ABSTRACT OF CAPSTONE

Carol E. Templeton

The Graduate School

Morehead State University

March 24, 2019

AN ANALYSIS OF THE PEDAGOGICAL AFFORDANCES OF A VIRTUAL LEARNING ENVIRONMENT IN A CATHOLIC SCHOOL

Abstract of Capstone

A capstone submitted in partial fulfillment of the
Requirements for the degree of Doctor of Education in the
College of Education
At Morehead State University

By

Carol E. Templeton

Milton, West Virginia

Committee Chair: Dr. Michael W. Kessinger, Assistant Professor

Morehead, Kentucky

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The purpose of this mixed study was to examine the pedagogical affordances of a virtual learning environment at a 4th grade and 7th grade level in one Catholic school. The study analyzed student academic achievement scores over a two-week testing window in two science classes. The quantitative measurements consisted of pretest and posttest assessments. The study focused on the utilization of zSpace's augmented virtual reality devices to convey scientific information, theory, and concepts. In addition to the pedagogical component of the study, qualitative data were collected to compare student motivation, interest levels, and peer collaboration between a traditional learning environment and an environment supporting the virtual reality devices, zSpace, designed to help students discover and understand abstract and complex concepts through manipulation and dissections of 3-Dimensional images.

The study revealed that there were no statistically significant pedagogical differences between the traditional learning environment compared to the experimental learning environment at the 4th grade and 7th grade levels. The quantitative data, however; did reveal trends demonstrating higher academic gains from the pretest to the posttest in the experimental environments.

The study's qualitative data revealed that there is value to the use of virtual reality regarding increased student motivation, interest levels, and collaborative learning opportunities. The qualitative data support the inclusion of the augmented virtual reality device, zSpace, as a unique learning tool to support student learning, independence skills, and individualized instruction. In addition to this, the use of zSpace devices sparked curiosity, higher-level thinking, and fostered a deeper meaning of science concepts amongst students.

Limitations of the augmented virtual reality devices, although minimal, were noted such as motion sickness, technical issues, and overstimulation of software upon users.

This study provides additional information to the field of education where limited research has been conducted at the elementary and middle school level regarding the use of virtual reality as a viable learning tool. Future recommendations have been identified to explore the affordances of such technology within the areas of special education and the building of student-centric educational environments where learning is not limited to traditional methods of instruction and resources.

KEYWORDS: Virtual reality, student learning, motivation, collaboration

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Candidate Signature

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Date

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DEDICATION

I would like to dedicate this capstone to my parents, Captain John Duff and Mrs. Margaret Duff, for their continued support and belief in my work and for understanding my commitment and passion towards learning and accomplishing new goals.

My father encouraged his children to love learning, travel the world, and to be inspired to explore new experiences. My mother instilled within her children the importance of strong morals and values, a solid work ethic, and a determination to be strong independent individuals.

Finally to my two wonderful boys, Liam and Lucas who demonstrated outstanding patience during this journey and for showing tremendous support and love for their mother.

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To Dr. Vincent de Paul Schmidt for his guidance, support, and his sense of humor as a friend, work colleague, and mentor. An innovative and charismatic Catholic school superintendent, Dr. Schmidt exhibited exemplary leadership qualities and the ability to make positive change occur. I am thankful for the many years I worked with Dr. Schmidt learning systems and operations at the central office level.

Thank you to my Chair, Dr. Michael Kessinger, for his guidance, words of wisdom, and tremendous encouragement he provided as I progressed through the doctoral program. As an inspirational and caring professor, I feel honored to have had Dr. Kessinger as my Chair offering his support and belief in my ability to complete this capstone.

To my faculty, staff, students, and community members of St. Joseph Catholic School, Huntington, West Virginia, for their overwhelming support of my endeavors and continued belief in my vision and goals for the school.

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Finally, to my pastor and superior, Monsignor Borgmeyer, for his support, encouragement, and understanding as a principal, parent, and parishioner of St. Joseph Catholic School and Church.

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Chapter 1

Introduction

Globally technology is evolving at an immense pace forging innovation and generating new inventions and ideas designed to enhance how we communicate, conduct business, travel, and develop programs to how we are entertained. Simsek (2016) supports this statement arguing "the rapid change in science and technology has made information more valuable in the information age we live in" (p. 1).

The education world is not alone from the influences of technological advancements. New technologies offer exciting and expanding ways for students to learn new concepts, develop skills, and interact with each other. Scott, Soria, and Campo (2017) recognize the influence technology has upon the learning process arguing "new ways of learning have emerged in the last years by using computers in education" (p. 262). Stosic (2015) claims that technology plays a vital role in education stating, "educational technology is a systematic and organized process of applying modern technology to improve the quality of education (efficiency, optimal, true, etc.)" (p. 111). According to Stosic, technology offers three main uses in education. First, technology is a tutor; it provides instruction and guidance to the student. Second, technology acts as a teaching tool delivering concepts and content to be learned, and finally, technology is a learning tool, a tool in which students can utilize, or manipulate to express their learning process.

Identifying technology that supports these three perspectives offers students the opportunity to explore concepts in a supportive learning environment designed to promote collaboration, critical thinking, and problem-solving activities. If used effectively by well-trained teachers, technology can help to facilitate the learning process, offering unique learning tools and multiple approaches to processing information. In a report to Congress, Dynarski et al. (2007) argue that technology not only provides assistive devices to help students with disabilities to learn concepts and skills but also to help all students learn difficult or challenging concepts that would not be feasible from textbooks or class lectures.

Educational institutions are continuously exploring new approaches for students to learn academic material and master concepts and skills. The use of 3Dimensional (3D) devices in the classroom offer students an alternative approach to learning that goes beyond traditional technology, textbooks, pencils, and pens (Cheng & Wang, 2011). Scott et al. (2017) also argue that the use of 3D technologies potentially provides students with an individualized and adaptive learning experience. Students are more engaged and motivated to participate in the learning process when offered a unique learning environment. This viewpoint has been the driving force behind this capstone to explore a new technology designed to provide students with an individualized and authentic learning experience, differing significantly from the traditional classroom environment.

Gardner (2000), in his multiple intelligence theory, argues that the creation of new technologies allows for a greater level of an individualized learning experience, offering students multiple ways to explore and learn new concepts, which Gardner refers to as Frames of Mind. Gardner supports the notion that new technologies are beneficial to human intelligences allowing for concepts to be viewed from multiple perspectives while utilizing multiple intelligences. The use of 3D virtual reality lends itself to Gardner's multiple intelligence theory allowing users to explore concepts from a linguistic, logical, spatial, musical, bodily, and naturalistic approach within a stimulating and engaging environment.

Virtual learning environments offer students an alternative to learning concepts beyond the traditional classroom and traditional resources such as textbooks. Chittaro and Ranon (2007) support this opinion, arguing virtual learning environments encourage students to become "more curious, more interested, and have more fun with respect to learning with traditional methods" (p. 15).

There is, however, limited empirical research providing the pedagogical effect virtual learning environments may offer to student learning. More research is needed to examine the impact of the use of a virtual learning tool in education. As stated by Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2012), "the rapid increase in the technological sophistication, diversity, and pervasiveness of 3D virtual learning environments, along with the proliferation of research on their effectiveness in educational settings, necessitates frequent systematic analytical syntheses of their effectiveness" (p. 30).

Statement of the Problem

Today's society offers an abundance of rapidly advancing technology platforms such as Smart devices, Google applications, and Apple products to name a few to how we communicate globally and to how we learn new concepts that go beyond the traditional classroom or formal teaching environment. In this perspective, Simsek (2016) argues that it is only through the inclusion of technology within the current education system that will meet the skills and expectations of students.

Sarkar, Ford, and Manzo (2017) claim that students in schools today learn differently from students of an older generation. Surrounded by multiple technologies, social media, and gaming devices, today's students naturally embrace the use of technology not only in their lifestyle but also as their approach to learning. These students are known as Digital Natives.

Originally coined by Prensky (2001), Digital Natives are students born into a digital age and are immersed within a multisensory technological world comprising of computers, video games, Smart devices, social media, and cell phones. Digital Immigrants are those individuals who have migrated to a digital age and have chosen to adopt and adapt to new technologies. Prensky contends that the Digital Native, due to their constant interaction with evolving technologies, has enabled them to think and process information differently from their predecessors. It is crucial, therefore, as stated by Prensky, that teachers today need to recognize that their students learn differently and that the educational environment needs to be conducive to meet the needs of Digital Natives.

Sarkar et al. (2017) believe there is a need for significant educational reform as current practices and learning environments, which are not technologically supported, are not addressing the individual needs of the digital generation. In his book, *Catching Up or Leading the Way,* Zhao (2009) supports this statement by arguing, “schools must cultivate diversity of talents, global competence, and digital competencies to cope with a world that has been significantly altered by globalization and technology” (p. viii). In addition to this, Zhao believes that it is only through the implementation of introducing new technologies, such as virtual learning environments in schools, that students will be afforded unique opportunities to compete in a global and virtual world.

Zhao (2009) describes virtual technology as a foreign culture, a new culture, which has been embraced by the corporate and media world. The presence and use of 3D learning tools within the educational environment has seen an increase over the past decade with growing interest to examine the possible affects such learning environments may have upon student learning and experience. Simsek (2016) recognizes how technology has evolved “from internet based learning to three-dimensional, multiple users” to “online virtual learning environments” (p. 2). The use of 3D virtual reality offers schools new teaching tools and students’ new opportunities to learn material and concepts in diverse environments. This opinion is shared with Wu, Lee, Chang, and Liang (2013) stating, “new possibilities for teaching and learning provided by augmented reality have been increasingly recognized by educational researchers” (p. 41).

The use of 3D platforms in education may not only offers teachers and students unique and alternative approaches to teaching and learning concepts, but also the possibility that virtual reality environments may have the potential to increase student academic gains. In the meta-analysis studies conducted by Sitzman (2011) and Vogel et al. (2006), the results in both studies indicated that students' learning outcomes were statistically increased due to the effects of interactive computer games and simulations. McMenemy and Ferguson (2009) discovered that students achieved higher in engineering sessions due to the task of creating their own 3D models.

This capstone examined the inclusion of a 3D virtual reality device, known as zSpace, in two science classes in a private K-8 Catholic school environment. The use of this 3D virtual reality desktop affords students the opportunity to explore concepts virtually and collaboratively, supporting Gardner's (2000) multiple levels of intelligence theory, Piaget (1952) theory, origins of intelligence and the constructivist approach to learning. Students utilized zSpace to examine abstract concepts and scientific phenomena that are not possible to experience physically or from a real-life perspective. More research is needed to examine the potential pedagogical applications 3D virtual reality offers to student learning as the use of such tools is still in the early research phase (Cheng & Tsai, 2013). This study intended to investigate the role of a 3D learning tool within a small educational setting.

Significance of the Problem

The study provided quantitative and qualitative research assessing the pedagogical affect virtual learning environments had upon student academic achievement. There is much research (Cho & Lim, 2015) on the influential benefits virtual learning environments offer students regarding motivation levels, collaborative learning, and co-presence experiences. However, there is limited research in terms of the academic impact virtual learning environments offer to academic achievements (Cho & Lim; Hew & Cheung, 2010).

Research is abundant regarding the use of virtual gaming environments for entertainment and academic purposes, but there is limited research regarding the benefits virtual environments may offer to the world of education (Chau et al., 2013). Chau et al. stated, “despite the fact that virtual worlds are mainly for entertainment purposes, it has been suggested that they have great potential to become innovative education platforms in the future, providing students with real-world-like experiential learning” (p. 1).

Koh et al. (2010) argue that the use of 3D technology had been well studied in fields such as engineering, medical and health education, science education, and the military, with literature supporting its effectiveness to improve students’ conceptual understanding and the learning process. However, more research is needed on the effects of 3D learning environments within the K-12 school system. Scott et al. (2017) support this argument stating “very little is know about both what factors are involved with adaptive 3D environments to achieve learning benefits and what assessment factors are present in the current studies” (p. 262).

Hew and Cheung (2010) not only recognize the limited volume of empirical studies supporting the educational value of 3D learning environments but also notes that most studies are descriptive and anecdotal in nature, relying heavily on obtaining subjective feedback from participants regarding their perceptions. The incorporation of a control group is absent in many self-reporting examples of research. Therefore, Hew and Cheung noted that improvements in students' learning could not be associated with the 3D learning environment but rather uncontrolled variables such as instructional strategies and teacher proficiency levels.

It was the intention of this capstone to offer not only descriptive feedback from participants but also provide quantitative data which examined the impact a virtual learning environment had upon student academic gains. The research utilized the zSpace augmented virtual reality devices to examine student academic gains and participants' perception of how the virtual learning environment affected their learning experience.

Background of the Problem

Virtual learning environments are demonstrating great potential to enhance, explore, and expand diverse learning opportunities for students across multiple academic fields. Dalgarno and Lee (2010) argue

> [That] internationally, educators and educational institutions envisage great potential in the use of 3D simulations, games and virtual environments for teaching and learning, as they provide the possibility of rich learner engagement, together with the ability to explore, construct and manipulate virtual objects, structures and metaphorical representation of ideas. (p. 11)

Furthermore, Cho and Lim (2015) argue that there is limited research with regards to virtual reality learning at the younger grade levels stating, "despite the potential of virtual worlds (VWs), few studies have investigated the effectiveness of collaborative learning within VWs in K-12 schools" (p. 15).

Koh et al. (2010) stated that 3D simulation offers substantial benefits providing augmented learning, increased motivation, and engagement levels that offer natural semantics in a safe and cost saving environment. Koh et al. conducted a study to examine the effects of simulation-based-learning (SBL) to improve student performance and motivational levels. Their study revealed that the students in the SBL environment perceived that their competency levels, basic needs, and autonomy were all met at a greater level than the controlled environment. Koh et al. notes, "this study indicates that SBL can potentially enhance self-determined motivational regulations as well as better understanding and application of learning" (p. 248).

Local Context

Location. The research took place within St. Joseph Catholic School, an urban parochial school in the Tri-State area of Huntington, West Virginia. Established in 1879 and accredited through AdvancED, the school served over 400 students and operates under the umbrella of the Diocese of Wheeling-Charleston, West Virginia. The school's student body was diverse in terms of religions, cultures, ethnicity, gender, special needs, and socio-economic status.

Curriculum. The school's curriculum adopted the diocese's Catholic Academic Standards of Excellence (CASE) policy, which included the West Virginia Content Standards, the Next Generation Reading Language Arts, Mathematics, and Science Standards, and also authentic standards specific to the needs of the school's curriculum.

Blended learning model. At the center of the study, was the goal to create a blended learning model, designed to infuse a technology curriculum not only in the school's technology center but also within the regular classroom environment. The term 'blended learning' in literature refers to models, which include a combination of synchronous and asynchronous learning environments (Picciano & Dziuban, 2007). Picciano and Dziuban argue that blended learning has different meanings to different people stating, "there are many forms of blended and a generally accepted taxonomy does not exist. One school's blended is another school's hybrid, or another school's mixed-mode" (p. 10-11).

In 'most typical' blended learning environments students learn via computer-based e-learning modules in combination with face-to-face instruction. The term blended for this study was to create a unique learning environment to embed technology within the school's current regular curriculum, thus removing the metaphorical four walls of the classroom. The intent of the initiative was to incorporate a virtual reality learning experience for students that allowed for global immersion and the opportunity to learn abstract concepts and nontangible experiences within the safety and comfort of their school environment.

Based on this premise, the concept of this blended learning model was to establish an environment that had a strong pedagogical consideration with the utilization of technology. Fowler (2015) supports this approach stating, "what is required to fully describe the learning experience is a framework that is not solely derived from technological affordances but also includes pedagogical requirements" (p. 415).

Teacher training. The teachers received several technology in-service training sessions focused on how to incorporate technology into the classroom and curriculum meaningfully. Professional Learning Communities (PLC) were established to research various technology programs, devices, and software designed to enhance student learning. Each PLC presented research at regularly scheduled review meetings. A technology rubric was established identifying specific requirements that must be fulfilled before purchase consideration. The rubric consisted of four points for consideration prior to purchase (see Table 1).

Table 1

Technology Integration Platform

Level	Elements for Consideration
Level 1	Usability and adaptability for student and teacher usage
Level 2	Curriculum alignment and assessment component
Level 3	Teacher training and technical support
Level 4	Cost, system requirements, and future maintenance requirement

Specific to the school's blended technology program, one aspect of the blended technology model included the implementation of a unique virtual reality-learning device named zSpace. Teachers received intensive training to learn the 3D functionalities and tools of the devices, the software program, and how to access specific units. The teachers also received training on how to create their own units and assessment modules specific to their grade level's standards and curriculum.

Curriculum units. Each year, teachers within the Diocese of Wheeling-Charleston were required to submit two technology units to a statewide diocesan database. The idea was to create teaching resources educators could share and utilize in their classroom. The researcher created a unit lesson template for the teachers across the diocese to use (see Appendix A). The unit plan provided an extensive overview of the standards, concepts, lessons, individualized instruction, and assessments covered over a period of time. In addition to this, the unit plan identified the resources, material, technology, and cross-curricular opportunities required to fulfill the unit.

Two unit plans were created specifically for this study reflecting the 4th (Appendix B) and 7th (Appendix C & D) grade levels subjects and topics covered. Each unit plan was identical in content except one unit utilized the zSpace devices to learn the concepts and the other unit used traditional resources such as textbooks and worksheets.

Research Questions

The research questions examined two aspects of the potential benefits of the use of virtual reality as a learning tool. The first pair of questions related to academic performance and the second pair considered the perception toward the use of a virtual reality-learning environment.

1. To what extent did the utilization of virtual reality affect student academic achievement levels at the 4th grade level?

2. To what extent did the utilization of virtual reality affect student academic achievement levels at the 7th grade level?
3. To what extent did virtual reality affect students' perceived motivation, perception, and interest levels at the 7th grade level?
4. To what extent did virtual reality affect students' motivation and engagement levels from the teachers' perspective?

Hypotheses

The capstone examined two null hypotheses, which compared the academic impact of a classroom environment, using regular resources and material to teach and demonstrate concepts to a learning environment that employed virtual reality as a medium to convey instructional content to the students. The zSpace devices, which offered augmented virtual reality, were used to help students understand and process the same content material provided in the regular classroom environment. The control group included the students in a regular classroom environment, and the experimental group consisted of students who were provided additional instructional reinforcement through the use of the zSpace virtual reality devices.

The null hypotheses examined in this capstone were:

H_o1: There is no difference in the student achievement on electricity activities for students in the control group compared to the students in the experimental group at the 4th grade level as measured by the pretest and posttest.

H_o2: There is no difference in the student achievement on anatomy system activities for students in the control group compared to the students in the experimental group at the 7th grade level as measured by the pretest and posttest.

Summary

Advances in technology in the education world have introduced new tools to enhance the learning experience for students and to provide teachers alternative means to explore and convey concepts and theory from multiple perspectives. The use of 3D devices, such as zSpace, offers students a unique approach to learning. Students explore world and scientific phenomena portrayed using zSpace's virtual reality devices, which offers students a close to real-life experience. Cai, Chiang, and Wang (2013) support this approach to learning stating "the significance of augmented reality in education rests with providing a self-oriented space for exploration for learners in the interaction mode closest to real life, which is especially inspiring and helpful for abstract knowledge" (p. 856-857).

The challenge currently observed in literature is the lack of empirical research supporting the pedagogical effects that virtual learning tools offer students in the K-12 classroom. The purpose of this study was to consider both quantitative and qualitative data regarding the impact virtual reality may have upon student academic gains and students' and teachers' perceived motivational and academic gains due to the use of zSpace.

Chapter 2

Review of Literature

Introduction

Technological advancements are changing the way individuals live, communicate, and transfer information, to how we learn (Siemens, 2005). Organizations around the world are continuously adapting and reinventing systems due to the evolving expansion and development of new technology. This advancement has created new opportunities for organizations to revolutionize current practices and optimize business models, streamline communication, and increase productivity levels. Bolman and Deal (2013) recognize the influence technology has upon organizations, arguing, “pressures of globalization, competition, technology, customer expectations, and workforce dynamics have promoted organizations worldwide to rethink and redesign structural prototypes” (p. 130).

The world of education has experienced many paradigms shifts with pedagogical changes and advancements in technology. Students today, at their fingertips, have access to multiple technological resources to obtain, process and learn new concepts and material. Zhao (2009) argues that society is experiencing another revolution, similar to the magnitude of the Industrial Revolution. The question Zhao presents is, “what should schools teach in order to prepare our children for the global and digital economy?” (p. 145).

The influence technology has had and continues to have upon education is evident at all levels. Educational leaders and school systems continue to recognize the value and importance of incorporating technology within the learning process. There is much research supporting the combination of learning with technology. Fowler (2015) argues that the learning process is intrinsically enhanced with the inclusion of technology and Clark (1994) argues that pedagogy cannot exist without technology. Quintana and Fernandez (2015) argue that "communication technologies are powerful tools that facilitate the teaching and learning processes in the new digital era" (p. 594).

The advancements in technology have enabled students to learn complex concepts, acquire knowledge, and develop skilled practices through intuitive and creative technological platforms. The inclusions of virtual reality devices are now being explored and considered as a viable learning tool in education. Virtual environments offer students a unique learning experience that goes significantly beyond textbooks, two-dimensional (2D) visualization, and representation of academic material. As stated by Shih and Yang (2008), "traditional text-based or web-based virtual reality systems are generally less attractive to students because of their lack of three-dimensional (3D) immersion and real-time voice interaction. Three-dimensional virtual reality technology can be exploited to compensate these weaknesses" (p. 56). Merchant et al. (2014) argue that "3D simulations can imitate real life processes or situations offering students a unique learning experience which 'enhances learners' cognitive skills" (p. 30). Dickey (2003) supports the idea that 3D learning environments increase not only learners' engagement but also the ability to learn abstract concepts.

Dede (2009) agrees that technology advancements will continue to explore the possibilities of immersive environments and user experiences. New technologies provide enhanced virtual environment simulation as stated by Dede, "beyond actional and symbolic immersion, advances in interface technology are steadily evolving towards virtual realities that induce sensory and physical immersion" (p. 8).

Schools today must equip students with the necessary technology skills to learn, explore, and work within the virtual world of today's advancing technologies. Merchant et al. (2014) stated, "more and more resources in the form of time and money are being devoted to the designing and developing of desktop-based virtual reality instruction for teaching K-12 and higher education curriculum" (p. 36). Wu et al. (2013) argue, "new possibilities for teaching and learning provided by augmented reality have been increasingly recognized by educational researchers" (p. 41). This research aimed to explore the benefits to student learning through the use of a new virtual desktop platform called zSpace, within one K-8 Catholic school setting.

History of Virtual Reality

The concept of virtual reality is not new. In fact, virtual reality dates back to the 1960s with the early experimental head-mounted work of Ivan Sutherland (1968). Sutherland formulated and explored the idea that 3D images could be placed on an observer's retinas to create the illusion of a 3D virtual perspective. Documented early, virtual reality efforts are highly evident in the fields of aviation, the military, medicine, and surgical procedures.

Three-dimensional (3D) technology advanced from the entertainment industry to the world of education and training in the 1980s with the launch of Atom World, Cell Biology, Science Space, and Global Change (Merchant et al., 2013). These platforms offered users peripheral devices to experience an immersed virtual environment.

The exploration of virtual learning environments and global online gaming such as World of Warcraft and EverQuest took off with the accessibility of the Internet in the 1990s. These Massively Multiplayer Online Role-Play Games (MMORPGs) became very popular on a global level, which prompted the creation of numerous virtual platforms designed for different purposes such as gaming, socialization, and education. An example of the implementation and presence of virtual environments within education can be traced back to 1999 when the founder of Linden Labs, Philip Rosedale created the popular virtual experience, Second Life (Dede, 2009). As stated by Dede, "quasi-virtual reality already is commonplace in 2-1/2-Dimensional virtual environments like Second Life and in Massively Multiplayer Online Role-Playing Games (e.g., World of Warcraft)" (p. 7).

Inspired by Neal Stephenson's science fiction book, *Snow Crash,* Rosedale's goal was not to create a new gaming program, but rather a new virtual universe that players could connect globally at any time to which transported the user into a world greater than real life (Leap, 2007). According to Morgan (2013), there are 50,000 users logged onto Second Life at any given time with 35 million users globally. Merchant et al. (2013) argue that many educators began integrating desktop-based virtual reality programs such as Second Life into their classrooms in order to create replicas of real-life places and to "actively engage in realistic activities that stimulate learning" (p. 30).

As technology continued to advance, new computer-based virtual platforms began to emerge, such as River City, designed specifically for middle school students to explore scientific inquiry and 21st Century skills and Vfrog, a program enabling students the ability to dissect a virtual frog (Lee, Wong, & Fung 2010).

Today, gaming programs such as Fortnite© and Minecraft© are popular MMORPGs virtual worlds enabling users to participate individually or connect with other gamers virtually. Programs such as Minecraft and even more recently Fortnite (Schwartz, 2018) may present academic opportunities for students as they learn to build, construct, and solve problems collaboratively. Although not a gaming platform, the introduction of zSpace's augmented virtual reality devices within the classroom environment offers students a different and unique approach to learning material and concepts that could revolutionize how students learn in today's classrooms.

Technology in Education

The implementation and use of technology within education has exploded exponentially over the past three decades, with one computer for every 125 children in schools in 1981, one for every 18 students in 1991, and one for every four children in 2000 (Christensen, 2011). At the time of this study, one-to-one deployments of devices such as Chromebooks and iPads were common practices in many schools with the addition of advanced technology equipment and programs such as 3D printers, e-learning platforms, distant learning consortiums, and commercial grade robotics.

Bulman and Fairlie (2015) stated at the time of their research that "greater investment in technology could improve the effectiveness of time dedicated to computer-based instruction and the corresponding reduction in traditional resources may reduce the effectiveness of time dedicated to traditional instruction" (p. 9).

Despite the belief that technology enhances and improves the learning experience and the on-going allocation of funds to increase access and quality of technology within schools, including virtual reality platforms, researchers such as Lee & Wong (2014) argue that the use of virtual reality devices as a meaningful learning tool is inconclusive stating "research findings are mixed with regard to the learning effectiveness of VR-based learning" (p.1).

There was a theory coined by Thomas Russell, (1998) which challenged the idea that the use of technology enhances the learning experience. In his book titled, *The No Significant Difference Phenomenon: A Comparative Research Annotated Bibliography on Technology for Distance Education*, Russell challenged the notion that students learn at a higher level due to the utilization of technology such as distance learning over face-to-face interactions. The research revealed that after analyzing numerous studies dating as far back as 1928, the results revealed no significant difference in student learning with the inclusion of technology or the absence of technology. Bulman and Fairlie (2015) also support this statement indicating that most technology research has "exploited policies that promote investment in computer hardware or Internet access. The majority of studies find that such policies resulted in increased computer use in schools, but few studies find positive effects on educational outcomes" (p. 14).

Clark (1983) presents an argument suggesting that technology is merely the tool in which to communicate and deliver content without influencing student achievement and that "most current summaries and meta-analysis of media comparison studies clearly suggest that media does not influence learning under any condition" (p. 445). Clark further mentioned that studies indicating improved results due to technology are confounded and misleading. Examples of confounding sources include uncontrolled effects such as instructional and delivery methods and the novelty effect, which diminishes over time. Clark points out "the negative impact of novelty effect disappears as students become more familiar with the technology" (p. 450).

Hew and Cheung (2010) also address the novelty effect impacting short-term studies stating "it is possible that students and teachers are more likely to use and enjoy virtual worlds because the technology is new to them compared with participants who used them for a longer period of time" (p. 45).

Clark (1983) sends a strong message indicating, "five decades of research suggest that there are no learning benefits to be gained from employing different media in instruction, regardless of their obviously attractive features or advertised superiority" (p. 450). In a study conducted by Elliott, Adams, and Bruckman (2002), the concept of math and spatial ability in 3D gaming upon student interest and achievement levels were examined through a program called AquaMoose. "The results from the visual ability test did not predict benefits from the AquaMoose intervention on content test scores or attitudes" (Elliott et al., p. 5). In addition to this, "the AquaMoose intervention had no impact on the students' performance on the content test or on the attitudes about mathematics" (Elliott et al., p. 5). In fact, the results showed that the students in the control class outperformed the students in the experimental 3D environment. It must also be noted that students with prior experience with 3D environments did not achieve higher scores compared to those who had no experience.

