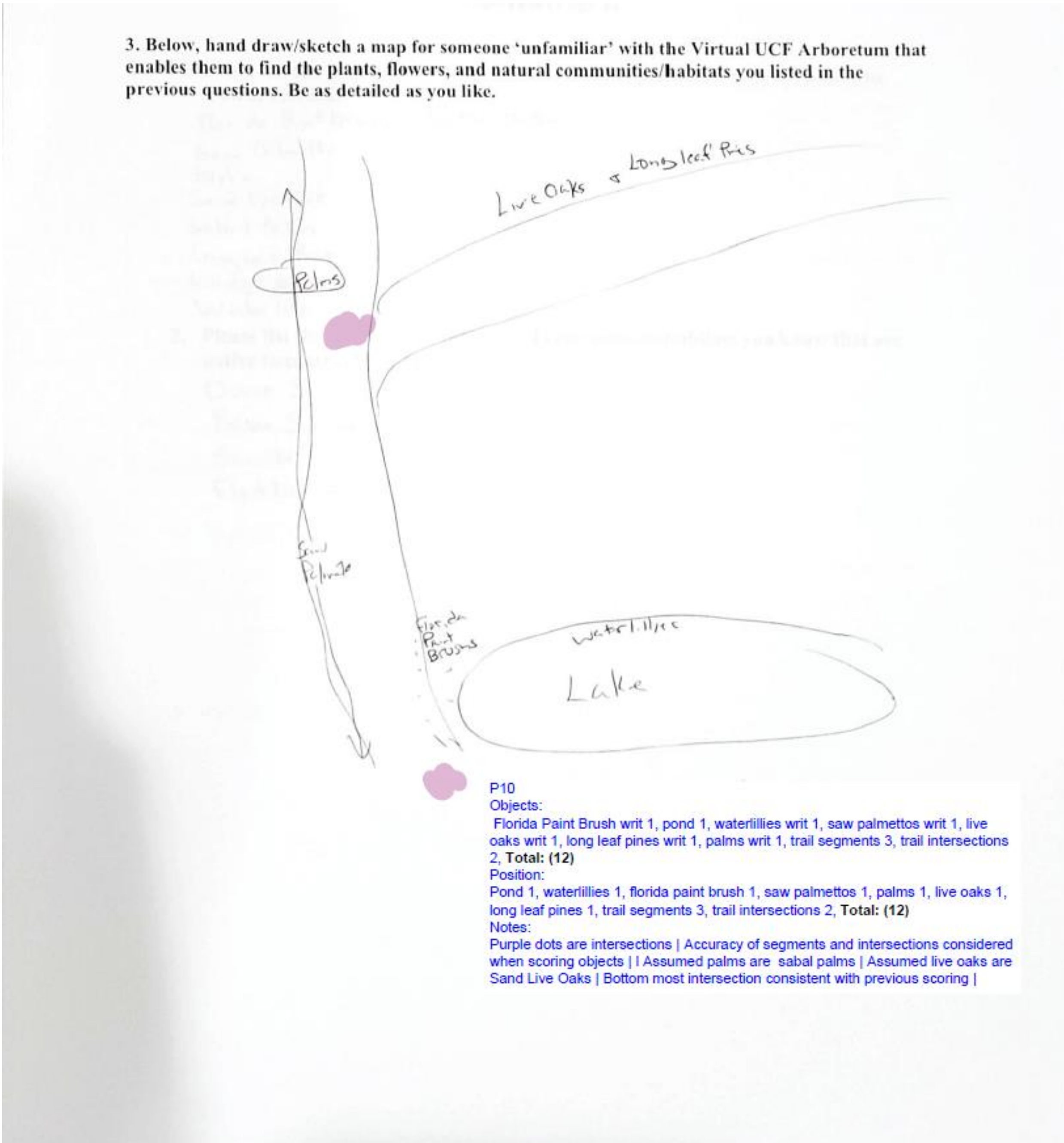
Desktop Condition
Map Grading Resource: (Harrington et al., 2021)



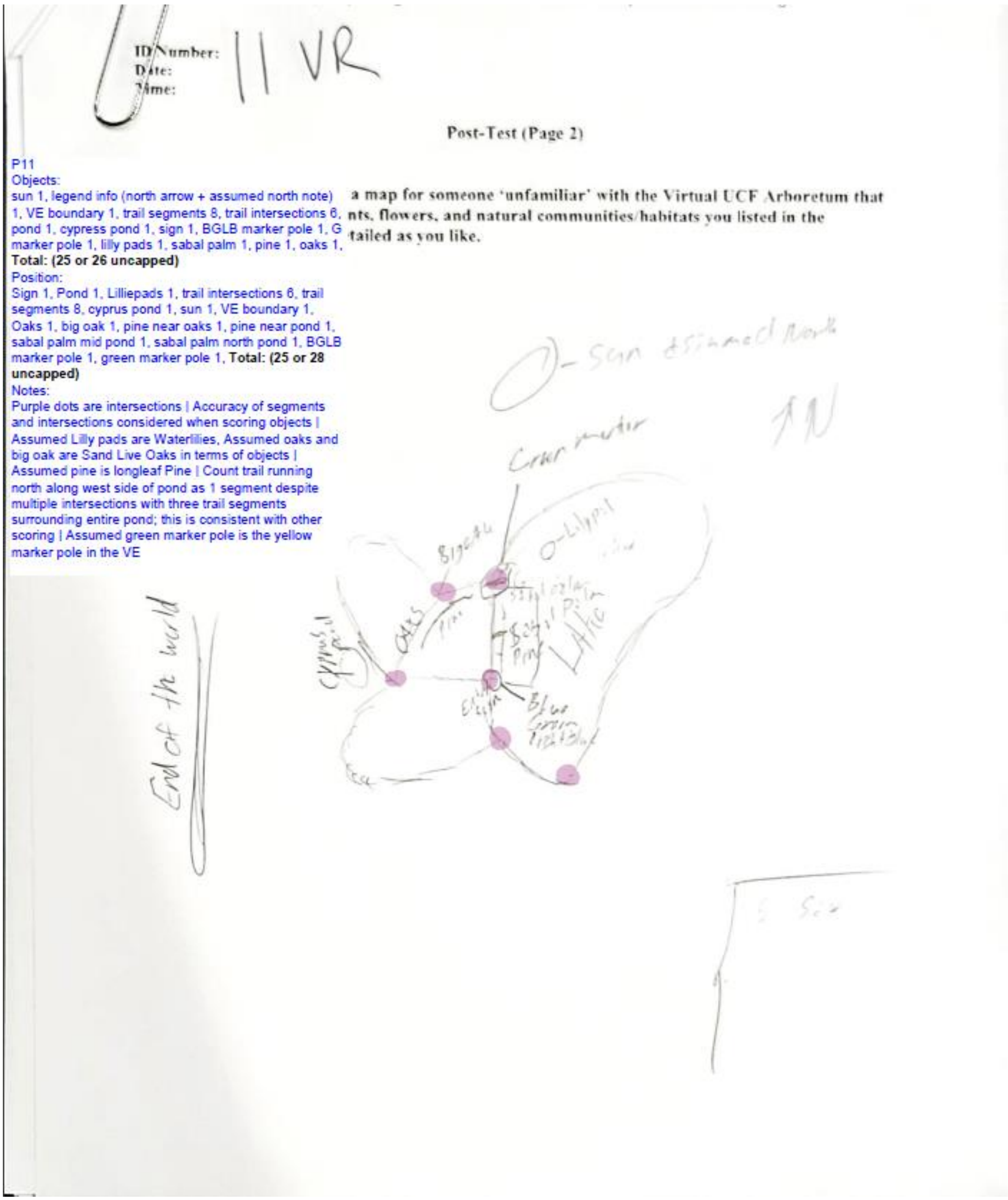
Desktop Condition
Map Grading Resource: (Harrington et al., 2021)



