ABSTRACT

THORNTON, TIMOTHY ROBERT. Understanding How Learner Outcomes Could be Affected through the Implementation of Augmented Reality in an Introductory Engineering Graphics Course. (Under the direction of Dr. Matthew Lammi and Dr. Aaron Clark).

The study was designed to investigate the implementation of augmented reality in an introductory engineering graphics course. The study was driven by three research questions that examined how augmented reality influenced student motivation, enhanced the learning experience, and/or affected the spatial visualization ability of students.

The sample used in the study consisted of 50 (N = 50) students from two different sections of an introductory engineering graphics course at North Carolina State University. The augmented reality intervention was conducted over six sessions that occurred on a weekly basis. Students were required to complete a weekly assignment with the assistance of augmented reality.

To measure the effectiveness of the augmented reality system used in the study multiple data collection methods were incorporated. This consisted of two different measurements: MSLQ, PSVT-R, and questions used in the approach of basic interpretive methodology on the student experience with augmented reality. Both the MSLQ and PSVT-R used a pre- and post-test format, while the seven-questions were administered at the conclusion of the study.

The results from the two instruments and student questions were mixed. A paired t-test was used to measure the mean scores of the MSLQ and PSVT-R. The results of the MSLQ (p = 0.57) showed no significant difference between pre- and post-test scores. The results of the PSVT-R (p < .01) showed a significant difference between the pre- and post-test scores, although this could not be solely attributed to the implementation of augmented
reality. The basic interpretive questions highlighted several benefits associated with the inclusion of augmented reality. The responses indicated that augmented reality was beneficial in aiding visualization ability, allowing students to obtain additional perspectives through manipulation, and as a motivational tool.
Understanding how Learner Outcomes Could be Affected through the Implementation of Augmented Reality in an Introductory Engineering Graphics Course

by

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BIOGRAPHY

Timothy Robert Thornton was born in Danville, IL on August 12, 1975. He spent his early years in Danville before moving to Charleston, SC during his sophomore year of high school. After graduating from Middleton High School, Timothy attended several schools and proceeded to move around the country. He finally settled down and graduated from Guilford College with a degree in Business Administration. Upon completion, he moved to Florida where he spent the next couple of years. After living in Florida, he returned to North Carolina and received his Master’s in the Art of Teaching in Business and Information Technology from East Carolina University. He then took a position teaching business at Monroe High in Monroe, NC. Timothy remained in Monroe for one year before again returning to school. He applied and was accepted to the Technology Education Program at North Carolina State University. During his time in the program, he served as a teaching assistant within the department, teaching digital media, and emerging technology courses.
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CHAPTER ONE: INTRODUCTION

The purpose of this study was to investigate how the inclusion of augmented reality in an introductory engineering graphics course influenced motivation, affected the spatial visualization ability of students, or enhanced the learning experience. Ronald T. Azuma, a leader within the field of augmented reality, defined augmented reality as allowing “the user to see the real world, with virtual objects superimposed upon or composited with the real world” (1997, p. 355). Augmented reality allows the user to take an active role in the learning process, which can be important since new methods of instruction should involve active exploration, construction, and learning of the material (Fosnot, 2005). Because of its potential capabilities, various teachers and researchers have begun experimenting with the use of augmented reality to improve instruction (Liarokapis & Anderson, 2010).

Background

The study was designed and built upon previous research surrounding the use of augmented reality in engineering graphics courses. The intention was to investigate the effectiveness of augmented reality as a supplemental learning tool in an introductory engineering graphics course. The study investigated the impact of augmented reality from three different perspectives. For one, the study was designed to determine how augmented reality affected the motivational attitudes of students. Additionally, the study examined the role of augmented reality as a tool to improve spatial visualization skills of students. Finally, the study investigated how students were able to manipulate, experiment, and engage with the augmented models.
Engineering Graphics

Engineering Graphics courses allow students to acquire, develop, and utilize highly defined spatial skills. The spatial skills developed in these courses continued to be refined and serve as a foundation for student success. These spatial skills are important in engineering and can be improved through appropriate activity (Olkun, 2003). An important spatial skill utilized in engineering graphics courses is visualization ability (Alias, Black, & Gray, 2002; Miller, 1999; Sorby & Baartmans, 2000). Spatial visualization skills allow users to mentally create and manipulate images. McGee (1979, p. 893) defines spatial visualization as “the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimuli.”

Students are to continually develop their visualization skills if they are to reach their capabilities and understand core competencies. A student’s spatial visualization skills should improve with purposeful experience as he/she is exposed to more complex problems (Gorska, Sorby, & Leopold, 2009; Bertoline, Wiebe, Hartman, & Ross, 2011). Students who struggle to grasp visual concepts may possibly struggle within the course and are prone to failure or withdrawal. The use of augmented reality as a visual aid could offset this by allowing students to manipulate their models and achieve a greater visual understanding of the object being modeled.

The field of engineering graphics education is continuously focusing on new methods to improve learner outcomes. There is a constant need to research and develop new methods for delivering instruction and with it a need to improve learner outcomes within engineering graphics. This may be in part accomplished through the integration of technology as a motivational tool to enhance the learning process. “The ability to do well and see relevance
in what is being taught is also paramount to a student’s motivation in a course, like a fundamentals of engineering graphics” (Clark, Ernst & Scales, 2009, p. 9).

**Augmented Reality**

Augmented reality operates by augmenting the landscape with digital information that allows the user to gain additional information about their surroundings, or through the enhancement of an object (Billinghurst, Kato & Poupyrev, 2001). Augmented reality enhances an individual’s physical environment through a collaboration of the virtual and real environments (Azuma, 1997). The viewer is given the ability to merge their physical environment into a pre-designed virtual environment (Barfield & Caudell, 2001). Augmented reality allows users to turn models into three-dimensional objects that become interactive, creating a more authentic learning experience with the real world environment serving as the baseline and backdrop to which virtual information is supplemented (Goldiez, Livingston, Dawson, Brown, Hancock, Baillot, & Julier, 2004).

There are several components that comprise an augmented reality system. Paramount is a high processing computer (Adams, 2004). The computer must be able to process information very quickly due to the fact that streaming content is constantly changing and there must be a confluent alignment between the virtual objects and the real world (Azuma, 1997). Through technical innovation, processors capable of running augmented reality software can now be found on personal computers, iPads, and smart phones. The system also requires a viewing device such as a webcam, camera, or head mounted display, as well as a marker. A fully functioning system superimposes three-dimensional virtual images onto real
world objects or environments when the viewing device interacts with the marker (Poonsri, 2011).

Evidence has indicated that augmented reality is a useful tool in education (Sumadio & Rambli, 2010). In education, the use of augmented reality software allows students to take an active role in the learning process. Accordingly, students are engrossed and motivated to learn new skills to solve problems (Norman & Spohrer, 1996). Studies have indicated that augmented reality can be a motivational factor in increasing interest and curiosity, leading to improved academic performance (Campos, Pessanha, & Jorge, 2011; Yusoff, Zaman, & Ahmad, 2011; Shea, Mitchell, Johnston, & Dede, 2009). Augmented reality has the potential to become a pedagogical tool that is motivational for students as it enhances the learning experience and allows for experimentation, manipulation, and engagement.

Motivation

Motivation is an important component in the learning process. A student who is motivated will be engaged in the learning process and obtain more from the educational experience, whereas an unmotivated student will gain little from a course and the learning experience will be minimal (Ames, 2003; Sull, 2007). In order for a student to be motivated, they have to have a vested interest in the subject. Students need to feel that the work is meaningful, and there needs to be a conceptual understanding of the content (Seifert, 2004). A conceptual understanding is important in engineering graphics where students are required to conceptualize a model and then recreate it using computer aided design (CAD). Based on the above information it can be hypothesized that augmented reality has the potential to
affect the motivation of students in an introductory engineering course (Allison & Hodges, 2000; Di Serio, Ibáñez, & Kloos, 2012; Lee, Wong, & Fung, 2010).

**Methodology**

This study was conducted at North Carolina State University in the spring of 2013. There were a total of 50 students who participated in the study. The participants were required to complete six assignments with the assistance of augmented reality. The augmented reality software used for the study was Augment®. The software was used in conjunction with an iPad and an augmented reality marker. The effectiveness of augmented reality was examined via multiple data collection instruments and basic interpretive method that consisted of seven questions.

The participants were students drawn from two separate sections of the same graphic communications course. The two sections were an introductory course titled Graphic Communications 120 *Foundations of Graphics* (GC 120). In general, an introductory engineering course consists primarily of first year engineering students (Crown, 2001). This is often their first exposure to engineering graphics at the university level and serves as a foundational course. Each section that participated in the study contained approximately 60 students, was taught by the same instructor, followed the same syllabus, and had identical requirements. The researcher used a design study in which all participants who took part in the study received the treatment of augmented reality.

