THE EFFECT OF AUGMENTED REALITY ON LEARNING IN THE
MATHEMATICS CLASSROOM

by

Justin Thomas Maffei

Liberty University

A Dissertation Presented in Partial Fulfillment
Of the Requirements for the Degree
Doctor of Education

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ABSTRACT

This study examined the impact of two treatments, augmented reality or concrete materials, on the Geometry knowledge of high school students. Participating classes were chosen from two secondary schools between two rural Virginia school districts. The sampling method selected for the study employed a convenience sample. There were 87 total participants in the study. The importance of this study emerged from a lack of research relating the use of augmented reality in the classroom to its effect on student learning. The purpose of this quantitative pretest-posttest, non-equivalent control group quasi-experimental study was to evaluate the difference in achievement scores, as measured by scores on the Three-Dimensional Figures Reporting Category of the Virginia Standards of Learning test, based on type of instructional delivery. Data analysis was completed using Quade’s Rank Analysis of Covariance to control for pretest scores. The study also evaluated the perceived learning for high school Geometry students, as measured by the CAP Perceived Learning Scale (Rovai, Wighting, Baker, & Grooms, 2009), based on the type of instruction. Data analysis on CAP Perceived Learning scores was completed using the Mann-Whitney U test.

**Keywords:** augmented reality, geometry, mathematics, mixed-reality
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List of Abbreviations

asseMbly Oriented authOring augmeNted reality (MOON)
Augmented Reality (AR)
Augmented Reality System (ARE)
Bangor Augmented Reality Education Tool for Anatomy (BARETA)
Cognitive, Affective, and Psychomotor (CAP) Perceived Learning Scale
Conventional Balance Training (CB)
Head-Mounted Projective Display (HMPD)
Improvised Explosive Devise (IED)
In Vivo (IVE)
Post-Traumatic Stress Disorder (PTSD)
Sensory Organization Test (SOT)
Situated Media Arts Learning Lab (SMALLab)
Virtual Reality-Augmented Balance Training (VR)
Working Alliance Inventory-Short adaptation to Virtual Reality and Augmented Reality Therapies (WAI-VAR)
CHAPTER ONE: INTRODUCTION

Overview

Augmented reality represents a blend between the real world and the virtual world. The potential benefits of augmented reality in the classroom include active participation by the students and the ability to have experiences that would otherwise be impossible or unsafe. The most well-known and universally accepted form of augmented reality in schools can be seen in the use of the SMARTboard. Some lesser known examples are Google SkyMap, Augmented Chemistry, learnAR, and Construct3D. Google SkyMap can be used to display information over a projection of the night sky. Students can get an up-close look at molecules and atoms using Augmented Chemistry. Using learnAR, internal organs become visible superimposed over an image of a person’s body. In Geometry class, students can create three-dimensional models using Construct3D (Lee, 2012a). Cuendet, Bonnard, Do-Lenh, and Dillenbourg (2013) acknowledged the use of augmented reality “can be an asset for learning, systems allow the learner to interact with the real world in ways that were not possible before” (p. 557). However, as stated by Yucuk, Yilmaz, and Goktas (2014), examples of augmented reality implementation in the classroom are necessary to study so that teachers will find the greatest impact from its use.

Background

Augmented reality was introduced during the World War II-era with the Mark VIII Airborne Interception Radar Gunsighting’s windsreen project created by the British. This windsreen project “superimposed on a pilot’s windshield a radar screen and information about whether or not nearby aircraft belonged to enemy nations” (Vaughan-Nichols, 2009, p. 19). However, the term augmented reality originated in the 1990s and was coined by a Boeing employee named Tom Caudell (Cheng & Tsai, 2013).
Milgram, Takemura, Utsumi, and Kishino (1994) introduced the Reality-Virtuality (RV) Continuum, a representation of what should be considered augmented reality and how augmented reality relates to the physical world and virtual environments. The continuum ranges from the real environment to the virtual environment with everything in between considered mixed reality (Figure 1). Augmented reality exists within the mixed reality section of the continuum. The continuum was expanded in 2002 by Steve Mann to include mediality along with reality and virtuality. Mann (2002) represented the relationships in a grid and as a bubble diagram to create a more descriptive figure called the Reality-Virtuality-Mediality Continuum represented in figure 2.

Educational research has traditionally trailed research done in the fields of medicine and business. Augmented reality research in education has also followed augmented reality research completed in the fields of medicine and business. Within medical field literature Yen et al. (2012) conducted an augmented balance training study of 42 people with Parkinson’s disease. Comparisons were made between three groups with 14 participants in each group. The three groups included a Virtual reality-augmented balance training group, a conventional balance training group, and a control group. Mirelman et al. (2013) proposed a similar study on 100 older adults, 100 patients with mild cognitive impairment, and 100 patients with Parkinson’s disease. The proposal called for participants to be randomly assigned to either the treatment group (treadmill training combined with virtual reality) or the active-control group (treadmill training without the use of virtual reality).

Also included in augmented reality literature are studies concerning the usability of augmented reality devices (Gabbard & Swan, 2008; Hanniff & Baber, 2003; Jeon, Shimand, &
Kim, 2006; Moore, 2003; Moore, 2006). However, augmented reality literature in the field of education has not focused on the impact that the use of augmented reality devices and falls short of the standards for rigorous investigations. Most existing studies have not studied the effect of augmented reality implementation on student achievement (Campos, Pessanha, & Jorge, 2011), involved sample sizes that were too small (Bergig, Hagbi, El-Sana, Kedem, &Billinghurst, 2011; Campos et al., 2011), or did not include a control group (Birchfield & Megowan-Romanowicz, 2009; Enyedy, Danksh, Delacruz, & Kumar, 2012; Tolentino et al., 2009).

The gaps in the literature regarding augmented reality in the education field are not present in the literature regarding augmented reality in the medical field (Mirelman et al., 2013; Yen et al., 2012) and in the military (Krum, Suma, & Bolas, 2012; Livingston, Zhuming, Karsch, & Gibson, 2011; Soares et al., 2012; Tsai, Liu, & Yau, 2013). Considerations of augmented reality in business and for everyday life (Ahn et al., 2015; Botella et al., 2016; Caruso, Re, Carulli, & Bordegoni, 2014; Huang & Tseng, 2015; Miragall, Banos, Cebolla, & Botella, 2015) also covered more topics more thoroughly than what the educational literature has. The present studies regarding the medical field represent the investigations that are currently most applicable to advancing the understanding of augmented reality in educational settings due to the inclusion of various types of training using augmented reality.

The literature on augmented reality remains limited as the ability to broadly implement augmented reality technology is still fairly new. However, augmented reality literature has been developed in more detail in the military, medical community, and business sectors than in the education field. The field of medicine has the most applicable studies since they have involved teaching or training.
The medical field has produced studies about the use of augmented reality for instructional or training purposes. Three relevant studies have been conducted or proposed which involve the use of augmented reality to improve the condition of individuals with difficulties with balance, such as individuals with Parkinson’s disease and elderly individuals with a history of falls, etc. (Espay et al., 2010; Mirelman et al., 2013; Yen et al., 2011). A study by Yen et al. (2012) was carried out with multiple groups, while Mirelman et al. (2013) proposed a study involving multiple groups. The purpose of multiple groups was to allow a true comparison to be made in order to determine the effect of the augmented reality devices. However, the study by Espay et al. (2010) did not include a control group.

Yen et al. (2011) found that the balance of individuals improved both through the use of augmented reality and through the use of conventional balance training and that both groups showed greater improvement than the control group. Similarly, a study by Leblanc et al. (2010), which involved seven practicing surgeons using cadavers and 27 practicing surgeons using an augmented reality simulator to perform hand-assisted laparoscopic sigmoid colectomy, found that students performed relatively the same but had greater satisfaction with their learning when using cadavers. The lack of significant improvement in student learning that has been shown to occur in augmented reality-based learning has displayed a need for further research.

**Usability of Augmented Reality Devices**

Multiple studies have been conducted concerning the usability of augmented reality devices (Gabbard & Swan, 2008; Hanniff & Baber, 2003; Jeon et al., 2006; Moore, 2003; Moore 2006). These studies include the usability of different viewing configurations of an augmented
reality system, a battlefield augmented reality system, a water-pump augmented reality tool, and a tangible, augmented street map. Lee, Billinghurst, Baek, Green, and Woo (2013) conducted a study on an augmented reality device, which featured a multimodal interface that the researchers compared to devices which were speech-only and gesture-only. Leitritz et al. (2014) studied the usability of Eyesi indirect, a binocular indirect ophthalmoscopy simulator. Another usability study was conducted by Ko, Change, and Ji (2013) on smartphone applications. Da-Ren, Mu-Yen, Tien-Chi, and Wen-Pao (2013) studied the usability of an augmented reality system which was used in Yehliu Geological Park. Usability studies did not seek to determine the value added using augmented reality (AR) technology.

**Education**

Educational research on the topic of augmented reality has increased in conjunction with the increase in availability of mobile devices. Understanding has been increased regarding the benefits that augmented reality technologies have on student motivation and the effect that augmented reality has on learning, even in studies with small samples. Campos, Pessanha, and Jorge (2011) conducted a study involving an AR game and Kindergarten students. The authors stated that “motivation levels were high because children never gave up the game. Even when feedback showed [the students] they were very wrong, nobody quit the game until reaching the solution” (Campos et al., 2011, p. 37). Birchfield and Megowan-Romanowicz (2009) determined, in Earth Science when working with approximately 15 to 20 high school students, that the achievement gains had occurred for students after a review of previously taught material while using an augmented reality tool known as SMALLab. However, Birchfield and Megowan-Romanowicz (2009) “were not able to compare the nature of collaboration in SMALLab against
other types of pedagogy” (p. 419) within their own study, as all students participated in SMALLab.

Enyedy et al. (2012), when studying physics with 43 six- to eight-year-old students, encountered similar issues and stated that “[pre-/post-test results were encouraging and show that young students are able, with the [AR] technology and activities to learn force and motion concepts at an earlier age than thought possible” (p. 376). All the students involved in the study by Enyedy et al. (2012) were in the treatment group. Like the study by Birchfield and Megowan-Romanowicz (2009), there was a lack of a control group within the study by Enyedy et al. (2012). Tolentino et al. (2009) failed to include a control group in their research study of the impact of SMALLab on the knowledge of 136 10th and 11th grade students. Due to the augmented reality instruction, “students were able to achieve significant learning gains in standards-based chemistry content knowledge” (Tolentino et al., 2009, p. 514). While this represents a positive outcome, the lack of a control group presents issues with reliability and validity. Tolentino et al. (2009) admitted researchers “were unable to gather retest data on an untreated control group for the knowledge assessment measure” (p. 514).

Another situation which presented issues with reliability and validity was small sample size. Bergig et al. (2011) had 12 students compare an elevation map to satellite images and then determine the relationship between the length and the steepness of various ski routes. First, students completed the task without the use of augmented reality. Once the students completed the task, they repeated it using In-Place Augmented Reality. Students were then asked whether the application made the task easier. All 12 students agreed that the application made the task easier. Though the studies by Bergig et al. (2011) and Campos et al. (2011) found increases in
learning, both studies used small sample sizes with only 12 participants and 22 participants, respectively.

Social Context

The availability of mobile technology continues to increase at an exponential rate. Digital literacy, defined by Visser (2012), represents “the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills” (What is Digital Literacy? Section, para. 1). With the increase in available technology, students have increased opportunities concerning digital literacy (Ng, 2012). Despite the increase in digital literacy opportunities, students have had limited use of educational technology (Ng, 2012). Current use of augmented reality can be found in everyday life but rarely in the classroom.

QR codes, the yellow line designating the first down during a football game, and the Amazon app, which finds a product on Amazon using a picture of the bar code, are some examples with which people may be familiar. The increased accessibility of augmented reality makes it important that “educators find strategies to introduce [it] to our students … because of the exciting new ways students can use it to create” (Raphael, 2011, p. 24). It has been suggested that AR could increase active engagement in instructional settings, motivate students, and provide enjoyment for learners (Chuang, 2014).