Furthermore, AquaMoose tests conducted at the end of the year revealed that the students demonstrated no significant retention levels from the experimental 3D learning environment and student reports indicated that they found that the 3D environment confused the concepts being explored. One student commented, "I did not learn a thing, my mind just got confused and disorientated" (Elliot et al., p. 6).

A study conducted by Hassell, Goyal, Limayem, and Boughzala (2011) regarding the effects of presence, co-presence, and learning outcomes in 3D learning spaces revealed that the learning environment did have a positive impact on personal satisfaction, yet there was no significant influence on learning effectiveness. In addition to this, when the control and experimental environments were compared, the results indicated no significant benefit to learning with virtual learning devices (Hassell et al.).

Basham and Kotrlik (2008) addressed the concept of spatial abilities and how these functions relate to 3D learning environments. The study indicated that there is a theory supporting the benefits of improving spatial abilities, which in turn can improve academic achievement in mathematics and science (Basham & Kotrlik). The results revealed that the use of 3D learning models could possibly increase student spatial ability only when in combination with teacher-led and student-led instruction (Basham & Kotrlik). Students who were not exposed to teacher-led and student-led instruction showed no increase in spatial ability through the sole use of the 3D learning environment (Basham & Kotrlik).

Lee and Wong (2014) administered a study to examine the impact virtual reality had upon students with different spatial abilities; their performance and interaction compared to a virtual reality based-learning environment and a traditional classroom environment. The research indicated that the virtual reality environment improved student performance on low spatial ability learners but not for high functioning spatial learners. In a study conducted by Merchant et al. (2013) regarding chemical learning through the use of a virtual learning environment, the results revealed that there were no statistical gains due to the use of virtual reality.

Despite the argument opposing the support or recognizing the benefits of 3D learning environments, there is a growing philosophy and understanding amongst researchers and practitioners today that technology does play a vital role in our children's education system and how students process concepts and gain a greater understanding of knowledge (Dalgarno & Lee 2010). Dalgarno and Lee argue that learning and technology are intrinsically interwoven, each dependent on the other. Clarke (2009) supports this philosophy indicating that learning and technology cannot exist without the other. Dede (2009) noted that "in education, technologies achieve their power indirectly, as catalysts for deeper content, more engaging activities, more active forms of learning and instruction, and richer types of assessment" (p. 7).

Wu et al. (2013) made a valuable point regarding the use of virtual technology platforms within education stating, "like many innovations, the educational values of augmented reality are not solely based on the use of technologies but closely related to how augmented reality is designed, implemented, and integrated into formal and informal learning settings" (p. 41).

The formal learning environment comprises of an educational system, which utilizes traditional teaching methods, resources, and instruction from educators (Chittaro & Ranon, 2007). Informal learning consists of every environment outside of the traditional educational system. Informal learning environments are those that are flexible in space, maximize the utilization of intuitive technologies, foster collaboration and creativity and are symbolic of 21st Century characteristics and values (Mahajan, 2017).

The use of virtual reality not only has a place within the formal education setting, but also lends itself to an informal learning style promoting self-direction, exploration, and discovery. In the informal learning environment, the use of virtual reality affords students the opportunity to learn in a less restricted and rule-driven environment. zSpace virtual reality applications allow students the opportunity to freely explore concepts not only beyond the textbook but the confines of their classroom walls.

Types of Virtual Environments

Virtual reality environments can be generalized as a class of computer simulations pertaining to a representation of 3D space and human-computer-interaction. There are two types of 3D environments, Immersive virtual reality and Non-immersive virtual reality (Lee & Wong, 2014). Within these two virtual environments, there is a range of virtual reality and the level at which the user is virtually immersed. The non-immersive virtual reality experience spans from 3D pictorial representation on a regular desktop or iPad, which includes games, virtual worlds, and simulation (Lee & Wong) such as Minecraft, Fortnite, and Second Life, to a complete virtual reality immersion experience through head-mounted displays (HMD) devices such as the Oculus Rift® or the Vive®. Head-mounted display devices remove external distractions in order to elevate the user's experience and sensation of being completely immersed within a virtual environment devoid of real-time presence and location.

The variations in virtual reality platforms typically fall into one of four areas: head-mounted displays, cave automated virtual environments, mixed or augmented reality, and three-dimensional pictorial representation. (See Table 2)

Table 2

Types of virtual learning environments (VLE)

Head–Mounted Displays (HMD),	Devices such as the Oculus Rift and Vive provide a fully immersed virtual experience. Games and educational applications can be downloaded offering users a wide variety of virtual experiences such as the virtual art program, Google Tilt, the geographical travel application, Google Earth to countless games, music, engineering, and exploration programs.
Cave Automated Virtual Environments (CAVE).	This form of augmented virtual reality requires the image to be projected onto a wall. This form of virtual reality is common in museums or exhibitions to allow large numbers of visitors to enjoy a unique virtual experience.
Mixed Reality (MR) or Augmented Reality (AR),	MR/AR such as zSpace enables the viewer to visualize the augmented image within the real (classroom) physical environment through the use of a specially designed desktop and 3D glasses.
Three-dimensional pictorial representations	This environment occurs on desktop computers, televisions through gaming consoles such as Play Station, XBOX or iPad devices for gaming, simulation, and virtual world games.

Cheng and Tsai (2013) describe virtual reality as an environment that allows the user to become immersed within a synthetic environment, whereas augmented virtual reality enables the user to experience “a real world with virtual elements overlapped upon it in real time” (p. 451). Thornton, Ernst, and Clark (2012) describe augmented virtual reality as the ability to “superimpose a virtual overlay of data and experiences onto a real-world context” (p. 18) which holds great potential for educational use in the 21st Century classroom environment. Cai et al. (2013) support this description of augmented reality by stating:

> [It] is commonly agreed that augmented reality is the technology integrating 2D or 3D virtual information generated by a computer into authentic contexts around the user with the assistance of 3D-graphics technology, human-computer interaction techniques, various sensing technologies, computer vision techniques, and multi-media techniques. (p. 856)

Klopfer (2008) suggests refraining from defining augmented virtual reality as a specific concept but rather to consider the augmented reality that could be applied to any technology that combines real and virtual information in a unique and meaningful approach.

Milgram and Kishino (1994) created the concept of the Reality-Virtual Continuum starting with a completely real learning environment to an experience that requires complete virtual immersion. Wu et al. (2013) argue “within this continuum mixed reality can be defined as a situation where real world and virtual world objects are present together” (p. 42). Wu et al. also describe the notion of mixed reality as two ideas, “augmented reality and augmented virtuality” (p. 42).

Klopfer (2008) presents the idea of a spectrum to depict the level of augmentation the viewer experiences. Wu et al. (2013) provide a clear description of Klopfer’s virtual spectrum explaining,

> [A] lightly augmented reality refers to a situation in which users utilize a large amount of information and physical materials from the real world, and have

access to relatively little virtual information. On the other hand, heavily augmented world, most immersive technologies, such as head-mounted displays, are implemented (p. 42).

Milgram and Kishino (1994) offer the concept of a Virtuality Continuum, which includes a board spectrum of mixed reality spanning from a real environment to a virtual environment (Figure 1). The Virtuality Continuum places the environment, which uses virtual reality devices, such as zSpace, towards the left of the continuum, whereas, the use of full immersion devices, such as the Oculus, is located on the far right-hand side of the spectrum.

Figure 1: Virtuality Continuum, (Milgram & Kishino, 1994, p. 3)

Experience of 3D Learning Devices

Dede (2009) states that immersive virtual environments are a psychological experience that affords users "the willing suspension of disbelief" (p. 7). Wu et al. (2013) argue that virtual reality should be viewed as a concept rather than a type of technology. Cai et al. (2013) argue that the virtual learning experience provides users with an opportunity to develop their perception of world principles from different angles, thus expanding user imagination through natural operations.

Azuma (1997) offers valuable discussion regarding the definition and variation of what is considered and agreed upon regarding the concept of virtual reality. Azuma identifies virtual reality as placing the user within an immersed synthetic environment reality. In addition to this, Azuma defines virtual reality as combining three properties, real world with virtual worlds, including interaction, and representing the information in 3D. Heeter (1992) addresses the concept of immersion through virtual reality arguing that immersion is a subjective impression as the user experiences a comprehensive and realistic environment.

Theoretical Frameworks of 3D Learning Environments

Several theoretical frameworks have been developed by researchers designed to classify or taxonomies applications and learning activities supported by virtual reality learning environments (Dalgarno & Lee, 2012). Within these frameworks, the use of specific vocabulary has been used to express and describe the virtual learning environment and experiences. The term ‘affordance’ is often associated, in literature, with virtual reality environments. First coined by Gibson (1977), ‘affordance’ is used to describe the benefits an environment or object offers to an animal or person. Bower and Sturman (2015) state, “under Gibson’s definition an “affordance” exists as long as the person (or animal) can take the necessary actions to utilize it” (p. 345). Norman (1988) defines affordance as “the perceived and actual properties of a thing” (p. 1). Affordance, therefore, provides users with an authentic experience that is individually unique which can only be achieved through the utilization of virtual reality devices and platforms.

Salzman, Dede, and Loftin (1999) provide three potential frames of reference when examining the virtual environment. The first, exocentric frame of reference, offers users the ability to view objects, images, and concepts from an outside perspective. The second concept is when the user receives the information from an egocentric perspective, which involves a fully immersed sense of virtual reality. A bicentric approach is a combination between the two virtual experiences. Salzman et al. (1999) argue that it is the combination of exocentric and egocentric that optimum learning is ideally experienced.

After reviewing over 20 years of published research, Dalgarno and Lee (2010) identified ten specific learning characteristics afforded by virtual learning environments. The model, 3D Virtual Learning Environments (Figure 2), first represents six characteristics of 'representational fidelity' of virtual reality. These consist of the *realistic display of environment, smooth display of view changes and object motion, consistency of object behavior, user representation, spatial audio, and kinesthetic and tactile force feedback*. The four characteristics of 'learner interaction,' which relate to the learner-computer interactivity, consist of *embodied actions, embodied verbal and non-verbal communication, control of environment attributes and behavior, and construction/scripting of objects and behaviors.*

Dalgarno and Lee (2010) argue, "the ten environmental characteristics give rise to three characteristics associated with the experience of using or 'being in' the virtual environment" (p.1). These characteristics, which are commonly associated with virtual communities, such as Fortnite, are the *construction of identity, sense of* *presence,* and *co-presence*. It is important to note that the benefits of identity and co-presence are not evident in the use of devices, such as zSpace, as users do not create aviators to navigate the virtual program. However, the sense of presence in terms of allowing the user to virtually experience concepts, material, and locations is highly evident through the use of the zSpace platform.

The learning outcomes of the environmental and experiential characteristics, as argued by Dalgarno and Lee (2010) offer five potential learning benefits to the user. These benefits include *spatial knowledge representation, experiential learning, engagement, contextual learning,* and *collaborative learning.* Dalgarno and Lee's 3D Virtual Learning Environments Model symbolizes the multiple learning benefits students experience when engaged in a virtual reality environment. It could be argued that through the use of virtual reality devices, students are afforded the opportunity to expand their spatial understanding of non-tangible or abstract concepts beyond 2D representation. Virtual reality allows students to experiment without harm or discomfort, to increase engagement levels virtually through collaborative learning techniques, and ultimately expand their knowledge and understanding of global and classroom applicable concepts. In addition to the examination of student academic performance due to the inclusion of the virtual reality device, zSpace, this capstone also analyzed student and teacher perceived benefits in relation to Dalgarno and Lee's 3D Virtual Learning Environments model and the five potential learning benefits as stated above.

The 3D Virtual Learning Environments model offer a wide variety of potential learning outcomes and benefits through the use of virtual platforms, however, Dalgarno and Lee (2010) do acknowledge the argument that, "the technologies themselves do not directly cause learning to occur, but that the afforded learning tasks may give rise to certain learning benefits" (p. 2). This is an important point which suggests that while virtual learning environments, such as zSpace, may not only offer students a unique tool in which to process and construct information from different perspectives that surpass traditional teaching strategies, techniques, and material, the use of augmented reality may also enable students to enhance their learning experience and advance their learning capabilities.

In addition to offering a unique approach to learning, Dalgarno and Lee's (2010) model also supports the Constructivist Theory, which argues that students learn through experimental learning immersed within a collaborative, social, and engaging environment. Virtual learning environments allow students to explore practical and real-world applications without limitations. Collaboratively students build, construct, and expand their knowledge and understanding of concepts while identifying solutions to problems within an authentic learning environment.

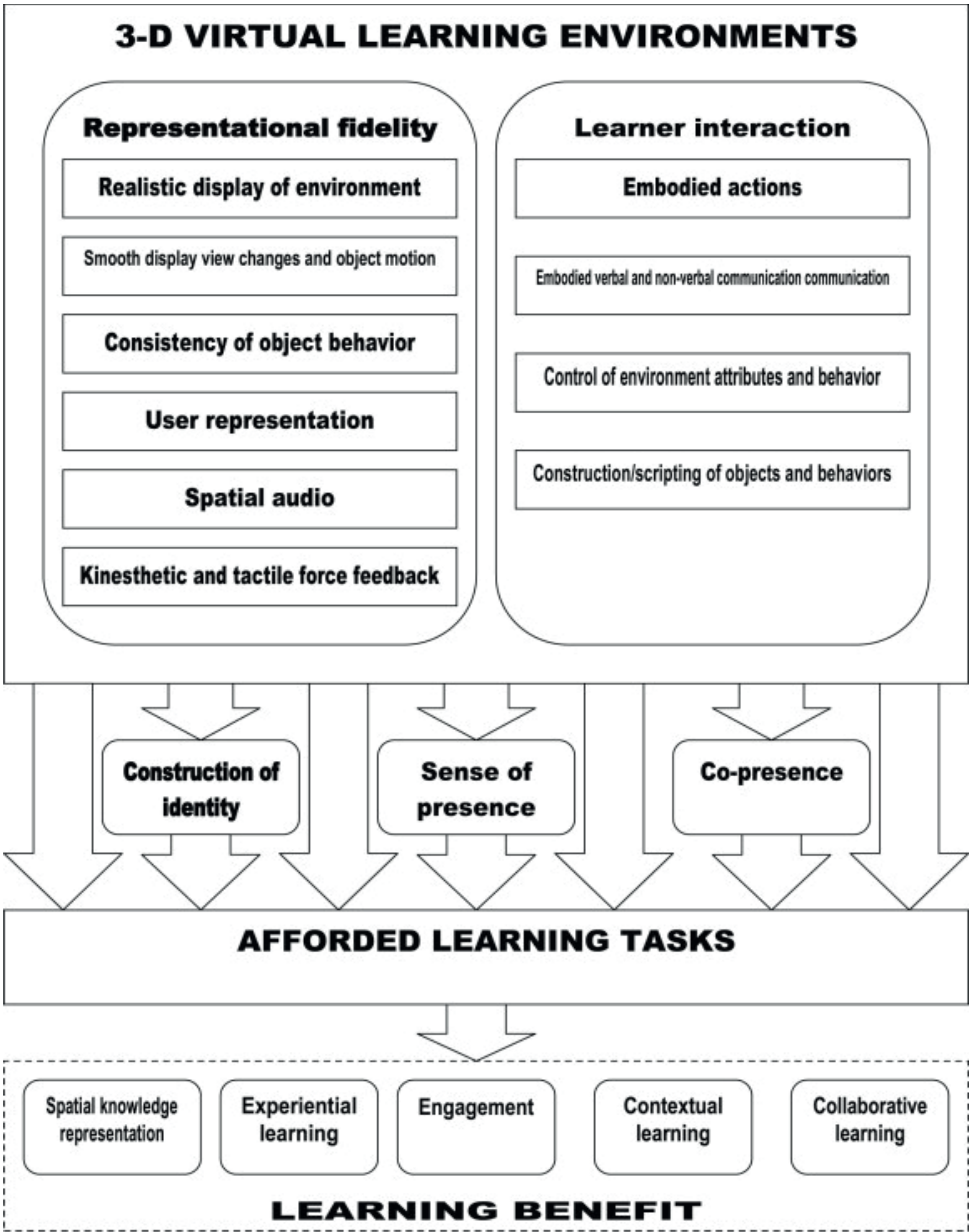


Figure 2: A model of learning in 3D VLEs (Dalgarno & Lee, 2010)

zSpace®

The zSpace technology offers users an augmented and virtual mixed reality lifelike experience through the use of a desktop device, stereoscopic display, a stylus, and two forms of 3D glasses. Azuma (1997) argues that this form of augmented reality allows "the user to see the real world, with virtual objects superimposed upon or composited with the real world" (p. 335). Thornton et al. (2102) state, "augmented reality allows greater detail, explanation, and clarity of examples through the establishment of visual and spatial relationships" (p. 20). Simulated objects and activities can be manipulated to explore and discover interactive applications in numerous content areas such as human antonym, the Periodic Table, electricity, laws of force and motion, engineering and architecture, space and travel, and ecosystem exploration to name a few.

The desktop device creates a virtual image based on the perception of depth that appears outside of the computer's interface, taking on a 3D appearance that can be manipulated by the use of a stylus. The stylus provides a kinesthetic realism experience as users hold, move, remove, and expand objects through the use of buttons located on the stylus. Built-in infrared cameras and infrared reflectors and tracking devices on the glasses and stylus, update the virtual images continuously as the user moves their head and stylus. The zSpace technology is designed to provide high definition images (1080p, 120Hz) and resolution levels.

The system also simulates a haptic (vibration sensation) feature enhancing user experience. The program contains numerous Science, Technology, Engineering, and Mathematics (STEM) applications at the K-12 education level, health and science, and career and technology level, which are updated every six months. zSpace offers over 2,500 units for students aged Kindergarten through higher education including medical school level. Currently, zSpace offers the following applications:

- zSpace Studio
- Franklin's Lab
- Human Anatomy
- Euclid's Shapes
- Geogebra
- Labster
- Newton's Park
- Curie's Elements
- VIVED Science
- Leopoly 3D
- zSpace Experiences

zSpace offers three devices, zSpace All in One, zSpace All in One Pro, and zSpace Laptop. Each device operates with Windows 10 and provides the user with wireless capabilities. The zSpace applications, once downloaded and updated, run independently of the Internet. The devices may also serve as a regular desktop for classroom use.

zSpace was initially designed to provide virtual reality learning environments within the government and medical fields. However, in 2007 the company expanded its focus towards education. zSpace has since partnered with NASA to virtually build future robots and more recently with Google Chrome: WebGL to provide a Google platform.

This new form of virtual reality is gaining global interest with more educators recognizing the potential impact virtual learning environments may offer students at different ages and with different learning styles. To date, there is limited empirical research to support academic gains due to the utilization of zSpace as a viable teaching tool within the classroom. This capstone explored student achievement gains through the use of zSpace devices.

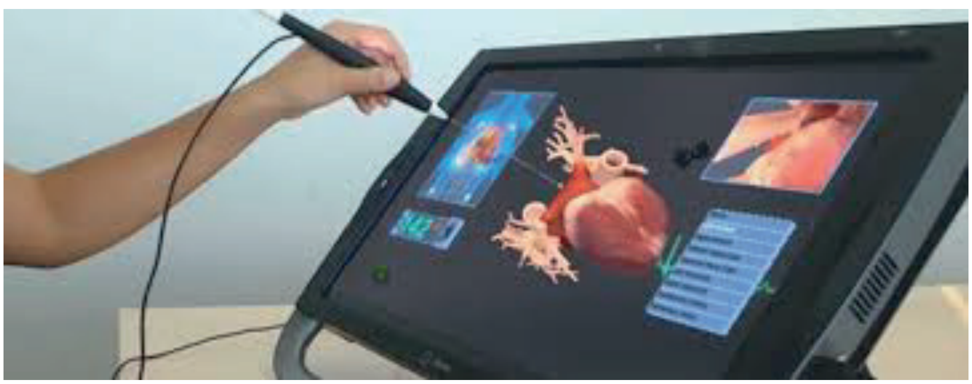


Figure 3. Use of the stylus to grab, hold and turn the heart to explore and view all angles. The stylus allows the user to remove parts of the heart to allow for internal viewing. The camera allows the user to travel inside the heart exploring all chambers and values. The stylus offers the user haptic sensations simulating the beat of the heart.

Figure 4. Stylus allows the user to explore the human muscular system by removing body parts to explore all areas.

zSpace is a unique learning tool that is currently only available to students during their designated technology lessons on-site at the school. At the time of the study, there were no students at St. Joseph Catholic School who had obtained zSpace for personal usage at their homes. Their experience with this form of augmented virtual reality is only specific to their enrollment within the school program.

Theoretical Frameworks of Learning Styles

Gardner's Frames of Minds: Theory of Multiple Intelligences (1983) describe seven different approaches to learning which include, linguistic, logical-mathematical, musical, bodily-kinesthetic, spatial, interpersonal, and intrapersonal (Zhao, 2009). Gardner argues that individuals exhibit different levels of intelligence within each style of learning.

Virtual reality environments may offer students an individualized learning experience designed to address different learning styles. The inclusion of zSpace devices within the learning environment provides students the affordance to learn abstract concepts through different approaches kinesthetically, spatially, and collaboratively.

The aptitude-by-treatment interaction (ATI) is a teaching strategy, which adapts instruction to meet the specific abilities and learning styles of the student (Plass, Kalyuga, & Leutner, 2010). Plass et al. argue that this approach lends itself to the use of virtual reality as it allows educators to expand and identify teaching strategies, which work best for each student. Educators encourage students to explore learning concepts from different perspectives and mediums, such as virtual reality, in order to determine successful connections between effective teaching practices and student success.

Piaget's (1965) Theory of Cognitive Development offers four stages or periods tied to the development of intelligence: the sensorimotor stage, the preoperational period, followed by the concrete operation stage, and finally the formal operations or propositional operational stage.

The concrete operation stage includes an age range between 7 to 12. It is at this age that the child deals with logical processes and relations through the manipulation of objects (Piaget) and it is at this stage that a child formulates basic concepts but cannot find logical inclusion. The child's thought process is concrete in nature as they begin to develop the concepts of object substance, serialization, and reversibility of objects, weight and length of objects. It could be argued that at this developmental stage, students are limited within their cognitive ability to effectively process abstract pictorial images presented in 3D representation.

Simsek (2016) offers a different perspective regarding the use of a 3D representation of abstract information for students in the concrete operational stage. Simsek suggests that the presentation of abstract concepts or objects in 3D presents advantages to students in the concrete cognitive stage. Using the example of geometry such as solids and shapes, a student may not fully grasp the concept of a cube or a sphere from a 2D pictorial representation. Presented as a 3D image, students can manipulate the object virtually allowing them to explore all the aspects and features of the shape from different angles, thus developing a greater understanding of the concept.

In a study conducted by Lee and Wong (2014), the findings suggest “the desktop virtual reality instructional intervention has helped to reduce extraneous cognitive load and engages learners in active processing of instructional material to increase germane cognitive load” (p. 1). The study’s results suggested that the use of 3D imagery increased the academic results of students with a low cognitive spatial ability. Such findings could provide educational value and support for the use of virtual reality devices to assist students, specifically those with a low spatial ability to process and understand complex and abstract concepts.

At the last stage in the development of intelligence, the formal operations or propositional operations, which typically occurs at the age of 11 to 12 years, the child cognitively begins to process abstract information. According to Piaget (1965), “the child becomes capable of reasoning not only on the basis of objects, but also on the basis of hypotheses, or propositions” (p. 105).

It is at the formal operational stage that the child is able to process information abstractly. This process is achieved first through a combinative structure, followed by the operations of proposition, reversibility, reciprocity, cancellation, and combination. The next level consists of the understanding of reasoning and proportions, and finally the construction of new operational structures. It could be argued that it is at this developmental phase that students are more able to effectively absorb and process the abstract concepts displayed in 3D learning environments (Simsek, 2016).

Siemens (2005a) presents a theory of learning titled, Connectivism, which not only recognizes the advancement of technology but also how technology has altered the way that information is processed. Siemens acknowledges the theories of behaviorism, cognitivism, and constructivism, which were formulated prior to the expansion of technology stating, "these theories, however, were developed in a time when learning was not impacted through technology" (p. 1).

The theory of Connectivism includes the 21st Century skills of collaboration, innovation, and communication, which can only be achieved through the use of innovated technology, such as virtual learning environments. It is Siemen's (2005a) belief that experience is the best teacher for the acquisition of knowledge. Virtual learning platforms, therefore offer students a close to real-life experience of new material, abstract concepts, and world phenomena. Siemens states, "Technology is altering (rewiring our brains). The tools we use to define and shape our thinking" (p. 1). In addition to this, Siemens argues that in order to learn from new experiences, to obtain knowledge and to develop understanding it is necessary "to plug into" technological sources to explore and enhance the learning experience and to have real-life application. The inclusion of virtual learning environments presents students with an opportunity to become immersed in a real-life learning environment from within the walls of their classroom.

Constructivist and Collaborative Learning Approach

The Constructivist Theory requires individuals to interact and communicate with others in order to share ideas, concepts, and knowledge. Students learn through real-life experiences of the world, building and constructing knowledge in a meaningful way (Chittaro & Ranon, 2007). Siemens (2005a) states that Constructivist learning allows the learning to take place outside of the person, building upon prior knowledge through social interaction and argue the point of view that, "learning is a socially enacted process" (p. 3).

Virtual learning environments support and promote an environment for collaborative learning, interactions, and the performance of tasks and discussion (Chau et al., 2013). Cho and Lim (2015) argue that virtual world technologies allow students to learn new concepts in an authentic and collaborative context. In addition to this, Cho and Lim argue that collaborative and problem-solving learning opportunities "allow students to share their knowledge and new information, engage in shared tasks with high situational interest, and elaborate or challenge each other's viewpoints" (p. 2).

Through collaborative learning, students share common goals, rely on each other, and take responsibility for their learning (Chittaro & Ranon, 2007). Collaborative learning, immersed within a 3D learning environment enables students to process abstract, complex material that is not easily accessible in an open-ended exploratory learning environment. Potentially this may help to promote the acquisition of higher-level cognitive functions, problem-solving abilities, ease in scientific expression and the development of communication, social and higher-order thinking skills (Konstrantinidis & Pomportsis, 2009).

Shih and Yang (2008) argue that there is growing research supporting the effectiveness of Constructivist and collaborative learning within 3D environments. Such environments support knowledge construction, self-direction, and immersion interactivity within the educational process. Dziuban, Hartman, and Moskal (2004) suggest that such approaches to brain-based learning and Constructivist learning should be viewed as an educational transformation or paradigm shift within our school systems. Chittaro and Ranon (2007) describe collaborative interaction as a learning solution promoting personal cognitive development designed to enhance social and management skills in individuals.

According to Chau et al. (2013), there is great potential for these technological devices to become innovative educational platforms, providing students with real-world-like experimental learning. Students today utilize technology to communicate, process information and construct learning. The use of 3D learning platforms, such as zSpace devices, offers students a Constructivist learning experience, which enables students to build upon new ideas or concepts based upon current and past knowledge (Chau et al.). Shih and Yang (2008) identify virtual learning environments as Constructivist and collaborative learning tools. Felemban, Gardner, and Callaghan (2017) identify the benefits of collaborative learning, which enable students to interact with their peers to develop and acquire new skills and build and share knowledge.

Winn (1993) argues that it is through first-hand experiences, real or virtual, that students' construction of learning is more meaningful and personal, rather than from a 3rd person's perspective or description of the world which lacks depth and personal experience. Chittaro and Ranon (2007) support this theory stating "interaction in a virtual environment can be a valuable substitute for a real experience, providing a first-person experience and allowing for a spontaneous knowledge acquisition that requires less cognitive effort than traditional educational practices" (p. 7).