The augmented reality software, Augmentedev®, was introduced during the initial presentation of the study to both course sections. The researcher highlighted the basic functions of the technology and went into further detail during the first required session.
Throughout the first session, the researcher individually guided each student through a tutorial and modeled how to effectively use the software. The augmented reality software was used with six different assignments for a total of six 90-minute sessions. Each of the six assignments was designed to increase in complexity and difficulty and reinforce previously learned engineering principles.

The data collection methods used in this study incorporated three different assessments. All participants were required to complete the Motivated Strategies for Learning Questionnaire (MSLQ) and Purdue Spatial Visualization Test for Rotations (PSVT-R) in a pre- and post-test format, as well as a basic interpretive approach on the effectiveness of augmented reality. The pre-test for the PSVT-R was given two weeks prior to the start of the treatment and the pre-test MSLQ was given during the first day of the treatment. The MSLQ post-test was administered during the last treatment session, and the PSVT-R post-test was administered three weeks later. All participants completed the questions during the last treatment session, which consisted of seven-questions regarding the participant’s experience using augmented reality.

The MSLQ is a self-reported instrument containing 81 questions within two sections containing 15 subscales. The MSLQ was chosen for this study because it was designed to measure a student’s motivation in a college classroom (Pintrich, Smith, Garcia, & Mckeachie, 1993). The instrument is designed to assess participants’ motivational orientation and use of cognitive learning strategies (Pintrich et al., 1993; Salisbury-Glennon & Stevens, 1999). The two sections contained within the instrument are motivation orientation and learning strategies. The motivation orientation section consists of 31 questions and includes
three components: Value, expectancy, and affect. The value component consists of three subscales including: Intrinsic goal orientation, extrinsic goal orientation, and task value. The expectancy component contains two subscales, which are control of learning beliefs and self-efficacy for learning and performance. The affect component only includes one subscale, which is test anxiety (Pintrich, Smith, Garcia, & McKeachie, 1991).

The learning strategies section contained a total of 50 questions and three scales: Cognitive strategies, meta-cognitive strategies, and resource management (Credé & Phillips, 2011). The cognitive scale addressed strategies students use to process information from lectures and texts and includes four subscales (Pintrich et al., 1993). The meta-cognitive scale addressed strategies student use to control and regulate their cognition and includes one subscale (Pintrich et al., 1993). The resource management scale addressed how students manage other resources not associated with cognition and includes four subscales (Pintrich et al., 1993).

For the purpose of this study only the motivation orientation component was utilized. Within the 31-question motivation orientation section the affective component was omitted. This component was omitted because it assesses test anxiety, which was not addressed in this study. The entire learning strategies section was also excluded because it was not relevant to the research.

The PSVT is a spatial ability test developed by Roland Guay (Guay, 1980). The PSVT was used in this study because of its effective ability to measure spatial visualization skills (Branoff, 2009). The PSVT consists of three sections: Developments, rotations, and views. The only section of the PSVT included in this study was the rotations (PSVT-R).
According to Ault and John (2010) the majority of graphic researchers only use the object rotations portion of the PSVT. The PSVT-R is a spatial ability test that provides students with an object and then rotates this object and asks the student to select the correct rotation (Guay, 1980). The instrument is designed to evaluate the student’s ability to visually comprehend the rotation of the object. The instrument includes 30 multiple choice questions consisting of 13 symmetrical and 17 nonsymmetrical figures of 3-D objects all of which are displayed in a 2-D isometric format (Maeda & Yoon, 2011).

The basic interpretive approach consisted of seven questions. The questions were designed to analyze the effect of augmented reality on learner outcomes. The questions were administered at the conclusion of the study and allowed the participants to provide feedback on their exposure to augmented reality. The questions were tailored to address issues surrounding the use of augmented reality as a motivational tool that allows for experimentation, manipulation, and engagement. The questions also gauged the student’s perception of augmented reality to assist the visualization of the assignments.
Students who attended the make-up session completed the MSLQ post test and survey on their experience using augmented reality.

5th Session with augmented reality

Make-up Session with augmented reality for students who missed a session

4th Session with augmented reality

Students who attended the make-up session completed the MSLQ post test and survey on their experience using augmented reality.

3rd Session with augmented reality

2nd Session with augmented reality

Students completed the PSVT-R post test and survey on their experience using augmented reality.

1st Session with augmented reality

Pre-test MSLQ completed

Research study presented to both sections of GC 120, and informed consent forms were collected.

IRB Approved

Students complete PSVT-R pre-test

Survey designed PSVT-R and MSLQ selected

Review of literature

Figure 1. Augmented Reality Intervention
Data Analysis

After completing the administration of all tests utilized in the study, the data was collected and analyzed. The cumulative results of the pre- and post-test MSLQ were analyzed using descriptive analysis and a paired t-test (Salisbury-Glennon & Stevens, 1999). Additionally, there were five subscales of the MSLQ examined: intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs and self-efficacy for learning and performance. A paired t-test was also used to analyze and compare the results from pre- and post-test PSVT-R (Medina, Gerson, & Sorby, 1998). A Pearson correlation was included to determine if there was a relationship between the post-test scores on the MSLQ and post-test scores on the PSVT-R (Ernst & Clark, 2012). Finally, the responses of the questions were gathered and coded thematically. The students’ responses were sorted by key words and then the keywords were grouped together into categories. After coding and reviewing the responses multiple times, trends and themes were noted. These trends and themes were measured against existing literature and theory.

Statement of the Problem

The problem this study addressed was how augmented reality influenced learner motivation and outcomes in an introductory engineering graphics course. One of the purposes of this study was to determine if the inclusion of augmented reality as a pedagogical tool to model objects in an engineering graphics course affected motivation, spatial visualization skills, and learning outcomes.
Significance of the Study

The significance of the study is that learner outcomes and motivation have the potential to be enhanced through the implementation of augmented reality in an introductory engineering graphics course. As augmented reality is a relatively new technology there has been little research conducted on the application of augmented reality in engineering graphics communications education (Liarokapis & Anderson, 2010; Shelton & Hedley, 2002). Augmented reality is a technology that has the potential to provide multiple uses in the classroom, as well as affect the motivational attitudes of students (Dunleavy, Dede, & Mitchell, 2009). Through augmented reality, learners are provided with an interactive three-dimensional model allowing for a greater manipulation, experimentation, and engagement of objects by creating an additional augmented point of view and perspective.

Research Questions

1. Will the implementation of augmented reality affect the motivational attitude of students in an introductory engineering graphics course as measured by the MSLQ? If so, how?

2. Will the implementation of augmented reality improve the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R? If so, how?

3. What are the students learning experiences with augmented reality?
   a. How does the use of augmented reality promote experimentation including: examination, comparison, and problem solving?
b. How does the use of augmented reality allow the student to manipulate the models by providing the following: multiple viewing perspectives, rotation, and scalability?

c. How does augmented reality engage students through: active participation, kinesthetic learning, and inquiry?

**Hypothesis**

Learner outcomes will be positively affected through the implementation of augmented reality as a supplemental tool that allows for experimentation, manipulation, and engagement in an introductory engineering graphics course. The focus of this study is an understanding of the impact that augmented reality can have in an engineering graphics classroom at the postsecondary level. The two null hypotheses have been developed concerning the use of augmented reality in a graphics communication course at North Carolina State University.

**Null Hypothesis**

1. The implementation of augmented reality will not have a statistically significant effect on the motivational attitudes of students in an introductory engineering graphics course as measured by the MSLQ.

2. The implementation of augmented reality will not have a statistically significant improvement on the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R.
Limitations

The following limitations were identified for the study:

1. Participants in the study were students in Graphic Communications 120 at North Carolina State University and were not selected randomly.
2. Students enrolled in GC 120 at North Carolina State University are not a representative sample of engineering students in the United States.
3. The study was limited to undergraduate students taking a Foundation of Engineering Graphics course at North Carolina State University during the spring of 2013.
4. Augmentedev® software was the only augmented reality application that was used for the experiment.
5. The Augmentedev® software used in the study was free and did not include all of the features of the paid version.
6. The augmented reality software was only used on iPads.

Assumptions

There are several assumptions that are taken into account for the purpose of the research

1. The participants were actively engaged.
2. The instructor taught both sections similarly.
3. Each of the classes received the same amount of time to work on each task once augmented reality was introduced.
4. The Purdue Spatial Visualization Test for Rotations (PSVT-R) is a valid measurement of a student’s visualization skills.

5. The Motivated Strategies for Learning Questionnaire (MSLQ) is a valid measurement of a student’s motivational attitude.