Theory Overview

The theoretical framework augmented reality comes from two separate theories. These theories provide a basis for the use of augmented reality in the field of education. The first theory developed by Vygotsky is the Activity Theory. Morten et al. (2002) suggested that
“[f]undamental to modern activity theory is the idea that the development of thoughts and cognitive activity requires social interaction and exchange with a physical environment” (p. 155). With augmented reality, students interact with a virtual environment while working collaboratively. The collaborative environment allows for social interaction between students. The virtual environment provided by augmented reality technology creates a virtual replacement of the physical environment. The second theory, which provides the basis for the use of augmented reality, is the Social Constructivist Theory, also developed by Vygotsky. The Social Constructivist Theory “emphasizes the social and collaborative nature of learning” (Cheng & Tsai, 2013, p. 461). Socialization and collaboration are made necessary and possible in more instances through the use of augmented reality. Students interact with the virtual environment in addition to interacting with one another.

**Problem Statement**

The current research on augmented reality use covers many topics. The usability of augmented reality systems has been studied (Da-Ren et al., 2013; Gabbard & Swan, 2008; Hanniff & Baber, 2003; Jeon et al., 2006; Ko et al., 2013; Lee et al., 2013; Leitritz et al., 2014; Moore, 2003; Moore, 2006). Some of the literature described the impact that using augmented reality has had on student achievement (Bergig et al., 2011; Birchfield & Megowan-Romanowicz, 2009; Campos et al., 2011; Chang, Wu, & Hsu, 2013; Liu & Tsai, 2013; Enyedy et al., 2012; Santos et al., 2016; Tolentino et al., 2009). Concerns exist regarding the validity and reliability of these studies due to the lack of a control group for comparison (Birchfield & Megowan-Romanowicz, 2009; Enyedy et al., 2012; Tolentino et al., 2009) or the small sample sizes involved (Bergig et al., 2011; Campos et al., 2011; Chang et al., 2013; Liu & Tsai, 2013; Santos et al., 2016). Perez-Lopez and Contero (2013) involved larger numbers of students and a
control group. An issue with the Perez-Lopez and Contero (2013) study is that different instructional strategies were used in the different groups. The question becomes whether the augmented reality or the specific instructional strategy improved student achievement.

Only one study, performed by Chiang, Yang, and Hwang (2014), was found to have conducted studies on larger groups of students, involved comparison groups, used similar instructional strategies, and studied the effect of augmented reality technology on student achievement. Chiang et al. (2014) found significant gains for the group using augmented reality. Bergig et al. (2011) and Santos et al. (2016) suggested that their augmented reality studies should be conducted on larger groups of individuals. Billinghurst and Dunser (2012) asked, “what is the real educational benefit from using this technology in the classroom?” (p. 60). According to these researchers (Bergig et al., 2011; Billinghurst & Dunser, 2012; Santos et al., 2016), augmented reality technology should be compared with another form of instruction. Therefore, the problem is that augmented reality education has not been compared to traditional methods with sample sizes that are large enough to potentially produce a significant effect.

**Purpose Statement**

The purpose of this quantitative pretest-posttest, non-equivalent control group quasi-experimental study was to evaluate the change in the achievement scores (dependent variable), as measured by scores on the Three-Dimensional Figures Reporting Category of the Virginia Standards of Learning test released in 2014, of high school students based on the type of instruction (independent variable) while adjusting for pretest scores, as measured by scores on the Three-Dimensional Figures Reporting Category of the Virginia Standards of Learning test released in 2013. The study also evaluated the perceived learning (dependent variable) for high school Geometry students, as measured by the CAP Perceived Learning Scale (Rovai, Wighting,
Baker, & Grooms, 2009), based on the type of instruction (independent variable). The types of instruction used were traditional methods, which included the use of concrete three-dimensional figures and two-dimensional representations of three-dimensional figures, and augmented reality-based methods, which used three-dimensional figures represented using augmented reality technology. The sample was comprised of Geometry students in Virginia high schools. Some participants received instruction using concrete three-dimensional figures. The rest of the participants received instruction using augmented-reality technology in place of the concrete three-dimensional figures.

The null hypothesis was that there was no statistically significant difference between the groups which used the augmented reality and those that used the concrete three-dimensional figures. The independent variable in this study was the type of instruction used. The types of instruction were traditional methods, which included the use of concrete three-dimensional figures and two-dimensional representations of three-dimensional figures, and augmented reality-based methods, which used three-dimensional figures represented using augmented reality technology. The dependent variables for the study were student achievement and perceived learning. Student achievement was defined by scores on the Three-Dimensional Figures Reporting Category of the 2014 version of the Virginia Geometry Standards of Learning End-of-Course Geometry test. Perceived learning was defined by scores on the Cognitive, Affective, and Psychomotor (CAP) Perceived Learning Scale (Rovai et al., 2009).

**Significance of the Study**

There are several situations which would benefit from determining the effects of using augmented reality in education. One of the more difficult issues to overcome in education deals with financial capabilities. Shelton implied that “AR [augmented reality] has not been adopted
into academic settings due to little financial support from the government and lack of the awareness of needs for AR in academic settings” (as cited by Lee, 2012a, p. 14). The novelty of augmented reality technology also presents issues. New technologies are typically costly due to the necessity for hardware, software, maintenance, content development, and educator training (Pribeanu, 2013). There are three areas of concern for new technology. These areas for concern are the (a) value added using the technology, (b) the usability of the technology, and (c) the acceptability of the technology (Pribeanu, 2013).

Some researchers have considered the applicability and utility of augmented reality but Kapp, in an interview with Balkun (2011), called for additional research saying, “In terms of AR, the jury is out and I don’t believe we have enough research to make any broad conclusions” (p. 110). It will be important to determine the value added to the classroom using the technology. Some studies have attempted to quantify the added value but have limitations (i.e., small sample sizes and no control group). This study worked toward overcoming those issues. The significance of the study is that research of this type would allow decision makers at the school district level to decide whether the technology is worth the start-up investment required.

**Research Questions**

The research questions for this study were:

**RQ1:** Is there a difference in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores?
**RQ2**: Is there a difference in the perceived learning scores, as measured by the CAP Perceived Learning Scale (Rovai et al., 2009), of high school students taught using augmented reality and students taught using traditional methods?

**Definitions**

1. *Augmented reality* – Augmented reality is defined “a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it” (Carmigniani et al., 2011, p. 342).

2. *Digital immigrants* – “A digital immigrant is an individual who was born before the widespread adoption of digital technology. The term digital immigrant may also apply to individuals who were born after the spread of digital technology and who were not exposed to it at an early age. Digital immigrants are the opposite of digital natives, who have been interacting with technology from childhood.” (Janssen & Janssen, 2017a, para. 1).

3. *Digital literacy* – Digital literacy was defined by Visser (2012) as “the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills” (What is Digital Literacy? Section, para. 1).

4. *Digital natives* – “A digital native is an individual who was born after the widespread adoption of digital technology. The term digital native doesn't refer to a particular generation. Instead, it is a catch-all category for children who have grown up using technology like the Internet, computers and mobile devices. This exposure to technology in the early years is believed to give digital natives a greater familiarity with and
understanding of technology than people who were born before it was widespread.” (Janssen & Janssen, 2017b, para. 1).

5. **Virginia Geometry Standards of Learning End-of-Course Geometry test** – The Virginia Geometry Standards of Learning End-of-Course Geometry tests were developed by the Virginia Department of Education with the help of classroom teachers, curriculum specialists, and other local educators. The Virginia Geometry Standards of Learning End-of-Course Geometry tests consist of 50 graded questions and 10 field questions which measure four Reporting Categories: (a) Reasoning, Lines, and Transformations, (b) Triangles, (c) Polygons and Circles, and (d) Three-Dimensional Figures (Virginia Department of Education, n.d.).
CHAPTER TWO: LITERATURE REVIEW

Overview

A severe disconnect occurs in classrooms throughout the United States. Major changes have occurred in the way that students think (Kaiser, 2010). However, the way that teachers present information has remained relatively the same (Kaiser, 2010). According to Kaiser (2010) children and teens aged 8–18 used technology an average of seven hours and 38 minutes each day but actually experienced 10 hours and 45 minutes’ worth of information in that time due to media multitasking. The amount of time spent using technology caused major changes in the way that they process information; however, students were forced to power down in many classrooms throughout the country. For various reasons teachers were reluctant to add technology into the classroom. As cited by Cheng and Tsai (2013) “the 2011 Horizon Report … suggested that [augmented reality] should be adopted in the next 2–3 years to provide new opportunities for teaching, learning, research, or creative inquiry” (p. 449).

A lack of augmented reality research in the education field has caused hesitancy from teachers. There are examples of augmented reality use in the medical, business, and military fields. The literature in the educational field showed a gap in key areas. This research became necessary because as Cheng and Tsai (2013) stated “investigating how technology assists students’ learning is an important issue” (p. 450). Wasko (2013) further stated, “Given the potential benefits for students and availability of hardware and software resources, the time has come for practitioners to start designing and using AR enhanced learning environments with their students” (p. 21). In order for these benefits to be realized, educators should be shown the benefit and appropriate instructional designs to gain the greatest advancements from augmented reality technology.
Theoretical Framework

Augmented reality use in the classroom centers around two theories, both developed by Vygotsky. These theories are the Activity Theory and the Social Constructivist Theory. Munnerly et al. (2012), discussing augmented reality, stated that “it is important to note connections with constructivist approaches, activity theory, and the concept of visual learning” (p. 40). The Activity Theory connected social interaction with an exchange in a physical environment. Students have the potential to discuss that which they are witnessing and how they are interacting with the technology. Some environments are more virtual than physical. Augmented reality technology may provide a physical-like environment where such an environment had not previously been available. The use of tools, such as augmented reality technology, to interact with the environment represents the other part of Activity Theory (Lai, Chen, & Yang, 2014).

The Social Constructivist Theory proves to be a fitting theory for augmented reality, because students would certainly have greater opportunities to act out ideas in a virtual world which has less restrictions than the real world. As Cheng and Tsai (2013) stated “the theory of social constructivist learning is appropriate for the basis on which … AR activity design is founded” (p. 461). Social Constructivist Theory may be enacted by students through concrete means as well. While each of these theories fits with augmented reality, the technology need not be present for these theories to be evident. These theories could be presented in a carefully constructed lesson plan.
Related Literature

New Students, New Times

According to Kaiser (2010) students spend a tremendous amount of time on phones, computers, tablets, and other technological devices. Students’ experience with these devices provides students with valuable understanding of technology that some teachers do not possess. According to Janssen and Janssen (2017b):

A digital native is an individual who was born after the widespread adoption of digital technology. The term digital native doesn't refer to a particular generation. Instead, it is a catch-all category for children who have grown up using technology like the Internet, computers and mobile devices. This exposure to technology in the early years is believed to give digital natives a greater familiarity with and understanding of technology than people who were born before it was widespread. (para. 1)

An and Reigeluth (2011) explained that technology has become a part of everyday life for adolescents. Students spend time communicating and sharing pictures on Facebook, Twitter, Instagram, Kik, and Snapchat. Students create videos to share on TikTok, Vine, and YouTube.

Prensky (2001) indicated that the educational system was falling behind and failing these students whose brains have changed due to the use of technology by stating that “[t]oday’s students are no longer the people our educational system was designed to teach” (p. 1).

Buabeng-Andoh (2012) said that “there is a growing demand on educational institutions to use ICT [Information Communication and Technology] to teach the skills and knowledge students need for the 21st century” (p. 136). The statement by Buabeng-Andoh (2012) would align with Lev Vygotsky’s Activity Theory and Social Constructivist Theory. Augmented reality would allow students to interact with physical or virtual objects in a social context.
Further, Safar, and Alkhezzi (2013) discussed the potential of Information Communication and Technology to provide beneficial materials to educationally disadvantaged regions, thus potentially closing the achievement gap. Staples and Edmister (2014) also found that “[t]echnology has served to (a) provide experiences that prepare students for life beyond school, (b) support academic course work by either providing extra skill practice or serving as an information resource, (c) and/or equalize students’ access to curriculum instruction” (p. 137). All schools incorporated some form of technological resources, but the use of these resources lagged behind (Kaiser, 2010).

**Teacher Reluctance to Technology**

Unlike our digital native students, the same cannot be said for all of the teachers of those students. These teachers, who are not digital natives, would be called digital immigrants. According to Janssen and Janssen (2017a):

> A digital immigrant is an individual who was born before the widespread adoption of digital technology. The term digital immigrant may also apply to individuals who were born after the spread of digital technology and who were not exposed to it at an early age. Digital immigrants are the opposite of digital natives, who have been interacting with technology from childhood.  