Computer-Supported Collaborative Learning

The learning structure of zSpace promotes the concept of collaborative learning mediated through the use of technology. Computer-supported collaborative learning supports the idea of grouping two or three students per computers. zSpace encourages students to work and learn collaboratively with a partner as they explore and discover new concepts. Cho and Lim argue (2015), "virtual worlds have affordances to enhance collaborative learning in authentic contexts" (p. 1). In a study conducted on collaborative-problem solving, Cho and Lim's results suggest that student motivation levels were more effective compared to student motivation levels in teacher-led learning environments.

Robinson (2014) noted that “great learning” occurs when students are afforded the opportunity to collaborate and as social beings, collaborative learning increases not only levels of productivity but also achievement levels. Dalgarno and Lee (2010) also support this perspective stating, “three-dimensional virtual environments that allow learners to engage simultaneously in shared task and/or produce joint artifacts by operating the same objects in real time can pave the way for rich and truly collaborative experiences that foster positive interdependence within a learning group” (p. 22). The zSpace devices are specifically designed to embrace the collaborative learning approach. Numerous zSpace applications are available for classroom use with thousands of units to select, which are structured to build collaboration and generate peer-to-peer discussion and student and teacher dialogue.

Motivation and Engagement Levels

Research indicates that the use of virtual reality environments to help assist students in the learning process increases levels of motivation and engagement as argued by Koh et al. (2010), “the impact of emerging technologies on students’ motivation to learn still offers many avenues for exploration” (p. 237). In an augmented reality 3D imaging experiment in a physics lesson conducted by Cai et al. (2013), the results indicated that students perceived to demonstrate a positive attitude to the use of the 3D technology and that the devices increased levels of motivation and ability to be more attentive to learn the concepts.

Bosch-Sijtsema and Haapamaki (2014) define engagement as “intense absorption to the task” and argue that motivation and engagement levels are higher in virtual learning environments over any other form of media. The use of zSpace devices may not only offer a unique learning tool but also cultivates a collaborative learning environment in which students are engaged, connected, and motivated to explore and learn.

Chittaro and Ranon (2007) state that positive experiences may also increase student interest and engagement levels, as virtual reality environments are more appealing and entertaining. They also noted that the use of virtual environments would be associated with heightened pleasure, thus increasing levels of retention and acquired knowledge (Chittaro & Ranon).

Data collected by the study conducted by Dynarski et al. (2007) revealed that students exposed to the use of technology increased not only the motivation and interest levels of the students but also their desire to participate in questioning and answering sessions and to collaborate with their peers compared to the students in the controlled environment. This capstone explored, through the use of open-ended discussions with students and teachers, the impact and effect virtual reality experiences had upon student learning, engagement, and interest levels and how virtual reality motivated their learning experience.

Benefits Afforded by 3D Devices

According to Zhao (2009), the advancement of technology “has shortened physical bounded local experiences to global ones” (p. 116). Through the use of 3D devices, such as zSpace, students are not limited by the confines of their classroom walls. Students can safely explore concepts that would require space travel, trips to volcanoes, the center of the earth, rainforests or under the oceans to a medical operating room through zSpace designed lessons and experiences. Chittaro and Ranon (2007) supports this view stating that virtual learning environments can “provide a wide range of experiences, some of which are impossible to try in the real world because of distance, cost, danger or impracticability” (p. 9).

In addition to this, zSpace 3D learning also offers students the ability to explore abstract concepts; such as nuclear fusion, Newton’s Law of gravity, kinetic energy, and the Periodic Table without obtaining material or matter. This is a concept supported by Dickey (2005) who argues “investigations reveal that virtual environments offer many benefits such as opportunities for experimentation without real-world repercussion, opportunities to ‘learn by doing’ and the ability to personalize an environment” (p. 106). Cai et al. (2013), support this opinion suggesting that virtual learning environments offer the user the ability to observe objects from a real-life perspective and to explore inaccessible concepts that exist only through imagination.

Chittaro and Ranon (2007) support the use of 3D learning environments over traditional teaching methods, which require students to learn concepts from 2D representations such as textbooks or directly from teachers, which lacks real-life application. Chittaro and Ranon argue that virtual learning environments “provide a good level of realism and interactivity and provide life-like situated learning experiences that link experience to theory" (p. 7). In addition to this, Chittaro and Ranon found that students acquire higher levels of information when more senses are being stimulated. Virtual learning environments require the student to see, listen, hear, and feel (haptic sensation), which provides a rich multisensory experience, thus deepening levels of understanding.

Cai et al. (2013) also noted that 3D learning environments provide the user with immediate feedback. Immediacy is an essential factor in the learning process, as it provides the learner the opportunity to process and analyze the information, readjust and evaluate their responses in a timely fashion, thus increasing knowledge retention. Ash and D'Auria (2013) support this argument stating, "providing immediate and specific feedback is a powerful way to increase the depth and pace of student learning" (p. 127).

Dalgarno and Lee (2010) recognize the benefits 3D learning environments offer students in terms of allowing the learner to "create and manipulate virtual objects, explore novel environments (e.g., oceans, space, historical sites), and have embodied experience" (p. 22). Cho and Lim (2017) support this argument recognizing that unique learning experiences can only be achieved through virtual environments rather than through everyday experiences or activities. Merchant et al. (2014) recognize the cost-saving aspect of using virtual reality stating, "simulation can provide cost-effective practice of procedures using virtual apparatus that in real life could be cost prohibitive" (p. 30). The zSpace concept affords students the ability to explore concepts and skills within a safe environment free from smells, deceased animals, and mess.

In addition to this, zSpace allow students to practice medical procedures on virtual patients eliminating the risk of injury or death to a real patient. Merchant et al. (2014), have also recognized this benefit to virtual reality stating, “medical students can avoid the risk of applying certain procedures directly on the patient without sufficient practice, which may endanger patients’ life” (p. 30).

Cheng and Tsai also believe that augmented reality may provide valuable spatial and situated cognition experiences as well as social constructivist learning in the field of science education. In a study conducted by Kaufmann and Schmalstieg (2003), students used 3D imagery to understand geometric shapes and lines. The results suggested that there was an improvement in the students’ spatial abilities, which could be contributed to the observance of 3D objects from textbooks. The students were also afforded the opportunity to collaborate and further discuss their findings. Cai et al. (2013) support the blend of a virtual learning environment with the opportunity to collaborate stating “students will have a better understanding of otherwise confusing spatial concepts in this environment through a blend of reality and virtuality” (p. 857).

Hew and Cheung (2010) recognize the ‘fundamental attribute’ 3D simulation, and imaginary affords spatial development as students process abstract concepts. Winn (1993) argues that virtual learning environments allow the user to process abstract concepts through the manipulation of the 3D image in terms of size, transduction, and reification. The virtual reality environment allows the user to expand, compare, sensationalize, and concretize abstract concepts through a real-life simulation effect.

Implications for Special Education

Catholic schools in America have seen an increase in the enrollment of students diagnosed with a learning disability over the past 20 years. In the 2002 United States Conference of Catholic Bishops (USCCB) study, the population of students identified with a disability within Catholic schools was reported to be over 7% with 28% of those students identified with mental retardation, hearing and vision impairment, autism, physical disabilities, emotional and behavioral disorders, or traumatic brain injury (Crowley & Wall, 2007).

In 2016-2107, almost 7% of the 1,878,824 million students enrolled in Catholic schools were identified with special needs (NCEA, 2017). Catholic schools not only have an obligation to embrace all learners regardless of wealth and individual needs, but they must also seek creative and alternative means to diversify instruction, to transform the traditional way of thinking towards special education and implement new strategies and approaches to include special education in the Catholic school environment.

Augmented reality through the use of zSpace devices may offer students of different learning styles and academic ability the opportunity to learn and process new concepts and skills in a unique method significantly different from traditional approaches. Hew and Cheung (2010) support this argument suggesting that virtual worlds present an opportunity for learning to consider individual differences and cultural perspectives. Koh et al. (2010), argues that virtual learning environments have been used for a wide range of purposes including differentiated instruction, customized learning, addressing diverse abilities, promoting collaborative learning, and developing student skill set mastery levels.

Chittaro and Ranon (2007) argue that virtual learning tools offer students with physical or cognitive limitations the opportunity to explore a broader range of real-life experiences that would not be possible or accessible from within the traditional or regular classroom environment.

In a study conducted by Lee and Wong (2014), they examined the learning effectiveness of a desktop virtual-based learning device in which students at the high school level were given a pretest and posttest experimental design. The results indicate that student performance was at a higher rate with a desktop virtual reality device compared to the students in the controlled environment without access to a desktop virtual reality device. In addition to this finding, the study revealed a difference in low spatial (ability to relate, the perception of relationships, and problem solve) ability learners' performance compared to high spatial ability learners. Lee and Wong state, "the results signify that low spatial ability learners' performance, compared with high spatial ability learners, appeared to be more positively affected by the desktop VR-based learning environment" (p. 1).

Such studies may provide statistical support for the use of virtual reality devices for students who exhibit lower cognitive functioning levels in the areas of spatial visualization, which enables the student to problem-solve information through extraction, reconstruction, and manipulation. Students exhibiting lower spatial abilities lack the ability to visually reconstruct concepts mentally unlike higher-level spatial ability thinkers, therefore; through the use of virtual reality, the construction process affords low spatial ability students the tools to effectively process information (Lee & Wong, 2014).

In addition to considering diversity in student learning, technology accessibility and distribution of technological resources and training differ between students, schools, and districts. Koh et al. (2010), identified that technology proficiency levels could be influenced by the student's educational background, gender, and knowledge of technology. Additional external factors such as language barriers, gender bias, technology prior knowledge and accessibility could also be determining factors influencing the results of studies.

Across America, there are examples of dioceses and Catholic schools that are working to identify and create effective and sustainable special education programs designed to embrace a wider range of students with learning differences and demographics and to seek innovative and alternative approaches to learning beyond the traditional classroom environment (Schmitt, 2015).

Limitations and Restrictions

Cheng and Tsai (2013) argue that more research is needed in the field of augmented reality with regards to student motivation levels, learner characteristics, and the potential issue surrounding cognitive overload. In addition to the lack of empirical studies regarding virtual environments as a learning tool, there is also suggested research drawing our attention to the possibilities of limitations and restrictive use of 3D devices. Moreno and Mayer (2004) argue that 3D virtual environments may impose high cognitive overload because of extraneous material used to increase representational fidelity (Cho & Lim, 2017). Wu et al. (2013) also argue this point stating, “students in augmented reality environments may be cognitively overloaded by the large amounts of information they encounter, the multiple technological devices they are required to use, and the complex tasks they have to complete” (p. 41).

Pass, Renkl and Sweller (2004) warn of the possible extraneous cognitive overload, exceeding working memory. Pass, Renkl and Sweller argue that this cognitive overload is detrimental to knowledge and skill acquisition.

Merchant et al. (2014) recognize the financial constraint that for many educational institutions to obtain such devices is a significant challenge stating “the cost of both procurement and maintenance of various sophisticated devices to create an immersive environment made mass use of this technology prohibitive” (p. 30). Chittaro and Ranon (2007) also recognize the financial limitations virtual reality technologies pose for school districts noting the high costs of specialized hardware, such as head-mounted displays and 3D input devices required to offer students with a unique learning tool.

In addition to the financial constraint of purchasing virtual learning devices, Merchant et al. (2014) argue that efforts to train teachers effectively must also be taken into consideration. Chittaro and Ranon (2007) argue that the attitude of educators to utilize new technologies must also be explored stating "some teachers may not be interested in new technologies, perceiving them as a waste of time or as a too radical change to their traditional methodology" (p. 15). Chittaro and Ranon also point out the importance of virtual reality curricula integration stating virtual environments at a minimal level "can deal only with the examples and exercises proposed by a traditional textbook. At a more ambitious level, the 3D environment, from a constructivist point of view, could come before the textbook as the main way to familiarize with the topics" (p.15).

Lee and Wong (2014) not only point out the financial constraints of virtual reality devices, but also the issue of simulator sickness associated with fully immersive environments. Lee and Wong argue that desktop computers offering an augmented reality experience are an alternative approach to offering a mixed virtual reality experience.

Technology, such as zSpace, which uses low-cost peripheral devices, have made it possible for schools in the K-12 environment to financially secure and offer students a unique learning experience beyond textbooks and lecture style learning environments. In addition to this, zSpace provides intensive teacher training sessions to schools in order to ensure the effective implementation and use of the zSpace devices and to maximize teacher proficiency levels and quality of instruction.

Hew and Cheung (2010) present an argument that short-term use of new technology could influence research data due to the novelty effect. Users are more inclined to exhibit higher interest levels when exposed to new technology. Hew and Cheung further state “this may introduce a significant bias with respect to some of the obtained results” (p. 45).

In an effort to reduce the novelty effect, most participants selected for this study have been exposed to the use of the virtual learning environment, zSpace from a long-term perspective spanning over two academic years. Hew and Cheung (2010) supported this approach to research arguing, “studies with either experienced students, or started a few years after the initial virtual world projects are initiated would also mitigate novelty effects” (p. 46).

Conclusion

It is important for educators to understand that education cannot evolve without the presence of technology and its advantages. Educational institutions are charged with the responsibility to prepare students for an unknown tomorrow. Today, students are faced with unforeseen challenges, and they need to be prepared not only academically, through advanced learning techniques and technology, but also socially to develop teamwork and leadership skills through collaborative practices. It is through the use of advanced and innovative technology that allows the learning experience to move away from formal educational practices to accept and embrace informal learning approaches designed to prepare individuals to work in future fields unrelated or unknown in today’s society (Siemens, 2005a).

The Bureau of Labor Statistics projected the employment of Computer and Information Technology jobs to increase by 12% from 2014 to 2024. Occupations in this field are projected to experience one of the most significant increases in employment unlike other fields, such as postal services and catering, with a projected increase in Computer and Information Technology fields from 3.9 million jobs to 4.4 million jobs by 2024.

More research, therefore, is needed in the field of technology in education to better understand the impact technology has on learning experiences. The challenge we are faced with is the lack of empirical research on the effects of technology on learning in formal school settings (Kebritichi, Hirumi, & Bai, 2010). Cho and Lim (2017) make the argument that "more research is necessary not only to explore new pedagogical models using virtual worlds but also to examine the effectiveness of the models for student achievements" (p. 202).

Merchant et al. (2014) recognize the importance of further research in the field of virtual reality stating, "the rapid increase in the technological sophistication, diversity, and pervasiveness of 3D virtual learning environments, along with the proliferation of research on their effectiveness in educational settings, necessitates frequent systemic analytical syntheses of their effectiveness" (p. 30). In addition to this, Merchant et al. highlight that "to date, there is no systemically analyzed evidence of the instructional effectiveness virtual reality-based instruction has at different levels of retention" (p. 36). Kotrlik and Williams (2003) argue that more statistically evidenced-based research is needed to judge the influence virtual environments present to student academic gains, thus increasing the validity of the use of 3D technology as a viable learning tool.

Therefore, an indirect goal of this study was to address the lack of research in the field of technology within education and to provide an insight into the benefits that one 3D technology platform, zSpace, may offer to educational environments and student academic achievement, and motivation levels.

Chapter 3

Methodology

Introduction

Three-dimensional learning environments may have a positive impact on student academic achievements within the K-8 educational system, as stated by Quintana and Fernandez (2015) "three-dimensional settings could generate an additional advantage to the traditional methodologies, allowing users to interact in simulated work environments" (p. 595). However, the literature supports the argument that more research needs to be conducted in the area of academic gains (Cho & Lim, 2017). Cheng and Tsai (2013) stated, “augmented reality (AR) is currently considered as having the potential for pedagogical applications. However, in science education, research regarding AR-aided learning is in its infancy" (p. 449). It was, therefore, the intention of this study to analyze both quantitative and qualitative data to support or reject the argument that the use of augmented virtual reality devices impacted student learning.

There have been a growing number of studies with regards to the motivational and interest level virtual reality platforms offer users. However, there is limited research that identifies the academic gains and benefits virtual reality affords students as stated by Cho and Lim (2017) "more research is necessary not only to explore new pedagogical models using virtual worlds but to examine the effectiveness of the models for student achievements" (p. 202). Cheng and Tsai (2013) argue, "more research is required to explore learning experience (e.g., motivation or cognitive load) and learner characteristics (e.g., spatial ability or perceived presence) involved in AR" (p. 449).

Research suggests there is a growing need to examine the potential impact virtual reality has on student academic achievement levels. This study was designed to examine the effects of using augmented reality devices, such as zSpace, in the St. Joseph Catholic K-8 school environment in Huntington, West Virginia.

Research Design

The design of the study involved a mixed-method approach to assess the pedagogical impact due to the utilization of a virtual learning environment. The study utilized both quantitative and qualitative data to examine student academic achievement scores and to collect student and teacher feedback regarding motivation, collaboration, and interest levels through the use of the zSpace virtual reality tool to learn new concepts.

Creswell (2008) argues “a mixed methods design is conducted when one type of research (quantitative or qualitative) is not enough to address the research question or problem” (p. 552). The mixed method approach provided important information regarding student and teacher perceived benefits of a virtual learning environment, which enabled the researcher to expand beyond statistical data and to analyze and reflect on the perceptions and opinions of others with regards to the inclusion of virtual reality within the learning environment. Creswell presents the argument that “the rationale for a concurrent mixed methods design is that one data collection form supplies strengths to offset the weaknesses from the other form” (p. 557).

The quantitative data allowed for the examination on how students, exposed to the use of the zSpace virtual reality platform, performed academically. In a single science unit at the 4th and 7th grade levels, students exposed to the zSpace platform were compared to students who learned the same concepts through the use of traditional teaching resources and materials such as two-dimensional textbooks and worksheets. The study conducted pretest and posttest assessments in order to obtain quantitative student academic achievement data.

The study's qualitative data were obtained from open-ended questions. The use of open-ended questions was selected in order to allow the participants the freedom to share their opinions and perceptions beyond the limitations of a questionnaire or survey. Bazeley (2002) supports this argument stating, "people responding to interviews or open-ended questions will often raise quite different issues to those provided for in a structured questionnaire asking essentially the same question" (p. 4). In addition to this Bazeley also argues the point that qualitative data lends itself more to smaller sample sized studies stating, "typically one expects quantitative research to rely on a large, randomly drawn sample, while qualitative studies are associated with smaller, purposive (non-random) samples" (p.5).

The open-ended questions sessions included two of the highest performing students and two of the lowest performing students from experimental posttest scores. The 7th grade experimental student group was selected over the 4th grade experimental student group due to the fact they were older and would be able to provide a greater level of articulation with regards to their responses to the open-ended questions.

In addition to this, both the 4th grade and 7th grade teachers provided the researcher with feedback, which compared the different learning tools utilized within the experimental and controlled environments. The teachers provided responses to the open-ended question, which compared the use of the zSpace virtual reality devices in the experimental environment with traditional educational resources and materials used in the controlled environment.

During the open-ended question sessions, students were encouraged to share, from their perspective, how the zSpace devices helped or hindered their learning experience, motivation, and interest levels. The students also provided feedback comparing the use of augmented virtual reality as a learning tool compared to resources and materials they commonly utilized daily within their learning environments.

The selected teacher group received the same opportunity to provide their professional opinion and perception of the benefits of the zSpace's virtual learning environment upon student academic progress, motivation, and interest levels.

In addition to open-ended question sessions, field observations were noted throughout the duration of the testing window to obtain additional qualitative data from the two learning environments at the 4th and 7th grade level.

Student Population. The school's student population consisted of over 400 students and was diverse in terms of ethnicity, race, socio-economic levels, and religion and academic ability. In 2018, the school's student body represented 37 nationalities, every major religion of the world and 43% of the students received varying degrees of tuition assistance. The school's standardized test scores are historically ranked above the national average in all subject areas. In addition to this, the school also provided services, programs, and support to students with a wide range of exceptionalities and disabilities. The school, along with the county, serviced 8% of the student body with Student Support Plans, designed to address the individual needs of students. These plans offer students a wide variety of services including individualized instruction, individual or small group pull out sessions, modified instruction, Speech, English Second Language (ESL), Enrichment, and Talented and Gifted programs. The school's mission statement and environment welcome students of all academic abilities and special needs.

The study's student population consisted of two heterogeneously grouped 4th grade (9 and 10-year-olds) classrooms and two heterogeneously grouped 7th grade (13 and 14-year-olds) classes in a co-education school setting. The 4th grade classes comprised of 44 students and the 7th grade classes comprised of 34 students. A total of 78 students participated in the study, which represented the largest two grade levels in the school. The study experienced an attrition rate of 0% by the end of the study.

In a review of 3D learning environments, Scott et al. (2017) present an argument that the use of 3D devices not only positively impacts domains of knowledge but also affects students differently depending upon their cognitive developmental phase. Therefore, this study selected grade levels, which addressed two cognitive developmental phases. The 4th grade students, according to Piaget (1965), were in the *concrete operational* stage of cognitive development, and the 7th grade students were in the *formal* or *propositional* operation stage of development. Selecting the 4th grade and 7th grade classes identified the middle grade for the intermediate grade level and the middle school grade level and two stages of cognitive development.

Table 3

Student Demographics

	Gender		Special	ELS	Low	Prior
	M	F	Education		SES	zSpace User
4th Grade Control (22)	50%	50%	9%	14%	14%	91%
4th Grade Experimental (22)	59%	41%	9%	18%	5%	91%
7th Grade Control (17)	44%	56%	25%	19%	6%	94%
7th Grade Experimental (17)	61%	39%	6%	17%	17%	94%
Total (78)	55%	45%	12%	17%	12%	92%

Science Units

Annually, teachers within the Diocese of Wheeling-Charleston were required to create two unit plans based on their subject area or grade level. To assist and guide the teachers with their unit planning, the researcher designed a unit template (Appendix A), which consisted of various categories and subheadings such as curriculum standards, teaching strategies, cross-curricular opportunities, use of technology, and differentiated instruction.

The units created by the teachers addressed state science standards and utilized a variety of resources including the reputable textbook series, Glencoe, STEM Curriculum for K-12, and teacher created learning and assessment tools. The concept behind the units was to encourage teachers to be creative in their planning, authentic in their resource adoption, and to infuse cross-curricular opportunities. The units were uploaded to a diocesan-wide database, which could be accessed and viewed by employed teachers within the diocese. This curriculum planning approach has provided teachers access to a wide variety of units, lessons, and resources and encouraged teachers to share ideas and to collaborate across the state. This method of planning resulted in broadening resources available to the teachers of the diocese and allowed educators to expand their curriculum portfolios.

Fourth Grade. The 4th grade unit addressed the concept of electricity (Appendix B). The students investigated static and current electricity over a period of ten days. The students explored circuitry and how atoms move through electrical currents (Appendix F & G). The students learned the structure of the atom, including the positively charged nucleus, the negatively charged electrons which surrounded the nucleus (Appendix H). In addition to this, the students studied the differences between conductors and insulators and finished with creating electrical series and parallel circuits.

The teacher incorporated teaching strategies such as collaborative discussions, group work, labeling diagrams, note taking, and examining artifacts in both learning environments. The unit utilized various resources such as Put a Spark in It, Teach Engineering Curriculum: STEM Curriculum for K-12, Learning Lab, and Teachers Pay Teachers. zSpace devices and content designed to explain electricity was also used in the experimental group throughout the unit (Appendix G). The teacher incorporated regular formative assessments using Quizlet to review vocabulary and student progress. The controlled and experimental learning environments were identical in terms of teacher instruction and lesson objectives. The experimental environment utilized the additional technology devices, zSpace, to explore lesson objectives. A pretest was administered prior to the start of the unit and a posttest was conducted at the conclusion of the unit.

Seventh Grade. The 7th grade unit studied three human anatomy systems (Appendix C and D). These included the skeleton system, muscular system, and the nervous system. The lessons took place over a 10-day period. The study began with students examining the different major muscles of the body, followed by smaller muscles found throughout the body, such as the muscles of the face (Appendix K & L). Once the students had completed the portion of the unit focusing on the muscles, the students examined the skeleton system, identifying all the bones of the body and their different functionalities. Lastly, the students finished the unit with a review of the human nervous system. The students also dissected the brain to identify key parts and their purposes such as memory, sending and receiving messages, and communication.

The teacher utilized the school's current science textbook series, Glencoe, worksheets, Internet, and zSpace's VIVED Science for human anatomy in the experimental group. The teacher used a variety of teaching strategies such as whole group, small group, and individual work along with formative assessments to track student understanding in both learning environments. The controlled and experimental learning environments were identical in terms of teacher instruction and lesson objectives. The experimental environment utilized the additional technology devices, zSpace, to explore lesson objectives. A pretest was administered prior to the start of the unit, and a posttest was conducted at the conclusion of the unit.

Instrumentation

The research conducted a pretest and a posttest for both the control and experimental classes in the 4th grade and 7th grade classrooms. Thirty questions were used for the pretest and posttest at the 4th grade level (Appendix F) and 40 questions for the 7th grade level (Appendix G) science concepts. The questions comprised of a mixture of multiple-choice questions, fill in the missing blanks, and open-ended responses. The questions were adapted from the Glencoe textbook series (7th grade), Teach Engineering: STEM Curriculum for K-12 (4th grade) and teacher-created assessment tools. The teachers utilized a school-wide science rubric assessment tool (Appendix E) in order to determine the appropriate points received for each of the open-ended responses. The grading rubric tool provided consistency in the teachers' grading. Utilizing state-approved textbook series and science kits increased the validity of the pretest and posttest assessments.

In addition to the pretest and posttests, open-ended discussions took place to collect feedback from four selected 7th grade students and the two science teachers regarding their perception of how the use of zSpace affected their learning and teaching environment. The open-ended discussions adopted Dalgarno and Lee’s (2010) 3D virtual learning environment’s benefits to learning (Appendix P & Q). The open-ended questions addressed the five learning benefits, including *spatial* *knowledge representation, experiential learning, engagement, contextual learning,* and *collaborative learning*. The questions were constructed to be age appropriate according to student level and teacher level. The students were afforded the opportunity to discuss and build upon individual responses.

Procedures

This study examined the academic achievement, motivation, and interest levels of two grade levels within one Catholic school in Huntington, West Virginia. The two grade levels selected for this study comprised of the school's two 4th grade classes and the school's two 7th grade classes. The classes are each grade level's homeroom consisting of students with mixed academic ability. The students were assigned to homeroom classes based on the decisions of the school's counselor, classroom teachers, and assistant principal. The researcher did not assist in the student placement process.

A total number of 78 students participated in the study, consisting of 44 students at the 4th grade level and 34 students at the 7th grade level. The classes consisted of students of mixed ability, gender, ethnicity, and socioeconomic levels. At each grade level, one class was randomly selected to be the controlled learning environment and the remaining classroom the experimental learning environment. The researcher did not experience any concerns or questions from the students' participating in the study. No parent indicated concern regarding their child's placement in either the controlled or experimental environments. The controlled classroom used traditional forms of teaching methods and materials to learn science concepts, and the experimental classroom learned the same science concepts through the use of the augmented virtual reality platform, zSpace.

The study took place in the grade level's classrooms (Appendix H & K) as well as the school's technology room, known as the XSTRREAM (Science, Technology, Reading, Religion, Engineering, Art, and Mathematics) Center (Appendix I & L). Two teachers were used for the purpose of the study, one intermediate grade school science teacher, and one middle school science teacher. The teachers held a valid West Virginia Teaching License with over ten years of teaching experience in their endorsed field. To reduce a threat to validity regarding teacher proficiency levels, each teacher conducted the lessons in the controlled environment and experimental environment in their respective grade levels. In addition to this, both teachers had received equal zSpace's teacher in-service training on how to use the devices, access units, and how to develop their own lessons and content using the augmented virtual reality tool.

The teachers created a science unit using the researcher's unit-planning template. The units' standards aligned with the West Virginia Next Generation Science Standards and the school's curriculum. The units comprised of several lessons and activities, which took place over a two-week period. Prior to the commencement of the units, a pretest was administered one week before the units were introduced to the students.

The one-week window was incorporated into the study's procedures to reduce testing familiarity. The pretest served as an academic baseline of how much the students understood the concepts prior to the introduction of the unit. Administering baselines is a common practice in the school's academic program as the data provided valuable information to assist teachers with curricular placements, planning, and pacing. In the case of this study, the pretest data provided an average academic percent for each group in each grade.