6. Participants of the study had little experience with augmented reality.

7. Students only used augmented reality during the weekly laboratory period.

8. The use of augmented reality only occurred during six class periods.

9. The instructor did not use augmented reality during other instruction times.

10. Only the researcher modeled augmented reality.

11. Only the researcher worked with students during the process.

12. The capabilities of the augmented reality software Augmentedev® have limitations.

13. Augmented reality was not designed to improve computer aided design techniques.

**Definitions**

*Augmented Reality (AR):* Computer application that allows users to view the real world with a superimposed virtual image layered over top (Azuma, 1997).

*Augment®:* An augmented reality application created by Augmentedev®, a company located in France, that specializes in the development of Virtual and Augmented Reality applications. The software is a mobile application allows a simple way of integrating digital content in real world through the visualization of three-dimensional products through a mobile device (http://www.augmentedev.com/home.php#home).
Engineering graphics: “A communications method used by engineers and other technical professionals during the process of finding solutions to technical problems. Engineering graphics are produced according to certain standards and conventions so that they can be read and accurately interpreted by anyone who has learned those standards and convictions” (Bertoline et al., 2011).

Graphic communications: The visual communication of information through the use of graphic elements such as words, drawings, photography, or a combination of these (Prust, 2003).

Introductory Engineering Graphics Course: “Introductory course providing orientation to language of graphics for students majoring in any field. Designed to help develop ability to use Computer-Aided Design (CAD) within the context of a concurrent design process to understand how everyday objects are designed, analyzed and created. Emphasis placed on decision-making processes involved with creating geometry and development of modeling strategies that incorporate intentions of designer” (North Carolina State University, 2012).

Motivational Strategies Learning Questionnaire (MSLQ): The MSLQ is an 81-question Likert-type instrument that is designed to assess participants’ motivational orientation and use of cognitive learning strategies (Salisbury-Glennon & Stevens, 1999).

Spatial Visualization: “The ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimuli” (Mcgee, 1979, p. 893).
Technology integration: The incorporation of technology resources and technology-based practices into the daily routines, work, and management of schools (Technology in Schools Task Force, 2002).

Chapter Summary

The goal of the study was to understand how learner motivation, affective traits, and instructional outcomes could be affected through the implementation of augmented reality in an introductory engineering graphics course. The study was conducted in two introductory engineering graphics sections during the spring semester in 2013. The augmented reality software, Augmentedev®, was used to model objects throughout the semester in six different assignments that increased in complexity for a total of six weeks. The MSLQ, PSVT-R, and seven questions on the students’ experience using augmented reality were the three methods of data collection used to determine the impacts of augmented reality. The MSLQ was used to determine if the inclusion of augmented reality affected the motivational attitudes of students, the PSVT-R was used to determine whether or not augmented reality improved visualization skills, while the structured questions delved into the student experience of augmented reality.
CHAPTER TWO: LITERATURE REVIEW

The purpose of the study was to investigate how learner outcomes could be affected through the implementation of augmented reality in an introductory engineering graphics course. The role of mixed reality within education was presented in the review of literature. Mixed reality includes both augmented and virtual reality. The role of augmented reality within education was further examined through the identification of relevant research studies, prior methodologies, and the implications from the collection of these studies. In addition, the role of mixed reality and other technologies within graphic communication education were detailed. This included analyzing the use of new technologies in graphic communications, their effect on spatial visualization, and resulting impact on student motivation. The identification of multiple motivational strategies that connect the use of augmented reality to improved learner outcomes in an engineering graphic course was then detailed. The chapter concludes with a description of both the MSLQ and PSVT-R and by providing the rationale for the use of each of the instruments in this study.

**Mixed Reality**

Mixed reality is defined as the merging of real and virtual worlds to create new environments in which users can interact with virtual objects in real environments (Milgram and Kishino, 1994) (Figure 2). The origins of mixed reality can be traced back to the rise of computers and the *Sensorama* machine developed by Morton Heilig in 1962 (Strickland, 2007). This mechanical simulator recreated visual, audio, and sensory affects leading to the development of virtual and augmented reality.
Figure 2. Mixed Reality Spectrum (Milgram, Takemura, Utsumi, Kishino, 1995)

Virtual Reality in Education

The technological predecessor of augmented reality is virtual reality. Studies have linked the use of virtual reality to increased motivation (Allison and Hodges, 2010; Lee et al., 2010; Virvou, Katsionis, & Manos 2005), improved training (Sowndararajan, Wang, & Bowman, 2008), and assistance in analyzing simple and complex problems (Roussou, Oliver, & Slater, 2006). Augmented reality separated from the realm of virtual reality in the early 1990s, but they still share several of the same technologies. Figure 2 provides a visual explanation of augmented reality in relation to the realm of mixed reality. Augmented reality is a blend of real and virtual environments, with the real environment on one end of the spectrum and virtual environment on the opposite end. In a virtual reality system the user is completely immersed in a computer-created environment and there is no interaction with the real world (Goldiez et al., 2004). The virtual world is then viewed through glasses or a head mounted display. Within the virtual environment the user is able to manipulate objects or
perform tasks. The creation of augmented reality comes from the blending of virtual information onto a real environment.

**Similarities Between Virtual Reality and Augmented Reality**

There are several similarities between augmented reality and virtual reality systems. According to Kaufmann (2003) both augmented reality and virtual reality can be effectively used in the classroom; however, additional research is necessary to determine how best to implement these technologies. Due to the similarities between the two technologies, many of the research findings on virtual reality are applicable to augmented reality and to the present study. From a technical standpoint, both systems incorporate virtual imagery, require a powerful computer for processing and graphics, and require a viewing device. Each system uses a viewing device to immerse the user into a digital world where the user is able to interact with the environment. These characteristics allow both technologies to be interactive and immersive while providing information sensitivity (Yuen & Johnson, 2011).

**Reasoning for Selecting Augmented Reality**

Although virtual and augmented reality shares several of the same characteristics, several differences exist as well. These differences coupled with limitations associated with implementing virtual reality in the classroom provide the rationale for selecting augmented reality as opposed to virtual reality for the present study (Pantelidis, 2010).

The major difference between the two systems is that in a virtual reality system the entire environment is virtually created with no real world interaction (Goldiez et al., 2004). The student becomes isolated from the outside world and is encompassed in a controlled virtual environment. Augmented reality on the other hand creates an environment that
encompasses both real and virtual worlds (Biocca, Owen, Tang, & Bohil, 2006). The seamless integration of real and virtual worlds allows students to work in the real world while interacting with virtual objects.

Kaufmann and Schmalstieg (2002) noted that there has been no progress made on a universal virtual reality system for educational purposes. There are several limitations to the use of virtual reality in the classroom. In order to create effective virtual reality; the user’s entire environment must be virtual. If the virtual environment is not fully immersive the authenticity of the exercise can be hampered. Virtual reality software needs to be detailed and immersive which takes a great deal of time and effort to be fully encompassed in a virtual environment (Allison & Hodges, 2000). As a result, a virtual reality system can be expensive to develop and implement (Pantelidis, 2010; Waller & Knapp, 1998). On the contrary, augmented reality does not require an immersive environment and has a lower cost of implementation (Goldiez et al., 2004). The only cost associated with the augmented reality system used in this study was the iPads. The iPads used in the study were provided by the media center at North Carolina State University. While the augmented reality software and makers were downloaded for free from Augmentedev®. Since augmented reality combines real and virtual environments there is not a need to completely develop a world in which to use augmented reality. This makes the use of augmented reality more time efficient and cost effective.

**Augmented Reality in Education**

Augmented reality has begun to capture the attention of educational researchers (Yusoff, Zaman, & Ahmad, 2011). Empirical research on the implementation of augmented
reality within the field of education has been limited, but has been increasing in the past few years (Klinker, Ahlers, Breen, Chevalier, Crampton, Greer, Koller, Kramer, Rose, Tuceryan, & Whitaker, et al., 1997). The research that has been conducted crosses multiple content areas, with disciplines ranging from engineering to science. The implementation strategies for augmented reality have also varied greatly. Through these studies, researchers are beginning to identify potential uses of augmented reality and design effective instruction that incorporates this technology (Dunleavy et al., 2009; Fehrig, 2006).

**Research Studies**

Numerous studies have been conducted to examine the use of augmented reality in education. Their primary focuses have been on motivation, spatial ability, and learning experiences. These studies have been conducted across multiple content areas with varying grade levels. Each of these studies detailed in the review of literature have advanced the field of augmented reality and provided the blueprints for this study.