(para. 1)

Wachira and Keengwe (2011) described the barriers educators are confronted with as either external or internal. External barriers include availability of technology, unreliability of technology, and the lack of technology support and technology leadership. The internal barriers are comprised of lack of time, lack of knowledge, and anxiety and confidence. Improved training can help overcome teacher reluctance to use technology (Teczi, 2011). Proper training permits educators to become confident in digital knowledge so that those educators can create
learning experiences in a timelier manner (Teczi, 2011). However, simply understanding the technology does not suffice. Teczi (2011) suggested that teachers need to be trained on incorporating technology into traditional teaching methods and on how to create a student-centered, technological lesson in order to promote student learning. The student learning from the use of technology would continue and become a guiding point of continued research.

The Effectiveness of Technology Integration

Keebler et al. (2014) stated that an issue with many of the studies has been that “they are more of a proof of concept and, therefore, focus on technological development instead of their effects on learning” (p. 3). In an interview with Baker (2014), Dr. Jason Ravitz reiterated the statement by Keebler et al. (2014) by recognizing that the use of technology in the classroom was not being evaluated. This stands as an alarming statement due to the strong push for the integration of technology into the curriculum. In schools there exists an attempt to create new and better technology without knowing the benefit of the technology that exists (Keebler et al., 2014). Educators should be using proven techniques to maximize the potential of producing successful learners.

Major concerns regarding the integration of technology involve the teachers and the students. There are administrative issues to consider as well, as described by Rollins and Bailey (2014). Rollins and Bailey (2014) stated that the major administrative concerns are balancing the cost and benefit of a district purchasing technology, the fact that education has been unable to keep up with the exponential growth of technology, and that the technician-to-teacher ratio is too small. The small technician-to-teacher ratio is perhaps the most severe problem, because it “creates an ‘us versus them’ mentality” (Rollins & Bailey, 2014, p. 37) which puts teachers and technicians at odds. The oppositional mentality takes away from the true purpose for education:
the students. Coleman (2011) summarized the issues that face teachers and students as “[a]ssessment; training; timeliness and consistency of implementation; psychosocial, cultural and environmental factors; and motivation and effort” (p. 14).

The issue of assessment can be attributed to a lack of assessment or a misunderstanding of the purpose of the technology. Zubillaga and Alba (2013) found that more than half of participants, who were students with disabilities, “do not believe technology helps them overcome social obstacles in their educational process” (p. 169). One educator’s statement summarized the need for further assessment. Reel (2009) quoted a participant as saying:

I don’t know if I have ever seen any evidence that shows the integration of technology into the curriculum leads to improved student learning. Whether it does or it does not, it does not mean that it is not worthwhile to pursue because it is so much a part of our culture. It is where we live now. (Pedagogical (instructional) use of technology section, para. 3).

While the importance of educators understanding the need for students to know that technology exists, the fact that the educators do not have faith that technology improves results will likely affect educators’ use of technology in the classroom. The use of technology has a theoretical basis in Vygotsky’s Activity Theory, which states that learning occurs through active involvement with a physical environment. Research is needed which shows the appropriate uses of technology so that improved student learning does occur. The technology alone is unlikely to lead to improved student learning.

In order for educators to be confident in incorporating technology in a meaningful way, training opportunities should be present. Educators must have knowledge of what technologies are available, how to use the technologies, how to incorporate the technologies, and where to get
training on the technologies (Coleman, 2011). According to Wynn (2013) students expressed a concern that technology learning occurs at a greater rate when teachers are trained and competent. Without knowledge of how to use and incorporate technology, educators leave open the dangers of connectivity. In fact, some districts are so concerned about “children having the potential for unsupervised use of technology” that they “have opted to prohibit the use of mobile devices by students until the time comes when Internet safety is not a concern” (Foulger et al., 2013, p. 22).

However, with the exponential growth of technology, internet safety remains a concern. The prohibition of the use of technology limits the ability for students to socialize. Vygotsky’s Activity Theory and Social Constructivist Theory stress the importance of socialization in gaining new knowledge. Teachers may also face what Dr. Jason Ravitz calls a “lack of technology fluency” which refers “to the ability most of us have (or don’t have) to shape new technologies to meet our needs” (Baker, 2014, p. 14). Lack of technology fluency can be solved through professional development and guided use. However, other concerns remain.

Another major concern for teachers involves the lack of time available to properly create an integrated lesson. Kirkscey (2012) reported that instructors believe “they have inadequate preparation time to implement new technology applications in the classroom” (p. 25). Teachers working in a school with block scheduling typically have around 90 minutes of planning time built into the school day. During those 90 minutes, educators’ tasks typically involve planning the curriculum content to be taught in the near future, differentiating those lessons for students, making copies, calling parents, grading papers or tests, and many other tasks. It is understandable that teachers have concerns regarding a lack of time for planning (Kirkscey, 2012).
However, with more appropriate professional development, these issues could be mitigated (Murthy, Iyer, & Warriem, 2014). For educators to implement strategies with educational technology, Murthy et al. (2014) asserted that educators must learn both the skills required to use the educational technology and appropriate ways to incorporate those strategies into the classroom. Additionally, teachers feel stressed because they “believe they have insufficient time in class to teach both course content and computer technology” (Murthy et al., 2014, p. 25).

The additional time necessary to instruct students in the use of technology presents a concern for the teacher. If a student does not understand how to use a specific technology, instruction on the use of the specific technology needs to become part of the instruction (Murthy et al., 2014). Time spent on instruction of a technological device results in time taken away from the content. Spending time on the instruction of technology would also depend upon the teacher being well-versed in the technology; however, not all teachers have experience with all forms of technology. Hammonds, Matherson, Wilson, and Wright (2013) stated that “when it comes to employing technology as a pedagogical tool, teachers often must play catch-up, while still acting as instructional guides” (p. 36).

Socialization and the stress of learning, particularly while learning content simultaneously, are among the foremost concerns of students. Some students “fear that virtual communication might replace face-to-face interaction in their contact with lecturers and fellow students” (Zubillaga & Alba, 2013, p. 171). There are students, however, who are opposed to technology in general. One respondent in Wynn’s (2013) study stated “I don’t really like it when technology is pushed upon me because I am not really quick in that area yet. They should just
keep in mind that not everyone is big on technology” (p. 28). While this is not typical, it represents an important case to consider.

Additionally, though Coleman (2011) wrote about students with disabilities, Coleman’s findings could apply to all students who are learning to use technology in conjunction with the course content. Students with disabilities require training on the technology, the academic content, and how to merge the two (Coleman, 2011). According to Coleman (2011) “the successful use of assistive technology depends on the user’s motivation to perform the task outweighing the combination of the cognitive effort, physical effort, linguistic effort, and time load needed to perform the task with the device” (p. 13). Essentially Coleman (2011) explained that a student is unlikely to appreciate the use of technology within the educational environment unless the merging of the technology and content becomes understandable and beneficial. When a user’s motivation does not outweigh the combined effort and time necessary to perform the task “a high rate of abandonment and under use” occurs which “results in wasted financial resources” (Coleman, 2011, pp. 4–5). The best way to overcome the numerous concerns regarding the integration of technology into the curriculum involves completing the task in the most appropriate way (Coleman, 2011). However, this may only occur once research is done to provide evidence of the appropriate uses of specific technologies within the classroom.

Rollins and Bailey (2014) suggested:

At a minimum, technology initiative planning should: involve educational stakeholders and key administrative personnel; be guided by the educational needs of those receiving the training; provide specific objectives related to national and local educational goals; and incorporate technology practices which have been proven to provide education benefits to students. (p. 34)
Curriculum alignment with technology integration should be a focus of such planning (Rollins & Bailey, 2014; Staples & Edmister, 2014). Oftentimes the difficulty of incorporating technology has resulted from a teacher allowing the technology to take over the lesson. However, “technology has to be blended with other teaching and learning experiences which are offered in the curriculum” (Sandars, 2012, p. 536). The goal of using technology should not be “to simply ‘spice-up’ an old lesson” but “to create lessons that otherwise would not be possible” (Rollins & Bailey, 2014, p. 35). Another key aspect of planning a technological lesson based on the Vygotsky’s constructivist philosophy is to make it a real-world experience, evaluating current problems in society (Holcomb et al., 2011).

**Augmented Reality**

Augmented reality has been defined as “a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it” (Carmigniani et al., 2011, p. 3). The important determinant exists that the real world be viewed in real-time with virtual information superimposed on it. Azuma (1997) further stated three necessities for a technology to be considered augmented reality are “1) Combines real and virtual, 2) Interactive in real time, and 3) Registered in 3-D” (p. 356). While credit for the term *augmented reality* goes to former Boeing researcher Tom Caudell, who was credited with coining the term in 1990, the technology was in use decades before (Lee, 2012b).

In 1957 Morton Helig began the production of Sensorama, which allowed an individual “a cinematic experience to take in all your senses” (Sung, 2011, Beginnings section, para. 1). Though the part that made it augmented reality rather than simply virtual reality was “that the environment itself was … the real world viewed in a real time situation” (Sung, 2011, Beginnings section, para. 1). Research on augmented reality actually began in the 1960s but has
only gained steam recently (Bimber, 2012). There are four main ways of interaction in augmented reality devices: (a) tangible augmented reality interfaces use physical tools in conjunction with the augmented reality technology, (b) collaborative augmented reality interfaces allow for multiple displays of the technology so as to allow collaboration between individuals, (c) hybrid augmented reality interfaces combine different types of interfaces, and (d) multimodal augmented reality interfaces are essentially comprised of multiple sensory inputs from the user (Carmigniani, 2011).

Types of augmented reality tracking. In addition to augmented reality technology being a unique, more interactive experience, different types of augmented reality tracking technology exist. Three main types of augmented reality tracking technology exist: (a) sensor-based tracking, (b) vision-based tracking, and (c) hybrid tracking (Rabbi & Ullah, 2013). Sensor-based tracking occurs when the technology responds to sensors placed in the environment. Sensor-based tracking can be broken further into optical sensor tracking, magnetic sensor tracking, acoustic sensor tracking, inertial sensor tracking, or hybrid sensor tracking (Rabbi & Ullah, 2013). Optical sensor tracking involves the use of a video camera. Magnetic sensor tracking involves the use of numerous magnetic fields. Ultrasound transmitters and acoustic sensors are used in acoustic sensor tracking. Inertial sensor tracking conserves movement. Any combination of these types of sensor tracking is known as hybrid sensor tracking (Rabbi & Ullah, 2013).

Vision-based tracking occurs as either marker-based tracking or markerless tracking. Marker-based tracking uses visual markers to begin the augmented reality technology. Conversely, markerless tracking does not use visual markers and instead reacts to the real world. Typically, markerless tracking uses Global Positioning System (GPS). Finally, hybrid tracking
represents a combination of sensor-based tracking and vision-based tracking (Rabbi & Ullah, 2013).

**Figure 3:** Classification of Augmented Reality Tracking. Reprinted from “A Survey on Augmented Reality Challenges and Tracking” by I. Rabbi and S. Ullah, 2013, *Acta Graphica*, 24(1-2), p. 35. Image “Classification of Augmented Reality Tracking” is licensed under CC BY-ND 4.0 (See Appendix C).

**Augmented reality in use.** Augmented reality appeared in the fields of medical, business, military, and education in addition to daily life. Medicine, business, and military research has been extensive, studying the usability, acceptability, and added value of augmented reality. With everything known about augmented reality, an assumption exists that the technology would be beneficial in the classroom. Billinghurst and Dunser (2012) explained that augmented reality technology “supports the understanding of complex phenomena by providing unique visual and interactive experiences that combine real and virtual information and help communicate abstract problems to learners” (p. 56). The ability to create a physical environment where a physical environment either would be impossible or unsafe to visit and the ability to communicate effectively are central to the theories on which augmented reality is based. Vygotsky’s Activity Theory and Social Constructivist Theory stressed the need for students to be able to interact with the environment while discussing what they are experiencing. The issue
remains that the use of augmented reality in the classroom has not yet been shown to increase student learning due to gaps in the research.

**Usability of augmented reality devices.** Several studies have been conducted to test the usability of augmented reality devices. These studies are important because they describe the feasibility of individuals to complete tasks using the devices. Lee, Billinghurst, Baek, Green, and Woo (2013) studied the usability of an augmented reality multimodal interface. The device was compared to one which was speech-only and one which was gesture-only. The multimodal interface was found to be more efficient than the gesture-only and similar in the amount of user errors as the other interfaces. Participants felt that the multimodal interface was “more natural, easier, and more effective to use than the other two unimodal interfaces” (Lee et al., 2013, p. 304).