In order to reduce extraneous variables, the unit lessons were structured and administered in the same way for both the controlled and experimental group. The teaching methods, instructional styles, materials, and resources remained consistent among each group. The amount of teacher-led and collaboration time remained equal in both groups. The only factor that changed in the experimental group was the access to the use of the zSpace devices as an additional learning tool. Students in the experimental group were able to explore and discover each lesson's content using zSpace's augmented virtual reality devices. The students completed the same activities in both groups.

The lessons were structured to allow students the opportunity to collaborate in pairs to examine, discover, and discuss the new learning concepts. This collaborative approach supports the Constructivist Theory, which supports the argument that students develop a deeper and more meaningful (conceptualize) level of understanding through the benefits afforded by collaboration rather than through the process of receiving information via lecture or teacher directed environments. Kapur (2010) supports this argument in a study, which indicated that students achieved higher levels of academic gains in independent small group activities over teacher-led instruction. The rationale for including collaborative learning opportunities in the units' lessons was based on the premise that the zSpace devices were designed to encourage collaboration amongst users (Appendix O). One student would lead the manipulation of the images as the other student would observe, discuss, and take notes. This practice would alternate between leaders and observers throughout the lessons.

At the conclusion of the two units, a posttest was administered to determine academic growth and achievement levels in each learning environment. In order to reduce testing familiarity, the pretest and posttests were not identical tests but rather similar only in content and question style. These results provided the study with the opportunity to analyze and compare results between the controlled and experimental classes at each grade.

In addition to the posttest, selected students and the two teachers were interviewed in two open-ended discussions, which focused on the use of the zSpace devices. Four students from the experimental 7th grade class were selected to share their perspective and experience on how the zSpace devices provided support as a learning tool throughout the unit. The two science teachers conducting the unit plans were also interviewed separately in order to obtain their perspective and feedback regarding zSpace as a viable learning tool within their lessons. The open-ended question sessions took place the school's XSTRREAM Center in which the students were organized in a large circle, and the teachers were sat at one table with the researcher. The session encouraged students and teachers to share their observations and express their opinions openly. This approach allowed each participant to build upon answers and generate other questions and discussion points.

Procedure

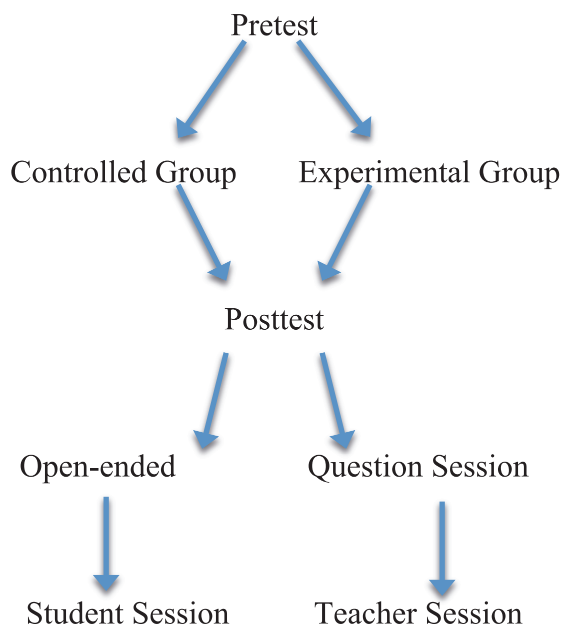


Figure 5: Pretest and Posttest Testing Procedures

Data Analysis

Quantitative data. The research data were analyzed using an independent two-tailed *t*-test. The *t*-test analyzed how the controlled groups and the experimental groups performed in the pretest and the posttest with a significance level of 0.05. The pretest provided a baseline assessment. This baseline assessment revealed the students' academic mastery level of the content that was to be delivered in each of the two units and testing environments. The posttest assessment provided data indicating student academic performance at the conclusion of each unit at each grade level.

Figure 5 provides a visual overview of the study's design model, which was applied to the 4th grade control and experimental groups as well as to the 7th grade control and experimental groups.

Table 4

Research Design

Data Analysis: Independent *t*-test		
Groups	Pretest	Posttest
Control	C1	C2
Experimental	E1	E2

The results reported the mean and statistical difference for both groups on the pretest and posttest assessments. An independent *t*-test was used to examine C1 and E1, to establish academic equality between the two groups. After the unit was completed, a posttest was administered. An independent *t*-test examined the students' academic performance between C2 and E2. Additional analysis also included the average academic performance between C1 and C2, and again between E1 and E2 on the pretest and posttests assessments at the 4th grade and 7th grade levels.

Qualitative data. The open-ended discussions addressed Dalgarno and Lee's (2010) 3D virtual learning environment's benefits to learning. Based on these learning benefits identified by Dalgarno and Lee, open-ended questions were presented to four 7th grade students to obtain their perception regarding the benefits of the zSpace devices and its application in the science lessons.

The 4th grade and 7th grade teachers were also interviewed to collect their feedback pertaining to the benefits and challenges of using the zSpace devices. The responses were recorded and categorized according to the stated questions and various themes identified by the students and teachers relating to the use of the virtual reality platform to enhance student learning.

zSpace. zSpace is a learning tool unique to the school's curriculum. The students in this study do not own a zSpace device for personal usage at home; therefore, the students' exposure to this device was authentic and specific to school use, thus eliminating the bias of prior experience or knowledge of the zSpace augmented reality devices outside of the school environment. This eliminates the threat of prior exposure, which may influence the study's data and findings.

Excluding newly enrolled students within the school, the students received equal exposure and training in the use of the zSpace devices within their respective grades. The 7th grade students received a greater level of exposure to zSpace due to the fact that the middle school science teacher had an additional zSpace device permanently located in the science classroom for regular usage. Classroom teachers of all grade levels received the opportunity to schedule time withinin the school's XSTRREAM Center to explore concepts through the use of the zSpace devices.

Chapter 4

Findings/Identified Strategies and Products

Introduction

The study examined the pedagogical affordances due to the use of zSpace's augmented virtual reality devices at the 4^{th} and 7^{th} grade levels in a Catholic school in Huntington, West Virginia. The study utilized a mixed method approach, which used a quantitative measure to analyze student academic achievement scores and a qualitative assessment to determine motivation, interest, and engagement levels. The purpose for using both quantitative and qualitative methods in this study was to identify strengths or weaknesses of the use of augmented reality devices in the educational environment not discernable through one data collection method as argued by Bryman (2006) "multi-strategy research frequently brings more to researchers' understanding than they anticipate at the outset" (p. 111).

The academic impact of the use of the augmented virtual reality devices, zSpace, was measured statistically using a two-tailed independent *t*-test to determine whether or not virtual reality environments increase student learning. The test analyzed participants' pretest and posttest academic performance between two controlled and experimental groups at the 4^{th} grade and 7^{th} grade levels.

The effect of the treatment was also analyzed qualitatively through participant responses (teachers and students) through open-ended questions based on the Learning Affordances of Dalgarno and Lee (2010) Model of Learning in 3D. These learning affordances included the following; *Spatial Knowledge Representation,* *Experimental Learning, Engagement*, *Contextual Learning*, and *Collaborative Learning*. A final question identified the benefits and limitations of using zSpace augmented reality devices within the academic environment. Observer notes from lesson observations were also included in the analysis of the qualitative data and contributed to the overall qualitative data collection.

The study used two null hypotheses to examine the academic impact of zSpace augmented reality devices upon the learning environment.

The null hypotheses examined were:

H_o 1: *There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 4th grade level as measured by the pretest and posttest.*

H_o 2: *There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 7th grade level as measured by the pretest and posttest.*

Testing Environment and Procedures

The study consisted of two classes at the intermediate grade (4th) and two classes at the middle school (7th) grade. These two grade levels represented the middle point at each developmental level of the intermediate and middle school level. The 4th grade groups consisted of 22 students in each testing environment with a total of 48 students. The 7th grade groups consisted of 17 students in each testing environment with a total of 34 students. A total of 78 students participated in the study. These two grade levels reflected the largest grades within the school at the time of the study. The study experienced a zero-attrition rate with students completing both the pretest and posttest at the 4th grade and 7th grade level.

The 4th grade and 7th grade teachers followed the school's curriculum planning policy, and each teacher created a two-week unit respective of their grade levels' state standards in science. The 4th grade's unit focused on electricity, atoms, and conductors, while the 7th grade's unit studied the human anatomy of the skeleton system, muscular system, and the nervous system. In order to reduce testing familiarity, each grade level conducted a pretest one week before the introduction of the units to the controlled and experimental groups. The unit lessons for each grade level spanned over a two-week period finishing with a posttest. The posttest design was not an exact duplication of the pretest's questioning structure. The posttests utilized similar multi-choice questions and different ordering of questions compared to the pretest and comprised of data labeling and open-ended responses.

Student attendance was tracked throughout the duration of the study as shown in Table 2. Student attendance rates for both the pretest and posttest sustained a 100% attendance rate for each grade level and testing environment. Student absences throughout the duration of the unit's lessons were minimal within each grade level and testing environment with the highest attendance rate in the 4th grade experimental group of 99.54% and the lowest attendance rate of 98.23% in the 7th grade controlled environment. An overall attendance rate of 98.92% was experienced throughout the duration of the study and 100% student attendance during the pretest and posttest assessments.

Table 5

Student Attendance

	Pretest Attendance Rate	Unit Lessons Attendance Rate	Total Days Absent Over 10 Days	Posttest Attendance Rate
4th Grade Control (*n*=22)	100%	99.09%	2	100%
4th Grade Experimental (*n*=22)	100%	99.54%	1	100%
7th Grade Control (*n*=17)	100%	98.23%	3	100%
7th Grade Experimental (*n*=17)	100%	98.82%	2	100%

The testing environment took place in the school's XSTRREAM Center for the experimental fourth and 7th grade groups as shown in Figures 6 and 8. The 4th grade and 7th grade controlled environments consisted of a traditional classroom setting as shown in Figures 7 and 9. The 4th grade controlled group took place in the school's XSTRREAM Center but only utilized traditional forms of teaching tools such as a Smartboard, worksheets, and Chrome Notebooks. The 7th grade controlled group took place in the school's middle school's science lab and utilized textbooks, worksheets, and an overhead projector. Typically, all middle school science lessons are housed in the school's science lab. One zSpace device is located in the middle school science lab for additional educational access; however; for the purpose of this study, the zSpace device was not utilized during the controlled environment.

Figure 6: 4th Grade Experimental Environment in the XSTRREAM Center

Figure 7: 7th Grade Experimental Environment in the XSTRREAM Center

Figure 8: 4th Grade Controlled Environment in the XSTRREAM Center

Figure 9: 7th Grade Controlled Environment in the Middle School Science Lab

In order to ensure an equal balance of the time of day lessons were conducted, the 4th grade's controlled environment took place in the morning, and the experimental group took place in the afternoon. This was reversed for the 7th grade groups. The 7th grade experimental lessons took place in the morning, and the controlled group's lessons were conducted in the afternoon. The purpose of this scheduling arrangement was to reduce teacher or student preference or bias with regards to the best or most optimal time of the day to learn or conduct lessons.

Quantitative Analysis

Quantitative data were collected from fourth and 7th grade students' pretests and posttests assessments. The results were statistically measured using multiple two-tailed independent *t*-test designed to analyze and compare sample means between two different populations (controlled and experimental) at two different testing times including a pretest and posttest.

Demographics. The students in each grade level were assigned to two homeroom classes based on the school's placement criteria. Student placements were determined at the commencement of the school's academic year and were based on the recommendations of the school's counselor, assistant principal, and classroom teachers. Student placements created two mixed groups with regards to socio-economic needs, gender, and academic ability including students with Student Support Plans, Title I students, and English Secondary Learners. Table 3 provides an overview of the student demographics for each grade level and testing environment.

Table 6

Student Demographics

	Gender M F	Special Education SSP, Title I	ELS	Low Socio-Economic	Prior zSpace User (Full Academic Year)
4th Grade Control (*n*=22)	50% 50%	9%	14%	14%	91%
4th Grade Experimental (*n*=22)	59% 41%	9%	18%	5%	91%
7th Grade Control (*n*=17)	44% 56%	25%	19%	6%	94%
7th Grade Experimental (*n*=17)	61% 39%	6%	17%	17%	94%
Total (*n*=78)	55% 45%	12%	17%	12%	92%

An analysis of the school's CTB Terra Nova III standardized academic achievement tests scores and the West Virginia State Testing results, Table 6 and 7, revealed that the school's student body collectively performs above national averages and West Virginia state performance levels in all subject areas and grade levels.

Table 7

St. Joseph Catholic School 4th and 7th Grade Terra Nova III 2018 Test Scores

Data represent grade level Mean Normed Curved Equivalent (MNCE) scores

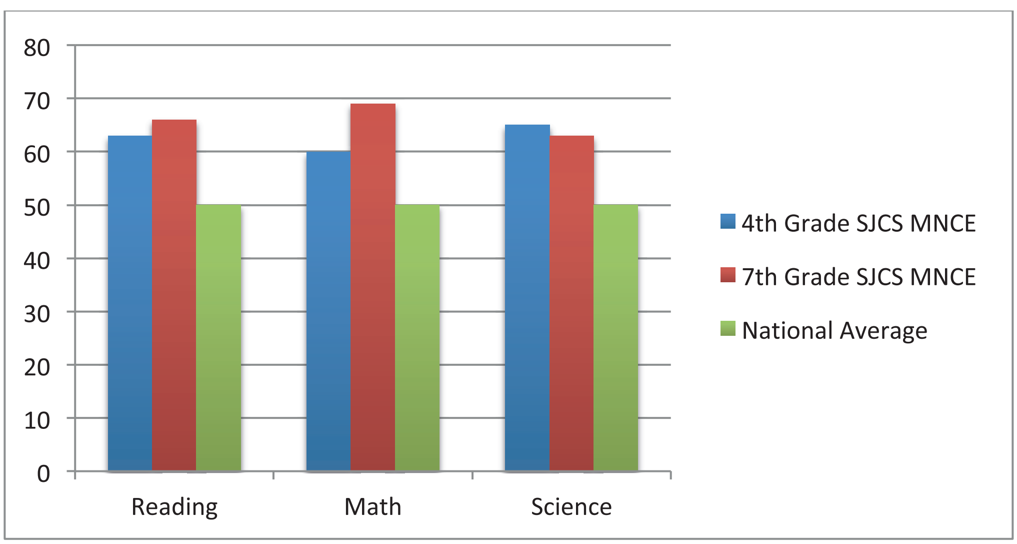
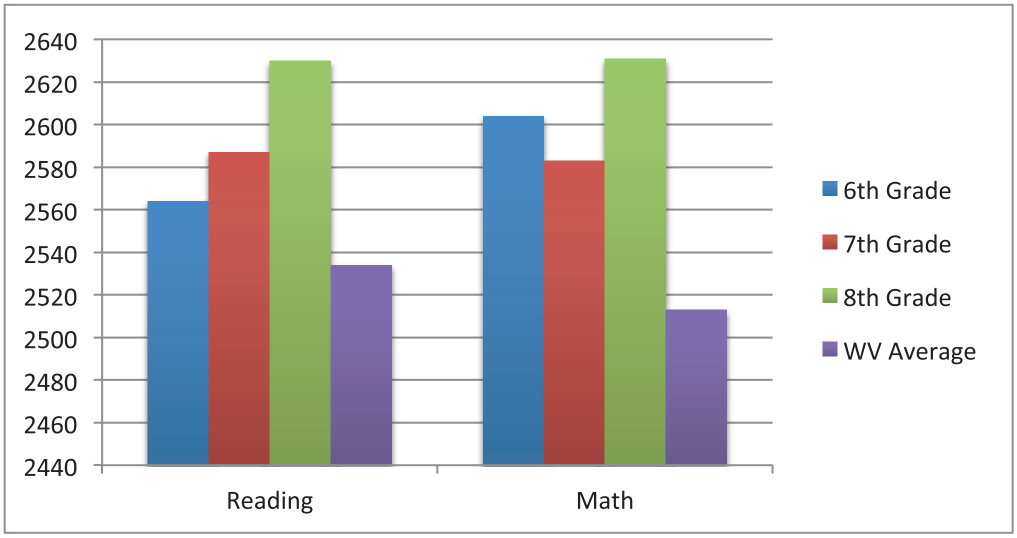


Table 8

St. Joseph Catholic School 6th, 7th, and 8th Grade 2017 West Virginia State Test Scores

Data represents Scale Scores



Pretest and Posttest Data.

Fourth grade. Prior to the execution of each grade level's unit plans, an independent *t*-test was applied to a pretest in both the controlled and experimental learning environments at the 4th grade and 7th grade levels. The independent *t*-test compared the academic performance of the controlled groups and the experimental groups to determine if a statistically significant difference existed between each group's scores. Table 8 shows the results of the independent *t*-test for the 4th grade.

Table 9

Independent t-test for Pretest and Posttest for 4^th^ Grade Control and Experimental

Grade Level	**N**	**M**	**SD**	**SE of Mean**	***t***	**df**	***p***	***d***
Pretest								
4th Grade: Control	22	31.636	14.029	2.991	0.680	42	0.500	0.20
4th Grade: Experimental	22	28.955	12.065	2.572				
Posttest								
4th Grade: Control	22	63.955	15.117	-3.223	0.720	42	0.475	0.22
4th Grade: Experimental	22	67.091	13.728	2.927				

The results revealed that there is no statistically significant academic difference between the 4th grade controlled group and the 4th grade experimental group, $t(42) = 0.680$, $p > 0.05$ for the pretest with a Cohen's *d* of 0.20. This finding indicates that each of the two groups' pretest results were comparable in academic performance.

The posttest results indicated that there was no statistically significant academic achievement between the 4th grade controlled and experimental groups, $t(42) = 0.720$, $p > 0.05$, with a Cohen's $d = 0.22$. The results showed that each learning environment did not yield an academic performance that would be considered statistically significant. Based on this finding, the rejection of the null hypothesis, "*There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 4th grade level as measured by the pretest and posttest*" was not warranted.

Although the results did not generate statistically significant data between the pretest and posttest, it was observed that students in the experimental group did perform at a higher rate than the students in the controlled environment. The students in the experimental group experienced a M=38.136 growth rate compared to a M=32.319 growth rate in the controlled group demonstrating a difference of M=5.817 between the two groups. The mean difference between the two groups from the pretest to the posttest grew from 2.682 to 3.136 with the experimental group out-performing the controlled group.

Seventh grade. The 7th grade pretest and posttest academic scores were also analyzed using an independent *t*-test (Table 9).

Table 10

Independent t-test for Pretest and Posttest 7th Grade Control and Experimental

Grade Level	**N**	**M**	**SD**	**SE of Mean**	***t***	**df**	***p***	***d***
Pretest								
7th Grade: Control	17	30.941	13.050	3.165	0.235	32	0.816	0.08
7th Grade: Experimental	17	31.941	11.750	2.850				
Posttest								
7th Grade: Control	17	81.529	21.949	5.323	0.707	32	0.484	0.24
7th Grade: Experimental	17	86.059	14.665	3.557				

The results showed that there is no statistically significant difference in student academic achievement levels between the 7th grade controlled group and the 7th grade experimental group on the pretest t(32) = 0.235, p > 0.05, with a Cohen *d* of 0.08. This finding indicates that the two groups at the 7th grade level are comparable in academic performance.

The results indicated that there was no statistically significant academic achievement between the 7th grade controlled and experimental groups on the posttest, t(42) = 0.707, p > 0.05 with a Cohen *d* of 0.24. The results revealed that each learning environment academically performed within a non-statistically significant range. Based on this finding, the rejection of the null hypothesis, "*There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 7th grade level as measured by the pretest and posttest"* was not warranted.

Similar to the results from the 4th grade learning environments, the 7th grade experimental group outperformed the controlled environment from the pretest to the posttest with a mean difference of 1.000 at the pretest to a growth rate mean difference of 4.529. The students in the experimental group experienced a M=54.118 growth rate compared to a M=50.588 growth rate in the controlled group demonstrating a difference of M=3.53 between the two groups.

Summary of Quantitative Data

Although the data analyzed yielded non-significantly statistical academic differences between the controlled and experimental groups, a trend regarding the growth rate between the pretest and posttest did occur with the experimental groups showing a higher level of academic growth over the controlled environments. In addition to this, although the population size tested from each grade level was small, the 4th grade pretest generated a small effect size greater than d=0.20 which increased to d=0.22 on the posttest. The 7th grade pretest revealed no practical difference on the pretest with an effect size of 0.08; however; on the posttest, the 7th grade scores reflected a small effect size of d=0.24.

Based on this information, the study's results indicated that a small effect size was evident in the posttest scores for both experimental groups at the 4th grade and 7th

grade levels, with the 7th grade experimental scores demonstrating a higher level of academic growth over the controlled group (Bryman, 2006).

Qualitative Analysis

To expand the scope of the investigation, qualitative data were collected to obtain multiple perspectives beyond the quantitative data. This approach in obtaining qualitative opened-ended data generated opportunities for greater research discussions and changes in direction, which often produce unforeseen surprises and new insights.

Qualitative data were collected through open-ended questions at the conclusion of the posttest. The open-ended question sessions included comments from the 4th grade and 7th grade teachers along with the comments from four 7th grade students. Student selection for the open-ended question session included the top two academically performing students and the lowest two academically performing students from the experimental group. The intention of the student selection was to achieve an equal balance between student achievement and student feedback. At the conclusion of the open-ended question sessions, each teacher and student were asked to score Dalgarno and Lee's (2010) Model of Learning in 3D learning affordances (*Spatial Knowledge Representation, Experimental Learning, Engagement*, *Contextual Learning*, and *Collaborative Learning)* using a 5-Point Likert Scale.

In addition to the open-ended questions, observer's notes were obtained as an additional qualitative data source. Observer's notes were recorded during each lesson throughout the duration of the testing period in both the 4th grade and 7th grade controlled and experimental learning environments.

The examination and analysis of both quantitative and qualitative measures provided the study with multiple perspectives thus provided opportunities to cross-reference data using a triangulation approach to data analysis.

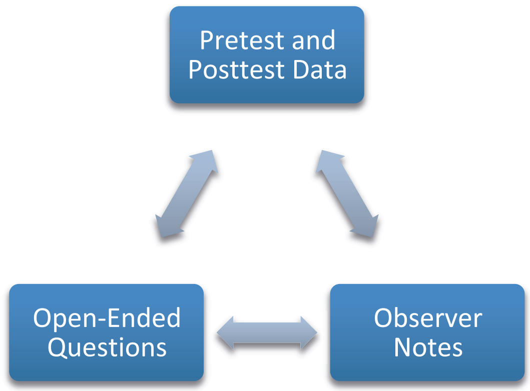


Figure: 10 Quantitative and qualitative triangulation method of data analysis

The data collected revealed several trends from the feedback obtained from the teachers and students' open-ended questions and the collection of observer's notes. To begin with, both the teachers and students unanimously agreed that the use of the zSpace augmented virtual reality devices significantly increased, not only the quality of learning, but also the learning experience itself. Using Dalgarno and Lee's (2010) Model of Learning in 3D, qualitative data collected from the teachers, students, and observer notes were categorized according to each of the five learning affordances as defined by Dalgarno and Lee's model using a 5-Point Likert Scale.

Spatial knowledge representation. Spatial knowledge representation increases the user's ability to visualize dynamic concepts and scientific phenomena in 3D, which goes beyond the limitations of 2D representation. Dalgarno and Lee (2010) argue spatial knowledge affords the learner the ability "to construct a personal knowledge representation and iteratively refine this representation as he or she undertakes exploration and experimentation" (p. 18-19). In addition to this, Dalgarno and Lee state, "three-dimensional technologies are well suited to such physical simulations because they enable the full physical behavior of objects to be modeled, rather than restricting the motion and behavior to two dimensions" (p. 19).

Table 11

Spatial Knowledge Representation: 5-Point Likert Scale

4th Grade Teacher	5
7th Grade Teacher	5
7th Grade Student 1	5
7th Grade Student 2	5
7th Grade Student 3	5
7th Grade Student 4	4
Total	**24/25**

Open-ended discussions. The teachers and students highly agreed with a 5-Point Likert Scale mean score of 4.8/5 (Table 10) that the use of the zSpace devices enabled learners to actively explore learning concepts beyond traditional methods of teaching material such as textbooks and worksheets or what is typically available within the confines of a regular classroom environment. The teachers argued that the students were able to visually explore abstract concepts such as atoms, the elements of the Periodic Table, and electrical currents with clarity, precision, and fascination. The 4th grade Teacher stated, "the students not only were so easily able to transfer abstract information and conceptions, but they were also able to visualize the processes, making real-life connections and seeing almost first-hand how things worked through the use of zSpace devices."

In addition to this, the teachers explained that they observed great conversations amongst the students in the experimental environment as the students shared with each other what they were observing, visualizing, and understanding due to the high definition fidelity of the images, many of which were also animated in nature. In the controlled environments, the teachers were unsure of what the students were visualizing and understanding since there was a distinct lack of discussion amongst the students and the presence of only 2D images.

The teachers noted that there was a heightened level of interest exhibited by the students to learn the concepts within the experimental environments compared to the controlled environments. Student comments revealed that they enjoyed the learning process with the utilization of the augmented reality devices, zSpace, and the lessons did not feel like work. Both teachers supported this argument stating that the zSpace devices provided a different learning experience from the controlled environments, which resulted in the students experiencing many different learning variables. Furthermore, the teachers noted that this environment allowed the students to independently explore the concepts and take the initiative to explore a deeper level of understanding.

In the open-ended discussion, the 4th grade teacher explained that within the experimental environment, learning was organic, not forced, unlike the controlled environment, in which the teacher maintained the pace and controlled the lessons' content. The 7th grade teacher described how the students were able to dissect the muscles of the human body by going beyond the constraints of the textbook or worksheets.

Field observations. Field observations supported many of the teachers and student comments. To begin with, field observations recorded heightened levels of interests from the students, which sparked curiosity and the desire to learn more. It was observed that several students made the comment, “now I get it.”

The field observations identified the students’ surprise in the experimental environment when they discovered that their predictions regarding the number of muscles in an arm, for example, were significantly lower than originally predicted. This realization was discovered due to the students’ ability to dissect the arm counting over forty muscles. This level of learning did not transpire in the controlled environment where the students were afforded the opportunity to identify only the major muscles of the arm from the textbook. The 7th grade teacher supported this observation stating “the students in the experimental group clearly demonstrated a better and higher level of understanding of the concepts than the students in the controlled group who could not understand the layers of the muscle. Their understanding was limited to my description only.”

Field observations also revealed that the students in the 4th grade could not truly appreciate the size or functionality of an atom on paper, but through the use of the zSpace devices, the students demonstrated an understanding on multiple levels. The students noted that learning through the use of zSpace was similar to gaming or watching a 3D movie. The ability to label and dissect images, from the students' perspective, enabled them to develop a higher level of understanding rather than trying to learn the material from a flat sheet or 2D image in a textbook. One student made the comment that zSpace enabled them to not only truly understand the structure and systems of the human body but to do so in a fun and engaging manner.

The teachers agreed that due to the zSpace devices, students not only were able to understand the concepts quickly, but they also took responsibility for their learning. This process encouraged the students to become more active, engaged, and motivated to learn more. The teachers argued that such an experience potentially could yield greater levels of material retention.

Experimental and Exploration of Learning. Students are afforded the opportunity to experiment and explore concepts and tasks within a 3D learning environment that would not be feasible, practical or accessible in the real world. Dalgarno and Lee (2010) argue that 3D learning environments afford students the opportunity to experiment and explore scientific phenomena through the process of reification, which enables the learner to process and understand abstract and challenging concepts that have no natural form.