Several studies analyzed the influence of an augmented reality system on student motivation in the learning process. These studies examined the effect through various methods of implementation. Studies by Campos, Pessanha, and Jorge (2011) and Frietas and Campos (2008) evaluated the effectiveness of an augmented reality game to enhance learning. Larsen, Buchholz, Brosda, and Bogner (2011) examined the pedagogical effectiveness of an augmented reality system in a science course to better understand concepts. Di Serio et al. (2012) compared an augmented reality system to a traditional presentation. Finally Allison and Hodges (2000) and Lee et al. (2010) looked at how a virtual reality system could assist in the education process.
Multiple studies have explored the potential of augmented reality to positively affect spatial visualization skills. Both Martín-gutiérrez, Saorín, Contero, and Alcañiz (2010) and Medicherla, Chang, and Morreale (2010) explored the potential of augmented reality to improve the visualization skills of mechanical engineering students. Huffman and Miller (2012) attempted to determine if augmented reality blocks could be used as a visualization tool.

Two foundational studies on the use of augmented reality to improve spatial visualization ability were conducted by Kaufmann and Schmalstieg (2002) and Shelton and Hedley (2002). These studies provided the initial blueprint for the inclusion of augmented reality in the classroom while also promoting the potential benefits of augmented reality. Both of these studies were instrumental in the development of self-designed augmented reality software. Both analyzed the potential of augmented reality to influence the spatial ability of students. Kaufmann and Schmalstieg (2002) created an augmented reality system that required students to use spatial skills to solve problems. The study by Shelton and Hedley (2002) examined the teaching of complex spatial concepts and content through the use of augmented reality.

The use of augmented reality to impact student learning through manipulation, experimentation, and engagement has been evaluated in several studies. Initially, studies focused on the use of manipulation to allow users to analyze objects from multiple viewing perspectives, virtually rotate objects, and use scalability to zoom in and out to examine specific features. This led to studies on experimentation and engagement. A study by Núñez, Quirós, Núñez, Carda, and Camahort (2008) researched the impact an augmented reality
system can have on the learning experience through manipulation, experimentation, and engagement.

The ability of augmented reality to assist in the learning process through manipulation was examined in several studies. Studies by Chen, Chi, Hung, and Kang (2011a) and Kaufmann and Schmalstieg (2003) used augmented reality to assist with 2-D and 3-D objects and software. Both Sin and Zaman (2010) and Woods, Billinghurst, Looser, Aldridge, Brown, Garrie, and Nelles (2004) had participants manipulate and interact with virtual models. Allen, Regenbrecht, and Abbot (2011) examined how the ability of augmented reality to rotate objects affected learning. Finally, Chen (2006) conducted a study to understand how students interacted with augmented reality.

Multiple studies have examined the effectiveness of augmented reality in enhancing the learning process through experimentation and engagement. Within these studies, participants were able to use augmented reality as a visual tool to examine, compare, and explore educational content. A study conducted by Salmi, Kaasinen, and Kallunki (2012) provided a kinesthetic learning experience for the participants by allowing them to interact physically and mentally with learning scenarios. This approach was shared by Kerawalla, Luckin, Seljeflot, and Woolard (2006) who explored the potential for augmented reality on inquiry based learning, and Banu (2012) who used an augmented reality system to create interactive simulations to foster learning. Gelenbe, Hussain, and Kaptan (2005) used augmented reality as an experimental tool to ask “what if” questions by allowing students to view objects from multiple perspectives and then compare and evaluate results in order to predict capabilities and limitations of their projects. Both Dunleavy et al. (2008) and Núñez
et al. (2008) researched how augmented reality can affect student engagement. Dunleavy et al. (2008) highlighted the effectiveness of a mobile augmented reality system in a school setting to engage learners through the provision of active learning while Núñez et al. (2008) analyzed student engagement through the inclusion of augmented reality to solve problems.

The effect of augmented reality in assisting student learning by reducing the time spent on tasks was examined in various studies by (Balcisoy, Kallmann, Fua & Thalmann, 2000; Biocca et al., 2006; Henderson & Feiner, 2009). Each of the studies incorporated augmented reality in a different fashion. Balcisoy et al. (2000) incorporated an augmented reality system into manufacturing, Biocca et al. (2006) into a guidance system, and Henderson and Feiner (2009) in maintenance.

**Methodology Strategies Utilized**

The methodologies used in the studies analyzed in the review of literature varied greatly. The combination of methodologies did not reveal a clear design plan for the development of this study, but it did present several different possibilities. The studies reviewed implemented augmented reality in several different content areas, including multiple participants, with great variance in sample size, and incorporated several different measures of assessment.

The compilation of studies revealed four educational content areas in which augmented reality has been researched. The first content area examined was engineering (Borrero & Márquez, 2011; Chen, Feng, Mo, Cheng, Guo, and Huang, 2011b; Huffman & Miller, 2012; Martín-gutiérrez et al., 2010;). Another major content area was mathematics where Kaufmann and Schmalstieg (2003) studied 3-D geometry and Banu (2012) researched
descriptive geometry. Several studies explored the use of augmented reality in science. (Frietas & Campos, 2008; Kerawalla et al., 2006; Larsen et al., 2011; Medicherla et al., 2010) used augmented reality to teach science topics, Sin and Zaman (2010) experimented in astronomy, and (Y. Chen, 2006; Núñez et al., 2008; Shelton & Headley, 2002) examined chemistry. Studies by Di Serio et al. (2012) and Haley-Hermiz et al. (2012) examined the role of augmented reality in visual arts. Finally, Salmi et al. (2012) and Woods et al. (2004) used an augmented reality system to exhibit different museum artifacts.

The studies examined in the review of literature encompassed an extensive range of grade levels and included both students and teachers. The range in grade level went from kindergarten through college. Campos et al. (2011) worked with kindergarten students as participants, while Frietas and Campos (2008) used second graders as the subjects in their study. (Dunleavy et al., 2009; Di Serio et al., 2012; Kerawalla et al., 2006; Medicherla et al., 2010) conducted their study on middle school students and Santan-Mancill, García-Ruiz, Acosta-Díaz, & Juárez (2012) conducted research in a high school setting. (Chen et al., 2011b; Haley-Hermiz, Connelly, Gasper, Scalone, Sceusa, & Staehler, 2012; Huffman & Miller 2012; Martín-gutiérrez et al., 2010; Núñez et al., 2008) all examined college students in conducting their research. Finally, studies conducted by (Borrero & Márquez, 2011; Larsen et al., 2011; Medicherla et al., 2010) used a combination of students and teachers as participants.

The sample sizes within the studies varied greatly. There were multiple studies that included small sample sizes of less than 30. The study conducted by Alves and Sánchez (2008) contained 19 students, while Kaufmann and Schmalstieg (2002) had 14 subjects.
Matcha and Rambli (2011) only had six participants. Additional studies had sample sizes of greater than thirty. The study conducted by Shelton and Headley (2002) contained 34 subjects, while both Frietas and Campos (2008) and Di Serio et al. (2012) had subject counts in the 60s. Salmi et al. (2012) had a total of 292 participants.

Throughout the numerous studies conducted, several different assessment strategies have been incorporated. (Chen et al., 2011a; Di Serio et al., 2012; Martín-gutiérrez et al., 2010; Sin & Zaman 2010; Sumadio & Rambli, 2010) used a combination of a mixed methods approach. In their mixed methods approach both Martín-gutiérrez et al. (2010) and Sin and Zaman (2010) incorporated a post-test questionnaire on usability. (Borrero & Márquez, 2011; Salmi et al., 2012; Shelton & Headley, 2002) used quantitative research methods. Qualitative methods were implemented by (Kaufmann & Schmalstieg, 2002; Larsen et al., 2011; Matcha & Rambli, 2011; Núñez et al., 2008; Woods et al., 2004). Studies by (Campos et al., 2011; C. Chen, 2006; Frietas & Campos, 2008; Martín-gutiérrez et al., 2010; Shelton & Headley, 2002; Sin & Zaman, 2010) incorporated a pre-post-test format.

A couple of additional themes emerged from the review of literature. (Banu, 2012; Chen et al., 2011a; Frietas & Campos, 2008; Haley-Hermiz et al., 2012; Matcha & Rambli, 2011; Sumadio & Rambli, 2010) all incorporated an augmented reality prototype. The augmented systems used in their studies were unique to that particular study and not universal. Studies by (Sin & Zaman, 2010; Sumadio & Rambli, 2010; Woods et al., 2004) made a point of including subjects with no prior experience working with augmented reality. Finally, (Y. Chen, 2006; Medicherla et al., 2010; Núñez et al., 2008) used simple augmented reality systems that required only a webcam, computer and open source software.
Implications Obtained From Studies

There were numerous implications relevant to this study identified in the review of literature. The implications were gathered, analyzed, and categorized into three major themes: The use of augmented reality as a motivational tool, as a means of improving spatial visualization ability, and its impact on learning experiences. The findings provided the foundation for the design of this study, and established the rationale for the research questions. The results and implications also identified holes in the literature where additional research is needed.