Leitritz et al. (2014) conducted a study on 37 fourth-year medical students which found Eyesi Indirect, an augmented reality simulator for binocular indirect ophthalmoscopy, had an uncomplicated, positive impact on student training. The students showed significantly better performance locating disc vessels after only one short training session. The usability of smartphone applications was tested and new usability principles were defined by Ko, Chang, and Ji (2013). Additionally, Da-Ren, Mu-Yen, Tien-Chi, and Wen-Pao (2013) studied an augmented reality system used in Yehliu Geological Park. The program was adaptive, which means it individualized its performance based upon the level of understanding of the user. Da-Ren et al. (2013) found that the program did increase engagement, but the technology had “unacceptably long latency to load relevant content” (p. 5).

The research of Da-Ren et al. (2013) has led to some concern over the potential hardware and software issues and the effect that those issues would have on student engagement and
learning. The studies by Lee et al. (2013), Leitritz et al. (2014), Ko et al. (2013), and Da-Ren et al. (2013) provide evidence that usability of the augmented reality technology has been studied in the educational setting. In reference to Pribeanu (2013), though, there is no proof of added value in these studies.

**Everyday Life and Business**

Augmented reality has increased in popularity in recent years in both everyday life and business. Part of the draw results from the availability of augmented reality on handheld devices, such as smartphones. Augmented reality has also been used in settings of immersive therapy to overcome phobias. Miragall et al. (2015) studied 75 participants who suffered from katsaridaphobia (a fear of cockroaches), aviophobia (a fear of flying), or adjustment disorder. There were 40 individuals suffering from a fear of cockroaches, 20 individuals with a fear of flying, and 14 individuals with adjustment disorder. Miragall et al.’s (2015) system, known as Working Alliance Inventory-Short adaptation to Virtual Reality and Augmented Reality Therapies (WAI-VAR), was studied for its effectiveness in helping patients overcome their phobias. Study participants with a fear of cockroaches took part in a three-hour session of augmented reality exposure therapy. The psychologist could change the number, movement, and size of cockroaches in addition to whether the participant could “kill” the cockroach.

Participants with a fear of flying received virtual reality exposure therapy in six sessions over three weeks. There were three virtual scenarios for the participants: “(1) packing at home, (2) waiting for boarding at the airport, and (3) sitting in the airplane while taking off and during flight” (Miragall et al., 2015, p. 3). Finally, participants with adjustment disorder took part in six weekly virtual reality sessions. The study, though limited in sample size, found that “WAI-VAR
constitutes an excellent instrument that should be used in therapies supported by [augmented reality] and [virtual reality]” (Miragall et al., 2015, p. 8).

Similarly, Botella et al. (2016) studied the role that augmented reality could play in overcoming small animal phobia. Sixty-three participants were recruited through advertisements. The participants were separated into two groups. The in vivo (IVE) group was comprised of 31 of the participants; the augmented reality system (ARE) group was comprised of the other 32 participants. An example of the ARE system can be seen in Figure 4.

![Figure 4: Use of AR System during exposure session. (a) virtual cockroaches; (b) virtual spiders. Reprinted from “In Vivo Versus Augmented Reality Exposure in the Treatment of Small Animal Phobia: A Randomized Controlled Trial,” by C. Botella, M. Pérez-Ara, J. Bretón-López, S. Quero, A. García-Palacios, and R. Baños, 2016, PLOS ONE, 11(2), p. 6. Image “Use of AR System during exposure session. (a) virtual cockroaches; (b) virtual spiders” is licensed by CC BY 4.0 (See Appendix D).](image)

The treatments were performed in individual sessions lasting up to three hours. Though the authors admit that they were limited by sample size and the lack of a control group, they reported minimal differences between IVE and ARE.
Other researchers decided to study the benefit that augmented reality could have on grocery shopping. Ahn et al. (2015) conducted an in-person survey on 15 individuals who were using a health food shopping application for their smartphones. The application was found to substantially reduce “the amount of time it takes for shoppers to find desired healthy food products and avoid unhealthy ones” (Ahn et al., 2015, p. 16:22). The individuals were able to find their products at least two to three times faster with the use of the augmented reality application. In addition to the in-person survey, an online survey was conducted with over 100 subjects. Nearly 75% were highly satisfied compared to only around 5–10% who were dissatisfied.

Yet another way in which augmented reality was studied was in interior design. Caruso, Re, Carulli, and Bordegoni (2014) studied the use of a marker-based augmented reality system for interior decorators. The testing session for the device was completed by 20 students at the School of Design of Politecnico di Milano. Those 20 students were all working toward the Master Degree in Interior Design. The augmented reality system allowed the students to determine what furniture would look like in a location without having to actually load the furniture into a truck and carry it to the location. They would simply place a marker where they wished the furniture to be and the furniture would be superimposed on the real environment as shown in Figure 5 below.
The interior designers who took part in the study were pleased with the ease of use. It did not take the students long to learn how to use the technology either. The participants were concerned, however, that consumers may prefer seeing the real objects in the location. This was another situation of a small sample size, though some positive results still came from the study. Another design related study by Huang and Tseng (2015) involved individuals who shopped for clothing online. Huang and Tseng (2015) wanted to test out an experience where the consumer could superimpose clothing onto a real-time picture of themselves instead of seeing the clothing on an unfamiliar model. The belief was that the image of themselves in the clothing would create a vivid memory and a greater sense of ownership. Huang and Tseng (2015) found that the ability for an individual to self-reference in clothing would lead to great consumption.
The military has produced several studies related to augmented reality. The military studies have been limited by small sample sizes. Soares et al. (2012) studied a sample of 32 men between the ages of 20 and 40. The participants used a headset and game controller to travel through a virtual city identifying snipers. Some participants had a minimap on the device’s screen to help them navigate. Others had directional arrows providing directional instructions. The difficulty level could be adjusted, which would change the number of snipers that would appear to either 10 or 20. Completion time, reaction time to identify a sniper, and the error rate for sniper detection were studied to determine participant success.

While there was no non-augmented reality control group for comparison, the participants using the in-view directional arrows did experience faster completion and reaction times (Soares et al., 2012). The benefit of a system such as this is that it removes the danger of practicing sniper identification in the field for soldiers (Soares et al., 2012). It is one more way in which they can be prepared to enter a hostile area.

Livingston et al. (2011) sought to assist military entering a hostile area. The augmented reality technology studied by Livingston et al. (2011) was specifically designed for urban combat and was able to be used in the field. The augmented reality studied by Livingston et al. (2011) used a mini-netbook and a head-mounted display. On the head-mounted display, information was superimposed on the real-world environment. According to the research by Livingston et al. (2011), some of the uses of this technology would include superimposing a patrol route, defense area, or target area of attack. It could also display the range of the individual’s firearm and the potential impact zone of an improvised explosive device (IED). Fourteen subjects took part in the study. The participants studied six different views to determine the most helpful representations of depth.
The different representations were: (a) opacity, where lower opacity meant a more distant object; (b) stipple, which used solid, dashed, and dotted lines to represent distance; (c) ground grid, which used visual cues such as relative size and height; (d) edge map, where occluding edges conveyed the depth of an object; (e) virtual wall, which increased the density of edges to display greater distance; and (f) virtual tunnel, which created virtual holes to display distance (Livingston et al., 2011). The lowest error came from the virtual tunnel. The study by Livingston et al. (2011) was a pilot study to determine the best display for greatest achievement.

Another training-related study was done by Krum et al. (2012). Krum et al. (2012) used a head-mounted projective display (HMPD) known as REFLCT which provides a “personalized, perspective-correct imagery that is uniquely compositied for each user directly into and onto a surrounding environment, without any optics positioned in front of the user’s eyes or face” (p. 17). Two participants took part to determine the usability and functionality of the device. The participants interacted with a virtual US Army sergeant to learn their mission. The virtual sergeant could make eye contact with each participant individually.

The participants reported that they were able to determine which of them was being instructed. The authors found that “REFLCT reinvigorates team-based mixed reality training” (Krum et al., 2012, p. 25).

One situation, which was very difficult to replicate for training, concerns a nuclear accident. Therefore, Tsai, Liu, and Yau (2013) created an exploratory study using augmented reality to prepare for a nuclear accident. There were six participants involved in the training. The six participants were placed into two groups: one used e-Maps-based escape guidelines while the other used augmented reality-based guidelines. The e-Maps-based version provided a map while the augmented reality-based version provided a combination of the real scene and a virtual scene. The differences can be seen in Figures 5 and 6.

Figure 7: e-Maps-based escape guidelines. Reprinted from “Using Electronic Maps and Augmented Reality-based Training Materials as Escape Guidelines for Nuclear Accidents: An Explorative Case Study in Taiwan,” by M. Tsai, P. Liu, and N. Yau, 2013, British Journal of
The participants used assigned devices to locate an assigned shelter to escape the nuclear accident. Only one of the trainees, one who was using the e-Maps-based system, did not complete the test, though he spent 74 minutes attempting to find his shelter. The average time spent finding the shelter for the e-Maps-based group was 65 minutes compared to 51 minutes for those using the augmented reality-based system (Tsai et al., 2013). Tsai et al. (2013) stated that “the effectiveness of the AR-based escape guidelines seemed better than those using e-Maps,” (p. E21), but the sample size was small.

The military has also used augmented reality in the assembly of vehicles. Servan, Mas, and Menendez (2012) studied the use of augmented reality in the assembly of the AIRBUS A400M. The study revolved around a Work Instruction, specifically the creation time,
consulting time, and maintenance time involved. According to Servan et al. (2012) “Work Instruction (WI) describes both the sequence of operations to be performed by the workers and fundamental and critical parameters of operation (drawings of components, torques to be applied, sealing system characteristics, etc.)” (p. 634). The study compared the conventional method of Work Instruction and the new augmented reality-based Work Instruction called MOON (asseMbly Oriented authOring augmeNted reality). In terms of creation time, the conventional method took 30 minutes compared to three minutes for MOON. Consulting time was cut in half from two minutes to one minute using MOON. Finally, maintenance time took only one minute with MOON compared to 10 minutes for the conventional method. The amount of time saved shows the benefit of the augmented reality technology.

Thirty-four preclinical medical students took part in a study by Wilson et al. (2013) on the potential benefits of an augmented reality support for combat medics to assist in the treatment of tension pneumothoraces. Though the individuals taking part in the study were not in the military, the study was done for the purpose of military personnel. There were two randomly assigned groups: one which would use the augmented reality technology and one which would act as a control group.

After a PowerPoint presentation on thoracic emergencies, participants were brought into a cadaver lab to test their knowledge and skills. Participants using the augmented reality goggles interoperated with data stored on the computer. A mini microphone allowed those participants to initiate a description of the sequence of steps in order to perform a needle decompression, the medical response to a tension pneumothorax. A minicamera projected information onto the thoracic cavity of the body. Finally, the students received voice responses through a minispeaker. Those using the augmented reality goggles had greater success than the control
group. Wilson et al. (2013) stated that the augmented reality technology that they studied “increases the likelihood of completing invasive procedures when the performer has only cursory familiarity about the procedure” (p. 985).

A study conducted by Rothbaum et al. (2014) utilized a larger sample size. The study participants were 156 Iraq and Afghanistan war veterans between the ages of 22 and 55 with post-traumatic stress disorder (PTSD). It was a double-blind, placebo-controlled study. Baseline screening was performed followed by six treatment visits. Follow-up assessments were done at 3, 6, and 12 months posttreatment. The participants were separated into three groups. Fifty-three participants were assigned d-cycloserine; 50 participants were assigned alprazolam; another 53 participants were assigned the placebo.

While on their drug or placebo, participants took part in a virtual reality exposure through a head-mounted display that included “a computer-generated view of a virtual Iraq or Afghanistan environment that changed in a natural way with head and body motion” (Rothbaum et al., 2014, p. 642). Some environments consisted of driving a Humvee, while others were required to navigate on foot. The participants used stereo earphones for greater immersion into the environment. They navigated through the use of a handheld controller. Overall, individuals experienced significant improvement in their symptoms after the use of the virtual reality device. The drugs had varying effects. While d-cycloserine seemed to enhance outcomes, alprazolam diminished the efficacy of the exposure therapy. Though the previous two studies dealt specifically with military personnel, there is also the medical aspect of it. Many other studies were done specifically within the medical environment.