Table 12

Experimental and Exploration of Learning: 5-Point Likert Scale

4th Grade Teacher	5
7th Grade Teacher	5
7th Grade Student 1	4
7th Grade Student 2	4
7th Grade Student 3	4
7th Grade Student 4	5
Total	22/25

Open-ended discussions. The teachers and students' feedback (Table 11) provided a 4.4 mean score on the 5-Point Likert Scale regarding the experimental and exploration benefits of a 3D learning environment. The teachers reiterated the value and positive impact the zSpace devices offered the students in terms of providing a sense of freedom to experiment and explore concepts without limitations or constraints. Allowing the students to explore in this way, the teachers argued, increased the students' levels of curiosity and desire to probe for more information and answers. This, in turn, deepened their level of understanding, which prompted additional questions. A statement made by the 4th grade teacher supported this perspective stating, "one aspect of the study indicated that the exploration of concepts was occurring was the additional time it took to teach the concepts in the experimental environment. The students were exploring, expanding upon knowledge, and formulating good conversation."

While recognizing the high level of engagement in the experimental environments and the desire to explore additional concepts, the 7th grade teacher explained that it was necessary to ensure the students focused their attention on the material that the students would be assessed. The use of zSpace reduces the teacher's ability to teach to the test due to the students' excitement to foster teachable moments. It could be argued that using traditional means to test concept mastery does not lend itself to the learning environment created by augmented virtual reality.

The 7th grade teacher made an interesting point regarding the use of technology, such as zSpace, that should not entirely replace the value of hands-on, real-life experiences such as "the need to know how to pour and measure material and what it feels like or looks like to actually dissect a frog or a cow's heart or liver." The 4th grade teacher supported this statement arguing, "technology is an additional skill, not a complete replacement of hands-on learning, such as experiencing paper money to the virtual management of money through the use of credit cards."

As with all technology, there are often drawbacks and limitations. The 4th grade teacher explained how today telephone books are often thrown out, as telephone numbers are now stored on smartphones; however; the memorization of telephone numbers has become a lost skill. Therefore, the teachers agreed that the use of zSpace should be balanced with real-life experiences and rely more so on zSpace devices for scientific phenomena that cannot be replicated within the classroom.

Field observations. It was observed during the field observations that the students utilizing the zSpace devices were disappointed to bring the lessons to a closure but demonstrated enthusiasm to pick up where they left off at the commencement of their next lesson. This level of enthusiasm and eagerness to learn was not observed in the controlled classrooms where the students successfully completed the activities as outlined by the assignments, but did not generate further discussions or additional questions that could be considered beyond the scope of the lessons' objectives.

Field observations also noted that the use of zSpace's augmented virtual reality devices afforded students the opportunity to explore concepts unobtainable within the traditional classroom environment. According to the teachers' feedback, student learning was limited to the resources available and the opportunities to experience new concepts or material. The use of zSpace reduces these limitations or restrictions. Students were free to explore concepts such as space, atoms, the layers of the world, and electricity through virtual reality technology.

Engagement of Learning. Three-dimensional learning environments, according to Dalgarno and Lee (2010) may afford users the opportunity to learn concepts in first person experiences, thus increasing levels of engagement. Such experiences, Dalgarno and Lee argue increases real-world application and the learning experience due to the heightened levels of visual and sensory realism achieved through 3D learning tools.

Table: 13

Engagement of Learning: 5-Point Likert Scale

4th Grade Teacher	5
7th Grade Teacher	5
7th Grade Student 1	5
7th Grade Student 2	5
7th Grade Student 3	5
7th Grade Student 4	4
Total	24/25

Open-ended discussions. The teachers and students scored a mean 5-Point Likert Scale of 4.8/5 for engagement of learning (Table 12). The open-ended discussions revealed that the teachers' actions and behaviors differed between the controlled environments and experimental environments. To begin with, the 4th grade teacher stated, "I had to do a lot of walking, maintaining close proximity to remind the students in the controlled environment to remain focused and on task. This was not the case in the experimental environment as it was exciting to observe the students generating the conversations between themselves." This viewpoint was also shared by the 7th grade teacher who felt the students were not only more engaged in the experimental environment but also increased confidence levels to participate in the learning process. In addition to this, the teachers explained how they observed students working out the concepts themselves rather than having to raise their hands to explain the answers.

Regarding classroom disruptions, the 4th grade teacher made the observation that not a single student requested to leave the classroom for a bathroom or water break in the experimental environment, however; this was the case in the controlled environment, thus creating minor interruptions to student learning and the flow of the classroom.

Student feedback indicated that they agreed that their motivation and engagement levels were increased due to the use of zSpace as supported by one student's remark, "I was more interested to learn through zSpace as it is like a game. It is better to see the heart in front of me and to feel its beats through the stylus than in a textbook."

The 7th grade teacher explained how students' engagement levels increased when they made real-life applications to the zSpace devices, such as describing how their parents utilize virtual reality devices to perform surgeries or to create 3D human anatomy structures first using virtual reality platforms before manufacturing the equipment or material for bone replacement purposes. The teacher used the word "storytelling" as the students made real-life connections and demonstrated the desire to share these connections with their fellow colleagues.

Field observations. Field observations revealed that student engagement and motivation levels were noticeably higher in the experimental environments compared to the controlled environments. It was observed at both the 4th and 7th grade levels, over the two-week window, that students in the experimental environments were highly engaged through peer-to-peer dialogue and collaboration. The experimental learning environment fostered regular discussions; however, field observations noted that students in the controlled environment predominately completed the work individually without collaboration or limited interactions from fellow colleagues. The students heavily relied upon the direction and guidance of the teachers. Field observations also noted a higher level of problem-solving and critical thinking interaction between students. Students were actively engaged in deep conversations as they worked to problem-solve concepts that often went beyond the parameters of the textbook and lessons' objectives.

Contextual Learning. According to Dalgarno and Lee (2010), 3D learning environments, through the peer-to-peer collaboration and communication, support the user's ability to make real-life applications and connections of challenging and abstract concepts. This learning experience provides the user the opportunity to evaluate and assess tasks from multiple perspectives, thus expanding knowledge and real-life application.

Table 14

Contextual Learning: 5-Point Likert Scale

4th Grade Teacher	5
7th Grade Teacher	5
7th Grade Student 1	5
7th Grade Student 2	4
7th Grade Student 3	5
7th Grade Student 4	4
Total	23/25

Open-ended discussions. Teacher and students' feedback (Table 13) indicated a mean score on the 5-Point Likert Scale of 4.6/5. The students described how there were many "aha" moments, which they experienced due to the utilization of the zSpace devices within the experimental environment. Students openly explained to each other how they could now visualize the material and also understand the material. Students actively pointed to the various augmented reality images while explaining to their peers the learning concepts of the lessons. Such actions sparked the interest levels of fellow peers generating the desire to discover new material further and to discuss. One student remarked, “the zSpace computers made it easier to grasp the concept, see it clearly, and now I understand it.” Another student remarked, “the zSpace computers are interactive, I was able to label the parts of the body, dissect the body, manipulate the images, and to become immersed within the concepts. Textbooks are static; they do not offer any more detail than what is on the page.” The teachers supported these statements arguing that the zSpace devices offered a higher level of information in terms of volume and depth than the textbooks or worksheets. The 7th grade teacher explained, “the students using zSpace, in 45 minutes discovered so much more in terms of depth and knowledge than the controlled group. They may not have remembered everything as there was a lot of information, but the level of learning surpassed the controlled environment.”

The teachers noted that the student learning took different directions in the experimental group and expanded beyond the units and lessons’ objectives. The learning environment in the controlled environment was structured and linear in nature. The 4th grade teacher described how the students in the controlled environment read the questions and tried to answer them; however, they seemed to struggle to find the answers on their own. The teachers stated, “they wanted me to give them the answers. I was considered the individual who held all the answers." Contrary to this observation, the students in the experimental environments exhibited a different mindset to their approach to learning and discovering the answers. The students demonstrated confidence to explore the concepts virtually without the assurance or guidance of the teacher. The teachers argued that this sense of confidence was due to the students' ability to master the concepts and truly formulate a sound understanding of the material. In addition to this, the teachers also noted that the zSpace devices challenged and expanded the students' scientific vocabulary beyond the lessons' content, which did not occur in the controlled environments.

The students indicated that while they initially considered the zSpace devices as "advanced" computers, they realized that the devices afforded them the opportunity to discover content matter that went significantly beyond worksheets and textbooks. One student commented, "I began to explore the zSpace computer using the stylus, and mouse and I realized there was so much information to learn which was more enjoyable than learning from a textbook."

Beyond the discussion regarding textbooks versus zSpace, the teachers discovered that through the use of zSpace the need to find charts and diagrams to assist students in learning concepts were eliminated as all the images and activities were readily available to the students in high definition interactive images. Reducing or eliminating the need to collect material for lessons afforded the teachers more time to analyze and assess student learning and track progress.

Field observations. Field observations revealed that the use of virtual reality, such devices as zSpace, might offer alternative strategies to learning concepts within the field of special education. Students with Student Support Plans (SSP), although low in numbers, in the experimental environment, demonstrated higher levels of confidence when exploring new concepts compared to students with SSP within the controlled environment. Three observations were made indicating higher levels of learning amongst students with SSP within the experimental environment. First, the virtual reality perspective provided a supportive learning tool beyond the traditional textbook. Students did not have to rely solely on printed text to understand concepts, but instead, they could manipulate the concepts at their own pace, thus taking responsibility and control of their own learning. Second, the visual images increased the students' ability to process the concepts and provided a visual pictorial image of concepts. This approach to learning may positively impact low spatial ability learners in the classroom who are challenged when understanding abstract concepts. Third, the collaborative nature of the learning environment offered students' peer-to-peer support and the opportunities to dialogue with fellow peers without relying on teacher intervention to provide further explanation. The teachers argued that such findings might suggest that through the use of virtual reality tools could balance the field between different learners, therefore narrowing the academic spectrum and the need to differentiate instruction. The use of zSpace devices allows students to become independent learners offering greater approaches or styles to learning. Teacher comments and observations support the notion that virtual reality may academically enhance the performance levels of students with low spatial ability. High functioning students may not need to rely on additional methods to learn concepts as they naturally exhibit the ability to obtain content mastery regardless of zSpace, but those students that need, interaction, visual imagery, and extra help will benefit from the use of zSpace as a virtual reality environment. Researcher observations suggest that students identified with ADHD (Attention Deficit Hyperactivity Disorder) were readily engaged and maintained focus within the experimental environments which was a sharp contrast in the controlled environments, in which such students exhibited challenging behaviors regarding attention and remaining on task.

At the 4^{th} grade level, each learning environment contained students officially diagnosed with dyslexia. While it is understood that every child is different, the 4^{th} Grade teacher stated, "in the experimental environment it was not clear or obvious which student had the learning disability of dyslexia. However, in the controlled environment, the student diagnosed with dyslexia was highly obvious as they exhibited challenges in taking notes and processing the information." Observations also indicated a difference in learning obtainment, with higher levels of engagement and academic performance on the tests from the students with a diagnosis participating in the experimental environment.

Collaborative Learning.

Dalgarno and Lee (2010) argue that the use of 3D technology increases the levels of collaborative learning opportunities amongst learners. Dalgarno and Lee state 3D technology helps to "facilitate tasks that lead to richer and/more effective collaborative learning than is possible with 2D alternatives" (p. 23).

Table: 15

Collaborative Learning: 5-Point Likert Scale

4th Grade Teacher	5
7th Grade Teacher	5
7th Grade Student 1	5
7th Grade Student 2	5
7th Grade Student 3	5
7th Grade Student 4	4
Total	24/25

The teachers' and students' 5-Point Likert Scale (Table 14) received a 4.8/5 mean score indicating that both the teachers and students ranked collaborative learning as one of the top three learning affordances along with spatial and engaging learning opportunities.

Open-ended discussions. Teacher and student feedback indicated that the due to the ability to learn concepts in a unique approach to learning through the use of augmented virtual reality not only generated a greater level of communication and collaboration amongst the students but also inspired the students to ask deeper higher leveled questions and to work together collaboratively to find the answers.

The teachers argued that the experimental groups became intrigued to ask questions and demonstrated thought processes that went beyond the lessons' goals and objectives. One student commented, "rich conversation took place with the zSpace application to the point that we would sometimes go off topic, get so far into it, and forget that someone is next to you because you are so engaged in learning." The 7th grade teacher explained that she observed great conversations taking place in the experimental group between partners, however, in the controlled group conversation was limited and at times the conversations that did transpire did not relate to the lessons' concepts or objectives. The 7th grade teacher stated, "there were no limitations to learning with zSpace." In addition to this, the 4th grade teacher noted that each group discovered different questions, which were raised and discussed as a whole class.

Feedback from the teachers' open-ended discussion indicated that the controlled and experimental learning environments exhibited two very different styles of learning. The controlled environments reflected a teacher-led instructional model in which the students depended heavily upon the teachers for information, content matter, and directions, whereas, in the experimental environments, the students took responsibility for their learning, thus exhibiting independence skills and taking control of their learning experience. The teachers discussed how they naturally assumed a "facilitator" instructional model in the experimental environment, which allowed the students to take control of their learning and demonstrated the ability to have the confidence to do so. The 4th grade teacher noted, "instead of me being the teacher explaining the concepts and reasons behind why something is the way it is, the children are exploring and finding out the answers themselves. Ultimately, I became the facilitator rather than regurgitating knowledge." The 7th grade teacher concurred with this statement in which she felt as if she contained the information, the “pitcher of knowledge” which the students absorbed, further stating, “I was pouring the knowledge, but in the controlled environment I was not getting much back. In the zSpace environment, the students themselves were the ones holding the conversations and sharing the information. I became the facilitator rather than being on the stage talking about the concepts.”

The teachers described the two learning environments as the need to maintain control of the lessons in the traditional classroom environment compared to the sense of letting the students dictate the flow of the lessons within the experimental classrooms. The 4th grade teacher explained, “in the experimental environment I had to talk myself down from telling them what to do. It was a different form of teaching. I had to keep reminding myself that they will find out the answers themselves as they were all engaged within their learning. I had to change my teaching approach”. This opinion was not duplicated in the controlled environments according to the teachers’ feedback or field observations.

Field observations. Field observations revealed that the sharing of new ideas generated more-in-depth conversations amongst students, groups, and the class as a whole within the experimental environments. In the controlled environments, the students obediently and comfortably completed their assignment work; however; rich and deeper conversations regarding atoms or anatomy systems did not transpire.

The field observations also supported the teachers’ feedback regarding the teachers assuming two very different learning styles within each of learning the environments. It was observed that the teachers in the controlled environments provided the students with direct information, which in the experimental environments, the teachers assumed a facilitator's model providing only prompts and guidance, rather than directives. Consequently, the students obtained answers and concept explanation through conversation and discovery.

Limitations and Challenges. As with all technology, the teachers, students and field observations recorded limitations regarding the use of the zSpace devices. Most notably, there were examples of technical issues, which inhibited the ability of some students to become fully engaged in the learning experience. During a few lessons between 4th grade and 7th grade, it was observed occasionally that a zSpace device became dysfunctional. The teachers were able to absorb the students into another group in order to keep the flow of the lesson moving. Additional technical glitches were experienced several times in both the 4th and 7th grade experimental lessons. A stylus or a mouse at times became non-responsive resulting in replacements, the Sandbox scientific application for some devices failed to launch or unexpectedly crashed. Such technical encounters prohibited students from successfully completing the entirety of the lessons' objectives on their designated device.

Prior to the commencement of a 7th grade lesson, the teacher discovered one zSpace science lesson and objectives did not correspond to the actual application. An update was necessary to ensure lesson alignment to the concepts and standards was in place. The zSpace devices do not require Internet connectivity during normal operating times; however, six-month updates, which require connection to the

Internet, are necessary to keep the applications current. It was necessary at times to recalibrate the devices to ensure full functionality was restored.

Field observations and feedback from teachers and students complained of occasional motion sickness, which would require the removal of the infrared 3D glasses. Students could still explore the concepts without the added 3D feature. Over-stimulation of images was, although rarely, was noted by some students who felt they became overloaded with the imagery content. These students focused more on the integrity of the images rather than the lesson's objectives at times.

There is also the financial constraint upon the school to not only initially purchase the devices but also to maintain and update the various applications annually. The school currently utilizes third source funding to cover the purchases, updates, and annual application subscriptions.

Summary of Qualitative Analysis

An analysis of the qualitative data revealed several trends from the perspectives of the teachers, students, and field observations. These trends, although anecdotal in nature, revealed positive benefits of the use of augmented virtual reality, such as zSpace, upon student learning. It was collectively agreed from the teachers and students' feedback and field observations that students within the experimental environments were exposed to a unique learning experience, which yielded several positive outcomes. Compared to the traditional learning environments, the students in the experimental classroom environments exhibited a greater level of understanding of abstract scientific phenomena that was not accessible within the regular classroom environments. Students were able to make real-life connections to the virtual reality experiences and were able to share these connections collaboratively and meaningfully with their peers with a greater level of confidence and enthusiasm. The qualitative data revealed that students were highly engaged, motivated, and sought opportunities to learn more concepts beyond the scope of each lesson's objectives compared to the traditional classroom environments.

Teacher and field observations also revealed that there are possible benefits and implications regarding the use of augmented virtual reality within the realm of special education. Low spatial and visual learners may benefit from tools such, as zSpace, to develop a greater understanding of abstract concepts. In addition to this, the teachers argued that the use of the zSpace devices promoted the concept of "no limitations to learning." Students were free to explore, manipulate, and expand their knowledge at their own level and pace. Such an approach to learning lends itself to the informal learning model, in which learning is natural, organic in nature, and unrestricted to expectation and direction.

Perhaps the most revealing aspect of the study indicated that the teachers within the experimental environments became the facilitators of learning rather than the teachers, the regurgitation of knowledge. Students worked collaboratively and independently from the teacher to expand their knowledge and understanding of concepts. Students ultimately took responsibility for their learning due to increased levels of motivation, curiosity, collaboration, and engagement.

Technical issues were observed and identified which understandably impeded the student learning experience within the experimental environments. Such technical issues did not negatively impact the controlled environments, which relied heavily on textbooks, worksheets, and traditional technology devices such as Smartboards and online practice supplemental websites.

Chapter 5

Conclusions, Actions, and Implications

Introduction

This study examined the pedagogical impact of one augmented virtual reality-learning environment in a Catholic school in Huntington, West Virginia at the 4th and 7th grade levels. Dalgarno, Hedbery, and Harper (2002) recognized over 15 years ago how the inclusion of 3D technologies would not only revolutionize the gaming world but also offered great possibilities and an increased learning experience in the field of education. Dalgarno et al. argue, “3D environments have great potential in educational context as they provide the possibility of rich learner engagement together with the ability to explore, construct, and manipulate virtual objects, structures, and metaphorical representation of ideas” (p. 149). Virtual learning environments present a unique learning experience, which offers students the possibility to explore world concepts and scientific phenomena in a safe environment (Chittaro & Ranon, 2007).

In addition to the pedagogical impact, the study also analyzed student motivation, interest and collaboration levels between two learning environments. The controlled learning environment adopted a traditional approach to learning material, which utilized textbooks, worksheets, and classroom resources to teach students science concepts. The experiential learning environment incorporated the use of an augmented virtual reality computer device, zSpace, designed to provide students with a unique tool for learning science and STEM-related concepts. Student motivation and interest levels along with collaborative learning opportunities were also assessed at the 4th and 7th grade levels.

This chapter summarizes the findings of the researcher's analysis and interpretation of data collected. The chapter also provides a summary of the results and discusses the conclusion, actions, and implications of the study. In addition to this, the study identified recommendations and actions for future research on the topic of virtual reality as a viable learning tool within the field of education at the elementary and middle school level.

Summary of Results

The investigation used a mixed-method approach consisting of quantitative and qualitative approaches to examine the study's hypotheses and to provide supporting evidence upon which conclusions and recommendations were drawn. The study presented and tested two null hypotheses.

H_o 1: *There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 4th grade level as measured by the pretest and posttest.*

H_o 2: *There is no difference in the student achievement on science activities for students in the control group compared to the students in the experimental group at the 7th grade level as measured by the pretest and posttest.*

Quantitative data. The quantitative data compared student academic achievement levels between a pretest and a posttest at the 4th and 7th grade level in two grade level science classes over a two-week period. An independent two-tailed *t*-

test was applied to both the control and experimental groups to determine if the presence of statistically significance differences occurred between the pretest and posttest at each grade level.

The study's quantitative data revealed that there was no significant statistical difference between the controlled and experimental groups at the 4th grade level on the pretest and the posttest. In addition to this, the results demonstrated that there was no significant statistical difference between the controlled and experimental groups also at the 7th grade level on the pretest and posttest. Based on the analysis of the quantitative data, the rejections of null hypotheses for both grades were not warranted.

Additional analysis revealed that the 4th grade's pretest showed a small effect size between the controlled group and the experimental group, which increased between the two groups on the posttest. The 7th grade pretest did not reveal an effect size between the controlled group and the experimental group, however; the data on the posttest revealed that a small effect size occurred between the controlled group and experimental group. The study's data trends also demonstrated that the academic gains of the students in the experimental groups at the 4th grade and 7th grade levels increased at a higher rate than the academic gains of the students in the controlled groups from the pretest and posttest.

Qualitative data. The qualitative data collected from the open-ended question sessions along with field observations were also examined. Questions presented to the teachers' open-ended question session and the 7th grade students' open-ended question session utilized Dalgarno and Lee's (2010) Model of Learning in 3D learning. The model identified five learning affordances, which, according to Dalgarno and Lee, are achieved through the use of virtual reality. These affordances include; *Spatial Knowledge Representation, Experimental Learning, Engagement, Contextual Learning,* and *Collaborative Learning.*

Based on the analysis of the qualitative data collected, two distinct learning environments yielded different results regarding student engagement, motivation, and collaborative learning opportunities. The teacher, student, and field observations, although anecdotal in nature, provide strong evidence supporting the value and benefits of an augmented virtual reality-learning environment, through the use of zSpace devices, compared to a traditional learning model. The qualitative data identified three main areas in which specific benefits and student accomplishments were achieved within the experimental environments compared to the traditional learning environments. These three areas included the overall learning environment, teacher verses facilitator model, and student approach and accountability towards their learning.

Learning Environment. The experimental classroom exhibited a learning environment, in which restrictions, boundaries, or limitations to learning did not exist. This environment also allowed students to expand their knowledge and understanding of concepts beyond the traditional learning environment, which used resources such as textbooks, worksheets, or relying on teacher knowledge and input. The students in the experimental classrooms were immersed within an environment that supported the learning of abstract concepts, challenging objectives, and the discovery of scientific phenomena. This approach to learning was only possible due to the use of the augmented virtual reality devices, zSpace. Through the use of zSpace devices, students were afforded the opportunity to understand, rationale, and master complex material beyond the physical confinement of their classroom walls. As argued by Cai et al. (2013), “this feature makes it possible for users to observe objects in the real world that are inaccessible to human beings or in the microworld that only exist in our imagination” (p. 857). In addition to this, the zSpace devices provided students the opportunity to manipulate, dissect, and expand real-life images through hands-on activities, many of which offered haptic sensations. Students were afforded the opportunity to analyze objects from different perspectives, angles, and principles.

Qualitative data revealed that students in the traditional classroom environment had the opportunity to learn material within the confinements of a static environment relying on textbooks, worksheets, or information derived from the teacher. Once printed, textbooks soon become outdated and often physically worn. The zSpace devices provide up-to-date information due to bi-annual application updates.

Field observations and teacher feedback indicated that the learning experience within the experimental environments generated greater levels of curiosity, interest, and motivation than within the traditional environments. In addition to this, the use of the augmented zSpace devices fostered an environment in which students asked more questions as they made independent discoveries, thus establishing a deeper level of understanding of the content material. Students also exhibited higher levels of enthusiasm and a natural desire to learn more concepts within the experimental classrooms compared to that of the traditional classroom.

The use of zSpace devices supports the informal approach to learning in which students learn material through non-traditional means or teaching strategies. In this environment, the student takes responsibility for their learning, determining pace and direction. The concept of exploration is a key factor to the benefits of virtual reality. Students demonstrated independent learning skills as they discovered new material.

Collaborative learning moments were highly evident within the zSpace experimental environment in which, by design, encouraged students to interact with each other as they progressed through the activities. In both the controlled and experimental learning environments, the students had the freedom to make their own discoveries. However, observations and open-ended feedback support the argument that the use of the virtual reality devices generated greater discussions, student movement, and higher levels of critical thinking and questioning amongst the students. These findings support the theory of Constructivism in which students learn from one another through observations, modeling, and the transactions of ideas and knowledge (Chittaro & Ranon, 2007). The findings also support the theory of Connectivism, in which students network with each other to make real-life connections, applications, and share their findings (Siemens).

Teacher and facilitator. The qualitative data provided strong evidence to suggest that the presence of two distinct teaching strategies emerged within each learning environment. The traditional learning environments placed the teacher at the center of the learning model, whereas the experimental learning environments utilized a student-centered approach to learning whereby the students became responsible for their own learning, discoveries, and communication amongst their fellow peers. It was evident that the experimental environments fostered an environment in which students became the independent learner, taking responsibility for their learning accomplishments, and seeking answers independently of the teachers. In the traditional classroom settings, the students relied upon the direction, pace, and knowledge of the teacher to accomplish lesson objectives.

Student learning. Students exhibited similar and at times different characteristics within each learning environment, for example, the students in both learning environments demonstrated a willingness and desire to learn the material. Behavioral issues or classroom disruptions were minimal and at most times non-observable. This observation clearly reflects the learning and behavior expectations of the students and that of the school's culture.

As a private Catholic school, the expectations of students to reach their full potential is set high by administration, teachers, and parents. There is a clear understanding of the school's mission that learning is a priority and external factors are reduced to avoid compromising the learning process. Catholic education is not free; therefore parents must pay a premium to send their child to a Catholic school.

The parents are financially invested in their child's future; therefore it is understood by the students that they are not only responsible for their academic achievements but will also be held accountable.

Coleman and Hoffer (1987) support this perspective attributing parental support, student discipline, homework, and high attendance for the main reasons why Catholic schools academically outperform other private school models as well as the public school sector. Coleman and Hoffer also argue that due to the nature and culture of the 'typical' Catholic school learning environment and expectation levels of students, Catholic schools on average accomplish three grade levels over two academic years compared to two grade levels over two academic years on average in the public sector. This finding supports the argument that Catholic schools set high expectations for their students and anticipate a greater coverage of content within a shorter period of time.

Beyond the learning expectations of the students, qualitative data revealed that the students within the zSpace experimental environments exhibited higher interest and engagement levels. Scott et al. (2017) argue that virtual reality offers "unique environments that provide several benefits to learning such as keeping learners highly motivated and engaged as well as providing useful learning experiences through simulations and intuitive spatial awareness of their location and actions" (p. 262). Thornton, Ernst, and Clark (2012) also recognize the potential augmented reality offers students in terms of engagement and excitement stating "we must constantly utilize contemporary and cutting-edge technological applications to provide a more beneficial learning experience for students" (p. 18).

Special education implications. Feedback from the teachers and field observations indicated that there are possible benefits for the use of virtual reality as a tool to assist within the field of special education. Evidence suggested that through the use of the augmented virtual reality devices, zSpace, differences in student learning styles were enhanced. Scott et al. (2017) support this statement arguing, "technology has become more suitable to address particular issues of the individual learner such as interests, backgrounds, and abilities, so that diversity concerning learners is taken into consideration" (p. 262). The use of virtual reality lends itself to the visual learner and may potentially help low spatial learners to understand abstract and scientific phenomena that enables them to go beyond their cognitive abilities and the images presented in a 2D form, such as pictures in textbooks, worksheets, and other resources associated within the traditional classroom environment.

Augmented virtual reality devices may increase a student's ability to process information from different learning perspectives, which does not rely on written explanation. Students with a diagnosis of dyslexia or other reading impairment categories, for example, are provided an alternative approach to grasp and process concepts virtually through the use of a stylus and haptic manipulation, while at the same time, supported by written information. Students diagnosed with ADHD, through the use of zSpace, were immersed within a learning environment that easily captures the attention and focus of the user, thus sparking higher interest and engagement levels rather than through the use of textbooks and traditional resources. Technology, such as zSpace, offered students who need higher engagement and focus strategies the opportunity to learn content from an alternative teaching approach. The use of virtual reality platforms may potentially offer students a varied and individualized perspective or approach to learning as supported by Scott et al. (2017), “technology has become more suitable to address particular issues of the individual learner such as the interests, backgrounds, and abilities, so that diversity concerning learners is taken into consideration” (p. 262).