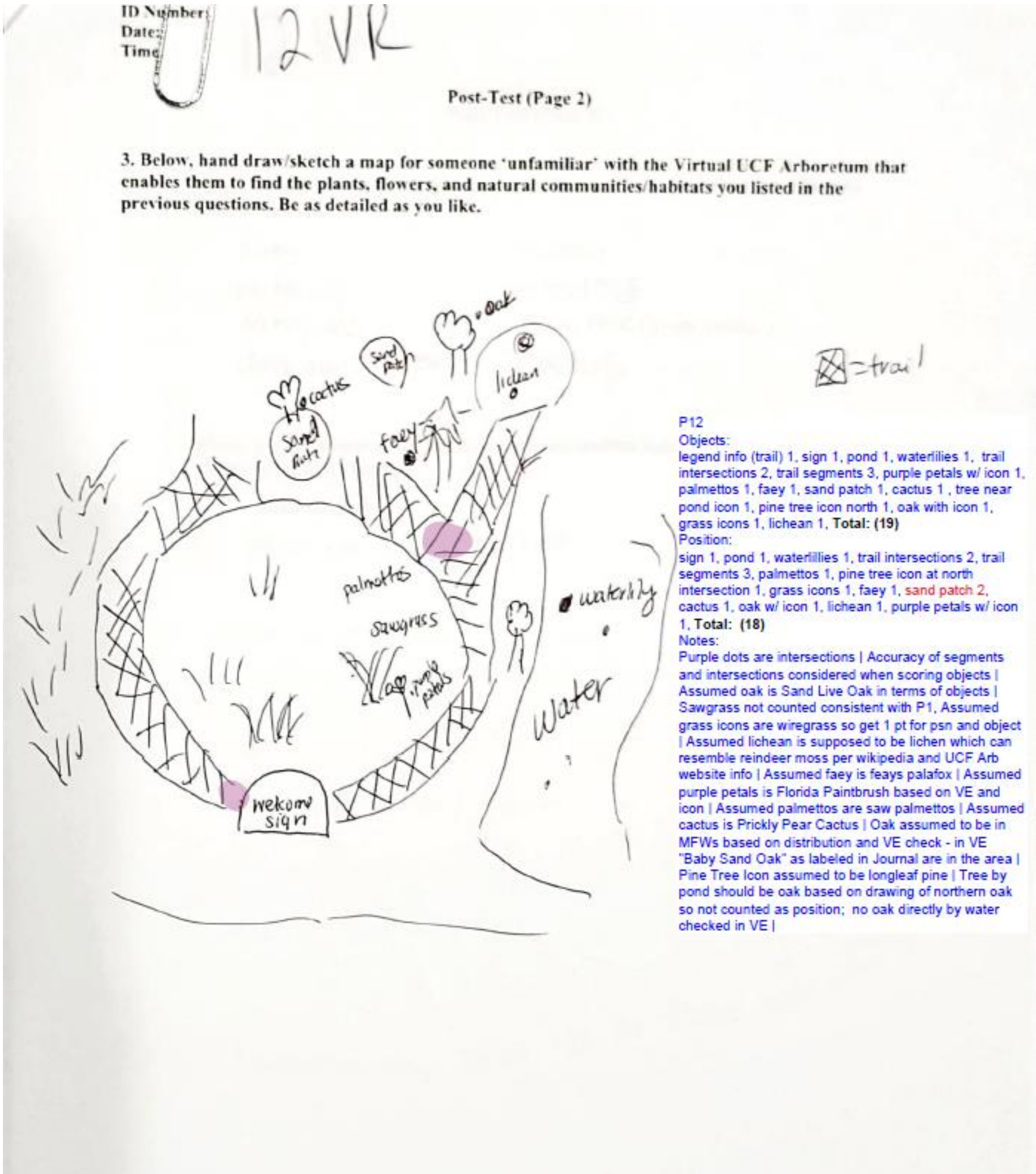
Desktop Condition
Map Grading Resource: (Harrington et al., 2021)



Desktop Condition
Map Grading Resource: (Harrington et al., 2021)



VR Condition
Map Grading Resource: (Harrington et al., 2021)