The effective use of augmented reality may lie in its use as a motivational tool to enhance the learning process. The review of literature indicates that augmented reality is a motivational tool when implemented in an educational setting. Several studies have shown that the technology provides an immersive learning environment (Allison & Hodges, 2000; Di Serio et al., 2012; Lee et al., 2010). Additional studies indicated that the ability to interact with augmented reality was motivational (Campos et al., 2011; Frietas & Campos, 2008; Lee et al., 2010; Serdar, Stevens, Ses, Esche, & Chassapis, 2007), and provides a learner centered approach to instruction (Di Serio et al., 2012; Larsen et al., 2011). In addition, the design of augmented reality allows for ease-of-use and enables technology to serve as a motivational tool (Larsen et al., 2011; Lee et al., 2010; Martín-gutiérrez et al., 2010).

Immersion through the inclusion of augmented reality in the classroom allows students to maintain higher levels of attention and interest in the content (Di Serio, et al., 2012). Allison and Hodges (2000) and Lee et al. (2010) used an immersive virtual environment to enhance learning. These studies revealed that students who used virtual
reality were fascinated, enthusiastic, and motivated (Allsion & Hodges 2000) and that the combination of realism and manipulation created from the inclusion of virtual reality was interesting and motivating for the students (Lee et al., 2010).

Lee et al. (2010) demonstrated that students can become motivated and interested through the combination of realism and manipulation provided through the inclusion of augmented reality. Students who used augmented reality were motivated to learn, enjoyed the experience, and showed increased curiosity (Campos et al., 2011). Evidence of the students’ motivation was observed as students refused to quit the game presented until the task was complete (Campos et al., 2011). These findings were also evident in a case study conducted by Serdar et al. (2007) which concluded that the inclusion of augmented reality in engineering graphic course led to increased student interest and awareness. Freitas and Campos (2008) indicated that augmented reality was effective at maintaining high levels of motivation, had a positive impact on student learning experience, and promoted active learning. They also found that augmented reality had a greater impact on the learning experiences of weaker students (Freitas & Campos, 2008).

Augmented reality allows for a student centered approach to instruction (Di Serio et al., 2012; Lamanauskas, Pribanu, Vilkonis, Iordache, and Klangauskas, 2007; Larsen et al., 2011). The ability to interact with models motivates students because they are actively involved in the learning process. Di Serio et al. (2012) reported that students showed high levels of engagement, were highly motivated, felt they had control of the activity, and could explore topics on their own. Active student participation increases motivation, engagement, involvement, and interest in the augmented reality models (Larsen et al., 2011).
The level of usefulness and ease-of-use is important for increasing motivational attitudes of students who use augmented reality (Lee et al., 2010). Teachers indicated that the augmented reality system simplified instruction and allowed students to become active participants (Larsen et al., 2011). Larson et al. (2011) also concluded that for continued integration, augmented reality needs to be user-friendly and reliable. A study conducted by Martín-gutiérrez et al. (2010) highlighted that when designed effectively participants had a positive attitude towards the implementation of augmented reality, were interested in the technology, and considered it a useful tool.

However, implementation of augmented reality may increase motivation due to the novelty effect. Allison and Hodges (2000) concluded that some of the enthusiasm surrounding the inclusion of augmented reality might be associated to the novelty of the technology. Di Serio, et al. (2012) also identified that the novelty of the technology may have influenced their results.

The participants in the aforementioned studies were children and adolescents. Campos, et al. (2011) used kindergarten students, Di Serio et al. (2012) middle school students, and Freitas and Campos (2008) studied seven and eight year old students. Thus, the effectiveness of application of augmented reality to older students in a college classroom who have already established learning strategies needs to be determined.

Multiples studies have emphasized the ability of augmented reality to positively impact spatial visualization skills. Studies by (Allen, et al., 2011; Y. Chen, 2006; Kaufmann & Schmalstieg, 2002; Martín-gutiérrez et al., 2010; Medicherla et al., 2010; Núñez et al., 2008; Shelton & Hedley, 2002) all highlighted the use of augmented reality as a visualization
tool to enhance the learning experience. Allen et al. (2011) noted that augmented reality helped subjects visualize the intention of the design, while Y. Chen (2006) believed users were able to visualize concepts and relationships that may not be evident when relying solely on conventional methods. The study conducted by Núñez et al. (2008) indicated that students had improved spatial intuition, a greater understanding of visual cues, and were able to better understand complex 3-D structures. Shelton and Hedley (2002) indicated that augmented reality was a powerful visualization tool that allowed students to explore content interactively.

Additional studies have exposed augmented reality’s ability to impact the academic performance of varying levels of visual learners. Y. Chen (2006) concluded that students with both low and high visualization skills showed improvement as compared to those who received no treatment. Building upon this, Frietas and Campos (2008) stated that augmented reality had a much higher impact on weak and average students. Finally, Larson et al. (2011) showed that augmented reality was able to reduce the learning curve when introducing new content.

Multiple studies have touted the capabilities of augmented reality to enhance the learning process through the ability to manipulate objects, provide the opportunity to experiment virtually, and the engage in kinesthetic learning. Studies showed that augmented reality can bridge the gap between formal and informal learning, as well as teacher-controlled learning environments and student-controlled learning environments (Salmi et al., 2012). The immersive hybrid learning environment created through augmented reality facilitates the
development of processing skills such as critical thinking, problem solving, and communicating (Dunleavy et al., 2009).

**Manipulation.** Numerous studies have indicated that augmented reality allowed students to manipulate models to obtain views from multiple perspectives. Instead of relying on a static image, users were able to manually rotate the 3-D object with their hands. Núñez et al. (2008) highlighted the impact an augmented reality system can have on the learning experience through manipulation. The study reported that students believed augmented reality provided an advantage through the ability to interact and manipulate structures, analyze models from multiple angles, and improve visual and spatial skills. A study by Gelenbe et al. (2005) added to this finding by stating that students were able to view objects from multiple perspectives in order to compare and evaluate results. In addition, students noted that they were able to predict capabilities and limitations of their projects.

The ability to manipulate objects allows for student interaction while promoting understanding of content. Shelton and Hedley (2002) indicated that augmented reality intervention improved students’ conceptual and factual understanding. Kaufmann and Schmalstieg (2002) concluded that the implementation of augmented reality allowed students to view and manipulate objects in 3-D, while finding anecdotal evidence that exposure to augmented reality led to a greater understanding of 3-D geometry concepts. Students enjoyed interacting with the augmented models and were able to view the models from multiple perspectives. In support of the above, Y. Chen (2006) and Chen et al. (2011b) reported that the ability to virtually manipulate objects through augmented reality aided in understanding. These findings were also supported by Woods et al. (2004) and Allen et al. (2011) who stated
that by manipulating models students were able to visualize the intention of the design, and that they would not have been able to visualize these concepts as efficiently without the use of augmented reality.

Through manipulation, augmented reality allowed for the combination of visual and sensory information that resulted in a powerful learning and cognitive experience (Shelton & Hedley, 2002). The ability to naturally interact with the augmented models allowed the students to gain a greater understanding of spatial relationships. Woods et al. (2004, p. 5) suggested that through manipulation augmented reality “can clearly demonstrate spatial concepts, temporal concepts and contextual relationships between both real and virtual objects.” Sin and Zaman (2010) determined that participants naturally manipulated the physical objects by ‘rotating’, ‘picking up’, and ‘placing and holding them’ allowing for an engaging learning experience that increased academic performance by 46 percent.

**Engagement and experimentation.** The review of literature indicated that augmented reality allowed students to engage in the learning process and become active participants through the provision of an additional method of instruction. This was demonstrated in the study conducted by Salmi et al. (2012) who noted that augmented reality can effectively provide ‘hands on’ experimentation. Through the ‘hands on’ approach, participants were able to interact physically and mentally to explore the learning scenarios. The teachers in the study believed the technology was an effective tool that connected learning environments (Salmi et al., 2012). Adding to this finding were studies by Dunleavy et al. (2009) and Núñez et al. (2008) that provided additional evidence of student engagement during the learning process.
Through the addition of augmented reality, students have been able to visually compare and explore concepts. Di Serio et al., (2012) indicated that students enjoyed actively exploring topics on their own through augmented reality. Students expressed their satisfaction in regards to material used, the possibility of receiving information in different formats, and the feeling of having control of the activity as they could explore the topics in the order they chose and could revisit materials as needed. Through active exploration, students became engaged in the learning process. The authors concluded that augmented reality had a positive effect on learning outcomes through a learner-centered approach. The study by Dunleavy et al., (2009) built on this idea by stating that participants in their study described the learning exercises as engaging. Kerawalla et al., (2006) added to this finding by noting in their study that exploring models in 3-D promotes inquiry based learning.