**Medicine**
The field of medicine has provided some of the most beneficial studies of augmented reality in training or education. Augmented reality training for postural control for patients with Parkinson’s disease was part of an experimental study conducted by Yen et al. (2011). The sample was chosen at random using a block randomized design. The sample was distributed between three groups using age-stratified randomization: (a) one used Virtual Reality-augmented balance training, (b) one used conventional balance training, and (c) one was a control group that took part in no balance training. The purpose of the study was to analyze the improvement of the condition of the patients.

There was a rather large bit of attrition since the study began with 42 participants, dwindled to 38 participants who completed the six-week trainings, and further diminished to 32 participants who were assessed at a four-week follow-up (Yen et al., 2011). The results of the research showed that “both the VR [Virtual Reality-augmented balance training] and the CB [conventional balance training] groups improved in 1 SOT [sensory organization test], whereas the control group did not change significantly in any SOT condition” (Yen et al., 2011, p. 872). The importance of this study stems from Yen et al. (2011) recognizing that while the intervention which included augmented reality training improved postural control, it was not necessarily more beneficial than conventional balance training.

A medical study proposed by Mirelman et al. (2013) dealt with balance issues. The researchers intended to study whether they could use augmented reality to decrease the fall risk in those individuals with a history of falls. The variable of interest in the proposed study was the participants’ fall rates. This study proposal displayed the necessary implements for a quality experimental study. Mirelman et al. (2013) suggested a randomized sample of 300 participants. Additionally, Mirelman et al. (2013) intended to distribute the participants between two groups.
The groups suggested were a control group which would use treadmill training only and a treatment group which would use the treadmill with the added aspect of virtual reality.

The medical field succumbed to some of the same limitations and gaps that exist in the field of education according to evidence provided by a study conducted by Espay et al. (2010). Similar to the studies of Yen et al. (2011) and Mirelman et al. (2013), Espay et al. (2010) studied improving the walking techniques of patients living with Parkinson’s disease. While the study showed that there was improvement in the patients’ gait, there were certain issues which limit this research’s benefit. The sample was comprised of only 13 participants who were not chosen at random but were instead recruited. Additionally, there was no use of a control group. Espay et al. (2010) explained this issue in saying that “the absence of a control group was unavoidable given the device’s lack of a ‘neutral mode’” and that they “could not ethically justify a placebo” (p. 579).

Thomas, John, and Delieu (2010) conducted research at the School of Medicine at Keele University. The 34 medical student participants learned about human anatomy with the use of an augmented reality education tool called the Bangor Augmented Reality Education Tool for Anatomy (BARETA). After participation with the device, students completed a questionnaire. The questionnaire used a five-point Likert scale with 1 representing strongly disagree and 5 representing strongly agree. One of the lines of inquiry on the questionnaire stated that “the students found that BARETA helped [the students] to understand the shape and the location of the ventricles within the human head” (Thomas et al., 2010, p. 11). Though participants who had previously dissected cadavers felt that the augmented reality technology was less effective, 32 of the 34 participants “recorded a score of 4 or greater for this line of inquiry” (Thomas et al., 2010,
p. 11). The fact that 32 of 34 medical students perceived an improvement in skills led elementary and secondary school educators to consider its potential value in the classroom.

Two pertinent studies have provided a blend of the medical and educational fields. Botden, de Hingh, and Jakimowicz (2009) conducted a study which blended the medical and educational fields. In their research Botden et al. (2009) studied a group of medical students who used an augmented reality device to learn suturing techniques. Some students were described as top students while other students were of average ability. The top students did not improve significantly in suturing abilities; however, the students of average ability did improve in suturing abilities. Similar to the study by Espay et al. (2010), this study by Botden et al. (2009) had limited participation with only 18 students. Another potential issue was that students reported that they were tired and lost focus during this study (Botden et al., 2009). That would cause one to question the validity of the results of this study. The issues that occurred in these studies can be found throughout the augmented reality literature within the field of education.

**Education**

Various studies have shown that progress has been made on studying the benefits that augmented reality technologies have on student motivation and even, in small samples, the effect that augmented reality has on learning (Bergig et al., 2011; Birchfield & Megowan-Romanowicz, 2009; Campos et al., 2011; Chang, Wu, & Hsu, 2013; Enyedy, Danish, Delacruz, & Kumar, 2012; Liu & Tsai, 2013; Santos et al., 2016; Tolentino et al., 2009). Campos et al. (2011) worked with kindergarten teachers to create an augmented reality game involving identifying animals and their habitat. The students were to drag the image of an animal to its appropriate environment. Students did not know whether an answer was correct until the end of the game when feedback could be requested from the technology. This study evaluated whether
the technology affected the students’ “(i) learning, (ii) motivation and (iii) collaboration levels” (Campos et al., 2011, p. 37). This study aligns with both the Activity Theory and the Social Constructivist Theory presented by Vygostky. Students interact with various devices and are then expected to collaborate to determine a solution.

There was a comparison between the augmented reality game and a similar game played on the SMARTBoard (Campos et al., 2011). Campos et al. (2011) noted a decided increase in motivation and collaboration levels. The authors stated that “motivation levels were high because children never gave up during the game. Even when feedback showed [the children that they] were very wrong, nobody quit the game until reaching the solution” (Campos et al., 2011, p. 37). The results did not adequately address the learning levels. There was only one statement that “the augmented reality system is a positive step forward toward achieving the goal of reducing the distance between children and knowledge” (Campos et al., 2011, p. 38). The other statement about learning said that “the system didn’t make the learning process go wrong” (Campos et al., 2011, p. 37).

Birchfield and Megowan-Romanowicz (2009) determined that the achievement gains did occur for students after a review phase while using an augmented reality tool known as SMALLab (p. 403). They “were not able to compare the nature of collaboration in SMALLab against other types of pedagogy” (Birchfield & Megowan-Romanowicz, 2009, p. 419). The Enyedy et al. (2012) study had similar issues. According to Enyedy et al. (2012) “[p]re/[p]ost-test results were encouraging and show that young students are able, with the [AR] technology and activities to learn force and motion concepts at an earlier age than thought possible” (p. 376).

Like the Birchfield and Megowan-Romanowicz (2009) study, there was no control group for comparison. The same can be said for the Tolentino et al. (2009) study, which found that due
to the augmented reality instruction “students were able to achieve significant learning gains in standards-based chemistry content knowledge” (Tolentino et al., 2009, p. 514). The authors admitted that they “were unable to gather retest data on an untreated control group for the knowledge of assessment measure” (Tolentino et al., 2009, p. 514).

Bergig et al. (2011), Campos et al. (2011), Chang et al. (2013), Liu and Tsai (2013), and Santos et al. (2016) found positive results in their augmented reality studies. Bergig et al. (2011) had students differentiate between ski slope lengths and steepness. All of the students found that the augmented reality device made completing their required task easier. Campos et al. (2011) worked with kindergarten students to place animals in their correct habitat and found increases in student motivation and willingness to collaborate. Chang et al. (2013) had students complete an inquiry-based task involving how radiation would affect students in various environments. The socialization aspect exists as an essential component to align with Vygotsky’s Activity Theory and the Social Constructivist Theory, which are the theoretical basis for the use of augmented reality in a learning environment. Significant improvement was noted.

Similar to the studies by Birchfield and Megowan-Romanowicz (2009), Enyedy et al. (2012), and Tolentino et al. (2009), the Chang et al. (2013) study did not include a control group. Additionally, the augmented reality technology was well-received by the class. Liu and Tsai (2013) conducted a study to determine if augmented reality was appropriate to use with English as a Foreign Language learners. Liu and Tsai (2013) did not use a control group for comparison sake, but the researchers found that the augmented reality technology benefitted linguistic and content knowledge. Santos et al. (2016) worked with students on improving vocabulary retention. They found that via the use of augmented reality technology, their participants retained more vocabulary.
All of these studies were limited in their sample sizes with Bergig et al. (2011) having 12 participants, Campos et al. (2011) having 22 participants, Chang et al. (2013) having 22 participants, Liu and Tsai (2013) having only five participants, and Santos et al. (2016) having 31 participants. These are issues that must be overcome, as acknowledged by some of the authors. Bergig et al. (2011) stated that they “would like to conduct experiments on larger groups of people” (p. 211). Chang et al. (2013) acknowledged that their sample size was small and instructed future researchers to conduct studies which would help to generalize the results. Santos et al. (2016) cautioned that due to “a small sample size … the results should be interpreted with caution” and that the “experiments should be replicated with a bigger sample size” (p. 13).

Estapa and Nadolny (2015) came the closest to overcoming these issues. Their study involved 61 students separated into two groups. One group used only website interaction while the other group’s interaction involved augmented reality. As with Campos et al. (2011) student motivation increased when using the augmented reality technology. While the study conducted by Estapa and Nadolny (2015) had a larger sample size than similar studies and found a significant difference in motivation, both groups achieved significant learning gains. Estapa and Nadolny (2015) were unable to show added benefit from the use of augmented reality as they stated, “[r]esults show both types of conditions lead to overall achievement with respect to mathematical learning of dimensional analysis” (p. 45).

The intent of a study conducted by Ibili and Sahin (2015) was to investigate the effects that augmented reality had on computer attitudes and computer self-efficacy. The authors went beyond those two topics. The study involved 100 students separated into two treatment groups and two control groups. The study’s results failed to find a significant difference in student
computer attitudes and computer self-efficacy. Qualitatively, Ibili and Sahin (2015) found that the augmented reality technology “positively contributed to students’ cognitive learning” (p. 335) and was helpful in relieving the fears and anxieties that students with negative math attitudes experienced.

A potential confounding factor in some of the comparison studies within the field of education remains the complete change of pedagogical practices using augmented reality technology versus traditional methods. Both changing instructional tools and pedagogical practices cause difficulty in deciphering whether the potential change in achievement was based on the technology or a more beneficial pedagogical strategy. In many of the augmented reality-based learning environments, students were engaged in collaborative problem solving. Research has shown that group performance is beneficial to later individual performance on various tasks (Barron, 2000; Cohen, Lotan, & Leechor, 1989; Johnson & Johnson, 1989; Laughlin & Adamopoulos, 1980; Laughlin, Carey, & Kerr, 2008; Laughlin & Ellis, 1986; Olivera & Straus, 2004; Stasson, Kameda, Parks, Zimmerman, & Davis, 1991). This would align with Vygotsky’s Social Constructivist Theory, which is one of the theories upon which the use of augmented reality is based.

Perez-Lopez and Contero (2013) conducted a study with 49 fourth graders. The students were broken into treatment and control groups. The treatment group was taught anatomy using interactive augmented reality technology. The control group used traditional methods. Each group learned a unit entitled “Changes in the last century” through traditional lecturing and textbook activities. When taught the unit entitled “Digestive system,” students took part in the augmented reality technology. The results showed students retained information on the digestive
system. The study lacked the ability to prove whether the subject material or the technology was the reason for any difference in results.

Chiang, Yang, and Hwang (2014) conducted a study involving 57 students broken into a treatment group and a control group. The students were introduced to the topic of aquatic plants after which they took a pre-test. Students in both groups used inquiry-based strategies during the 120-minute treatment phase. The treatment group used an augmented reality system, while the control group used mobile devices. Students then presented findings to the class prior to completing the posttest. Chiang et al. (2014) found that “the average learning achievement of the [treatment] group was significantly better than that of the control group” (p. 360).

Another study which used similar pedagogical strategies was conducted by Wang, Duh, Li, Lin, and Tsai (2014). Both groups used inquiry-based learning strategies within a mobile simulation learning environment to investigate elastic collision, with one using an augmented reality simulation, “AR physics,” and the other using a traditional two-dimensional simulation. The researchers found no statistically significant difference in the frequency of collaborative inquiry processes between the groups. A study of the behavioral patterns gave more insight. The augmented reality group exhibited four unique behavioral patterns while the traditional group showed only one with both groups experiencing an addition five shared behavioral patterns. Martin, Dikkers, Squire, and Gannon (2014) explained in their study that “situating learning activities in authentic contexts can enable a number of powerful pedagogical triggers” (p. 40).