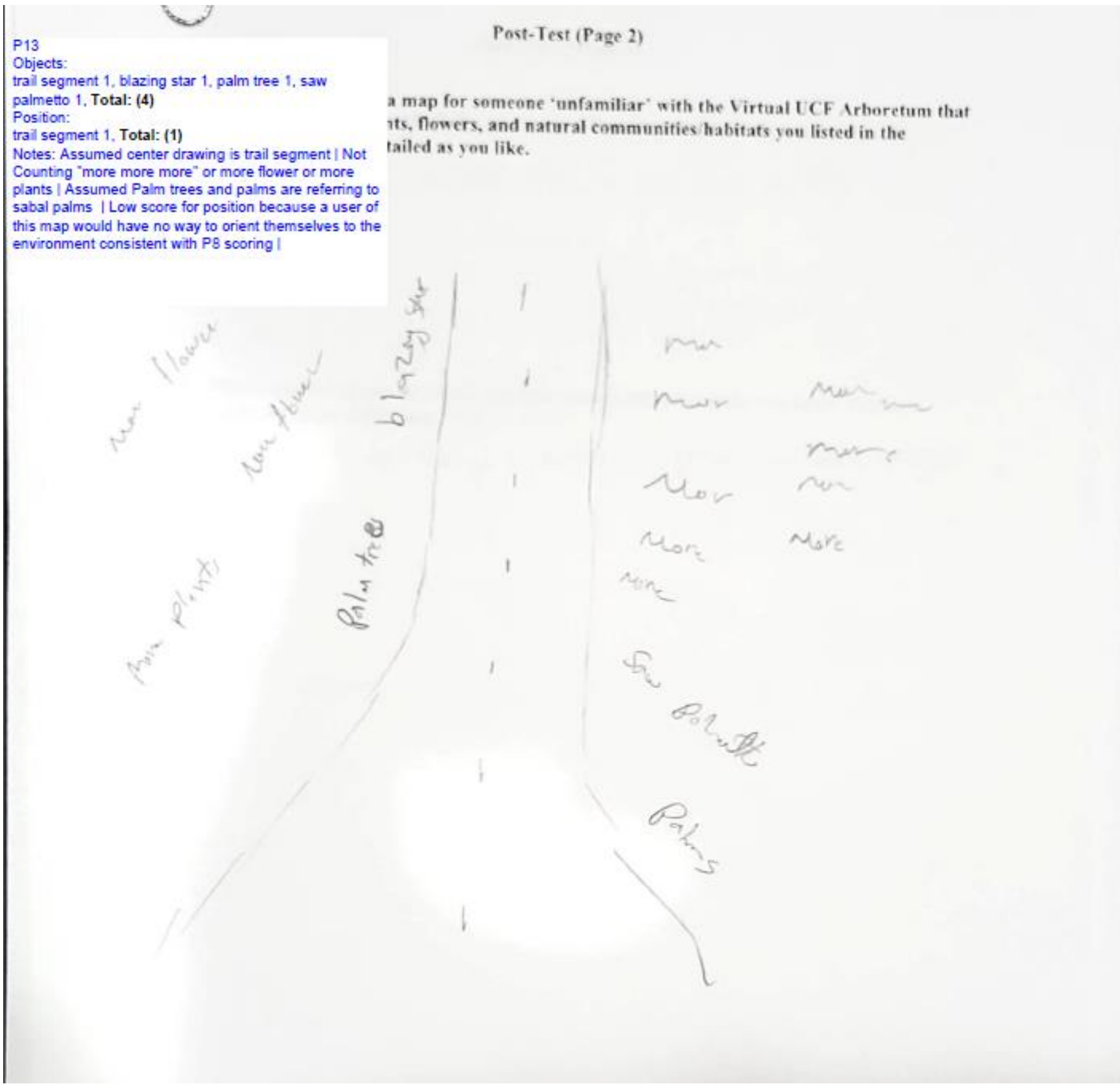

ID Number:
Date:
Time:

Post-Test (Page 2)

3. Below, hand draw/sketch a map for someone 'unfamiliar' with the Virtual UCF Arboretum that enables them to find the plants, flowers, and natural communities/habitats you listed in the previous questions. Be as detailed as you like.

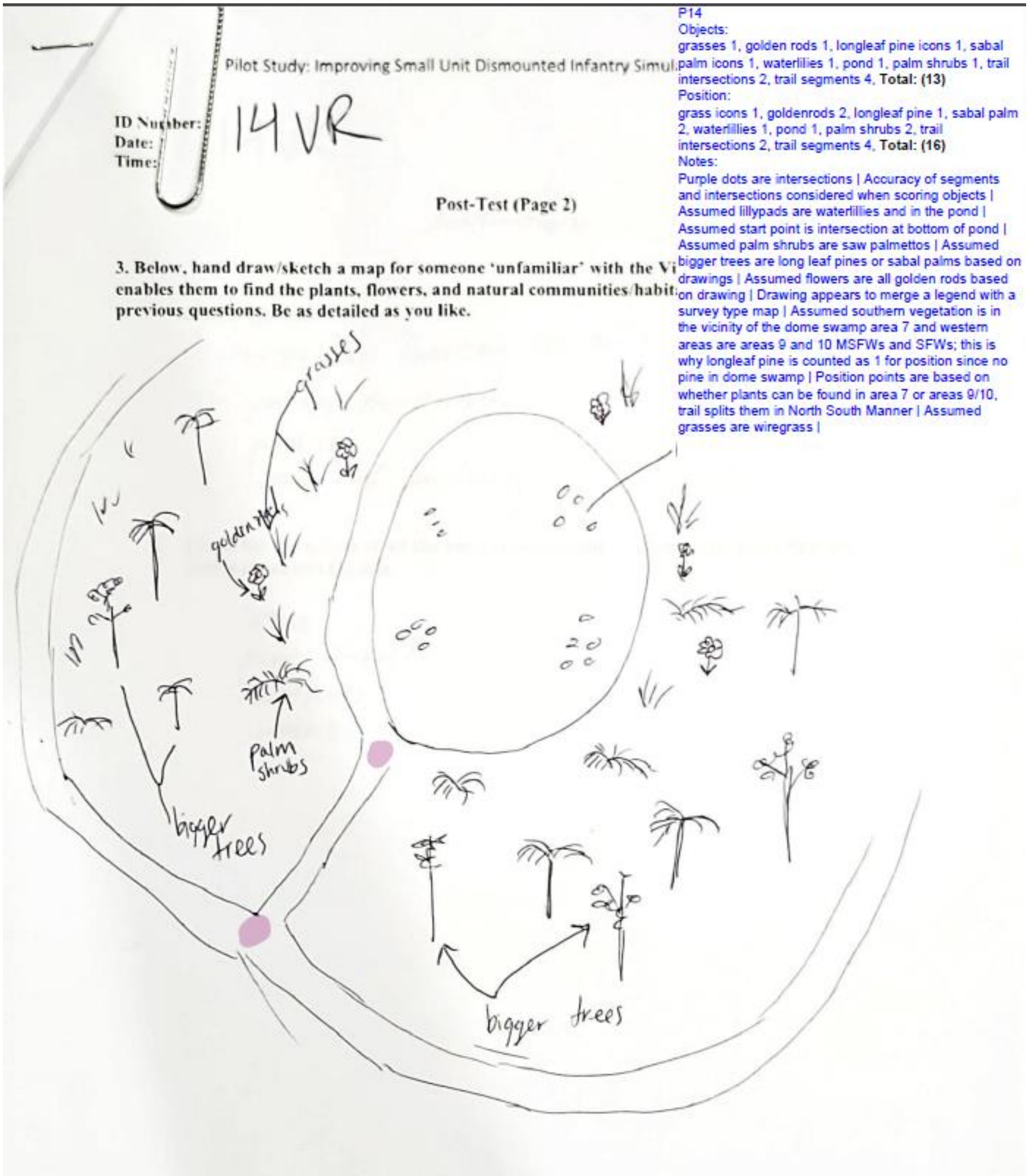
P12
Objects:
legend info (trail) 1, sign 1, pond 1, waterlilies 1, trail intersections 2, trail segments 3, purple petals w/ icon 1, palmettos 1, faey 1, sand patch 1, cactus 1 , tree near pond icon 1, pine tree icon north 1, oak with icon 1, grass icons 1, lichean 1, **Total: (19)**
Position:
sign 1, pond 1, waterlillies 1, trail intersections 2, trail segments 3, palmettos 1, pine tree icon at north intersection 1, grass icons 1, faey 1, sand patch 2, cactus 1, oak w/ icon 1, lichean 1, purple petals w/ icon 1, **Total: (18)**
Notes:
Purple dots are intersections | Accuracy of segments and intersections considered when scoring objects | Assumed oak is Sand Live Oak in terms of objects | Sawgrass not counted consistent with P1, Assumed grass icons are wiregrass so get 1 pt for psn and object | Assumed lichean is supposed to be lichen which can resemble reindeer moss per wikipedia and UCF Arb website info | Assumed faey is feays palafox | Assumed purple petals is Florida Paintbrush based on VE and icon | Assumed palmettos are saw palmettos | Assumed cactus is Prickly Pear Cactus | Oak assumed to be in MFWs based on distribution and VE check - in VE "Baby Sand Oak" as labeled in Journal are in the area | Pine Tree Icon assumed to be longleaf pine | Tree by pond should be oak based on drawing of northern oak so not counted as position; no oak directly by water checked in VE |