Augmented reality allowed participants to experiment with objects in order to obtain a greater understanding of concepts. Gelenbe et al. (2005) used augmented reality as an experimental tool to ask “what if” questions. As a result of this additional method of instruction, participants were able to obtain a greater understanding of the problem. The results of the study by Banu (2012) indicated that the combination of augmented reality, sketch interpretation, and 3-D geometrical reconstruction techniques provided an interactive learning experience and improved spatial ability by allowing participants to experiment with geometric models.
Mixed Reality in Graphic Communication Courses

To determine if augmented reality was effective in improving learner outcomes, it was implemented into an introductory engineering graphics course. An engineering graphics course was chosen because courses within the field focus heavily on the use and development of visualization skills, which were shown through the review of literature to be improved through the use of augmented reality. In addition, an engineering graphics course was chosen because Kaufmann and Schmalsteig (2003) determined that augmented reality’s effectiveness cannot be analyzed in isolation. To analyze the effectiveness of augmented reality the software needs to align with curriculum that could enhance the learning process. In fact, Kaufmann and Schmalstieg (2003) believed substantial content needs to be developed around augmented reality before the true effectiveness of the software can be determined.

There is no universal method of instruction for introducing students to 3-D modeling (Hartman & Branoff, 2005). Traditionally, engineering graphics used physical models and textbooks to teach concepts, emphasize design, and define models. This singular approach has changed with the advent of computers and influx of software to assist student comprehension. As the processing power of computers continues to grow, more viable methods for assisting modeling have become available. These advancements are important as the majority of concepts taught in an engineering graphics course deal with 3-D objects or concepts (Lieu, 1999). According to Howell (2004) both engineering graphics and computer-aided design subjects are difficult to comprehend solely through the use of a textbook, because of this additional visual aids are required. Instructors have begun to use virtual
modeling instead of physical modeling to aid students visually. Augmented reality has become the latest virtual technology to impact engineering graphics.

Studies conducted by (Y. Chen, 2006; Chen et al, 2011a; Haley-Hermiz, et al., 2012; Huffman & Miller, 2012) have compared the use of augmented reality to traditional physical models, with mixed results. Haley-Hermiz et al. (2012) suggested that the augmented reality software provided a more positive experience as compared to the practical props method. In contrast, were studies by Y. Chen (2006) Huffman and Miller (2012). Y. Chen (2006) found that some students preferred the ability to virtually manipulate objects through augmented reality while others preferred to interact and touch the physical models. Huffman and Miller (2012) compared the use of augmented reality blocks to real physical blocks and found that there was not a significant difference between the use of augmented reality blocks and real blocks. Huffman and Miller (2012) did suggest that the use of more challenging blocks should be used to gain a more accurate measure.

Equivalent findings were also reported by Chen et al. (2011a) who compared the effectiveness of tangible, paper based, and augmented reality models in an engineering graphics course. Students completed a paper based test using all three modeling formats to transform 2-D images into 3-D objects. According to the test results, the augmented reality model had minimal effects on transforming 2-D images into 3-D objects (Chen et al., 2011a). They authors noted that although the augmented models allowed for manipulation, the tangible models were more effective because they allowed students to physically touch and interact with the models (Chen et al., 2011a). However, approximately 70 percent of the
participants believed the augmented reality model provided the same improvement as the tangible models (Chen et al., 2011a).

There were several reasons why augmented reality was selected over traditional physical models for this study. Y. Chen (2006) believed that augmented reality was more convenient as a supplemental tool because it was portable, easy to make, and could display complex models, while the physical models took time to assemble, were fragile, and clumsy at times. Woods et al. (2004) provided the following rationale for choosing augmented reality as opposed to physical models: the use of virtual objects was less restricting than physical modeling, it can be animated and respond to user input, it can be modified and transformed, it can be combined with other media, and is not necessarily constrained by the laws of physics. Another reason for using an attractive technology is to draw the students' attention and increase interest. According to Martín-gutiérrez et al. (2010) courses that students find to be uninteresting have a high withdrawal rate, and can be avoided by using new technologies such as augmented reality.

Spatial Visualization in Engineering Graphics

In engineering graphics, visual thinking serves as a means of communication and as a tool of reasoning. This leads to the incorporation of visual thinking throughout the engineering curriculum (Condoor, 1999). An important component of engineering graphics is spatial ability. Because it has multiple implications, spatial ability continues to be actively researched (Moehler, 2009). Several studies have highlighted the fact that spatial ability is an important component for success in engineering courses (Strong & Smith, 2002; Burton & Dowling, 2009; McGee, 1979; Sorby, 2009a; Titus & Horsman, 1996). As such, students
who struggle in introductory engineering courses are more likely to fail, change majors, and transfer from the program. Spatial ability skills contain five different components including spatial perception, spatial visualization, mental rotations, spatial relations, and spatial orientation. Augmented reality has the capability to allow for exploration of all of these components.

It has been suggested that a greater emphasis should be placed on visualization skills because these skills play an important role in engineering graphics courses (Alias, Black, & Gray, 2002). The development of spatial visualization skills is heightened in an introductory engineering graphics course because the course is the student’s first exposure to engineering principles at the collegiate level and serves as a foundation course. In general, an introductory engineering course consists primarily of first year engineering students (Crown, 2001). In an introductory engineering graphics course these skills are developed through sketching, design, and computer based modeling. Nearly all of the topics encountered in an engineering graphics course deal with 3-D objects or concepts, which are often difficult to visualize. The ability to visualize is a powerful tool because it allows one to manipulate a model, mentally understand a model, and develop models not yet created (Bertoline et al., 2011).

Spatial visualization skills can improve over time. Potter (2009) concluded that a student’s three dimensional spatial perception is trainable and will develop through the first year at a university. In addition, visualization skills can be improved through teaching and learning (Alias et al., 2002; Güven & Kosa, 2008). These studies indicated that spatial visualization skills can improve regardless of whether or not augmented reality is
implemented. The results of a study conducted by Titus and Horsman (1996) indicated that students who were given extra visualization practice outperformed students who did not receive additional time.

Visualization skills are required by students in the creation of 3-D models. Modeling allows the user to represent abstract ideas, words, and forms through the orderly use of simplified text and images (Betoline et al., 2011). This begins with graphics communications, or the exchange of information in a visual format allowing for the effective communication of ideas. This is a central theme within an introductory engineering graphics course (Prust, 2003). Students begin the process by interpreting engineering drawings, transition into sketching, and finally evolve into 3-D modeling through the use of CAD software. To accomplish these tasks, students must be able to take a 2-D drawing and mentally visualize it as a 3-D object.

**Technology in Engineering Graphic Courses**

The implementation of technologies into the engineering graphic classroom to improve learner outcomes continues to be a popular research topic within the field of engineering. Technological innovations continue to provide a never ending supply of emerging technologies to be researched (Dominguez, Martin-Gutierrez, Gonzalez, and Corredeaguas, 2012; Mohler, 2001). These emerging technologies open new avenues for instruction by infusing new strategies and methods into the classroom (Baylor & Ritchie, 2002). According to (Barr, Krueger, & Aanstoos, 2009; De Leon & Winek, 2009; Unver, 2006), the method in which engineering design graphics has been and will be taught has been transformed because of the inclusion of computer technologies. This opinion was shared in a
study conducted on college/university faculty by Barr (2004) that indicated the preferred method of graphical communication was emerging computer graphics tools and techniques. The following studies highlight the impact of several technologies in an engineering graphic classroom and on spatial visualization ability.

The first technology analyzed was rapid prototyping. Studies by De Leon & Winek (2009) and Johnson, Coates, Hager, and Stevens (2009) examined the use of rapid prototyping to assist learning in an engineering graphic classroom. The impact of rapid prototyping can be seen in product design and development (Unver, 2006). Through the use of rapid prototyping, students were able to create scalable models that served as visual tools that assisted in the comprehension of the dimensions of an object. Johnson et al. (2009) studied how students used a rapid prototyping model and digital calipers to create a 3-D solid model in SolidWorks. The researchers found that all eleven students were able to use rapid prototyping and calipers to create their models, but also found that students were not as willing to use rapid prototyping to correct errors (Johnson et al., 2009). Deleon and Winek (2009) conducted a case study that determined students were able to create a working model consisting of a multiple part assembly through the use of rapid prototyping. Based on these findings, DeLeon and Winek (2009) believe rapid prototyping can add excitement and realism to the design process by allowing students to create a working physical model of an assignment.