Studies by Yi Hsing and Jen-ch’iang (2013) and Yoon, Elinich, Wang, Steinmeier, and Tucker (2012) were not conducted in a general school environment but still involved augmented reality and learning. Yi Hsing and Jen-ch’iang (2013) conducted a study on visitors to Chihkan
Tower. Half of the 60 visitors, ranging in age from 18 to 26, took part in augmented reality instruction while the rest were in the control group. The control group received the general presentation as it normally was organized. The treatment group used augmented reality in addition to the general presentation. The visitors were pre- and post-tested.

The results showed that student in the treatment group “had significantly better achievement than those in the control group” (Yi Hsing & Jen-ch’iang, 2013, p. 29). Yi Hsing and Jen-ch’iang (2013) warned that “[c]ourses with relatively no pressure are more suitable for such a system. Such learning systems may be unsuitable for learning objectives in schools” (p. 31). Yoon et al. (2012) performed a similar study with middle school students at a science museum. They split the students into four groups; a true control group without technology or scaffolding (C1), a group the used the augmented reality technology without scaffolding (C2), a group that used the technology with minimal scaffolding (C3), and the final group which used the technology with full scaffolding (C4). While Yoon et al. (2012) found that scaffolding was unimportant for basic knowledge, “scaffolds might be necessary to reach more advanced learning” (p. 538).

The literature on augmented reality in education involves studies on usability, motivation, and an increase in learning. There are some concerns about studies that focus on increased learning. Control or comparison groups, quantitative studies, knowledge assessment, and adequate sample sizes have been underrepresented in the research. Additionally, studies tying motivation experienced via the use of augmented reality to knowledge acquisition would be important. One such study that made contributions in this area was conducted by Solak and Cakir (2015). The authors used an augmented reality device to introduce new vocabulary to their participants. Their study found a significant positive correlation between academic achievement
and the motivation brought forth via the use of augmented reality technology. Additional research should be done on the correlation between motivation and academic achievement.

**Summary**

In the current educational climate, professional development in the area of technology pushes for its use within the classroom. The push for 21st century skills increases the need for educators to incorporate technology. However, research is necessary to determine the worth of such an initiative. Myers (2012) stated that “[e]ducators of all kinds are implementing this technology and the progress has been nothing short of excellent” (para. 2). There was no information given to provide evidence of this excellent progress. Jackson (2012) also pushed for the use of augmented reality in the classroom without providing evidence of its effect on learning. The encouragement of technology use within the classroom has the danger of deluding educators into false assumptions. Billinghurst and Dunser (2012) stated:

AR [augmented reality] provides a superior learning environment. However, before AR can enjoy wider use in the classroom, researchers must answer important questions about the technology’s application in an educational setting, such as does AR enhance elementary and high school education, and if so, how is AR superior to other technologies that promote learning. (p. 56)

This cautionary sentiment exists as the premise of the desired research. Careful exploration must be undertaken to determine proper use of augmented reality so that the technology can provide experiences that enhance learning.

Billinghurst and Dunser (2012) explained that the research has been positive regarding the use of augmented reality in the classroom but also stated that more profound research must be done on the topic. Billinghurst and Dunser (2012) also stressed that “[p]roviding [augmented
reality] experiences does not necessarily mean that people are learning more effectively from them” (p. 58), which suggests the necessity to understand how augmented reality performs in the classroom. Billinghurst and Dunser (2012) indicated that they were ready to accept the general use of augmented reality in the classroom but not before determining the most efficient ways to use the technology. The technology should provide enough benefits so as to outweigh the cost. Discovering whether the interest gained through the use of technology truly leads to greater knowledge acquisition is crucial.
CHAPTER THREE: METHODS

Overview

This chapter includes a description of the design of the study, research questions, null hypotheses, participants and setting, testing instruments used, procedures of data collection, and data analysis. This quantitative study sought to determine whether the use of augmented reality depictions of three-dimensional figures led to greater student achievement than the use of concrete three-dimensional figures. Additionally, the study sought to determine whether students perceived that they learned more from the augmented reality depictions of three-dimensional figures when compared to the use of concrete three-dimensional figures.

Design

The study was a quantitative pretest-posttest, non-equivalent control group quasi-experimental design. This method was chosen because the sample could not be randomized, the independent variable was categorical (Gall, Gall, & Borg, 2007), and Campbell and Stanley (1963) prescribed a non-equivalent quasi-experimental design when the impact of different treatments is being compared. Taradi and Taradi (2016) stated that a pretest-posttest, non-equivalent quasi-experimental study should be chosen when students will already be assigned to classes. In the proposed study, the independent variable was the type of instruction, which was either traditional methods that included the use of concrete three-dimensional figures and two-dimensional representations of three-dimensional figures or augmented reality-based methods that used three-dimensional figures that were represented using augmented reality technology. The dependent variable was achievement, which was measured by scores on the Three-Dimensional Figures Reporting Category of the 2014 Geometry Standards of Learning test.
covariate of pretest scores from the Three-Dimensional Figures Reporting Category of the 2013 Geometry Standards of Learning test was used as well.

**Research Questions**

The research questions for this study were:

**RQ1:** Is there a difference in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores?

**RQ2:** Is there a difference in the perceived learning scores, as measured by the CAP Perceived Learning Scale, of high school students taught using augmented reality and students taught using traditional methods?

**Hypotheses**

The null hypotheses for this study were:

**H01:** There will be no statistically significant difference in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores.

**H02:** There will be no statistically significant difference in the perceived learning scores as measured by the CAP Perceived Learning Scale of high school students taught using augmented reality and students taught using traditional methods.

**Participants and Setting**

Due to the nature of the study, a convenience sampling procedure was used for the selection of the participants. The population for this study was students taking a Geometry
course in rural and suburban high schools in northern Virginia. Participation was gained by a letter requesting permission (see Appendix H). This letter was personalized and sent to the superintendents of the intended divisions. No gifts or recompense were offered. The sample was comprised of students from Geometry classes taught by three teachers (Teacher A, Teacher B, Teacher C) in two secondary schools (School A, School B) in one rural school district and one suburban school district (District 1, District 2). Two Geometry classes, taught by the same teacher, were chosen at each school. One Geometry class did not use augmented reality and was assigned to the control group. The other Geometry class was taught using augmented reality and was assigned to the treatment group. The study had 35 participants in the control group and 52 participants in the treatment group for a total of 87 participants. Gall et al. (2007) suggested having between 96 and 166 participants for a medium effect size with 0.7 statistical power at an alpha level of 0.05. Students were in grades 9 to 12 and ranged in age from 14 to 18. Class sizes ranged from 5–26 students. The control group had 10 participants with Individualized Education Plans. The treatment group had five participants with Individualized Education Plans.

Instrumentation

The first instrument used for this study was the 2014 Virginia Geometry End-of-Course Standards of Learning test. The Geometry End-of-Course Standards of Learning test exists as a state test that was developed specifically to assess the Geometry Standards of Learning. Standards of Learning tests were first administered in 1998 in Virginia and were developed by the Virginia Department of Education with the help of classroom teachers, curriculum specialists, and other local educators. This state assessment is comprised of 50 graded questions and 10 field questions divided into three Reporting Categories: (1) Reasoning, Lines, and Transformations, (2) Triangles, and (3) Polygons, Circles, and Three-Dimensional Figures.
The scoring for the test comes in the form of a 0–600 scale. The 0–600 scale is derived from a raw score where a zero raw score is equal to a zero score on the Standards of Learning test, and a perfect raw score is equal to a 600 on the Standards of Learning test. The Virginia Department of Education sets 400 as the minimum score necessary to earn a Pass/Proficient rating and a 500 as the minimum for a Pass/Advanced rating. Each Reporting Category is also assessed on a scale. The Reporting Category scale is 0–50 with 30 representing approximate mastery of the concept.

Content validity has been established for the Geometry End-of-Course Standards of Learning test in the Geometry Standards of Learning Blueprint which states the number of questions from each Reporting Category to appear on the assessments (Virginia Department of Education, n.d.). The Geometry Standards of Learning tests contain 18 questions in the Reporting Category of Reasoning, Lines, and Transformations, 14 questions in the Reporting Category of Triangles, and 18 questions in the Reporting Category of Polygons, Circles, and Three-Dimensional Figures (Commonwealth of Virginia, 2010). This shows that there is strong alignment among the assessment, standards, and instruction.

While most questions were in multiple choice format, some were Technology Enhanced Questions. Technology Enhanced Questions could require a student to drag-and-drop items to the correct location, fill-in-the-blank by typing in a text box, selecting more than one correct answer, or placing a point at the correct location on a coordinate plane. Classroom teachers graded the multiple choice and Technology Enhanced Items. To grade the Technology Enhanced Items, teachers were provided with a list of possible correct answers. If an answer did not match the possible correct answers list, then the question was counted as incorrect. Virginia educators took part in the development and review of the instrument. Reliability has been
established for the Geometry End-of-Course Standards of Learning test by Cronbach alpha values falling in the range of .85 to .92 (Virginia Department of Education, n.d.).

The Geometry End-of-Course Standards of Learning test were administered by the classroom teachers in the classroom via paper-pencil means. The classroom teachers followed the instructions provided by the Examiner’s Manual provided by the Virginia Department of Education (2016). The Three-Dimensional Figures section required approximately 30 minutes to complete.

The second instrument was the CAP Perceived Learning Scale (Rovai et al., 2009). The CAP Perceived Learning Scale has been used in a number of studies (Akbas, Baturay, & Soker, 2016; Khodabandelou, Ab Jalil, Wan Ali, & bin Mohd Daud, 2014; Sarikoc, Ozcan, & Elcin, 2017). Permission was granted to use the CAP Perceived Learning Scale (Rovai et al., 2009) (see Appendix I). The CAP Perceived Learning Scale (Rovai et al., 2009) (See Appendix J) and directions on scoring the CAP Perceived Learning Scale (Rovai et al., 2009) (See Appendix K) were also provided. Scoring was done by the researcher. The purpose of this instrument was to measure the perceived cognitive, affective, and psychomotor learning of the participants.

The CAP Perceived Learning Scale was developed by Rovai et al. (2009) to be used as a self-report instrument of perceived learning. Rovai et al. (2009) noted that few self-report instruments for the purpose of measuring learning existed. After three phases of data collection and analysis, the CAP Perceived Learning Scale (Rovai et al., 2009) decreased from 80 items to nine items on which students would self-report. For each item, the student answered on a scale of zero, which represents “Not at all,” to six, which represents “Very much so.” The CAP Perceived Learning Scale took approximately five minutes to administer. The CAP Perceived
The CAP Perceived Learning Scale (Rovai et al., 2009) was printed out and handed out to students by their teacher. The students completed the CAP Perceived Learning Scale (Rovai et al., 2009) independently.

The CAP Perceived Learning Scale (Rovai et al., 2009) provides a total score ranging from 0 to 54. A score of 0 is the lowest possible score, meaning that the participant did not perceive any learning gain. A score of 54 is the highest possible score, meaning that the participant perceived the highest possible learning gain. Three subscales exist for the CAP Perceived Learning Scale: Cognitive, Affective, and Psychomotor (Rovai et al., 2009). Each subscale of the CAP Perceived Learning Scale consists of three items resulting in a score range of 0 to 18. A score of 0 is the lowest possible score and indicates that the participant did not perceive a learning gain within the subscale. A score of 18 is the highest possible score and indicates that the participant perceived the highest possible learning gain within the subscale. Reliability has been established for the CAP Perceived Learning Scale by a Cronbach alpha value of .79 (Rovai et al., 2009). Factor analysis and reliability indicate that the CAP Perceived Learning Scale has good construct validity (Rovai et al., 2009).

**Procedures**

Participating teachers and students received a packet from the researcher. The packet included a letter to inform the parties about the study and described where the instrument can be accessed on the Internet. Parent/guardian consent and student assent forms (See Appendix L) were also included in the packet. Once the forms were returned, teachers were trained on the administration of the Standards of Learning tests and how to use the smartphone application. Training for the Standards of Learning test was provided using the Examiner’s Manual (Virginia Department of Education, 2016). Training for the use of the smartphone application was provided in person by the researcher. The lessons were not dictated by the researcher. Rather,
the participating teacher taught the lesson the way that he or she typically would have instructed. The only researcher-introduced change was that during instruction the participants in the control group used concrete manipulatives to explore the various geometric solids, while the participants in the treatment group used augmented reality representations of the geometric solids.