VR Condition
Map Grading Resource: (Harrington et al., 2021)



VR Condition

Map Grading Resource: (Harrington et al., 2021)



VR Condition
Map Grading Resource: (Harrington et al., 2021)

ID Number: 15VR
Date:
Time:

Post-Test (Page 2)

3. Below, hand draw/sketch a map for someone 'unfamiliar' with the Virtual UCF Arboretum that enables them to find the plants, flowers, and natural communities/habitats you listed in the previous questions. Be as detailed as you like.

P15
Objects:
legend 1, pond 1, palmetto 1, wiregrass 1, golden rod 1, flattop goldenrod 1, palm tree 1, paintbrush 1, trail intersections 6, trail segments 10, **Total: (24)**
Position:
pond 1, palmetto 1, wiregrass 2, palm trees 2, goldenrod 2, paint brush 1, trail intersections 6, trail segments 10, **Total: (25)**
Notes:
Purple dots are intersections | Accuracy of segments and intersections considered when scoring objects | Assumed flattop golden rod is slender flattop goldenrod | Assumed palm tree is sabal palm | Assumed palmetto is saw palmetto | Assumed starting point is at southern most point of center trail | FGR not found in Scrub based on distribution so no score for position |

VR Condition
Map Grading Resource: (Harrington et al., 2021)

APPENDIX F: SPSS-GENERATED CORRELATIONS TABLE

Spearman's Correlations

		Condition: 0=Desktop, 1=VR, 2=ODT	Minutes in VE (Ratio)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	1.000	-.228
	Sig. (2-tailed)	.	.415
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	-.228	1.000
	Sig. (2-tailed)	.415	.
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.283	.146
	Sig. (2-tailed)	.307	.603
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.020	.235
	Sig. (2-tailed)	.943	.399
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.285	.411
	Sig. (2-tailed)	.302	.128
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	-.391	.638*
	Sig. (2-tailed)	.150	.011
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	-.029	.584*
	Sig. (2-tailed)	.919	.022
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.154	-.020
	Sig. (2-tailed)	.583	.943
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.318	.104
	Sig. (2-tailed)	.248	.712
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.340	.343
	Sig. (2-tailed)	.214	.211
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.333	.369
	Sig. (2-tailed)	.226	.175
	N	15	15

Page 1

Spearman's Correlations

		Q6. Rate own knowledge (PreSurv: Interval)	Q1 List Flowers (PreTest: Ratio: 0-35)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.283	.020
	Sig. (2-tailed)	.307	.943
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.146	.235
	Sig. (2-tailed)	.603	.399
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	1.000	.147
	Sig. (2-tailed)	.	.602
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.147	1.000
	Sig. (2-tailed)	.602	.
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.107	.266
	Sig. (2-tailed)	.703	.338
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.207	.492
	Sig. (2-tailed)	.459	.063
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.103	.338
	Sig. (2-tailed)	.716	.218
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.023	-.909**
	Sig. (2-tailed)	.934	<.001
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.206	.221
	Sig. (2-tailed)	.462	.428
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.246	.446
	Sig. (2-tailed)	.376	.096
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.254	.448
	Sig. (2-tailed)	.361	.094
	N	15	15

Page 2

Spearman's Correlations

			Q2 List Comms (PreTest: Ratio: 0-10)	Q1 List Flowers/Plants (PostTest: Ratio: 0-35)
	Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.285	-.391
		Sig. (2-tailed)	.302	.150
		N	15	15
	Minutes in VE (Ratio)	Correlation Coefficient	.411	.638*
		Sig. (2-tailed)	.128	.011
		N	15	15
	Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.107	.207
		Sig. (2-tailed)	.703	.459
		N	15	15
	Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.266	.492
		Sig. (2-tailed)	.338	.063
		N	15	15
	Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	1.000	.264
		Sig. (2-tailed)	.	.341
		N	15	15
	Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.264	1.000
		Sig. (2-tailed)	.341	.
		N	15	15
	Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.523*	.667**
		Sig. (2-tailed)	.045	.007
		N	15	15
	Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.210	-.164
		Sig. (2-tailed)	.453	.558
		N	15	15
	Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.440	.403
		Sig. (2-tailed)	.100	.136
		N	15	15
	Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.750**	.444
		Sig. (2-tailed)	.001	.097
		N	15	15
	Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.746**	.475
		Sig. (2-tailed)	.001	.073
		N	15	15