The next technology analyzed was Google SketchUp. Studies conducted by Glick, Porter & Smith (2012); Kurtulus and Uygan (2010); La Ferla, Olkun, Akkurt, Alibeyolu, Gonulates, and Accascina (2009); Martín-Dorta, Saorín, and Contero (2008) examined the
role of Google SketchUp to enhance spatial visualization skills and impact in an engineering graphic course. Google SketchUp Pro was used in the study by Glick et al. (2012) because of its low cost, ease of use, popularity, and high visual quality. In the study, the software was used to assist in lectures by providing multiple viewing perspectives for the students (Glick et al., 2012). Kurtulus and Uygan (2010) examined the use of Google SketchUp to improve spatial visualization skills. La Ferla et al. (2009) analyzed the effectiveness of manipulations designed in Google SketchUp software to teach three-dimensional shapes. Martín-Dorta et al. (2008) had students use Google SketchUp software to generate models in a remediation course.

The research from these studies was promising and all highlighted the ability of Google SketchUp to increase spatial visualization skills. The study by Kurtulus and Uygan (2010) found that Google SketchUp was an effective 3-D sketching software and believed it could be used interchangeably with other geometry software. La Ferla et al. (2009) determined that both spatial visualization and mental rotation had increased significantly as a result. Martín-Dorta et al. (2008) indicated that a Google SketchUp-based course was a viable option to assist learners in a remedial course for the purpose of improving spatial abilities.

Numerous studies have examined the impact of web based instruction on spatial visualization skills and within an engineering graphics. Through the use of web-based applications, opportunities are available for students to interact with models remotely (Unver, 2006). Contero, Naya, Company, and Saorin (2007) incorporated web-based graphics applications into remedial courses to assist freshman students who were struggling with their

The results from the studies on the use of web-based graphics indicted that it was an effective means to develop spatial ability. Contero et al. (2007) found that the web-based applications had a measurable and positive impact on spatial ability in remedial courses. Kuan and Chen (2005) determined that web-based instruction was equal to face-to-face instruction. The study by Rafi et al. (2008) determined that their web-based system effectively increased spatial visualization ability of students. The study also determined that their web-based animation system effectively increased spatial visualization ability of students (Rafi et al., 2008). The results of the study by Samsudin et al. (2011) indicated that spatial visualization was improved through increased visual perception because students were able to manipulate the objects. Wang et al. (2007) found a medium-sized effect in favor of the use of 3-D based media representations as compared to 2-D to improve visualization
ability. The researchers believed the small sample size was responsible for the insignificant results.

Multimedia software has been used by several researchers as an additional tool to assist learners at the college level. Sorby (2007) has used multimedia software to assist in the learning process since 1993, Lieu (1999) stated that University of California at Berkley used a multimedia computer CD to assist learners, and Crown (n.d.) implemented a CD to create an individualized learning environment. In all three studies the inclusion of multimedia has led to improved spatial visualization skills. Sorby (2007) noted that it was apparent that the use of multimedia software and workbooks were improving students spatial skills. Crown (n.d.) found that the use of a CD increased class enrollment and increased performance. Rafi, Samsudin, and Ismail (2006) examined the usefulness of computer-mediated engineering drawing instruction on spatial visualization and mental rotation. The study by Rafi et al. (2006) showed that spatial visualization skills increased through computer mediated instruction, but there was no change in the mental rotation reaction timing.

Studies have examined the influence of CAD software in engineering graphics. According to Wu and Chiang (2012) the use of CAD can accurately generate 2-D graphics and vividly create 3-D objects. A study by Cölln, Helmert, Kohler, Velichkovsky, and Pannasch (2012) compared the use of CAD to traditional engineering drawings in order to solve dimension search tasks with mechanical engineering students. Towle, Mann, Kinsey, O'Brien, Bauer, and Champoux (2005) examined the use of 2-D and 3-D CAD software to affect spatial ability and self-efficacy in engineering students. Güven and Kösa (2008) investigated the effect of 3-D software, Cabri 3-D, on the spatial skills of teacher candidates.
Cheng and Barbosa (2007) examined the potential use of freeware CAD in engineering graphics.

Several findings have emerged from the research conducted on the use of CAD software in engineering graphics. For one, CAD software has been able to improve the visualization skills of weaker students (Unver, 2006). Towle et al. (2005) built upon this by indicating that student spatial ability and self-efficacy were improved after a semester of CAD software training. The study also showed that students who were exposed to the 3-D CAD course had higher spatial ability and self-efficacy scores as compared to students who were exposed to the 2-D CAD course. Cölln et al. (2012) determined that CAD visualization was superior to traditional methods of instruction if users explored the 3-D object in an interactive manner. The study by Güven and Kösa (2008) found that the inclusion of the Cabri 3-D software significantly impacted the spatial ability of the teacher candidates in the study. However, studies by Leopold (2005) and Sorby (1999) indicated that 3-D CAD experience alone does not seem capable to enhance visualization skills. Finally, a study by Cheng and Barbosa (2007) found several freeware CAD software options that would meet the requirements of an engineering graphics course.

Studies conducted by (Sancho, Torrente, & Fernández-Manjón, 2009; Terlicki, Newcombe, & Little, 2008; Yang & Chen, 2010) have analyzed the effect of video games on spatial ability, motivation, and within engineering graphics. Sorby and Veurnik (2010) noted that evidence has linked the use of video game play to increased spatial skills. Terlicki, Newcombe, and Little (2008) studied the use of 3-D Tetris to teach spatial skills. The study found that the training provided by the 3-D Tetris video game improved spatial skills on a
variety of tasks (Terlicki et al., 2008). Yang and Chen (2010) studied the use of a digital pentominoes game to impact spatial ability and evaluated the comparison between genders. The authors determined the use of a digital game significantly improved student spatial skills and could reduce the spatial skills differences between males and females (Yang & Chen, 2010). Sancho, Torrente, and Fernández-Manjón (2009) studied the impact of multi-user virtual environment gaming on motivation to teach programming. The study found that the inclusion of games positively impacted student motivation (Sancho et al., 2009) as did studies conducted by Papastergiou (2009) and Sakat, Zaid, Zin, Muhamad, Ahmad, and Putra (2012).

Two studies that examined the use of 3-D simulation to improve spatial ability were conducted by Park, Kim, and Sohn (2011) and Wu and Chang (2012). Park et al. (2011) examined the effectiveness of a 3-D simulation technology to influence spatial visualization skills. The authors found that the inclusion of 3-D simulation alone was not yet sufficient to reduce traditional instruction, but has the potential to serve as an effective instructional tool (Park et al., 2010). The study also revealed that the 3-D simulation had a positive effect on the students’ learning curve (Park et al., 2010). Wu and Chang (2012) explored the use of 3-D simulation to teach orthographic views in a graphics course. The study compared the differences between 2-D static and 3-D animation object features. The results indicated that the application of 3-D animations increased visual comprehension and promoted student observation and engagement.
Motivation

To understand the role of motivation in education a working definition is required. The difficulty lies in the reality that numerous definitions of motivation exist with no precise agreement of its nature (Kleinginna & Kleinginna, 1981; Schunk, Pintrich & Meece, 2008). The definition used in this study was developed by Pintrich and Schunk (1996, p 4) who defined motivation as “the process whereby goal-directed activity is instigated and sustained.” Schunk et al. (2008) further defined motivation as a process involving the setting of goals either through physical or mental activity that is sustained until the goal is completed.

In order to be motivated, a student needs to be an active participant in the learning process and be cognitively engaged in the content (Pintrich, 2003). Active engagement in educational endeavors occurs when students value learning, achievement, and accomplishment, regardless of whether or not they find the specific topic to be of interest (Deci, Vallerand, and Ryan, 1991). According to Wigfield, Eccles, Schiefele, Roeser, and Davis-Kean (2006), to become fully engaged in the learning process the student must possess a desire to do the task. Eccles (2009) adds to this idea and believes full engagement occurs when the student is confident and places a high value on success in school.

The study of motivation and education is centered on the personal constructions regarding self-identity, attainment, and what one should become (Maehr & Meyer, 1997). Research conducted to advance the understanding of motivation is important because of its ability to increase student effort and persistence in learning activities (Ormrod, 2009). For the majority of educators, motivation serves as an essential component in understanding and
improvement of classroom learning (Hickey, 2009; Maehr & Meyer, 1997). This understanding has led to researchers throughout the years developing numerous theories on motivation (Maehr & Meyer, 1997; Öztürk, 2002; Zimmerman, 2008).

Motivation is often described as either being intrinsic or extrinsic, with students being capable of being motivated to learn through either means. Ryan and Deci (2000, p 56) define intrinsic motivation “as the doing of an activity for its inherent satisfaction rather than for some separable consequence.” Accordingly, a student who is intrinsically motivated completes an activity because of the enjoyment that is obtained from the activity (Ryan & Deci, 2000). The benefits associated with intrinsic motivation usually exceed those associated with extrinsic motivation (Ormrod, 2009).