Participants completed a pretest, which was the Three-Dimensional Figures section of the 2013 Geometry Standards of Learning test, prior to the treatment. The data from the pretests were collected and recorded in an Excel spreadsheet. Classroom teachers graded the multiple choice and Technology Enhanced Items. To grade the Technology Enhanced Items, teachers were provided with a list of possible correct answers. If an answer did not match the possible correct answers list, then the question was counted as incorrect. The names of the participants were replaced with a randomized numbering system. The spreadsheet was stored on a password-protected computer, and a copy was kept on an external storage device that was stored in a locked security box off-site away from any of the classroom locations.

After the pretests were completed, teachers taught using their designated instructional methods. The instruction process lasted approximately two weeks. Once the instruction had been completed, the participants took post-tests. Pre- and post-tests were administered in the classrooms or computer laboratories. Following post-testing the participants completed the CAP Perceived Learning Scale. Data were collected and transferred to a new column in the spreadsheet. Following the collection of the data, it was imported into SPSS and ANCOVAs were conducted.

**Data Analysis**

A one-way ANCOVA was used to analyze student achievement data, as measured by scores on the Three-Dimensional Figures reporting category of the Geometry Standards of
Learning test. The data analysis method was chosen based on the threat to internal validity that pretest-posttest studies exhibit. The concern was that pre-existing group differences could be the cause of different posttest scores, thus invalidating the findings. An ANCOVA, however, may be used to control for a possible confounding variable, such as pretest scores in this study (Gall et al., 2007). Ary, Jacobs, Sorensen, and Razavieh (2010) agreed that an ANCOVA can be used to “statistically adjust the posttest scores for the pretest differences” (p. 340).

Several assumptions must be met for an ANCOVA to be used (Pallant, 2007). First, the dependent variable should be a continuous variable. In this study the dependent variable student achievement, as measured by scores on the Three-Dimensional Figures reporting category of the 2014 Virginia Geometry Standards of Learning test, is a continuous variable. Another assumption is that there are independent observations meaning that the scores from the two groups are independent of each other. The influence of treatment on covariate measurement states that pretest measurement should occur prior to any treatment. The pretest occurred on day one of the study. Therefore, the influence of treatment on covariate measurement assumption was not violated.

Additional assumption tests were also conducted. The assumption of normality was tested using histograms and the Kolmogorov-Smirnov test for goodness of fit (Chakravart, Laha, & Roy, 1967). The assumption of linearity was tested using a series of scatterplots for the pre- and post-test data. Scatterplots were used to test the assumption of bivariate normal distribution. A univariate linear model was conducted to test for homogeneity of slopes. Finally, the assumption of equal variance was tested using Levene’s test for equality of variances.

An independent t-test was used to analyze perceived learning data, as measured by the CAP Perceived Learning Scale (Rovai et al., 2009). A t-test was chosen so that the mean scores
of two groups may be compared. Several assumptions must be met for a t-test to be used (Pallant, 2007). In this study the dependent variable perceived learning, as measured by the CAP Perceived Learning Scale, is a continuous variable. The independent variable type of instruction consisted of two categorical, independent groups; one experiencing instruction through the use of augmented reality and one experiencing instruction through the use of concrete three-dimensional manipulatives. There was independence of observation as each participant was in only one group.

The assumption of normality was tested using histograms and the Kolmogorov-Smirnov test for goodness of fit (Chakravart et al., 1967). The assumption of linearity was tested using a series of scatterplots for the pre- and post-test data. Scatterplots were used to test the assumption of bivariate normal distribution. Finally, the assumption of equal variance was tested using Levene’s test for equality of variances. The effect size for the study was measured using partial eta-squared. The alpha level for this study was set at .05. Included in reporting were assumption testing, descriptive statistics ($M$, $SD$), number ($N$), number per cell ($n$), degrees of freedom ($df$ within/$df$ between), observed $F$ value ($F$), significance level ($p$), post hoc or planned comparisons, effect size, and power.
CHAPTER FOUR: FINDINGS

Overview

The purpose of this quantitative pretest-posttest, non-equivalent control group quasi-experimental study was to determine if there was a statistically significant difference in student achievement for high school Geometry students who are instructed using traditional methods versus augmented reality-based instruction. In this chapter the findings of the study are presented, including all of the descriptive statistics that were calculated and how those results aligned with the null hypotheses.

Research Questions

RQ1: Is there a difference in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores?

RQ2: Is there a difference in the perceived learning scores, as measured by the CAP Perceived Learning Scale, of high school students taught using augmented reality and students taught using traditional methods?

Null Hypotheses

H₀₁: There will be no statistically significant difference in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores.
**Ho2:** There will be no statistically significant difference in the perceived learning scores, as measured by the CAP Perceived Learning Scale, of high school students taught using augmented reality and students taught using traditional methods.

**Descriptive Statistics**

The participants in this study consisted of 87 Geometry students from high schools in northern Virginia. Of the 87 participants, 52% were male and 48% were female. The average age of the participating students was 15. The control group score increased from a pretest mean of 1.11 ($SD = 1.02$) to a posttest mean of 3.06 ($SD = 1.43$). The treatment group score increased from a pretest mean of 2.00 ($SD = 1.52$) to a posttest mean of 3.65 ($SD = 1.57$). The overall sample score increased from a pretest mean of 1.64 ($SD = 1.41$) to a posttest mean of 3.41 ($SD = 1.54$). The control group reported a mean of 48.43 ($SD = 14.04$) on the CAP Perceived Learning Scale. The treatment group reported a mean of 50.38 ($SD = 10.36$) on the CAP Perceived Learning Scale. The overall sample reported a mean of 49.60 ($SD = 11.94$) on the CAP Perceived Learning Scale.

Table 1

<table>
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<tr>
<td></td>
<td>Total</td>
<td>49.60</td>
<td>11.94</td>
<td>87</td>
</tr>
</tbody>
</table>
Results

Results for Null Hypothesis One

Assumptions. The first four assumptions for a one-way ANCOVA were met: the dependent variable was continuous, the independent variable was dichotomous, a continuous covariate was continuous, and the study had independence of observations. The assumption of a linear relationship between the pretest and posttest scores for each group was violated, as assessed by visual inspection of a scatterplot. By visual inspection, there was a very low, positive correlation with no linear relationship.

![Grouped Scatter of Posttest by Pretest by Group](image)

*Figure 9: Scatterplot of Posttest by Pretest by Group*

A square transformation was performed on the covariate; however, the linearity assumption remained violated. The scatterplot still displays a very low, positive correlation with no linear relationship.
There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1, 83) = .229, p = .634$.

**Results.** With the assumption of linearity violated, it was necessary to choose a nonparametric test. "Further development of alternative methods of ANCOVA is needed to handle situations in which the usual assumptions of normality are not met. A nonparametric procedure given by Quade (1967) provides a reasonable alternative method" (Conover & Iman, 1982). Quade’s Rank Analysis of Covariance was performed to determine whether significant differences existed in the achievement scores, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores. The dependent variable was the achievement scores. The independent variable was type of instruction. To conduct Quade’s Rank Analysis of Covariance, the posttest and pretest values were ranked. A linear regression was conducted using the posttest
rank values and the pretest rank values, and the residuals were saved. The residuals were then used as the dependent variable in a one-way ANOVA. The result of the one-way ANOVA was that the difference between the control group and treatment group was not statistically significant, \( F(1, 85) = .409, p = .524 \). Therefore, the null hypothesis was not rejected.

Table 2

Results of Quade’s Rank Analysis of Covariance

<table>
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<th>( F )</th>
<th>Sig.</th>
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<td>1.971</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>168.374</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
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</table>

**Results for Null Hypothesis Two Assumptions.** The first three assumptions for the independent \( t \)-test have been met: the dependent variable was continuous, the independent variable was dichotomous, and the study had independence of observations. No outliers were found in the data, as assessed by inspection of a boxplot. The Shapiro-Wilk test was conducted to test the assumption of normality. The data was not normally distributed for the control group \( (p = .001) \) nor for the treatment group \( (p = .025) \). With the assumption of normality violated, it was necessary to conduct the Mann-Whitney \( U \) test. "The Mann-Whitney \( U \) test is the alternative nonparametric test that may be used when the data assumptions required of the independent-samples \( t \) test cannot be met." (Aldrich & Cunningham, 2016). The first three assumptions for the Mann-Whitney \( U \) test were met: the dependent variable was continuous, the independent variable was dichotomous, and the study had independence of observations. It was then necessary to perform the final assumption test. The distributions of the data should follow the same shape. The histograms of the data
show that the curves between the control group and the treatment group were different shapes (Figure 11). This is a violation of the final assumption. Therefore, it was not possible to make inferences about the differences in medians between the two groups. It is, however, possible to interpret mean ranks of the change in scoring from the pretest to the posttest.

**Independent-Samples Mann-Whitney U Test**

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<td>40.71</td>
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<tr>
<td>Treatment</td>
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<td>46.21</td>
</tr>
</tbody>
</table>

*Figure 11: Histogram of CAP scores for the treatment and control groups.*

**Results.** A Mann-Whitney U test was performed to determine whether significant differences existed in the CAP scores of high school students taught using augmented reality and students taught using traditional methods. The dependent variable was the CAP scores. The independent variable was type of instruction. Data analysis revealed that the control group had a
mean rank of 40.71, while the treatment group had a mean rank of 46.21. The Mann-Whitney $U$ test shows that the distributions and mean ranks were not statistically significantly different regarding the change in achievement between the control and treatment groups ($U = 1025.000, p = .319$). Therefore, the null hypothesis was not rejected.

Table 3

*Independent-Samples Mann-Whitney U Test Summary*

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<th>Value</th>
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<tr>
<td>Total $N$</td>
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</tr>
<tr>
<td>Mann-Whitney $U$</td>
<td>1025.000</td>
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<tr>
<td>Wilcoxon $W$</td>
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<tr>
<td>Test Statistic</td>
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<td>Standard Error</td>
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<tr>
<td>Standardized Test Statistic</td>
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</tr>
<tr>
<td>Asymptotic Sig. (2-sided test)</td>
<td>.319</td>
</tr>
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</table>
CHAPTER FIVE: CONCLUSIONS

Overview

Many of the existing research studies involving augmented reality education had smaller sample sizes or lacked a control group for comparison, and this study sought to help fill that gap. Chapter Five provides a discussion of the study results, implications and limitations of the study, and recommendations for future research.

Discussion

The purpose of this quantitative pretest-posttest, non-equivalent control group quasi-experimental study was to determine if a statistically significant difference existed in student achievement and perceived learning of high school students based on the type of instruction. The control group was taught via traditional methods, which included the use of concrete three-dimensional figures and two-dimensional representations of three-dimensional figures. The treatment group was taught via augmented reality-based methods, which used three-dimensional figures represented using augmented reality technology. The sample was comprised of 87 high school Geometry students in Virginia high schools. Thirty-five participants received instruction using concrete three-dimensional figures. Fifty-two participants received instruction using augmented-reality technology in lieu of using the concrete three-dimensional figures.

Discussion for Research Question One

The primary research question for this study was to determine if a statistically significant difference existed in student achievement, as measured by the Three-Dimensional Figures section of the Geometry Standards of Learning Assessment released in 2014, of high school students taught using augmented reality and students taught using traditional methods while adjusting for pretest scores. Quade’s Rank Analysis of Covariance was conducted on the
primary research question. The findings show that there was not a statistically significant
difference in student achievement based upon instruction type. The results were not statistically
significant according to Quade’s Rank Analysis of Covariance, $F(1, 85) = .409, p = .524$.
However, students taught via augmented reality technology had improvements in achievement
according to the treatment pretest ($M = 2.00, SD = 1.52$) and treatment posttest ($M = 3.65, SD =
1.57$) results. Thirty-seven (71.2%) of the 52 students in the treatment group saw improved
results. The existing literature found increases in learning utilizing augmented reality technology
(Bergig et al., 2011; Birchfield & Megowan-Romanowicz, 2009; Botden et al., 2009; Campos et
al., 2011; Chang et al., 2013; Chiang et al., 2014; Enyedy et al., 2012; Estapa & Nadolny, 2015;
Liu & Tsai, 2013; Perez-Lopez & Contero, 2013; Santos et al., 2016; Tolentino et al., 2009).
While students in the treatment group showed some improvement, those in the control group
found similar improvement according to the control group pretest ($M = 1.11, SD = 1.02$) and
control group posttest ($M = 3.06, SD = 1.43$) results. Twenty-nine (82.9%) of the 35 students in
the control group saw improved results. Estapa and Nadolny (2015) and Perez-Lopez and
Contero (2013) were likewise unable to differentiate between the improved achievement of the
control group and the improved achievement of the treatment group.