Regardless of how advanced and robust technology devices, platforms and applications have become over time, the issue of technical and programming glitches and malfunctioning accessories remains a reality. Technical issues disrupt the natural follow of a lesson leading to loss of instruction time and increased levels of frustration between both the teacher and students. With that being said, it is the intention of manufacturing companies to reduce glitches and technical complications with their product, thus increasing user satisfaction, efficiency, and usability and ultimately, sales. It was noted by the researcher that technical issues, glitches, or malfunctioning applications or accessories associated with the zSpace technology, applications, and products were immediately rectified with speed and efficiency through the company’s customer service.

Limitations, Delimitations, and Assumptions

Limitations. The study presented several limitations, which could potentially impact the reliability of the data and the data’s analysis of the findings. The first limitation of the study was the limited number of students and teachers who participated at the 4th grade and 7th grade levels. The study's population was restricted to the size of the student enrollment at each grade level within one Catholic school in West Virginia. Although the grades selected for the study consisted of the two largest classes in the school, the total number of participants could be argued as a small test size. The study did not include participants from other Catholic or public schools within the state of West Virginia as no school or school district within the state utilizes the use of augmented virtual reality through the use of the zSpace devices. The small population size would, therefore, reduces the overall generalizability of the data and the study's findings.

The researcher had no direct connection with other schools or districts nationally or internationally who have purchased the zSpace technology. The inclusion of other schools or districts would have presented many challenges during the study's testing window, such as oversight of testing variables including curriculum content, student assessment measurements, state standards, student demographics, and variations in testing environments along with teacher proficiency levels. Expanding the testing population to increase generalizability would be a recommendation for a future action.

A second limitation of the study that could be argued is the strength and quality of the teaching proficiency levels exhibited by the two teacher participants and observed by the researcher. The 4th and 7th grade teachers demonstrated exemplary teaching strategies, knowledge of content, and classroom management techniques. The experimental environment naturally supported a student-centered learning approach in which the students controlled the learning process. In the traditional classroom, the teachers directed the lessons, controlling and navigating the discussions and activities. Due to their exceptional teaching proficiency skills, it could be argued that the students in this setting received high-quality learning regardless of technology or educational material, whereas, the students in the zSpace classroom became the masters of their own learning, achieving their own discoveries and academic achievements beyond the scope of the teachers' proficiency levels. Therefore, it could be argued that this finding may have elevated student achievement scores in the traditional setting at a higher rate than the average classroom-learning environment. With that being said, it is noted from the quantitative data that the students in the experimental environments still out-performed the students in the controlled environments.

A third limitation of the study is the limited testing window afforded to the researcher. A three-week testing window consisted of a pretest, followed a week later by a two-week science unit, finishing with a posttest is only a small portion of the academic year. This testing window consisted of 6.1% of the academic year. The utilization of augmented virtual reality during the testing window afforded students in the experimental learning environment a total of nine zSpace experiences. Expanding the use of zSpace devices over a greater period of time may yield different results.

The fourth limitation of the study lies in the study's assessment tool. The study utilized a pretest and posttest approach to collecting student achievement scores. The design of the pretest and posttest applied traditional approaches to collecting student achievement scores, which consisted of multiple-choice questions, open-ended questions, and labeling diagrams. The students in the zSpace classroom were not afforded the opportunity, based on the structure and limitation of the posttest design, to demonstrate above and beyond content they learned from the zSpace devices. In addition to this, the students were not afforded the opportunity to demonstrate content mastery utilizing non-traditional assessment tools such as group discussions, collaborative demonstration, and hands-on manipulation of 3D images.

It could be argued that each assessment tool should mirror the learning environment rather than favor one form of assessment tool over another. Future consideration could be made to create an assessment tool or method, which is more reflective of the learning environment in which the students were taught. This raises the question; did reverting back to a paper and pencil assessment format defeat the purpose of the augmented virtual reality-learning environment? Would it have been more appropriate for the students in the experimental environments to have been tested using a different testing instrument?

The final limitation of the study was the technical glitches the zSpace environments occasionally experienced which resulted in the loss of instructional minutes and the ability to learn concepts using augmented virtual reality. Although limited, the result of technical issues raised frustrations amongst the teachers and students and altered the flow and structure of the lessons. The teachers and students were required to take alternative measures to ensure the lessons' objectives were still being covered and mastered.

Delimitations. The design of the study was planned so as not to interrupt the school's academic calendar, curriculum structure, and daily schedule. The two teachers selected for the study followed the school's curriculum policy and the diocesan requirement to create a unit plan within their grade level and content area. The teachers maintained their regular schedules and utilized the school's available academic materials and resources. Although the experimental environments utilized the use of zSpace technology, the teachers have been trained to incorporate the applications available on zSpace within their lesson plans and units.

In order to ensure students' classes were not disrupted, grade level homerooms, consisting of mixed ability and gender, were selected for the purpose of the study. The only change to the students' schedule involved switching the 7th grade control group's daily scheduled science lessons from a morning period to an afternoon period. The rationale behind this switch was to ensure that each of the two learning environments were represented in the morning as well as in the afternoon, thus reducing favoritism to one learning environment of what might be considered prime learning time, considered the mornings, and leaving the other learning environments to be conducted in the afternoon. This structure ensured an equal balance of when lessons transpired throughout the day.

Assumptions. The study presented several assumptions, which could be argued as being reasonable and reliable. These assumptions addressed the educational environment in which the study took place. To begin with, it was reasonable to assume that the participants in the study, such as the students and teachers, willingly and openly contributed to the study's validity and outcomes. The students, by their nature and supported by the learning culture and the high expectations of the school and home were positively engaged in the learning process in both the controlled and experimental groups. The grade level groups were balanced in terms of gender and academic abilities, thus increasing the generalizable population of the student body when compared to the average class within the school. It was assumed that the average Catholic school class consisted of a study body that was different in terms of academic ability compared to that of the average public school classroom. With that being said, for the purpose of this study, the student bodies per class and grade level were assumed to reflect the average demographics of a Catholic school environment.

Field observations also supported the assumption that the students actively and positively contributed to the study through their actions and levels of participation in all learning environments. In addition to this, the field observations also revealed that the teachers demonstrated high competency levels in terms of knowledge of academic content, student discipline, and classroom management techniques. Therefore, it was assumed that the quality of instruction was equal and balanced within each learning environment.

Prior to the execution of the testing window, the teachers planned a two-week unit of their respective grade level and content area. It was assumed that the teachers created two robust units which took into consideration alignment to state standards, the inclusion of meaningful resources and material, differentiated instructional strategies, individual learning needs of students, and appropriate assessment modules and tools. Each teacher designed a pretest and posttest within their grade level. As previously mentioned, the teachers within the diocese and school are expected to create two unit plans per academic year. The two teachers spent time researching, planning, and identifying resources and assessment tools designed to offer students with an exemplary learning experience in both learning environments.

These observations, combined with the teachers' unit plans and professional conduct, supported the assumptions that the learning environments were equitable in terms of teaching quality, curricular rigor, and student expectation.

The study's quantitative findings provided objective and factual data, which was presented in the findings of the study's pretests and posttests. The data offered a realistic and reliable indication of the students' academic gains throughout the testing period in both learning environments.

The study obtained qualitative data in terms of open-ended questions sessions. It was assumed that the participants, who included two teachers and four 7th grade students, openly and honestly provided feedback without reservation or biases. Although the feedback from the teachers and students can be considered subjective in nature, the qualitative data obtained is a realistic representation of one Catholic school's teachers and students' perspective. Future studies utilizing a greater variety of school environments may yield similar or different perspectives.

Finally, despite encountering minor technical issues with the zSpace devices and elements of user discomfort, it is to be assumed that the use of the augmented virtual reality devices will continue to be an integral part of the school's technology program. The field observations and feedback from the teachers and students support the argument that most teachers and students enjoyed using the technology to enhance the learning experience and to expand different approaches to learning content and objectives.

Recommendations

What is known and understood regarding the benefits and value supporting the use of virtual reality within the field of education is limited (Thornton, Ernst, & Clark). Therefore, this study contributed to the research void associated with the pedagogical affordances of a virtual learning environment at the elementary and middle school level. In order to extend this research further and to explore additional findings, several recommendations have been identified.

The first recommendation is to extend the footprint of the study beyond the scope of one school environment to several. Including a greater diversity of schools in terms of student demographics, geographical locations, and school culture and school systems (public and private schools), would significantly increase the study's generalizable population, thus increasing research validity and creditability.

Another recommendation would be to increase the testing window beyond the constraints of a two-week period. Implementing a longitudinal study, which utilizes a greater population and the use of zSpace devices, may yield more accurate results reflecting the pedagogical benefits or limitations of augmented virtual reality as argued by Hew and Cheung (2010), "longitudinal studies provides researchers with the opportunity to examine not only whether students' and teachers' perceptions of virtual worlds undergo change, but also whether there are any detrimental effects of using virtual world environments over a long period of time" (p.46).

A third recommendation would be to conduct a retention test to examine how much information have students retained over a specific period of time. Researching the retention rates of information may offer additional data supporting the inclusion of augmented virtual reality devices within the curriculum.

A fourth recommendation would be to examine the learning benefits of the use of augmented virtual reality within the field of special education. Understanding that all learners learn differently, the use of augmented virtual reality may lend itself as an alternative-learning tool to meet the individual needs of students with identified learning challenges.

A fifth recommendation would be to identify other virtual reality devices beyond zSpace technology in order to determine if there are specific trends in the use of virtual reality as a learning tool or if the learning benefits are greater with one virtual reality device over another.

The final recommendation from this study would be to consider an assessment tool designed to effectively and quantifiably evaluate the learning process, including abstract and subjective learning measurements through the use of augmented virtual reality devices. The assessment tool should mirror the learning environment generated by the use of augmented reality devices.

Future Actions

Future actions based on the finding of the capstone include expanding the use of zSpace devices across the entirety of the school's K-8 academic program and potentially to include a local Catholic high school. Establishing STEM curriculum committees would be essential in order to create a school-wide based technology program, designed to encapsulates all grade levels to incorporate state standards, cross-curricular opportunities, special education inclusion with the use of the augmented virtual reality devices, zSpace. The zSpace applications offer students of different grade levels and subject interests a wide variety of applications. Research and exploration into additional applications will be necessary to enhance the school's current curriculum.

Alternative student assessment modules will be essential to assess student learning from a holistic perspective, which includes the aspect of hands-on demonstration, collaborative learning, project-based learning, and group exploration.

The school's special education program will continue to expand its teaching strategies to include augmented virtual reality as an alternative approach to learning concepts. Students with SSP will be afforded the opportunity to utilize zSpace devices beyond regular classroom intervention strategies and intensive instructional minutes.

Reflections

The findings of this study, along with the study's research have provided a greater understanding and appreciation for the value and significance of virtual reality technology within the field of education. Prior to the commencement of researching the concept of virtual reality, I initially selected a different topic – special education within the Catholic school system. I spent my first year in the doctoral program researching special education and how to effectively integrate best practices into a school system, which historically has been limited with knowledge and expertise in the field of special education. It was after a school accreditation visit that I observed the use of augmented virtual reality devices as an exciting and new approach to learning. I was highly intrigued to learn more about this form of technology due to the high levels of collaboration and high-level thinking that I observed taking place between students. In my second year as a doctoral student, I switched my capstone topic and began discovering an unknown component of technology that was new or practically absent in the field of education within the Catholic schools of West Virginia.

Throughout the research process, I realized that the use of virtual reality is not new in many fields such as the world of medicine, surgery, aviation, space, and the military, yet virtual reality is still in its infancy stages within the world of education. I realized that there is limited research supporting the use of such technology from a pedagogical perspective. I intended to embark on a journey that would offer a new piece of research that would help aide schools in their decision whether or not to consider incorporating such technology within their school's curriculum as a new and exciting approach and perhaps philosophy towards learning.

Although the study did not yield statistically significant results to support the use of augmented virtual reality devices from a pedagogical perspective, the results did indicate that student learning did take place at a higher rate in the experimental environments (zSpace) over the traditional classroom setting. In addition to this, the feedback from the teachers and students highly supported the use of the zSpace virtual technology as an exciting and new approach to learning that allows the students to explore beyond the confinements of the traditional classroom walls and textbooks.

I believe the capstone has provided a starting point for other Catholic schools within the diocese to consider exploring and implementing virtual reality devices, such as zSpace, as a viable option to enhance their curriculum while attracting prospective students to consider a Catholic education as an alternative choice to education.

Conclusion

The purpose of this study was to analyze, using quantitative data, the pedagogical impact of a virtual learning environment at an intermediate and middle school grade level within one science unit. The study also used qualitative data, to investigate student motivation, interest, and collaboration levels between a traditional approach to learning and a learning environment, which incorporated augmented virtual reality technology. Although the quantitative data did not yield statistically significant findings supporting the use of augmented virtual reality, the data revealed a small effect size at both the 4th grade and 7th grade levels indicating that students did learn at a higher rate due to the use of augmented virtual reality over a traditional learning environment.

It is important to note that the study's qualitative data revealed an abundance of data and trends that went beyond the data collected quantitatively. Bryman (2006) argues that the use of both quantitative and qualitative often yields unexpected outcomes; however; the use of qualitative research often generates surprises, insights, often carving new directions for future studies. In this particular study, the qualitative data yielded a greater level of understanding and appreciation for the educational value virtual reality learning environments may offer to the world of education.

The study highlights the many benefits of the utilization of virtual reality learning devices, such as zSpace. Increased levels of student motivation and interest levels were observed. The presence of collaborative learning and high-level discussions amongst students were vibrant within the experimental environments compared to the controlled environments. Students were genuinely interested, engaged, and excited to learn concepts through the use of manipulating 3D objects and images. Students received instant feedback from the zSpace devices, thus solidifying and reinforcing what they were learning. Students were afforded the opportunity to guide and pace their own learning in the experimental environments, which was not as highly evident in the controlled environments. Students actively took responsibility for their learning without relying on the guidance and support of the teacher. It became apparent that the use of the zSpace devices naturally generated a student-centered learning environment, which cultivated great peer-to-peer conversations and student learning moments that went beyond the scope of lesson objectives.

The use of augmented reality fostered the sense of self-discovery, sparking more-in-depth and more meaningful conversations between students. In the controlled environments, students were confined to the information presented in the textbooks and knowledge of the teacher, whereas in the experimental environments learning exhibited no boundaries, as students were free and safe to explore and manipulate concepts virtually and to explore scientific phenomena that are beyond the scope of 2D representation. It could be argued that the students were learning the material without realizing that they are learning which lends itself to the informal model of learning, in which students learn through discovery, self-motivation, and interaction with others.

Although the investigation did not reveal statistically significant gains in terms of academic achievement levels, the qualitative data from teacher, student, and field observations clearly support the argument that students were highly motivated, highly engaged, and eager to learn at a higher rate through the use of augmented virtual reality compared to a traditional classroom approach to learning. The study's posttest assessment tool, by design, was unable to quantifiably assess the full scope of how much the students actually learned beyond the scope of lesson objectives. The posttest was a limited example of what the students truly learned from the use of the zSpace experience. Students were more confident and engaged to continue exploring, to discover, and share new concepts unprompted, thus generating many unplanned learning and teaching moments.

The study identified some limitations due to the use of augmented virtual reality devices, such as motion sickness, over stimulation, and technical issues; however, the benefits of virtual reality devices such as zSpace outweigh the negative implications experienced by the users. In addition to this, the use of augmented virtual reality holds future discussion and research in the field of special education. Based on the feedback obtained, the incorporation of augmented virtual reality may yield great prospectives for special education as an alternative technique for learning subject content and material. At the very least, augmented virtual reality offers teachers, students, and users an additional means and unique approach to learning new material beyond the scope of the traditional classroom environment or textbook.

Augmented virtual reality, therefore, offers a unique approach to learning that is not typical of a traditional classroom environment. The use of zSpace devices helps to bring the world of education into the world of technology, offering students the opportunities to make real-life connections, learn scientific phenomena, and to safely expand their learning beyond the confines of their classroom walls (Chittaro & Ranon, 2007).

References

Ash, P. B. & D'Auria, J. (2013). *School systems that learn: Improving professional practice, overcoming limitations, and diffusing innovation.* Thousand Oaks, CA: Cowin.

Azuma, R. T. (1997). A survey of augmented reality. *In Presences: Teleoperators and Virtual Environments, 4*(4), 335-385.

Bashm, K. L. & Kotrlik, J. W. (2008). The effects of 3-Dimensional CADD modeling on the development of the spatial ability of technology students. *Technology Education, 20*(1), 2008.

Bazeley, P. (2002). Issues in mixing qualitative and quantitative approaches to research. *Research Support P/L.* Retrieved from https://www.researchgate.net/profile/Pat_Bazeley/publication/228469056_Issues_in_Mixing_Qualitative_and_Quantitative_Approaches_to_Research/links/5570606308ae7d0f5f900d4a.pdf

Boleman, L. G. & Deal, T. E. (2013). *Reframing organizations: Artistry, Choice, & Leadership* (5th ed.). San Francisco, CA: Jossey-Bass.

Bosch-Sijtsema, P. M. & Haapamaki, J. (2014). Perceived enablers of 3D virtual environments for virtual team learning and innovation. *Computers in Human Behavior, 37*(2014), 395-401.

Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative Research, 6*(1), 97-113.

Bulman, G. & Fairlie, R. W. (2015). Technology and education: Computers, software, and the Internet. *Institute of Labor Economics.* Retrieved from https://www.econstor.eu/bitstream/10419/124948/1/dp9432.pdf

Bosch-Sijtsema, P. M. & Haapamaki, J. (2014). Perceived enablers of 3D virtual environments for virtual team learning and innovation. *Computers in Human Behavior, 37*(2014), 395-401.

Cai, S., Chiang, F-K., & Wang, X. (2013). Using the augmented reality 3D technique for a convex imaging experiment in a physics course. *International of Engineering Education, 29*(4), 856-865.

Chau, M., Wong, A. M., Lai, S., Chan, K. W. Y., Li, T. M. H., Chu, D., Chan, I. K. W., & Sung, W. (2013). Using 3D virtual environments to facilitate students in constructivist learning. *Decision Support Systems, 56,* 115-121.

Cheng, K. H. & Tsai, C. C. (2013). Affordances of augmented realitty in science learning: suggestions for future research. *Springer,* (2013) 22:449-462. Doi: 10.1007/s/10956-012-9405-9.

Chen, Y. & Wang, S.-H. (2011). Applying a 3D virtual learning environment to facilitate student's application ability-the case of marketing. *Computers in Human Behavior, 27* (1), 576-584.

Cho, Y, H. & Lim, K. Y. T. (2017). Effectiveness of collaborative learning with 3D virtual worlds. *British Journal of Educational Technology, 48*(1), 202-211.

Cho, Y. H., & Lim, K. Y. (2015). Effectiveness of collaborative learning with 3D virtual worlds. *British Journal of Educational Technology, 48*(1), 202-211.

Christensen, C. M. (2011). *Disrupting class: How disruptive innovation will change the way the world learns.* New York, NY: McGraw Hill.

Chittaro, L. & Ranon, R. (2007). Web3D technologies in learning, education and training: Motivations, issues, opportunities. *Computers & Education, 49*(2007), 3-18.

Clark, R. (1983). Considering research on learning from media. *Review of Educational Research, 53*(4) 445-459.

Clarke, E. (2009). Learning outcomes from business simulation exercises: Challenges for the implementation of learning technologies. *Education and Training, 51*(5-6), 448-459.

Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* Upper saddle river, NJ: Prentice Hall.

Crowley, A.L. & Wall, S. (2013). Supporting children with disabilities. *Journal of Catholic Education, 10*(4), 508-521.

Dalgarno, B., Hedberg, J., & Harper, B. (2002). The contribution of 3D environments to conceptual understanding. *UNITEC, Institute of Technology, 1,* 149-158.

Dalgarno, B. & Lee, M. J. W. (2012). Exploring the relationship between afforded learning tasks and learning benefits in 3D virtual learning environments. *In Future Challenges, Sustainable Futures.* Proceedings Ascilite, Wellington, (2012), 236-245.

Dalgarno, B. & Lee, M. J. W. (2010). What are the learning affordances of 3D virtual environments? *British Journal of Educational Technology, 41*(1*),* 10-32.

Dede, C. (2009). Introduction to virtual reality in education. *Themes in Science and Technology Education, special issue,* 7-9.

Dickey, M. D. (2003). Teaching in 3D: Pedagogical affordances and constraints in 3D virtual worlds for synchronous distance learning. *Distance Education, 24*(1), 105-121.

Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Campuzano, L., Means, B., Murphy, R., Penuel, W., Javitz, H., Emery, D., & Sussex, W. (2007). Effectiveness of reading and mathematics software products: Findings from the first student cohort. *Washington, DC: Institute of Education Sciences.* NCEE 2007-4005. Retrieved from https://ies.ed.gov/ncee/pdf/20074005.pdf

Dziuban, C. D., Hartman, J. L. & Moskal, P. D. (2004). Blended learning. *Education Center for Applied Research, 2004*(7) 1-12.

Elliott, J., Adams, L., & Bruckman, A. (2002). No magic bullet: 3D video games in education. *Proceedings of ICLS 2002.* Retrieved from http://www.cc.gatech.edu/ele/aquamoose/

Felemban. S., Gardner, M. & Callaghan, V. (2017). Towards recognizing learning evidence in a collaborative virtual environment: A mixed agents approach. *Department of Computer Science and Electronic Engineering, 6*(3), 22. doi:10.3390/computers603002.

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British Journal of Educational Technology, 46*(2), 412-422.

Gardner, H. (2000). Howard Gardner Talks About Technology. Weiss, Ruth Palombo, Training & Development, 10559760, Sep2000, Vol. 54, Issue 9.

Gibson, J. J. (1977). The theory of affordances. In *Perceiving, acting, and knowing: Toward an ecological psychology.* (pp. 67-82). Hillsdale, NY: Erlbaum.

Hew, K. H. & Chenug, W. S. (2010). Use of three-dimensional (3D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33-55.

Kaufmann, H. & Schmalstieg, D. (2003). Mathematics and geometry education with collaborative augmented reality. *Computers & Graphics, 27*(3), 339-345.

Koh, C., Tan, H. S., Tan, K. C., Fang, L., Fong, F. M., Kan, D., Lye, S. C., & Wee, M. L. (2010). Investigating the effect of 3D simulation-based learning on the motivation and performance of engineering students. *Journal of Engineering Education,* 99(3), 237-251.

Konstantinidis, T. Th. & Pomportsis, A. (2009). Collaborative virtual learning environments: design and evaluation. *Springer Science & Business Media BV, 44*(2009), 279-304.

Kotrlik, J. W. & Williams, H. A. (2003). The incorporation of effect size in information technology, learning, and performance research. *Information Technology, Learning, and Performance Journal, 21*(1), 1-7.

Klopfer, E. (2008). *Augmented learning: Research and design of mobile educational games.* Cambridge, MA: MIT Press.

Hassell, M. D. Goyal. S., Limayem, M., & Boughzala, I. (2011). Effects of presence, copresence, and flow on learning outcomes in 3D learning spaces. *Administration Issues Journal: Education, Practice, And Research,* 62-72. doi:10.5929/2011.2.1.4

Leap, D. (2007, February). Second Life: Creating a better virtual world. *theTrumpet.* Retrieved from https://www.thetrumpet.com/3373-second-life-creating-a-virtual-better-world

Lee, E. A. & Wong, K. W. (2014). Learning with desktop virtual reality: Low spatial ability learners are more positively affected. *Computers & Education,* 1-18. doi:10.1016/j.compedu.2014.07.010

Lee, E. A., Wong, K. W., & Fung, C. C. (2010). How does desktop reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education, 55*, 1424-1442.

Mahajan, R. (2017). Importance of informal learning over formal learning in the 21st century. *International Journal of Advanced Research and Innovation, 5*(2), 152-154.

McMenemy, K. & Ferguson, S. (2009). Enchaning the teaching of professional practice and key skills in engineering through the use of computer animation. *International Journal of Electrical Engineering Education, 46*(2), 164-174.

Merchant, Z., Goetz, E. T., Keeney-Kennicutt, W., Cifuentes, L., Kowk, O., & Davis, T. J. (2013) Exploring 3-D virtual reality technology for spatial ability and chemistry achievement. *Journal of Computer Assisted Learning, 29*(6), 579-590.

Merchant, A., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on student learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*(2014), 29-40.

Milgram, P. & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Sytems, E77-D*(12) 1321-1329.

Morgan, E. J. (2013). Virtual worlds: Integrating "Second Life" into the history classroom. *Society of History Education, 46*(4), 547-559.

National Catholic Education Association (2017). Retrieved from https://www.ncea.org/

Piaget, J. (1952). *The origins of intelligence in children.* New York, NY: International University Press (Original work published 1936).

Picciano, A. G. & Dziuban, C. D. (2007). *Blended Learning Research Perspectives.* Needham, MA: The Sloan Consortium.

Prensky, M. (2001). Engaging Digital Natives through social learning. *On the Horizon, 15*(2), 1-4.

Quintana, M. G. B. & Fernandez, S. M. (2015). A pedagogical model to develop teaching skills. The collaborative learning experience in the Immersive Virtual World TYMMI. *Computers in Human Behavior, 51*(2015), 594-603.

Robinson, K. (2014, October 14). Changing education paradigm. *YouTube.* Retrieved from: https://youtu.be/zDZFcDGpL4U.

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

Sarkar, N., Ford, W., & Manzo, C. (2017). Engaging digital natives through social learning. *Systems, Cybernetics And Information, 15*(2), 1-4.

Scott, E. Soria, A. & Campo, M. (2017). Adaptive 3D virtual learning environments-a review of the literature. *IEEE Transations on Learning Technologies, 10*(3), 262-276.

Schwartz, S. (2018, May). Fortnite may be addictive, but could also promote learning, say Stanford experts. *Education Week.* Retrieved from http://blogs.edweek.org/edweek/DigitalEducation/2018/05/stanford_experts_take_on_fortn.html

Shih, Y-C. & Yang, M-T. (2008). A collaborative virtual environment for situated language learning using VEC3D. *Education Technology & Society, 11*(1), 56-68.

Siemens, G. (2005a, January). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning. 2*(1), article 01. Retrieved from http://er.dut.ac.za/bitstream/handle/123456789/69/Siemens_2005_Connectivism_A_learning_theory_for_the_digital_age.pdf

Simek, I. (2016). The effect of 3D virtual learning environment on secondary school third grade students' attitudes toward mathematics. *The Turkish Online Journal of Education Technology, 15*(3), 162-168.

Schmitt, W. (2015). Alliance for Catholic Education. Retrieved from https://news.nd.edu/news/ace-to-send-forth-272-catholic-school-teachers-and-leaders-in-missioning-ceremonies/

Stosic, L. (2015). The importance of educational technology in teaching. *International Journal of Cognitive Research in Science, Engineering and Education, 3*(1), 111-114.

Sutherland, I. (1968). A head-mounted three dimensional display. *AFIPS '68,* 757-764. doi:10.1145/1476589.1476686

Thornton, T. Ernst, J. V. & Clark, A. C. (2012). Augmented reality as a visual and spatial learning tool in technology education. *Technology and Engineering Teacher, 71*(8), 18-21.

Vogel, J. J., Vogel, D. S. Cannon-Bower, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Experiences with CLARE: a computer-supported collaborative learning environment. *International Journal of Human-Computer Studies, 41*(3), 851-879.

Warnick, B., & Burble, N. (2007). Media Comparison Studies: Problems and Possibilities. *Teacher College Record, 109*(11), 2483-2510.

Winn, W. (1993). A conceptual basis for educational applications of virtual reality. Retrieved from http://www.hitl.washington.edu/research/learning_center/winn/winn-

Wu, H-K, Lee, S. W-Y, Chang, H-Y., & Liang, J-C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers in Education, 62*(2013), 41-49.