Page 3

Spearman's Correlations

		Q2 List Comms (PostTest: Ratio: 0-10)	Q1. Percent Change Score Pre_Post: List Flowers/Plants
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	-.029	-.154
	Sig. (2-tailed)	.919	.583
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.584*	-.020
	Sig. (2-tailed)	.022	.943
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.103	-.023
	Sig. (2-tailed)	.716	.934
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.338	-.909**
	Sig. (2-tailed)	.218	<.001
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.523*	-.210
	Sig. (2-tailed)	.045	.453
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.667**	-.164
	Sig. (2-tailed)	.007	.558
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	1.000	-.153
	Sig. (2-tailed)	.	.586
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.153	1.000
	Sig. (2-tailed)	.586	.
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	.317	-.124
	Sig. (2-tailed)	.250	.661
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.462	-.308
	Sig. (2-tailed)	.083	.264
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.461	-.301
	Sig. (2-tailed)	.083	.275
	N	15	15

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Spearman's Correlations

		Q2. Percent Change Score Pre_Post: List Comms	Q3. Draw / Sketch Map (PostTest: Ratio)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	-.318	.340
	Sig. (2-tailed)	.248	.214
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.104	.343
	Sig. (2-tailed)	.712	.211
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	-.206	.246
	Sig. (2-tailed)	.462	.376
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.221	.446
	Sig. (2-tailed)	.428	.096
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	-.440	.750**
	Sig. (2-tailed)	.100	.001
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.403	.444
	Sig. (2-tailed)	.136	.097
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.317	.462
	Sig. (2-tailed)	.250	.083
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.124	-.308
	Sig. (2-tailed)	.661	.264
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	1.000	-.295
	Sig. (2-tailed)	.	.285
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	-.295	1.000
	Sig. (2-tailed)	.285	.
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	-.289	.996**
	Sig. (2-tailed)	.295	<.001
	N	15	15

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Spearman's Correlations

		Q3a. Object Class (PostTest: Ratio)	Q3b. Position (PostTest: Ratio)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.333	.275
	Sig. (2-tailed)	.226	.322
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.369	.334
	Sig. (2-tailed)	.175	.223
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.254	.178
	Sig. (2-tailed)	.361	.525
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.448	.476
	Sig. (2-tailed)	.094	.073
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.746**	.720**
	Sig. (2-tailed)	.001	.002
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.475	.442
	Sig. (2-tailed)	.073	.099
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.461	.442
	Sig. (2-tailed)	.083	.099
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.301	-.314
	Sig. (2-tailed)	.275	.254
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.289	-.244
	Sig. (2-tailed)	.295	.381
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.996**	.973**
	Sig. (2-tailed)	<.001	<.001
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	1.000	.967**
	Sig. (2-tailed)	.	<.001
	N	15	15

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Spearman's Correlations

		Q1. Rate Learn (PostSurv: Interval)	Q2. Rate Engaging (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.291	.236
	Sig. (2-tailed)	.293	.398
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.165	.074
	Sig. (2-tailed)	.556	.792
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.320	.487
	Sig. (2-tailed)	.245	.066
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.167	-.046
	Sig. (2-tailed)	.551	.871
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.301	.115
	Sig. (2-tailed)	.275	.683
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.374	-.066
	Sig. (2-tailed)	.170	.814
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.476	-.049
	Sig. (2-tailed)	.073	.863
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	.028	.151
	Sig. (2-tailed)	.921	.590
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	.128	-.328
	Sig. (2-tailed)	.650	.232
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.242	-.031
	Sig. (2-tailed)	.385	.914
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.243	-.021
	Sig. (2-tailed)	.383	.940
	N	15	15

Spearman's Correlations

		Q3. Rate Realistic (PostSurv: Interval)	Q4. Rate Imagination (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.281	.569*
	Sig. (2-tailed)	.311	.027
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	-.160	-.253
	Sig. (2-tailed)	.570	.364
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.188	.027
	Sig. (2-tailed)	.503	.923
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.020	-.167
	Sig. (2-tailed)	.943	.553
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	-.023	.093
	Sig. (2-tailed)	.936	.741
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	-.002	-.285
	Sig. (2-tailed)	.995	.303
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.016	.078
	Sig. (2-tailed)	.954	.781
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	.043	.097
	Sig. (2-tailed)	.878	.732
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.123	-.124
	Sig. (2-tailed)	.663	.660
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.017	-.088
	Sig. (2-tailed)	.952	.756
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.029	-.075
	Sig. (2-tailed)	.920	.790
	N	15	15

Spearman's Correlations

		Q5. Rate curiosity (PostSurv: Interval)	Q6. Rate Feeling of Immersion (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.330	.602*
	Sig. (2-tailed)	.230	.018
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	.197	-.031
	Sig. (2-tailed)	.481	.912
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.121	.263
	Sig. (2-tailed)	.668	.343
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	-.016	-.103
	Sig. (2-tailed)	.954	.716
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.276	.142
	Sig. (2-tailed)	.319	.615
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.103	-.171
	Sig. (2-tailed)	.715	.542
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.187	-.039
	Sig. (2-tailed)	.504	.890
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	.073	.110
	Sig. (2-tailed)	.795	.698
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.139	-.273
	Sig. (2-tailed)	.622	.324
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.177	.099
	Sig. (2-tailed)	.529	.725
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.177	.109
	Sig. (2-tailed)	.527	.699
	N	15	15

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Spearman's Correlations

		Q7. Rate Present (PostSurv: Interval)	Q8. Want to visit real (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.541*	.109
	Sig. (2-tailed)	.037	.699
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	-.151	.433
	Sig. (2-tailed)	.591	.107
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.314	.155
	Sig. (2-tailed)	.255	.581
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	-.354	.189
	Sig. (2-tailed)	.195	.500
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	-.023	.719**
	Sig. (2-tailed)	.934	.003
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	-.158	.370
	Sig. (2-tailed)	.573	.174
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	-.008	.517*
	Sig. (2-tailed)	.979	.048
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	.340	.022
	Sig. (2-tailed)	.215	.938
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.118	-.364
	Sig. (2-tailed)	.676	.182
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	-.144	.626*
	Sig. (2-tailed)	.608	.013
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	-.119	.646**
	Sig. (2-tailed)	.673	.009
	N	15	15