This contradicts the results found by Chiang et al. (2014) and Yi Hsing and Jen-ch’iang
(2013), which found that the treatment group utilizing augmented reality technology performed
significantly better than the control group. The results of the current study are best summarized
by Campos et al. (2011) in the statement “the system didn’t make the learning process go wrong”
(p. 37). The results of the control group and treatment group do not show significant differences.
Discussion for Research Question Two

The secondary research question in this study sought to determine whether there is a difference in the perceived learning scores, as measured by the CAP Perceived Learning Scale, of high school students taught using augmented reality and students taught using traditional methods. The difference between the groups was not statistically significant according to the Mann-Whitney U test ($U = 1025.000$, $p = .319$). The CAP Perceived Learning Scale provides a total score ranging from 0 to 54. A score of 0 is the lowest possible score meaning that the participant did not perceive any learning gain. A score of 54 is the highest possible score meaning that the participant perceived the highest possible learning gain. Both the control group ($M = 48.43$, $SD = 14.04$) and the treatment group ($M = 50.38$, $SD = 10.36$) reported high scores on the CAP Perceived Learning Scale. These findings align with those of Thomas et al. (2010) and Ibili and Sahin (2015). Participants in both studies reported greater perceived learning.

Implications

Existing literature suggested that augmented reality could increase active engagement, motivate students, and provide enjoyment for learners as an exciting, novel technology (Chuang, 2014; Raphael, 2011), albeit without studying how this would impact student achievement. The call for the current research study came from several previous research studies: Cheng and Tsai (2013), who stated that “investigating how technology assists students’ learning is an important issue” (p. 450); Bergig et al. (2011) and Santos et al. (2016), who suggested that their augmented reality studies should be conducted on larger groups of individuals; Billinghurst and Dunser (2012), who asked “what is the real educational benefit from using this technology in the classroom?” (p. 60); Bergig et al. (2011), Billinghurst and Dunser (2012), and Santos et al.
(2016), who stated that augmented reality technology should be compared with another form of instruction. This research study serves to fill a gap in the literature.

Though in the current study the treatment group did not report statistically significant results compared to the control group, both groups did show similar improvement. This study sought to demonstrate that augmented reality-based instruction could provide significantly better results than traditional hands-on methods of instruction. While this did not occur, it seems that augmented reality-based instruction provided similar results to traditional hands-on methods of instruction. This has the potential to justify the use of augmented reality-based instruction in place of traditional hands-on methods of instruction, providing a way to differentiate learning and provide choice for students. The potential benefits of choosing augmented reality-based instruction include that the technology requires minimal storage space and maintenance. In some cases the technology may cost less than the physical manipulatives. Given that the control group and treatment group reported similar results, augmented reality may be included as a viable alternative for the classroom and provides instructors another pedagogical choice.

Limitations

The content taught within all six of the participating high school Geometry classes is prescribed by the Commonwealth of Virginia. Since students were populated into those classes prior to this study, there was not an opportunity for random assignment of participants. Students were selected from two high schools in the same Virginia region. It is assumed that the gender, racial, ethnic, socio-economic, and academic abilities are reflective of the population. The populations were only representative of a suburban/rural populations area in northern Virginia. Invalid inferences may result in generalizing the results of this study to dissimilar locations such as an urban school (Rovai et al., 2013). While teachers were chosen who taught two courses to
remove any extraneous variables which come from different instructors, teacher attitude toward
the instructional method, factors outside of the school, interruptions to learning, etc. could not be
controlled for in this study. The length of instruction, approximately two weeks, and the limited
amount of content covered during this time provides a limited opportunity to see significant and
generalizable results. It would be beneficial to have a larger sample size for future studies as
well.. Finally, this study was designed from a traditional teaching methodology-centered
perspective. Teachers were required to instruct the course using the traditional methods and
materials as they have done in the past. They were required to maintain the same instructional
methodology while replacing the traditional materials with augmented reality technology. This
has the potential to limit the impact of the augmented reality technology.

**Recommendations for Future Research**

Only one previous research study (Chiang et al., 2014) was found that performed studies
on larger groups of students, involved comparison groups, used similar instructional strategies,
and studied the effect of augmented reality technology on student achievement. Further research
is necessary to corroborate those findings. Given the results of this study, the researcher
suggests the following areas for future research:

- Expand the instructional phase to a longer duration.
- Research the connection between motivation using augmented reality and student
  achievement using augmented reality.
- Design a study from the augmented reality-centered focus. That is, design the instruction
to support the augmented reality technology in the treatment group with the control group
instructing using the same methods without augmented reality technology.
- Expand the sample size of the study.
REFERENCES


https://www.researchgate.net/publication/236461845_A_Survey_of_Augmented_Reality Challen ges_and_Tracking


Appendix A

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Paul

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University of Toronto
Dept. Mechanical & Industrial Engineering

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Permission to Reprint Figure 6: REFLCT's Virtual US Army Sergeant

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Fig. 2 An over the shoulder view of an animated virtual character, projected on a retroreflective surface by a REFLCT helmet from page 20

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## Appendix G

**Permission to Reprint Figure 7: e-Maps-based escape guidelines and Figure 8: Augmented reality-based escape guidelines**

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Figure 1: Screenshot of e-Maps-based escape guidelines and the left image of Figure 2: Screenshot of AR-based escape guidelines. Both found on page E19

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I am working under the supervision of Dr. David Nelson. I am writing to request your permission to conduct my research in [ ] Public Schools.

Participating divisions will be asked to provide a summary of participant ages, grade levels, genders, number of students with Individualized Education Program, and number of students labeled Gifted and Talented for each participating class. This data will be stripped of identifiers.

Participating teachers will be asked to receive training on the use of the augmented reality application from the researcher, pre-assess student knowledge of three-dimensional figures, provide instruction on three-dimensional figures, post-assess student knowledge of three-dimensional figures, and assess students’ perceived learning through the Cognitive, Affective, Psychomotor (CAP) Perceived Learning Scale (Rovai et al., 2009).

Students will be asked to complete a pre-assessment on three-dimensional figures, receive instruction on three-dimensional figures, complete a post-assessment on three-dimensional figures, and complete the CAP Perceived Learning Scale (Rovai et al., 2009).

The data will be used to determine whether augmented reality technology provides a benefit over traditional methods of teaching three-dimensional figures. Participants will be presented with informed consent information prior to participating. Taking part in this study is completely voluntary, and participants are welcome to discontinue participation at any time.

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Appendix J

CAP Perceived Learning Scale

Directions: A number of statements that students have used to describe their learning appear below. Some statements are positively worded and others are negatively worded. Carefully read each statement and then place an X in the appropriate column to the right of each statement to indicate how much you agree with the statement, where lower numbers reflect less agreement and higher numbers reflect more agreement. There is no right or wrong response to each statement and your course grade will not be influenced by how you respond. Do not spend too much time on any one statement but give the response that seems to best describe the extent of your learning. It is important that you respond to all statements.

Using the scale to the right, please respond to each statement below as it specifically relates to your experience in this course.

Not at all 0 1 2 3 4 5 6
Very much so

1. I can organize course material into a logical structure
2. I cannot produce a course study guide for future students.
3. I am able to use physical skills learned in this course outside of class.
4. I have changed my attitudes about the course subject matter as a result of this course.
5. I can intelligently critique the texts used in this course.
6. I feel more self-reliant as the result of the content learned in this course.
7. I have not expanded my physical skills as a result of this course.
8. I can demonstrate to others the physical skills learned in this course.
9. I feel that I am a more sophisticated thinker as a result of this course.

Appendix K

CAP Perceived Learning Scale Scoring Key

Total CAP Score

Score the test instrument items as follows:

- Items 1, 3, 4, 5, 6, 8, and 9 are directly scored; use the scores as given on the Likert scale, i.e., 0, 1, 2, 3, 4, 5, or 6. Items 2 and 7 are inversely scored; transform the Likert scale responses as follows: 0 = 6, 1 = 5, 2 = 4, 3 = 3, 4 = 2, 5 = 1, and 6 = 0.

- Add the scores of all 9 items to obtain the total CAP score. Scores can vary from a maximum of 54 to a minimum of 0. Interpret higher CAP scores as higher perceptions of total learning.

CAP Subscale Scores

Add the scores of the items as shown below to obtain subscale scores. Scores can vary from a maximum of 18 to a minimum of 0 for each subscale.

- Cognitive subscale: Add the scores of items 1, 2, and 5.
- Affective subscale: Add the scores of items 4, 6, and 9.
- Psychomotor subscale: Add the scores of items 3, 7, and 8.

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Appendix L

PARENT/GUARDIAN CONSENT AND STUDENT ASSENT FORM

The Effect of Augmented Reality on Learning in the Mathematics Classroom

Justin Maffei

Liberty University
School of Education

Your child is invited to be in a research study comparing the use of augmented reality technology and the use of traditional hands-on instruction of three-dimensional figures. He or she was selected as a possible participant due to being a high school geometry student in Northern Virginia. Please read this form and ask any questions you may have before agreeing to allow your child to be in the study.

Justin Maffei, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to determine whether augmented reality technology has an impact on student achievement and/or perceived learning. A number of classrooms will be observed for the study. In each participating school, a teacher's classes will be chosen if he or she teaches two high school geometry classes. This will help to avoid the instructor becoming a potential confounding variable. One class will become a part of the control group and be taught without the use of augmented reality technology. The other class will become part of the treatment group and will be taught through the use of augmented reality technology. This data will allow the researcher to determine whether augmented reality technology can improve student achievement and perceived learning, allowing administrators to determine whether funding should be allocated to purchasing and implementing the use of augmented reality technology in classrooms.

Procedures: If you agree to allow your child to be in this study, I would ask him or her to do the following things:

1. Complete a pretest on three-dimensional figures, which will take approximately 30 minutes.
2. Receive instruction on three-dimensional figures through the use of either augmented reality or traditional methods which will take approximately 2-3 weeks.
3. Complete a posttest on three-dimensional figures, which will take approximately 30 minutes.
4. Complete the Cognitive, Affective, Psychomotor (CAP) Perceived Learning Scale (Rovai et al., 2009) which will take approximately 10 minutes.

Groups will be assigned randomly. Your child may or may not receive the augmented reality technology intervention as part of his or her participation.

Risks: The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life.
Benefits: If augmented reality instruction is shown to improve student learning, students in the experimental group may experience improved academic achievement. Students in the control group should not expect to receive direct benefits.

Benefits to society include allowing administrators to determine whether funding should be allocated to purchasing and implementing the use of augmented reality technology in classrooms.

Compensation: Your child will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records.

- Requested archival data (class summaries of participant ages, grade levels, genders, number of students with Individualized Education Program, and number of students labeled Gifted and Talented) will be stripped of identifiers prior to being sent to the researcher.
- Student names will be replaced with a sequential numbering system.
- Data will be stored on a password protected computer and a copy will be kept on an external storage device that will be stored in a locking security box off site away from any of the classroom locations. Data may be used in future presentations. After three years, all electronic records will be deleted.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect his or her current or future relations with Liberty University or his or her current school and division. If you decide to allow your child to participate, he or she is free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If you or your child choose to withdraw from the study, please contact the researcher at the email address/phone number included in the next paragraph. Should you or your child choose to withdraw, data collected from your child will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Justin Maffei. You may ask any questions you have now. If you have questions later, you are encouraged to contact him at jmaffei3@liberty.com. You may also contact the researcher’s faculty advisor, Dr. David Nelson, at dcnelson3@liberty.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher you are encouraged to contact the Institutional Review Board, 1971 University Blvd, Green Hall 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information for your records.
Appendix M

IRB Approval

Liberty University
Institutional Review Board

November 26, 2018

Justin Maffei
IRB Approval 3163.112618: The Effect of Augmented Reality on Learning in the Mathematics Classroom

Dear Justin Maffei,

We are pleased to inform you that your study has been approved by the Liberty University IRB. This approval is extended to you for one year from the date provided above with your protocol number. If data collection proceeds past one year or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Your study falls under the expedited review category (45 CFR 46.110), which is applicable to specific, minimal risk studies and minor changes to approved studies for the following reason(s):

Your study involves surveying or interviewing minors, or it involves observing the public behavior of minors, and you will participate in the activities being observed.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,

G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
The Graduate School