Zhao Y. (2009). *Catching up or leading the way: American Education in the age of globalization.* Alexandra, VA: ASCD.

Appendices

Appendix A

St. Joseph Catholic School Diocese of Wheeling-Charleston				
Unit Planner				
Name of Teacher:		Grade Level:		
Subject Area:		Cross Curricular Opportunities:		
Unit Title:		Estimated Duration of Unit:		
Overview of Unit:				
Forms of Text (nonfiction/fiction):		Teaching Strategies:		
Catholic Identity Connections:				
Assessment (authentic/published - summative/formative):				
Standard Number	Standards	Description of Activity	Resources	Date of Completion
Differentiated Instruction Opportunities/Overview:				

Cross Curricular Opportunities level:				
Standard Number	Standards	Description of Activity	Resources	Date

Unit Teaching Strategies Checklist	
Writing	
	Paragraph
	Essay (narratives, fairy tales, realistic fiction)
	Summary
	Research
	Detailed answers (text supported)
	Notes (note taking skills, outlines)
	Complete sentences
Reading	
	Informational text
	Lexile
	Complex literature
	Speaking
	Listening
	Varied strategies and instructional methods
	Critical thinking in whole class discussion
	Student led activities
	common core standards (literature circles)

Technology	
	Smart board
	Computers
	iPads/Chrome Notebooks
	PowerPoint, Elmo etc.
Differentiated Instruction	
	Used multiple resources
	Domain Vocabulary
	Cross-Curricular
	Collaborative engagement (meaningful feedback)
	Higher level learning and teaching
Assessment	
	Project based
	Writing prompt
	Portfolio
	Observation
	Quiz
	Technology based
	Test
	Student created test
	Presentation
	Journal
	Think, pair, share
	Summary
	Oral questioning
	Analogy
	PowerPoint, or movie maker

Authenticity	
	Various activities
	Inquiry, research and evidence
	Evidence of time management and planning
	Problem solving strategies
Summary of Unit:	

Appendix B

<table>
<tr><th colspan="5">Diocese of Wheeling-Charleston</th></tr>
<tr><th colspan="5">CASE Unit Planner</th></tr>
<tr><td colspan="3">Name of Teacher: Holly Moore</td><td colspan="2">Grade Level: 4th Grade</td></tr>
<tr><td colspan="3">Subject Area: Science</td><td colspan="2">Cross Curricular Opportunities: Reading, Writing, Computer Science</td></tr>
<tr><td colspan="3">Unit Title: Electricity</td><td colspan="2">Estimated Duration of Unit (between 2-9 week): 2 weeks (10 days)</td></tr>
<tr><td colspan="5">Overview of Unit: Students investigate static and current electricity. Focusing more on current electricity, students will learn about circuitry, starting with the atom, moving to components of electric circuits including conductors and insulators and concluding with series and parallel circuits.</td></tr>
<tr><td colspan="3">Forms of Text (non fiction/fiction): non fiction</td><td colspan="2">Teaching Strategies: Whole group, collaborative groups, cooperative learning/protocols, science research</td></tr>
<tr><td colspan="5">Catholic Identity Connections: God gave us the intelligence and resources to discover and advance our world.</td></tr>
<tr><td colspan="5">Assessment (authentic/published - summative/formative): Summative and Formative</td></tr>
<tr><td>Standard Number</td><td>Standards</td><td>Description of Activity</td><td>Resources</td><td>Date of Completion</td></tr>
<tr><td></td><td></td><td>Pre-Test</td><td></td><td>Day 1</td></tr>
<tr><td>S.4.GS.2</td><td>Make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.</td><td>Introduction (whole group) - Introduce guided note taking. Provide students with the guided notes for this lesson and explain the format. Begin the lessons by posing the question to the class "What is electricity?" and allow time for Think-Pair-Share. Have students jot down their thoughts on during Think time in the designated area on their guided notes. Share out as a whole group and have students write a working definition in their notes. Next, introduce the two types of electricity, static and current. Refer to the blank Venn Diagram on their guided notes. Explain that they will use this graphic organizer to compare the two. Give an overview of the unit. Explain that to understand static and current electricity that we must start with understanding the atom.</td><td></td><td>Day 2</td></tr>
</table>

S.4.GS.2	Make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Part 1: The Atom - Pass out the guided notes for this lesson. Introduce the word "atom". Have students refer to the word in their guided notes. Explain to students that all matter (everything around them) is made of atoms. An atom has a positively-charged nucleus (proton and neutron) and negatively-charged electrons surrounding the nucleus. In the nucleus are protons, which have a positive charge, and neutrons, which have a neutral charge (neither positive nor negative). Write these points on the board so that students may copy them in their notes. Have students pair up to get on the Zspace in the computer lab and log on to "Curie's Elements". Once student should be the driver and the other student is the passenger. Have the driver enter the sandbox. Explain that the image they are seeing the Periodic Table. Provide a definition of the Periodic Table and explain that each element on the table is made up of atoms. Have students click on the Atom Builder, located at the bottom left of the Periodic Table. Have the whole class build an atom together explaining each part as the atom is built. Allow both students in the pair the opportunity to build an atom. After building their atom, have students draw the image of their atom in their notebook. As an closing activity, provide students with an image of an atom and ask them to label each part.	Put a Spark in It! - Electricity Unit from Teach Engineering: STEM Curriculum for k-12; ZSpace	Day 3
S.4.GS.2	Make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Part 2: Static Electricity and Electric Currents - Go back to the venn diagram that was introduced on day 1. Distribute the reading "Static Electricity" and read as a whole class. At the conclusion of the article, demonstrate static electricity by modeling the balloon activity described in the article. Rub a balloon on a sweater or piece of wool and then hold the balloon close to a student's hair. Observe that the student's hair stands on end. Ask the rest of the class to explain why this happens using the information from part 1 regarding the movement of electrons and charged objects. Fill in the information that was learned on static electricity in the Venn Diagram. Distribute the reading "Electric Currents" and read as a whole class. Discuss what is the difference between static electricity and current electricity. Complete the Venn Diagram. Conclude the lesson by having students' answer the questions found at the bottom of both articles with a partner.	Put at Spark in It! - Electricity Unit from Teach Engineering: STEM Curriculum for k-12; "Electricity and Magnetism Unit Activity" by Learning Lab Resources on Teachers Pay Teachers.	Day 4

S.4.GS.2	Make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Part 3: Electric Circuits and Electrons - Begin the lesson by reviewing static and current electricity. Now focus in on current electricity and electric currents. Show a flashlight that does work when turned on. Ask students why they think the flashlight is not working. Record possible answers. Discuss what could happen once these solutions are addresses (battery needs replace, wire is loose, bulb is shot). Discuss how all of the solution discussed complete an electric circuit. Have students get into pairs at the Zspace and log on to Franklin's Lab. One student will be the driver and one student will be the passenger. Have the driver log in to the sandbox. Introduce each component of the circuit and guide students in building their own circuit. Allow both the driver and the passenger time to build a circuit. Have the pair exit the sandbox and log in to activities in Franklin's Lab. Have the driver click on the activity, Investigation: Open and Closed. Allow the pair time to go through the activity on their own, following the directions for building an open and closed circuit. To conclude, discuss what is needed to create a complete circuit (energy source - battery, wires, light bulb) and introduce the symbols for each. Have students draw examples of open and closed circuits in their notes using the symbols.	Put at Spark in It! - Electricity Unit from Teach Engineering: STEM Curriculum for k-12; "Electricity and Magnetism Unit Activity" by Learning Lab Resources on Teachers Pay Teachers.	Day 5

S.4.GS.2	Make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Section 4: Conductors and Insulators - Review Electric Currents. Explain that the wires in our homes are made of copper, the same material as a penny. The reason that copper is used in electrical wires is because electricity can easily flow through copper. Electricity can flow more easily through some objects than others. The materials that electrons can move through are called **conductors**. Have students write this word and definition in their notebook. Explain that the atoms in a conductor have loosely-attached electrons and a negative charge buildup pushes electrons through the material. Electrons in metals are loosely attached to the atom, so metals are conductors. Next, introduce the vocabulary word **insulators.** Explain that when electrons are tightly attached to the atoms in a material and cannot be forced to move from one atom to another, no electricity flows. These materials are called insulators. Have students get into pairs at the Zspace and log on to Franklin's Lab. One student will be the driver and one student will be the passenger. Have the driver click on Explore Activities. Ask students to find the lesson titled "Investigation: Conductivity" and enter the lesson. Guide students through the activity to test the conductivity of the given items (pencil, 30 gauge rubber 1 km wire, gummy bear, 30 gauge cooper wire and penny). Ask students to what they notice about the circuit when the item is added to the circuit. Ask if they think is a conductor or an insulator based on their observation of the circuit. Make a T-chart on the board and write the item in the appropriate spot. To conclude the lesson, discuss what they notice about the items placed on the conductor's side of the t-chart and what they notice about the materials placed on the insulator side of the t-chart. Make a general statement about the types of materials that are conductors and that are insulators.	Put at Spark in It! - Electricity Unit from Teach Engineering: STEM Curriculum for k-12; "Electricity and Magnetism Unit Activity" by Learning Lab Resources on Teachers Pay Teachers.	Day 6

S.4.GS.2	make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Section 5: Series Circuits and Parallel Circuits - "Ask students if they ever had an electronic game or toy that required batteries? Ask how many batteries the game or toy needed. Ask students to brainstorm why some electronic games or toys require more batteries than other games or toys? Explain that several batteries are required because they can provide more voltage in a circuit. Distribute the reading "Batteries" and read as a whole class to learn more about how batteries provide energy in a circuit. Transition the discussion to explain that the energy in electric circuits can be distributed through a **series circuit** or a **parallel circuit**. Distribute the reading "Series and Parallel Circuits". Have pairs of students go to the Zspace and log on to Franklin's Lab. One student will be the driver and one student will be the passenger. Have the driver click on Explore Activities and log into the lesson "Investigation: Series vs. Parallel Circuits". Guide students through the lesson as they explore the similarities and difference of a series circuit and parallel circuit. At the conclusion of the Zspace lesson, have students draw in their notebook each type of circuit. Discuss the advantages of each.	Put at Spark in It! - Electricity Unit from Teach Engineering: STEM Curriculum for k-12; "Electricity and Magnetism Unit Activity" by Learning Lab Resources on Teachers Pay Teachers.	Day 7 and 8
S.4.GS.2	make observation to provide evidence that that energy can be transferred from place to place by light, sound, heat and electric current.	Vocabulary Review - Using quizlet, review the vocabulary learned in this unit on electricity.	quizlet.com	Day 9
		Post-Test		Day 10
Differentiated Instruction Opportunities/Overview: In this Investigation, students are instructed to solve the Problem of the Week as a mathematics connection to the Science instruction.				
Cross Curricular Opportunities:				
Standard Number	Standards	Description of Activity	Resources	Date
Teaching Strategies Checklist				
Writing				
X	Paragraph			

	Essay (narratives, fairy tales, realistic fiction)
X	Summary
	Research
X	Detailed answers (text supported)
X	Notes (note taking skills, outlines)
X	Complete sentences
Reading	
X	Informational text
	Lexile
	Complex literature
X	Speaking
X	Listening
X	Varied strategies and instructional methods
X	Critical thinking in whole class discussion
X	Student led activities
	common core standards (literature circles)
Technology	
	Smartboard
X	Computers
	iPads
	Powerpoint, Elmo etc.
Differentiated Instruction	
X	Used multiple resources
X	Domain Vocabulary

X	Cross-Curricular
X	Collaborative engagement (meaningful feedback)
X	Higher level learning and teaching
Assessment	
	Project based
	Writing prompt
	Portfolio
X	Observation
	Quiz
	Technology based
X	Test
	Student created test
	Presentation
X	Journal
X	Think, pair, share
X	Summary
X	Oral questioning
	Analogy
	Powerpoint, or movie maker
Authenticity	
X	Various activities
X	Inquiry, research and evidence
X	Evidence of time management and planning
X	Problem solving strategies

Appendix C

Diocese of Wheeling-Charleston

Unit Planner (MS & HS Word Doc)

Name of Teacher: Holly Cheshire	Grade Level: 7th
Subject Area: General Science	Cross Curricular Opportunities: Health, Language Arts, Reading
Unit Title: Structure, Movement, and Control	Estimated Duration of Unit: 2 weeks
Overview of Unit: Students will explore the major organs and tissues of the skeletal, muscular, and nervous systems. Students will discover how these systems are interrelated and dependent on one another to maintain homeostasis in the human body. Students have prior knowledge cells, cellular processes, cell theory, and the organization of the human body.	
Forms of Text (non fiction/fiction): McGraw-Hill iScience Level 2 Textbook (Group A), zSpace studio Activity Sheets (Group B), Handouts (Group A and B)	Teaching Strategies: Think-Pair-Share, Pre-test and Post-test, guided/group reading, brainstorming, direct teaching, whole class discussions, group work, partnered activities
CONTROL GROUP	
Assessment (authentic/published - summative/formative): Pre-test and Post-test	

Standards Addressed

Standard Number	Standards
S.7.LS.1	conduct an investigation to provide evidence that living things are made up of cells, either one cell or many different numbers and types of cells.
S.7.LS.2	develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
S.7.LS.3	use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

S.7.LS.4	gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.	
Description of Activity	Resources	Date of Completion
Day 1: Introduce unit theme to students. Administer pre-test composed of multiple choice, true/false, fill in the blank, and constructed response questions. Test questions are based on information gathered from Lesson 2 of the iScience textbook.	Teacher created test iScience Level 2 Textbook	
Day 2: The Skeletal System Whole Class Guiding Questions- What parts of the body are involved when raising your hand? What would happen if these parts didn't work together? Teacher will pass out concept maps and students will work together brainstorming the 4 functions of the skeletal system. Students will read Lesson 2, p. 244 and compare the functions they have listed to the functions listed in Lesson 2. Students will read p. 245 and complete Key Concept Builder p. 36 #1-7. Students will use this information to organize/complete part of their concept maps.	iScience Level 2 Textbook Key Concept Builder handout from textbook resources: p. 36	
Day 3: Guiding question: How do bones give the body structure and support? Teacher will ask students to describe what the terms spongy and compact mean to them. Students will compare these descriptions with that of the two types of tissue found in bones: spongy and compact bone. Students will complete p. 36 #9-11. Students will receive "Structure of the Bone" color plates and fill in information describing the function of each layer.	iScience Level 2 Textbook Key Concept Builder handout from textbook resources: p. 36 Structure of the bone diagram (www.education.com)	
Day 4: Students will receive a diagram of the skeleton. Students will label as many bones as they can based on prior knowledge. Students will then turn to a partner and compare. The teacher will discuss the bones and provide helpful hints for remembering the names of bones and facts. Some students may want to color each bone and label a matching color to aid in memory.	iScience Level 2 Textbook Skeletal System Labeling Sheet (www.education.com)	
Day 5: The Muscular System Guiding Question: What are the three types of tissue in the muscle system? What systems help the body move? Students will read p. 245 and complete Key Concept Builder p. 37 Students will receive a handout with the three types of muscle tissues as seen under a microscope. Students will transfer information from the Key Concept Builder into the Muscle System Worksheet (chart). Students will use this as a study aid.	iScience Level 2 Textbook Key Concept Builder handout from textbook resources: p. 37	

Day 6: The Nervous System Guiding Question: How does the body respond to changes in the environment? Students and teacher will read textbook p. 248-250 together. Students will complete the Science Notebook Main Ideas and Details Handout (p. 70-71) while reading. Handout contains identification, differentiation, sequencing, categorizing, and relationship questions. Students will transfer information from the Science Notebook into the Nervous System Diagram. Students will use this as a study aid. Students will color code the parts of the Central Nervous System (CNS) and Peripheral Nervous System (PNS).	iScience Level 2 Textbook Science Notebook Handout from textbook resources p. 70-71 Nervous System Handout (www.education.com)	
Day 7: Interactions of Systems- Students will revisit their activity sheets to pull information given relating to the interrelationships of all three systems. Students will pair with a partner to discuss. Students will then write an explanation of how the nervous system works to control the muscular system and skeletal system in order to achieve movement. Students and teacher will then work together as a group to refine the explanation.	iScience Level 2 Textbook	
Day 8: Brainpop Videos- Watch together in class and complete the quizzes using Plicker cards. Teacher will have questions transferred to Plicker app in order to pull student responses and re-visit/re-teach based on data collected.	Brainpop Videos The Nervous System: https://www.brainpop.com/health/bodysystems/nervoussystem/ Skeleton: https://www.brainpop.com/health/bodysystems/muscles/ Muscles: https://www.brainpop.com/health/bodysystems/muscles/	
Day 9: Quizlet Live review game - whole class. Students will launch Quizlet Live. Students will be placed in random teams and use their knowledge gained throughout the unit to win matches. Student teams will be shuffled every three rounds.	Game site: https://quizlet.com/live Teacher's assigned study set; https://quizlet.com/_54ku3f Chrome Notebooks	
Day 10: Administer post-test composed of multiple choice, true/false, fill in the blank, and constructed response questions. Test questions are based on information gathered from Lesson 2 of the iScience textbook.	iScience Level 2 Textbook	
Differentiated Instruction Opportunities/Overview: Activity will be modified for those needing extra support, group pairings, one on one teaching, graphic organizers, typing instead of handwriting, chapter summaries, oral reading, auditory textbook, reduced assignments, paired assignments/tasks.		
Cross Curricular Opportunities:		

Standard Number	Standard Description	Resources	Date

Checklist	
Writing	
	Paragraph
	Essay (narratives, fairy tales, realistic fiction)
x	Summary
	Research
x	Detailed answers (text supported)
x	Notes (note taking skills, outlines)
x	Complete sentences
Reading	
x	Informational text
	Lexile
	Complex literature
x	Speaking
x	Listening
x	Varied strategies and instructional methods
x	Critical thinking in whole class discussion
	Student led activities
	common core standards (literature circles)
Technology	
x	Smartboard
x	Computers
	iPads
	Powerpoint, Elmo etc.
Differentiated Instruction	
x	Used multiple resources
x	Domain Vocabulary
x	Cross-Curricular
x	Collaborative engagement (meaningful feedback)

x	Higher level learning and teaching
Assessment	
	Project based
	Writing prompt
	Portfolio
	Observation
x	Quiz
	Technology based
x	Test
	Student created test
	Presentation
	Journal
x	Think, pair, share
x	Summary
x	Oral questioning
	Analogy
	Powerpoint, or movie maker
Authenticity	
	Various activities
	Inquiry, research and evidence
	Evidence of time management and planning
	Problem solving strategies
Summary of Unit:	
At the end of the unit students will be able to identify the organs and functions of the skeletal system, muscular system, and nervous systems. Students should be able to explain the interconnections of the systems and how they work together to maintain homeostasis in the human body.	

Appendix D

Diocese of Wheeling-Charleston

Unit Planner (MS & HS Word Doc)

Name of Teacher: Holly Cheshire	Grade Level: 7th
Subject Area: General Science	Cross Curricular Opportunities: Health, Language Arts, Reading
Unit Title: Structure, Movement, and Control	Estimated Duration of Unit: 2 weeks

Overview of Unit: Students will explore the major organs and tissues of the skeletal, muscular, and nervous systems. Students will discover how these systems are interrelated and dependent on one another to maintain homeostasis in the human body. Students have prior knowledge cells, cellular processes, cell theory, and the organization of the human body.

Forms of Text (non fiction/fiction): McGraw-Hill iScience Level 2 Textbook (Group A), Zspace studio (Group B),Handouts (Group A and B)	Teaching Strategies: Think-Pair-Share, Pre-test and Post-test, brainstorming, direct teaching, whole class discussions, group work, partnered activities

EXPERIMENTAL GROUP

Note: All zSpace activities must be completed in partners due to the number of units available. Students will switch between "driver" and "passenger" every ten minutes. Some students are sensitive to the 3-D component of the zSpace which causes them headaches. The 3-D feature will be turned of for such students.

Assessment (authentic/published - summative/formative): Pre-test and Post-test

Standards Addressed

Standard Number	Standards
S.7.LS.1	conduct an investigation to provide evidence that living things are made up of cells, either one cell or many different numbers and types of cells.
S.7.LS.2	develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
S.7.LS.3	use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
S.7.LS.4	gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Description of Activity	Resources	Date of Completion
Day 1: Introduce unit theme to students. Administer pre-test composed of multiple choice, true/false, fill in the blank, and constructed response questions. Test questions are based on information gathered from Lesson 2 of the iScience textbook.	Teacher created test iScience Level 2 Textbook	

Day 2: The Skeletal System- Structure of Bones Whole Class Guiding Questions- What parts of the body are involved when raising your hand? What would happen if these parts didn't work together? Teacher will pass out concept maps and students will work together brainstorming the 4 functions of the skeletal system and the guiding questions for the activity. Students will set this aside to revisit after the activity. Guiding question: How do bones give the body structure and support? Teacher will ask students to describe what the terms spongy and compact mean to them. Students will launch the zSpace studio: Structure of Bones. Students will follow the steps to complete the activity and answer all questions. Upon completion, students will present what they learned from the activity. Students will be directed to highlight key information. Students will receive the "Structure of the Bone" color plate. Students will identify the function of each part of the bone.	zSpace Studio: Structure of Bones Handout: https://zspace.com/edu/content/subjects/life-science/anatomy/5638 Structure of the bone diagram (www.education.com) Students will need: Highlighters and colored pencils	
Day 3: The Skeletal System Students will launch the zSpace activity: The Skeletal System. Students will follow the steps to complete the activity and answer all questions. Upon completion, students will present what they learned from the activity. Students will be directed to highlight key information.	zSpace Studio: The Skeletal System Handout:https://zspace.com/edu/content/subjects/life-science/anatomy/4025 Students will need: Highlighters	
Day 4: Students will receive a diagram of the skeletal system. Students will launch zSpace Studio: Skeletal System. Students will follow the steps to complete the activity and label their diagram. After the activity the teacher will check the students' answers and provide helpful hints for remembering names. Some students may want to color each bone and label a matching color to aid in memory.	zSpace Studio: The Skeletal System Skeletal System Labeling Sheet (www.education.com) Students will need: Colored Pencils	
Day 5: The Muscular System Guiding Question: What are the three types of tissue in the muscle system? What systems help the body move? Students will launch zSpace studio: The Muscular System. Students will follow the steps the complete the activity. Upon completion, the teacher will confirm the students' answers as a whole group. Students will receive a handout with the three types of muscle tissues as seen under a microscope. Students will transfer information from the activity sheet into the Muscle System Worksheet (chart) accompanying the activity. Students will use this as a study aid.	zSpace Studio: The Muscular System Handouts: https://zspace.com/edu/content/subjects/life-science/anatomy/4024 Muscle Tissue Handout (www.education.com)	

Day 6: The Nervous System Students will launch zSpace studio: The Nervous System. Students will follow the steps the complete the activity. Upon completion, the teacher will confirm the students' answers as a whole group. Students will receive a handout with a diagram of the nervous system.. Students will transfer information from the activity sheet into the Nervous System Diagram. Students will use this as a study aid. Students will color code the parts of the Central Nervous System (CNS)and Peripheral Nervous System (PNS).	zSpace Studio: The Nervous System Handouts: https://zspace.com/edu/content/subjects/life-science/anatomy/3905 Nervous System Handout (www.education.com)	
Day 7: Interactions of Systems- Students will revisit their activity sheets to pull information given relating to the interrelationships of all three systems. Students will pair with a partner to discuss. Students will then write an explanation of how the nervous system works to control the muscular system and skeletal system in order to achieve movement. Students and teacher will then work together as a group to refine the explanation.		
Day 8: Brainpop Videos- Watch together in class and complete the quizzes using Plicker cards. Teacher will have questions transferred to Plicker app in order to collect student responses and re-visit/re-teach based on data collected.	Brainpop Videos The Nervous System: https://www.brainpop.com/health/bodysystems/nervoussystem/ Skeleton: https://www.brainpop.com/health/bodysystems/muscles/ Muscles: https://www.brainpop.com/health/bodysystems/muscles/ Plickers app and cards	
Day 9: Quizlet Live review game - whole class. Students will launch Quizlet Live. Students will be placed in random teams and use their knowledge gained throughout the unit to win matches. Student teams will be shuffled every three rounds.	Game site: https://quizlet.com/live Teacher's assigned study set; https://quizlet.com/_54ku3f Chrome Notebooks	
Day 10: Administer post-test composed of multiple choice, true/false, fill in the blank, and constructed response questions. Test questions are based on information gathered from Lesson 2 of the iScience textbook which mirror the information gathered from the zSpace activities.	iScience Level 2 Textbook	
Differentiated Instruction Opportunities/Overview: Activity will be modified for those needing extra support, group pairings, one on one teaching, graphic organizers, typing instead of handwriting, summaries, oral reading, auditory textbook, reduced assignments, paired assignments/tasks.		

Cross Curricular Opportunities:			
Standard Number	Standard Description	Resources	Date

Checklist	
Writing	
	Paragraph
	Essay (narratives, fairy tales, realistic fiction)
x	Summary
	Research
x	Detailed answers (text supported)
x	Notes (note taking skills, outlines)
x	Complete sentences
Reading	
x	Informational text
	Lexile
	Complex literature
x	Speaking
x	Listening
	Varied strategies and instructional methods
x	Critical thinking in whole class discussion
	Student led activities
	common core standards (literature circles)
Technology	
x	Smartboard
x	Computers (zSpace)
	iPads
	Powerpoint, Elmo etc.

Differentiated Instruction	
	Used multiple resources
x	Domain Vocabulary
	Cross-Curricular
x	Collaborative engagement (meaningful feedback)
x	Higher level learning and teaching
Assessment	
	Project based
	Writing prompt
	Portfolio
x	Observation
x	Quiz
x	Technology based
x	Test
	Student created test
	Presentation
	Journal
x	Think, pair, share
x	Summary
x	Oral questioning
	Analogy
	Powerpoint, or movie maker
Authenticity	
	Various activities
	Inquiry, research and evidence
	Evidence of time management and planning
	Problem solving strategies

Summary of Unit:
At the end of the unit students will be able to identify the organs and functions of the skeletal system, muscular system, and nervous systems. Students should be able to explain the interconnections of the systems and how they work together to maintain homeostasis in the human body.