Spearman's Correlations

		Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Q10. How interested learning plants now (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.329	.471
	Sig. (2-tailed)	.354	.076
	N	10	15
Minutes in VE (Ratio)	Correlation Coefficient	.534	.222
	Sig. (2-tailed)	.112	.428
	N	10	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	-.148	.480
	Sig. (2-tailed)	.684	.070
	N	10	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.644*	.200
	Sig. (2-tailed)	.044	.476
	N	10	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.614	.529*
	Sig. (2-tailed)	.059	.042
	N	10	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	.581	.194
	Sig. (2-tailed)	.078	.487
	N	10	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.622	.432
	Sig. (2-tailed)	.055	.108
	N	10	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.462	-.100
	Sig. (2-tailed)	.179	.722
	N	10	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	.151	-.326
	Sig. (2-tailed)	.677	.235
	N	10	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.731*	.489
	Sig. (2-tailed)	.016	.064
	N	10	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.731*	.523*
	Sig. (2-tailed)	.016	.045
	N	10	15

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Spearman's Correlations

		Q11. How interested learning comms now (PostSurv: Interval)	Q12. Rate Knowledge now (PostSurv: Interval)
Condition: 0=Desktop, 1=VR, 2=ODT	Correlation Coefficient	.608*	.345
	Sig. (2-tailed)	.016	.208
	N	15	15
Minutes in VE (Ratio)	Correlation Coefficient	-.026	.235
	Sig. (2-tailed)	.927	.398
	N	15	15
Q6. Rate own knowledge (PreSurv: Interval)	Correlation Coefficient	.211	.795**
	Sig. (2-tailed)	.450	<.001
	N	15	15
Q1 List Flowers (PreTest: Ratio: 0-35)	Correlation Coefficient	.108	.184
	Sig. (2-tailed)	.703	.511
	N	15	15
Q2 List Comms (PreTest: Ratio: 0-10)	Correlation Coefficient	.504	.192
	Sig. (2-tailed)	.055	.493
	N	15	15
Q1 List Flowers/Plants (PostTest: Ratio: 0-35)	Correlation Coefficient	-.226	.398
	Sig. (2-tailed)	.418	.142
	N	15	15
Q2 List Comms (PostTest: Ratio: 0-10)	Correlation Coefficient	.175	.402
	Sig. (2-tailed)	.532	.137
	N	15	15
Q1. Percent Change Score Pre_Post: List Flowers/Plants	Correlation Coefficient	-.200	-.035
	Sig. (2-tailed)	.474	.901
	N	15	15
Q2. Percent Change Score Pre_Post: List Comms	Correlation Coefficient	-.560*	.099
	Sig. (2-tailed)	.030	.726
	N	15	15
Q3. Draw / Sketch Map (PostTest: Ratio)	Correlation Coefficient	.368	.414
	Sig. (2-tailed)	.177	.125
	N	15	15
Q3a. Object Class (PostTest: Ratio)	Correlation Coefficient	.385	.409
	Sig. (2-tailed)	.157	.130
	N	15	15

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		Condition: 0=Desktop, 1=VR, 2=ODT	Minutes in VE (Ratio)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.275	.334
	Sig. (2-tailed)	.322	.223
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.291	.165
	Sig. (2-tailed)	.293	.556
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.236	.074
	Sig. (2-tailed)	.398	.792
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.281	-.160
	Sig. (2-tailed)	.311	.570
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.569*	-.253
	Sig. (2-tailed)	.027	.364
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.330	.197
	Sig. (2-tailed)	.230	.481
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.602*	-.031
	Sig. (2-tailed)	.018	.912
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.541*	-.151
	Sig. (2-tailed)	.037	.591
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.109	.433
	Sig. (2-tailed)	.699	.107
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.329	.534
	Sig. (2-tailed)	.354	.112
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.471	.222
	Sig. (2-tailed)	.076	.428
	N	15	15

Spearman's Correlations

		Q6. Rate own knowledge (PreSurv: Interval)	Q1 List Flowers (PreTest: Ratio: 0-35)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.178	.476
	Sig. (2-tailed)	.525	.073
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.320	.167
	Sig. (2-tailed)	.245	.551
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.487	-.046
	Sig. (2-tailed)	.066	.871
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.188	.020
	Sig. (2-tailed)	.503	.943
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.027	-.167
	Sig. (2-tailed)	.923	.553
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.121	-.016
	Sig. (2-tailed)	.668	.954
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.263	-.103
	Sig. (2-tailed)	.343	.716
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.314	-.354
	Sig. (2-tailed)	.255	.195
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.155	.189
	Sig. (2-tailed)	.581	.500
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	-.148	.644*
	Sig. (2-tailed)	.684	.044
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.480	.200
	Sig. (2-tailed)	.070	.476
	N	15	15

Spearman's Correlations

		Q2 List Comms (PreTest: Ratio: 0-10)	Q1 List Flowers/Plants (PostTest: Ratio: 0-35)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.720**	.442
	Sig. (2-tailed)	.002	.099
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.301	.374
	Sig. (2-tailed)	.275	.170
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.115	-.066
	Sig. (2-tailed)	.683	.814
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	-.023	-.002
	Sig. (2-tailed)	.936	.995
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.093	-.285
	Sig. (2-tailed)	.741	.303
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.276	.103
	Sig. (2-tailed)	.319	.715
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.142	-.171
	Sig. (2-tailed)	.615	.542
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	-.023	-.158
	Sig. (2-tailed)	.934	.573
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.719**	.370
	Sig. (2-tailed)	.003	.174
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.614	.581
	Sig. (2-tailed)	.059	.078
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.529*	.194
	Sig. (2-tailed)	.042	.487
	N	15	15