Appendix E

Science Rubric
St. Joseph Catholic School

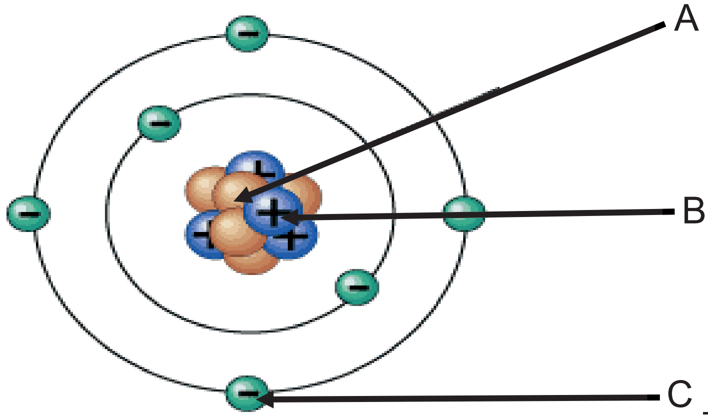
8 pts Exceeds Standards	6 pts Meet Standards	4 pts Below Standard	2 pts Little Progress Toward Standard	0 pts
• Explanation uses appropriate scientific vocabulary • Explanation includes examples to explain the relationships between the systems • The student demonstrates a thorough understanding of scientific connections • No errors or omissions are present in the response	• Explanation uses appropriate scientific vocabulary • Explanation include examples to explain the relationships within the content • The student demonstrates a thorough understanding of the science task • The response may contain minor errors that do not detract from the demonstration of understanding the scientific connections	• Basic definitions with some scientific vocabulary • Answer connected to relevant content • The student has provided a response that demonstrate s a general understandin g of the scientific connections	• Answer attempted with basic definitions • The student has provided a response that is only partially correct • The student does not make relevant scientific connections	• Not attempted • Off topic • Unintelligible

Appendix F

Electricity 4th Grade Test

Name: ______________________________

1. Label the atoms below:

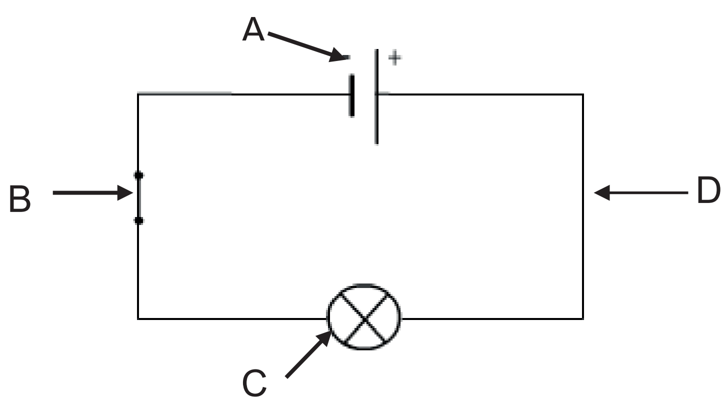


A ______________________________

B ______________________________

C ______________________________

2. Label each part of the circuit drawing below:



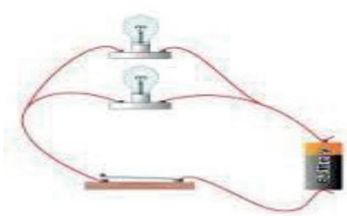
A ______________________

B ______________________

C ______________________

D ______________________

3. Identify each circuit below as simple, series, or parallel circuit.

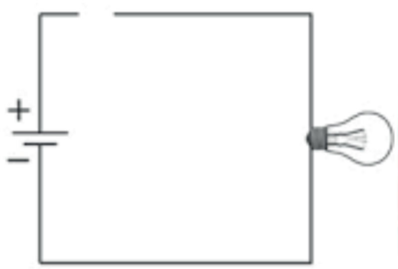


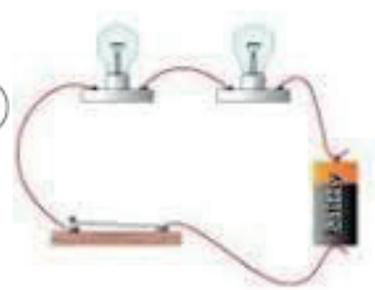
a. simple circuit
b. series circuit
c. parallel circuit

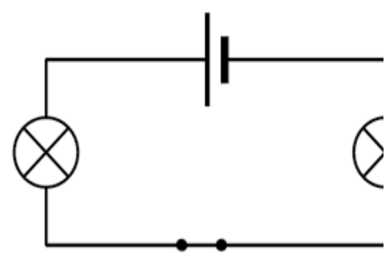
d. simple circuit
e. series circuit
f. parallel circuit

g. simple circuit
h. series circuit
i. parallel circuit

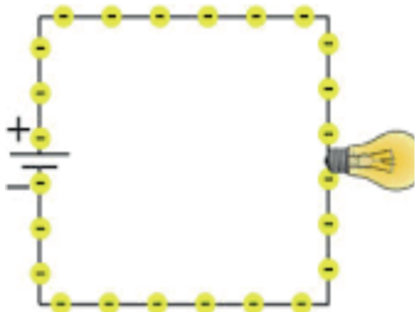
4. Determine if each circuit is open or closed. Write **open** or **closed** under each picture.

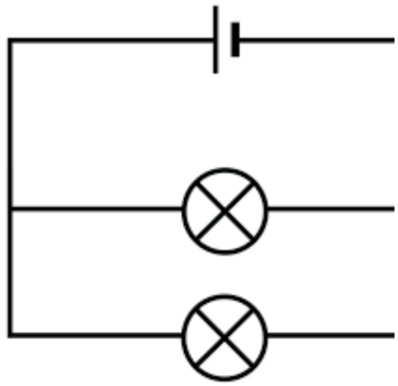


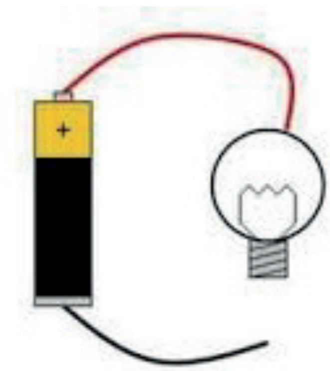




a.______________________ b.______________________ C.____________________







d. ____________________ e.____________________ f. ____________________

5. The flowing movement of electricity from place to place is..
   A. An electric circuit
   B. An electric current
   C. A switch
   D. A solar cell

6. A basic current current is made up of all of the following except…
   A. A power source
   B. A conductor
   C. An insulator
   D. A switch

7. What are the two types of electricity?
   A. Fast and slow electricity
   B. Static and current electricity
   C. Hot and cold electricity
   D. Protons and electron electricity

8. Why would a simple circuit **not** light a light bulb? Circle all that would apply.

a. The circuit is open.
b. The circuit is closed.
c. The light bulb in the simple circuit is blown out.
d. Cooper is used as the wiring in the circuit.

9. If a light bulb in a parallel circuit is blown, what will happen to the other light bulb in the circuit?

a. The other light bulb will light but will be dim.
b. The other light bulb will not light.
c. The other light bulb will light and will be the same brightness as before the light bulb blew.
d. The other light bulb will light and be brighter.

10. If a light bulb in a series circuit is blown, what will happen to the other light bulb in the circuit?

a. The other light bulb will light but will be dim.
b. The other light bulb will not light.
c. The other light bulb will light and will be the same brightness as before the light bulb blew.
d. The other light bulb will light and be brighter.

11. What is a conductor? Define and give one example.

____

____

____

____

12. What is an insulator? Define and give one example.

____

____

____

____

13. Mark each item below as a conductor or an insulator. Write **C** for conductor or **I** for insulator.

__________ copper wire	__________ nail
__________ gummy bear	__________ penny
__________ toothpick	__________ rubber band
__________ pencil	__________ aluminum foil
__________ eraser	__________ paper clip

14. In which of the following types of circuits does electricity follow **one** path?

  a. Complete circuit
  b. Series circuit
  c. Parallel circuit
  d. Incomplete circuit

15. How is static electricity different than current electricity?

____

Appendix G

Structure, Movement, and Control – 7th Grade Test

Name: ________________________________ Date: ______________

1) The skeleton does all of the following except_____________________.
   a) provide shape and support
   b) enables movement
   c) produces Vitamin D
   d) produces blood cells

2) All of the following are examples of moveable joints except______________________.
   a) skull
   b) wrist
   c) neck
   d) spine

3) The spaces in bone are filled with a soft connective tissue called __________________.
   a) cartilage
   b) tendons
   c) marrow
   d) marshmallow

4) Which type of involuntary muscle tissue is nonstriated and found inside many internal organs?
   a) skeletal
   b) smooth
   c) cardiac
   d) silky

5) Of the four types of tissue, which type provides for the body and connects all of its parts?
   a) nerve
   b) smooth
   c) epithelial
   d) connective

6) Which connective tissue attaches muscle to bone?
  a) cartilage
  b) joint
  c) tendon
  d) skin

7) A group of organs working together to perform a specific function is called a(n)___________________.
  a) cell
  b) tissue
  c) organ
  d) organ system

8) Which of the following is the correct order of the levels of organization of the body from smallest to largest?
  a) cell, organ, tissue, organ system, organism
  b) organism, cell, tissue, organ, organ system
  c) tissue, cell, organ system, organism, organ
  d) cell, tissue, organ, organ system, organism

9) What is the important job of the peripheral nervous system?
  a) to receive and process reflex signals
  b) to gather information about the environment
  c) to release chemical hormone messages throughout the body

10) a) Explain voluntary muscles and list two places where you would find voluntary muscles in your body.

10) b) Explain involuntary muscles and list two places where you would find involuntary muscles in your body.

Match the type of movable joint with the correct example.

11) __________ball and socket	a) neck
12) __________hinge	b)elbow or knee
13) __________gliding	c) hip or shoulder
14) __________pivot	d) wrist

Match the parts of the bone term with its correct description

15) __________red marroww
16) __________yellow marrow
17) __________spongy bone
18) __________compact bone

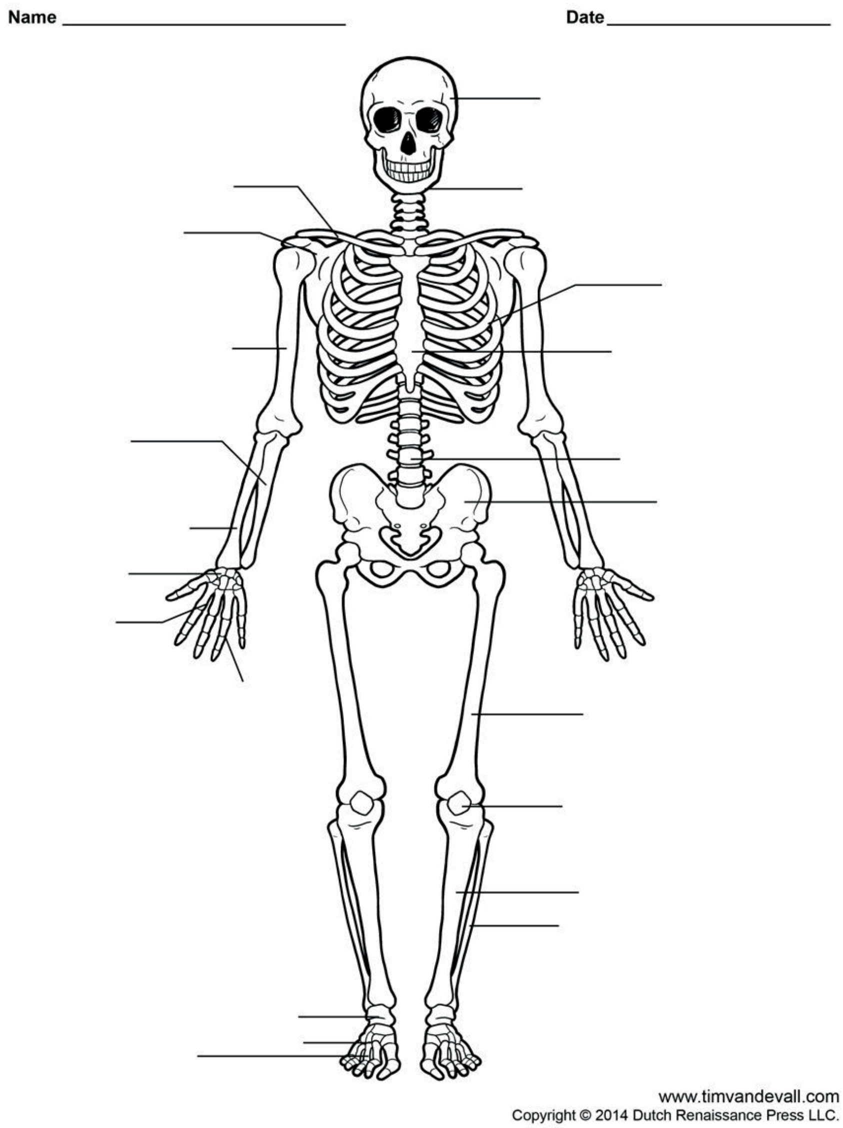
a) soft bone containing many holes and spaces surrounded by a layer of more dense compact bone.
b) stores fat, which serves as energy reserves
c) hard, dense bone tissue that is beneath the outer membrane of the bone; has canals with blood vessels and nerves running through it.
d) produces red blood cells

29) List three voluntary functions of the nervous system and three involuntary functions.

Voluntary:
1.
2.
3.

Involuntary:
1.
2.
3.

List the skeletal system and the parts of the bone.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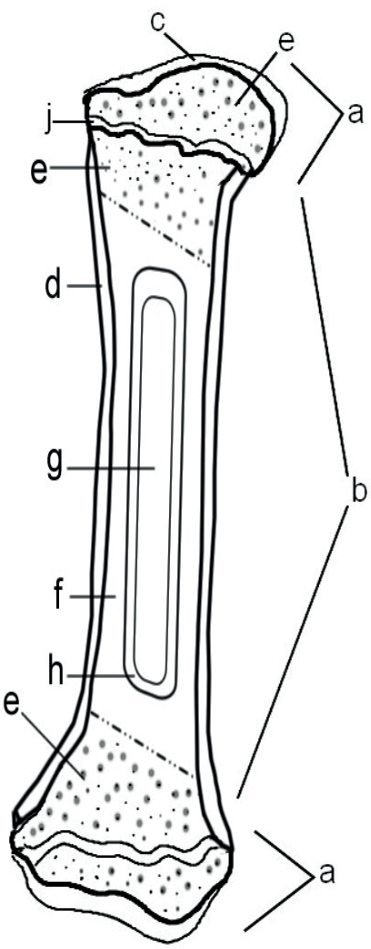


19) List the three types of muscle tissue and give an example of where each can be found in your body.

1.
2.
3.

Complete the sentence using the correct term.

Word Bank	Homeostasis	Hormone
Muscle	Nerves	Neurodes
Neuron	Reflex	Senses
Skin	Spinal cord	

20) ____________________________ is the ability of the body to maintain a stable internal environment.

21) ____________________________ is the basic unit of the nervous system.

22) An automatic movement in response to a stimulus is a ___________________________.

23) A _______________________ is a chemical message that travels through the circulatory system.

24) The brain and ___________________________ make up the central nervous system.

25) Bones can move because they are attached to _______________________________.

26) People detect their environment through their five _________________________.

27) Explain how the Central Nervous System and Peripheral Nervous System are connected:

28) Explain how the nervous system, muscular system, and skeletal system work together to allow you to move your arm. Be sure to include all tissues and organs needed in order for the bone to move:

Appendix H

4th Grade Controlled Environment

Appendix I

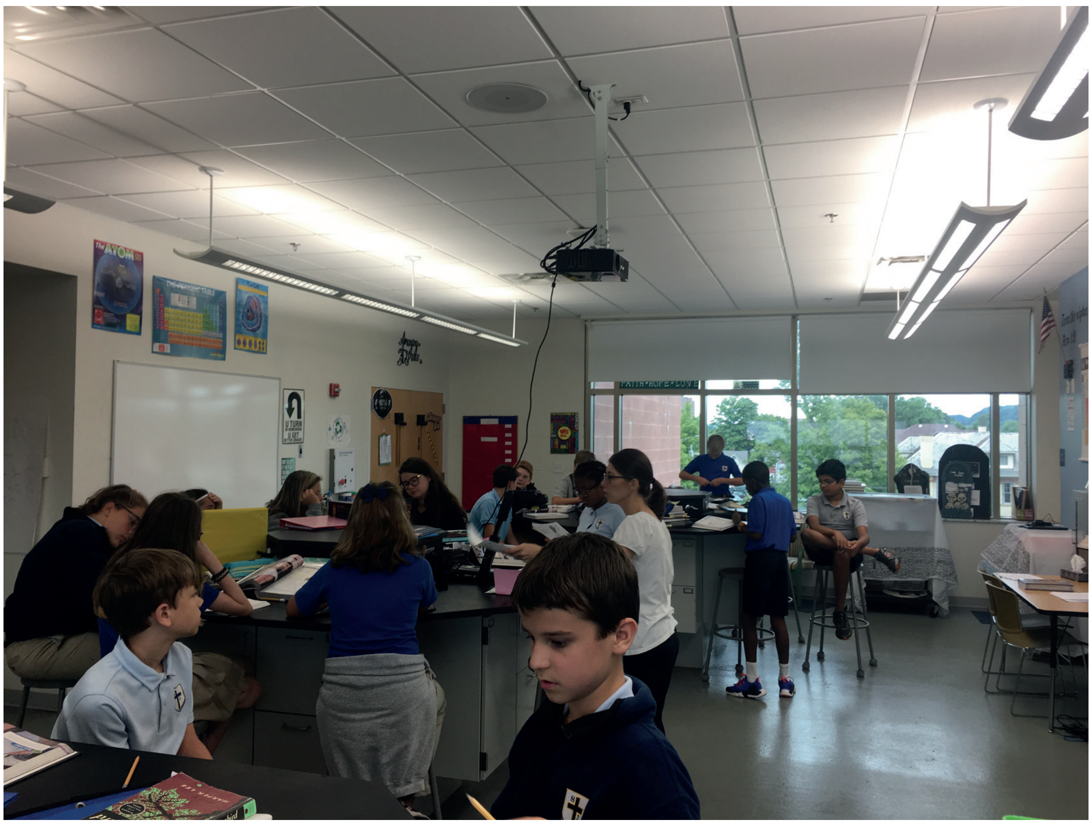
4th Grade Experimental Environment: zSpace

Appendix J

4th Grade Experiment Environment: Atom Building Activity, zSpace

Appendix K

7th Grade Controlled Environment: Middle School Science Lab

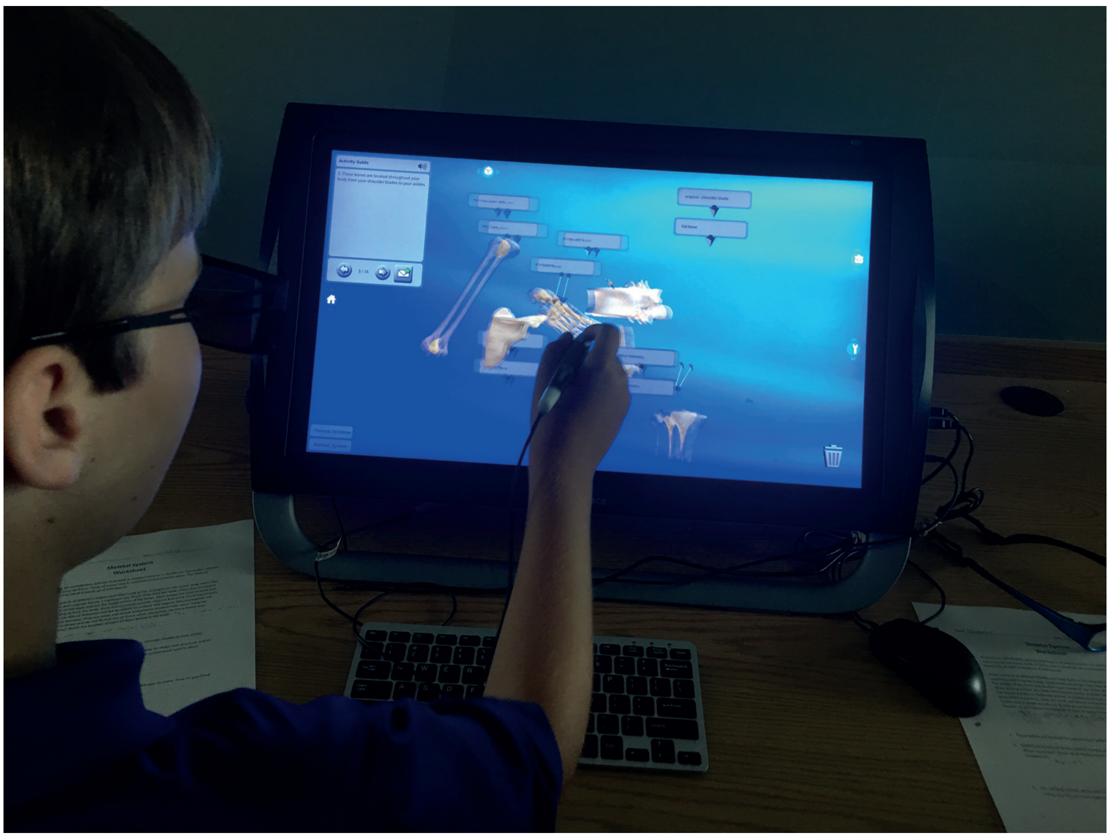


Appendix L

7th Grade Experimental Envirnonment: Period Table Analysis Activity, zSpace

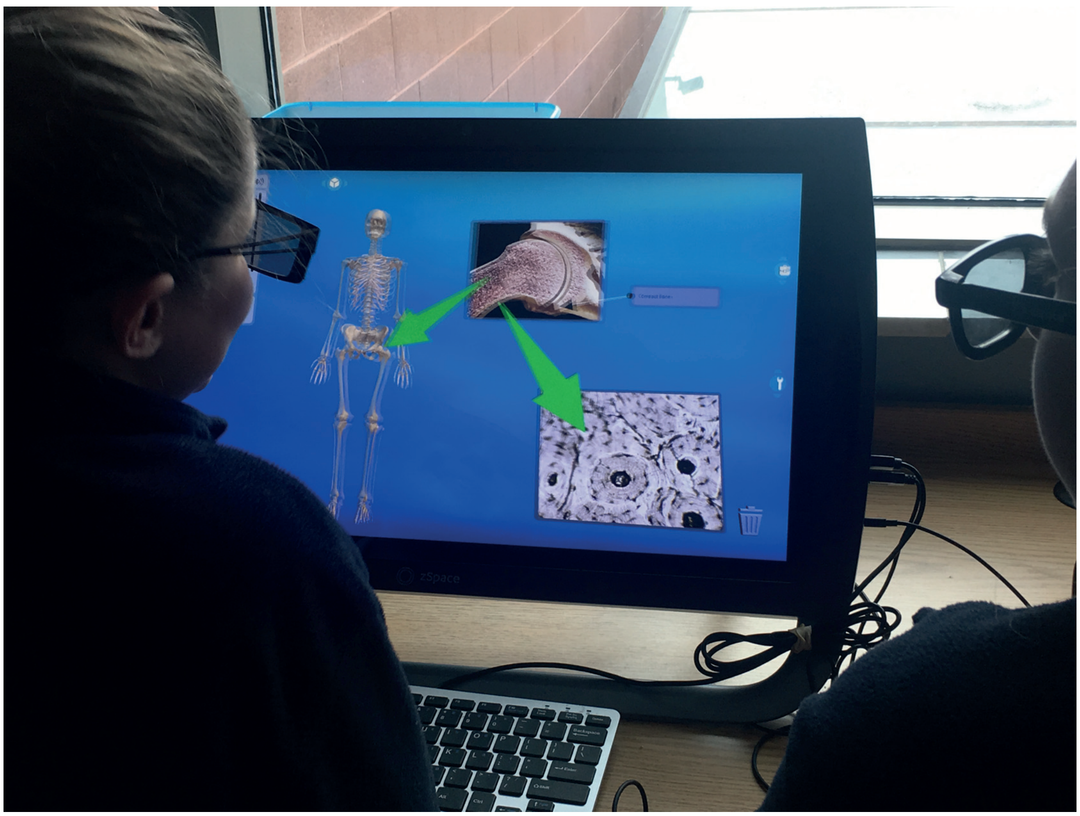
Appendix M

7th Grade Experimental Environment: Skeleton System Activity, zSpace



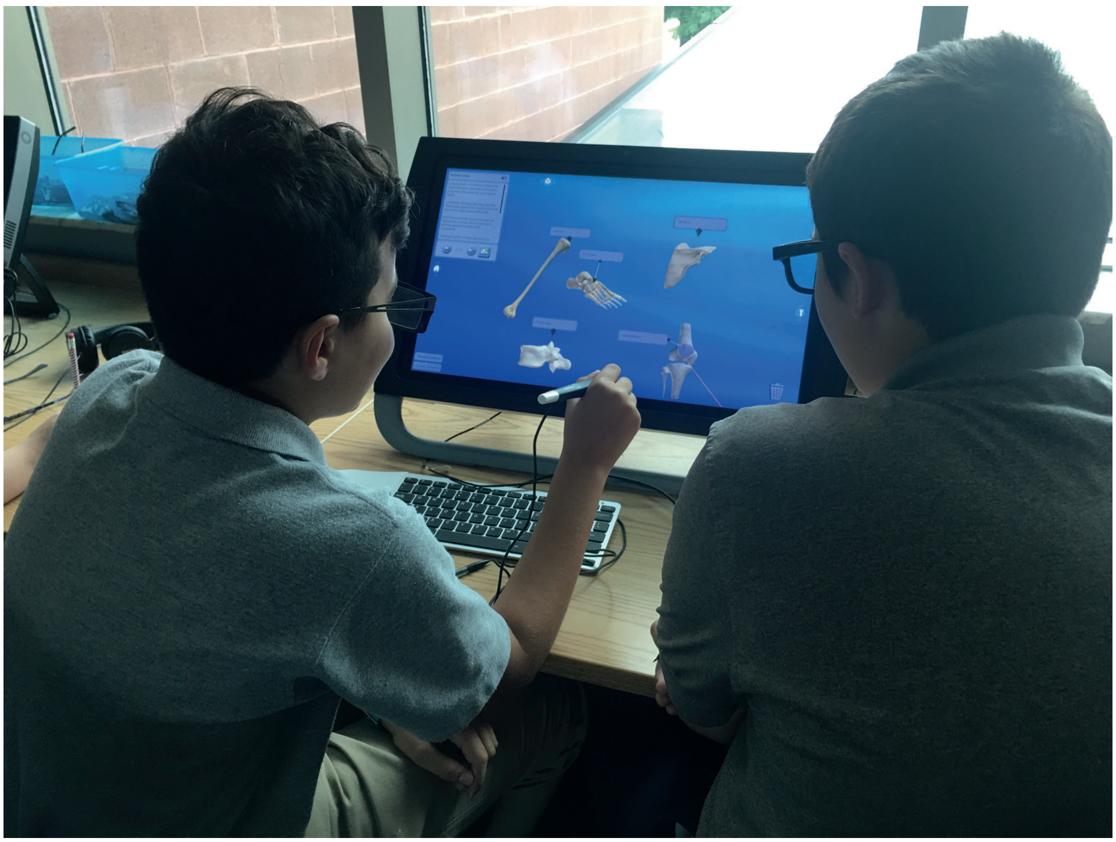
Appendix N

7th Grade Experimental Environment: Skeleton System (bones) Activity, zSpace



Appendix O

7th Grade Experimental Environment: Collaborative Learning Activity, zSpace



Appendix P

Student Open-Ended Questions

Dalgarno and Lee's (2010) 3D Virtual Learning Environment's Benefits to Learning

1). *Spatial Knowledge Representation:* On a scale of 1-5 (1 being low and 5 high), how much did the use of 3D images help you to understand and visualize the concepts?

2) *Experimental Learning:* On a scale of 1-5 (1 being low and 5 high), how much did the use of the zSpace devices provide you an opportunity to experiment and explore?

3) *Engagement*: On a scale of 1-5 (1 being low and 5 high), how much more were you engaged to learn the lessons through the use of the zSpace devices rather than using textbooks and worksheets?

On a scale of 1-5 (1 being low and 5 high), how much more would you rather use zSpace devices in your daily lessons to learn concepts?

4) *Contextual Learning:* On a scale of 1-5 (1 being low and 5 high), how much more did the use of the zSpace devices help you to understand the lesson's concepts? Did the use of the zSpace devices help you to understand difficult concepts better?

5) *Collaborative Learning*: Did working with a partner on zSpace help you to learn the concepts better? On a scale of 1-5 (1 being low and 5 high), how did the zSpace devices increase discussions regarding the lesson's concepts?

6) What are the benefits and limitations of using zSpace?

Appendix Q

Teacher Open-Ended Questions

Dalgarno and Lee's (2010) 3D Virtual Learning Environment's Benefits to Learning

1) *Spatial Knowledge Representation:* On a scale of 1-5 (1 being low and 5 high), how much did the use of the zSpace devices increase the students' ability to process and visualize the lessons' concepts?

2) *Experimental Learning:* On a scale of 1-5 (1 being low and 5 high), how much did you observe an increase in the level of experimental and exploration learning amongst the students?

3) *Engagement*: On a scale of 1-5 (1 being low and 5 high), how much did you observe an increase in the level of motivation, interest, and engagement due to the use of the zSpace devices compared to the traditional classroom environment?

4) *Contextual Learning:* On a scale of 1-5 (1 being low and 5 high), how much did the students experience an increase in their ability to learn abstract and difficult concepts?

5) *Collaborative Learning*: On a scale of 1-5 (1 being low and 5 high), how did the use of the zSpace devices increase student collaboration over the traditional classroom environment?

6) What are the advantages and disadvantages of using the augmented reality devices, zSpace?

VITA

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