Spearman's Correlations

		Q2 List Comms (PostTest: Ratio: 0-10)	Q1. Percent Change Score Pre_Post: List Flowers/Plants
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.442	-.314
	Sig. (2-tailed)	.099	.254
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.476	.028
	Sig. (2-tailed)	.073	.921
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	-.049	.151
	Sig. (2-tailed)	.863	.590
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.016	.043
	Sig. (2-tailed)	.954	.878
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.078	.097
	Sig. (2-tailed)	.781	.732
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.187	.073
	Sig. (2-tailed)	.504	.795
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	-.039	.110
	Sig. (2-tailed)	.890	.698
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	-.008	.340
	Sig. (2-tailed)	.979	.215
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.517*	.022
	Sig. (2-tailed)	.048	.938
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.622	-.462
	Sig. (2-tailed)	.055	.179
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.432	-.100
	Sig. (2-tailed)	.108	.722
	N	15	15

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		Q2. Percent Change Score Pre_Post: List Comms	Q3. Draw / Sketch Map (PostTest: Ratio)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	-.244	.973**
	Sig. (2-tailed)	.381	<.001
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.128	.242
	Sig. (2-tailed)	.650	.385
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	-.328	-.031
	Sig. (2-tailed)	.232	.914
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	-.123	.017
	Sig. (2-tailed)	.663	.952
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	-.124	-.088
	Sig. (2-tailed)	.660	.756
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	-.139	.177
	Sig. (2-tailed)	.622	.529
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	-.273	.099
	Sig. (2-tailed)	.324	.725
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	-.118	-.144
	Sig. (2-tailed)	.676	.608
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	-.364	.626*
	Sig. (2-tailed)	.182	.013
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.151	.731*
	Sig. (2-tailed)	.677	.016
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	-.326	.489
	Sig. (2-tailed)	.235	.064
	N	15	15

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Spearman's Correlations

		Q3a. Object Class (PostTest: Ratio)	Q3b. Position (PostTest: Ratio)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.967**	1.000
	Sig. (2-tailed)	<.001	.
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.243	.155
	Sig. (2-tailed)	.383	.581
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	-.021	-.100
	Sig. (2-tailed)	.940	.722
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.029	-.075
	Sig. (2-tailed)	.920	.791
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	-.075	-.181
	Sig. (2-tailed)	.790	.519
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.177	.058
	Sig. (2-tailed)	.527	.838
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.109	-.021
	Sig. (2-tailed)	.699	.940
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	-.119	-.278
	Sig. (2-tailed)	.673	.316
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.646**	.632*
	Sig. (2-tailed)	.009	.012
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.731*	.686*
	Sig. (2-tailed)	.016	.028
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.523*	.452
	Sig. (2-tailed)	.045	.091
	N	15	15

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Spearman's Correlations

		Q1. Rate Learn (PostSurv: Interval)	Q2. Rate Engaging (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.155	-.100
	Sig. (2-tailed)	.581	.722
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	1.000	.593*
	Sig. (2-tailed)	.	.020
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.593*	1.000
	Sig. (2-tailed)	.020	.
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.531*	.756**
	Sig. (2-tailed)	.042	.001
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.665**	.533*
	Sig. (2-tailed)	.007	.041
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.788**	.657**
	Sig. (2-tailed)	<.001	.008
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.599*	.793**
	Sig. (2-tailed)	.018	<.001
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.583*	.627*
	Sig. (2-tailed)	.022	.012
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.461	.458
	Sig. (2-tailed)	.084	.086
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.346	.211
	Sig. (2-tailed)	.327	.559
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.512	.436
	Sig. (2-tailed)	.051	.104
	N	15	15

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Spearman's Correlations

		Q3. Rate Realistic (PostSurv: Interval)	Q4. Rate Imagination (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	-.075	-.181
	Sig. (2-tailed)	.791	.519
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.531*	.665**
	Sig. (2-tailed)	.042	.007
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.756**	.533*
	Sig. (2-tailed)	.001	.041
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	1.000	.548*
	Sig. (2-tailed)	.	.034
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.548*	1.000
	Sig. (2-tailed)	.034	.
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.587*	.684**
	Sig. (2-tailed)	.022	.005
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.855**	.694**
	Sig. (2-tailed)	<.001	.004
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.720**	.747**
	Sig. (2-tailed)	.002	.001
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.317	.283
	Sig. (2-tailed)	.249	.306
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.459	.193
	Sig. (2-tailed)	.182	.593
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.243	.552*
	Sig. (2-tailed)	.383	.033
	N	15	15

Spearman's Correlations

		Q5. Rate curiosity (PostSurv: Interval)	Q6. Rate Feeling of Immersion (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.058	-.021
	Sig. (2-tailed)	.838	.940
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.788**	.599*
	Sig. (2-tailed)	<.001	.018
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.657**	.793**
	Sig. (2-tailed)	.008	<.001
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.587*	.855**
	Sig. (2-tailed)	.022	<.001
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.684**	.694**
	Sig. (2-tailed)	.005	.004
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	1.000	.759**
	Sig. (2-tailed)	.	.001
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.759**	1.000
	Sig. (2-tailed)	.001	.
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.612*	.848**
	Sig. (2-tailed)	.015	<.001
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.411	.309
	Sig. (2-tailed)	.128	.262
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.214	.373
	Sig. (2-tailed)	.553	.288
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.379	.355
	Sig. (2-tailed)	.163	.195
	N	15	15

Spearman's Correlations

		Q7. Rate Present (PostSurv: Interval)	Q8. Want to visit real (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	-.278	.632*
	Sig. (2-tailed)	.316	.012
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.583*	.461
	Sig. (2-tailed)	.022	.084
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.627*	.458
	Sig. (2-tailed)	.012	.086
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.720**	.317
	Sig. (2-tailed)	.002	.249
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.747**	.283
	Sig. (2-tailed)	.001	.306
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.612*	.411
	Sig. (2-tailed)	.015	.128
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.848**	.309
	Sig. (2-tailed)	<.001	.262
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	1.000	.101
	Sig. (2-tailed)	.	.720
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.101	1.000
	Sig. (2-tailed)	.720	.
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.108	.723*
	Sig. (2-tailed)	.767	.018
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.349	.746**
	Sig. (2-tailed)	.203	.001
	N	15	15

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Spearman's Correlations

		Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Q10. How interested learning plants now (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.686*	.452
	Sig. (2-tailed)	.028	.091
	N	10	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.346	.512
	Sig. (2-tailed)	.327	.051
	N	10	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.211	.436
	Sig. (2-tailed)	.559	.104
	N	10	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.459	.243
	Sig. (2-tailed)	.182	.383
	N	10	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.193	.552*
	Sig. (2-tailed)	.593	.033
	N	10	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.214	.379
	Sig. (2-tailed)	.553	.163
	N	10	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.373	.355
	Sig. (2-tailed)	.288	.195
	N	10	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.108	.349
	Sig. (2-tailed)	.767	.203
	N	10	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.723*	.746**
	Sig. (2-tailed)	.018	.001
	N	10	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	1.000	.492
	Sig. (2-tailed)	.	.149
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.492	1.000
	Sig. (2-tailed)	.149	.
	N	10	15

Spearman's Correlations

		Q11. How interested learning comms now (PostSurv: Interval)	Q12. Rate Knowledge now (PostSurv: Interval)
Q3b. Position (PostTest: Ratio)	Correlation Coefficient	.319	.343
	Sig. (2-tailed)	.247	.211
	N	15	15
Q1. Rate Learn (PostSurv: Interval)	Correlation Coefficient	.273	.575*
	Sig. (2-tailed)	.326	.025
	N	15	15
Q2. Rate Engaging (PostSurv: Interval)	Correlation Coefficient	.308	.333
	Sig. (2-tailed)	.264	.226
	N	15	15
Q3. Rate Realistic (PostSurv: Interval)	Correlation Coefficient	.159	.165
	Sig. (2-tailed)	.571	.557
	N	15	15
Q4. Rate Imagination (PostSurv: Interval)	Correlation Coefficient	.634*	.171
	Sig. (2-tailed)	.011	.542
	N	15	15
Q5. Rate curiosity (PostSurv: Interval)	Correlation Coefficient	.322	.405
	Sig. (2-tailed)	.241	.135
	N	15	15
Q6. Rate Feeling of Immersion (PostSurv: Interval)	Correlation Coefficient	.341	.278
	Sig. (2-tailed)	.214	.315
	N	15	15
Q7. Rate Present (PostSurv: Interval)	Correlation Coefficient	.281	.329
	Sig. (2-tailed)	.311	.231
	N	15	15
Q8. Want to visit real (PostSurv: Interval)	Correlation Coefficient	.565*	.224
	Sig. (2-tailed)	.028	.422
	N	15	15
Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Correlation Coefficient	.351	-.070
	Sig. (2-tailed)	.320	.848
	N	10	10
Q10. How interested learning plants now (PostSurv: Interval)	Correlation Coefficient	.855**	.507
	Sig. (2-tailed)	<.001	.054
	N	15	15

Spearman's Correlations

		Condition: 0=Desktop, 1=VR, 2=ODT	Minutes in VE (Ratio)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.608*	-.026
	Sig. (2-tailed)	.016	.927
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.345	.235
	Sig. (2-tailed)	.208	.398
	N	15	15

Spearman's Correlations

		Q6. Rate own knowledge (PreSurv: Interval)	Q1 List Flowers (PreTest: Ratio: 0-35)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.211	.108
	Sig. (2-tailed)	.450	.703
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.795**	.184
	Sig. (2-tailed)	<.001	.511
	N	15	15

Spearman's Correlations

		Q2 List Comms (PreTest: Ratio: 0-10)	Q1 List Flowers/Plants (PostTest: Ratio: 0-35)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.504	-.226
	Sig. (2-tailed)	.055	.418
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.192	.398
	Sig. (2-tailed)	.493	.142
	N	15	15

Spearman's Correlations

		Q2 List Comms (PostTest: Ratio: 0-10)	Q1. Percent Change Score Pre_Post: List Flowers/Plants
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.175	-.200
	Sig. (2-tailed)	.532	.474
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.402	-.035
	Sig. (2-tailed)	.137	.901
	N	15	15

Spearman's Correlations

		Q2. Percent Change Score Pre_Post: List Comms	Q3. Draw / Sketch Map (PostTest: Ratio)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	-.560*	.368
	Sig. (2-tailed)	.030	.177
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.099	.414
	Sig. (2-tailed)	.726	.125
	N	15	15

Spearman's Correlations

		Q3a. Object Class (PostTest: Ratio)	Q3b. Position (PostTest: Ratio)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.385	.319
	Sig. (2-tailed)	.157	.247
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.409	.343
	Sig. (2-tailed)	.130	.211
	N	15	15

Spearman's Correlations

			Q1. Rate Learn (PostSurv: Interval)	Q2. Rate Engaging (PostSurv: Interval)
	Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.273	.308
		Sig. (2-tailed)	.326	.264
		N	15	15
	Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.575*	.333
		Sig. (2-tailed)	.025	.226
		N	15	15

Spearman's Correlations

			Q3. Rate Realistic (PostSurv: Interval)	Q4. Rate Imagination (PostSurv: Interval)
	Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.159	.634*
		Sig. (2-tailed)	.571	.011
		N	15	15
	Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.165	.171
		Sig. (2-tailed)	.557	.542
		N	15	15

Spearman's Correlations

			Q5. Rate curiosity (PostSurv: Interval)	Q6. Rate Feeling of Immersion (PostSurv: Interval)
	Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.322	.341
		Sig. (2-tailed)	.241	.214
		N	15	15
	Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.405	.278
		Sig. (2-tailed)	.135	.315
		N	15	15

Spearman's Correlations

		Q7. Rate Present (PostSurv: Interval)	Q8. Want to visit real (PostSurv: Interval)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.281	.565*
	Sig. (2-tailed)	.311	.028
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.329	.224
	Sig. (2-tailed)	.231	.422
	N	15	15

Spearman's Correlations

		Q9. If: VR Rate Importance of terrain (PostSurv: Interval)	Q10. How interested learning plants now (PostSurv: Interval)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	.351	.855**
	Sig. (2-tailed)	.320	<.001
	N	10	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	-.070	.507
	Sig. (2-tailed)	.848	.054
	N	10	15

Spearman's Correlations

		Q11. How interested learning comms now (PostSurv: Interval)	Q12. Rate Knowledge now (PostSurv: Interval)
Q11. How interested learning comms now (PostSurv: Interval)	Correlation Coefficient	1.000	.178
	Sig. (2-tailed)	.	.526
	N	15	15
Q12. Rate Knowledge now (PostSurv: Interval)	Correlation Coefficient	.178	1.000
	Sig. (2-tailed)	.526	.
	N	15	15

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

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