An extrinsically motivated student is motivated to learn through an external factor. This could include completing a task in order to achieve a reward, avoid punishment, or as a component of separable consequence (Deci, Vallerand, & Ryan, 1991; Lepper, 1998). The student who is focused on the completion of the task is more likely to ask procedural related questions and not be concerned with content enhancing questions (Sansone & Smith, 2000). For a student who is extrinsically motivated, the engagement in a learning task is the means to an end (Bye, Pushkar, & Conway, 2007).

This research study was designed to evaluate what type of motivation was displayed by the students when augmented reality was introduced in an engineering graphic course. Several previous studies have examined the relationship between the use of augmented reality (Campos et al., 2011; Di Serio et al., 2012; Frietas & Campos, 2008; Lamanauskas et al., 2007; Larsen et al., 2011) and virtual reality (Allison & Hodges, 2000, Lee et al., 2010).
and student motivation. These studies provided a foundation for the understanding of the motivational aspects associated with the usage of augmented reality; however, additional research was necessary.

In addressing an intended goal of the study to investigate the effects of augmented reality on the motivational attitudes of students, two social-cognitive theories of motivation were used to evaluate student behavior. The two theories were self-regulated learning and the self-determination theory. The self-regulated learning and self-determination theory were analyzed in this study because according to Rowell and Hong (2012), these two theories are the basis for the following motivational components: beliefs, goals, values, and intrinsic/extrinsic motivation.

According to Zimmerman (2008, p. 166), “self-regulated learning (SRL) refers to the self-directive processes and self-beliefs that enable learners to transform their mental abilities, such as verbal aptitude, into an academic performance skill, such as writing.” Self-regulation consists of a set of proactive processes allowing for the acquirement of academic skill including: the setting of goals, selection and deployment of strategies, and the self-monitoring of one’s effectiveness (Zimmerman, 2008). During the initial phase, information is gathered about the task and the student then develops a perception of his/her ability to complete the task. This includes self-efficacy. The next phase is for the student to develop a plan and set goals based on his/her perceived ability to complete the task. In the final phase the student evaluates his/her performance and depending on the results, modifies his/her behavior to increase performance.
There is a direct relationship between academic performance, motivational beliefs, and self-regulated learning (Wigfield et al., 2006; Zimmerman & Martinez-Pons, 1990). The ability to effectively visualize concepts in engineering graphics can impact academic performance. Burton and Dowling (2009) determined that visualization ability, the ability to comprehend spatial forms and mentally rotate it in two dimensions before matching it to another form, was a predictor in determining a student’s academic success. This was also supported by Potter et al. (2006) who reported that a student’s ability to comprehend 3-D spatial relations influenced his or her academic success. Both of these studies showed that there was a direct link between academic performance and visualization ability. If augmented reality improves spatial visualization skills as shown in the review of literature, then academic performance should improve, resulting in increased motivation in the course.

The self-determination theory (SDT) was developed by Deci and Ryan and is based on competence, relatedness, and autonomous. The central theme behind SDT is that there exists a distinction between autonomous and controlled motivation (Gagné & Deci, 2005). In order for psychological growth to occur those three needs must be met. With competence, students need to gain mastery of tasks and learn different skills. Relatedness refers to students need to feel a sense of belonging and attachment to others. A student who is autonomous believes they have control over his/her behaviors and goals. This is important because when this is achieved, student engagement increases as does time willingly spent on tasks (Ryan & Deci, 2000). Upon experiencing these three needs, students become self-determined and intrinsically motivated to pursue their interests (Deci and Ryan 1985). An
important component of this theory is social interaction. Without proper social interaction students will never achieve full growth.

An important component in a student’s academic success is self-efficacy. The construct of self-efficacy was popularized through the work of Bandura (Graham & Weiner, 1996). Self-efficacy refers to a student’s confidence in his/her ability to master a task (Pintrich et al., 2003). A student’s perception of his/her ability is closely linked to his/her expectations to succeed in an educational situation (Tudor, Penlington & McDowell, 2011). A study by Al Khatib (2010) determined that self-efficacy was a powerful indicator of academic performance and noted that students’ with high levels of self-efficacy were associated with higher academic performance. This was also evident in a study conducted by Jones, Paretti, Hein & Knott (2010), which found that expectancies for success and self-efficacy were the greatest predictor of student engineering GPA. Self-efficacy is of importance in engineering graphics because students enter the classroom with a preconceived notion about their ability to succeed. A study by Towle et al. (2005) indicated that a student’s perception of his/her spatial ability was significantly correlated to his/her performance on the PSVT-R. These findings highlighted the connection between a student’s perceived ability and how he/she actually performed.

Understanding student motivation in engineering graphics is important because of student retention issues. Student retention remains a pertinent issue with engineering majors especially during their freshman year (Sheppard & Jennison, 1997). A student who struggles during the beginning of their academic career may become discouraged and withdraw from the engineering program (Sorby, 2009b). According to Sorby (2007), students who struggle
developing or possess weak spatial skills are at a high risk for withdrawing from engineering programs. Several different remediation courses, training exercises, and technologies have been developed to address the lack of spatial skills.

**Data Collection Methods**

A total of three data collection methods were used to investigate the effectiveness of augmented reality in an introductory engineering graphics course. The three methods were the MSLQ, PSVT-R, and student questions.

**Motivated Strategies for Learning Questionnaire**

The formal development of the MSLQ was begun in 1986 by Paul Pintrich and Wilbert McKeachie, who were attempting to create a measurement that would assess student motivation and learning strategies (Duncan & McKeachie, 2005). To further refine the effectiveness of the MSLQ data was collected and analyzed from 1986 to 1988 with the ultimate goal of improving student learning. The final version was completed in 1990 (Pintrich et al., 1993). One of the first empirical studies using the MSLQ was conducted by Pintrich and De Groot (1990).

The MSLQ contains 15 different scales within two sections that assess different components of motivation and self-regulated learning strategy uses. The scales can be used collectively or independently with researchers being able to use any combination of components or subscales to fit the need of their study. Within the 15 subscales there are a total of 81 Likert-type questions. The Likert-type questions are scored on a seven-point scale ranging from (1 = totally disagree to 7 = totally agree). Typically, a higher response score of 5, 6, or 7 is desired.
The motivation orientation section contains three different components including value, expectancy, and affective. The value component consists of the following three subscales; intrinsic motivation, extrinsic motivation, and task value. The subscale of intrinsic goal orientation addresses to what degree the student perceived participation to be associated with tasks for reasons such as challenge, curiosity, or mastery (Pintrich et al., 1991). The subscale includes four questions. The subscale of extrinsic goal orientation addresses the degree to which the student perceived participation to be associated with tasks for reasons such as grades, rewards, or performance (Pintrich, et al., 1991). This subscale includes four questions. The task value subscale is related to the student-perceived view of the course content in terms of importance, utility, and interest (Pintrich, et al., 1991). The subscale includes six questions. Each of the scale scores are calculated by summing the means of each question within the scale and finding the average.

The expectancy component includes scales for control of learning beliefs and self-efficacy for learning and performance. This component refers to a student’s belief to accomplish a specific task. The subscale of control of learning beliefs addressed the degree to which the student believed that he/she had control over academic performance (Pintrich, et al., 1991). The subscale includes four questions. The subscale of self-efficacy for learning and performance addressed the expectancy of success or performance expectations and self-efficacy or one’s ability and confidence to complete a task (Pintrich, et al., 1991). The subscale includes eight questions.

The affect component includes scales for test anxiety and contains five questions. This component focuses on the worry and concern associated with test taking. This
component was excluded from the study because the study involved no tests and was not relevant.

The Learning Strategies section included 50 questions, three components, and nine subscales. The Cognitive and Meta-cognitive Strategies component includes the following subscales: Rehearsal, elaboration, organization, critical thinking, and meta-cognitive self-regulation. The rehearsal subscale included four questions and assesses the uses learning strategy used to assist with memorization (Pintrich et al., 1991). The elaboration subscale includes six questions and assesses the student’s ability to draw connections between new material and prior experiences (Pintrich et al., 1991). The organization subscale includes four questions and assesses student ability to organize information effectively (Pintrich et al., 1991). The critical thinking subscale includes five questions and assesses student ability to use critical thinking skills to solve problems (Pintrich et al., 1991). The meta-cognitive self-regulation subscale includes 12 questions and assesses student ability to self-regulate their learning (Pintrich et al., 1991).

The Resource Management Strategies component includes the following subscales: Time and study environment, effort regulation, peer learning, and help seeking. The time and study environment subscale includes eight questions and assesses student ability to manage time and learning environments (Pintrich et al., 1991). The effort regulation subscale includes four questions and assesses the effort used by the student to complete a task (Pintrich et al., 1991). The peer learning subscale includes three questions and assesses the use of peer to assist with the understanding of course material (Pintrich et al., 1991). The
help seeking subscale includes four questions and assesses the use of help to assist with the understanding of course material (Pintrich et al., 1991).

The MSLQ was initially designed to be used in post-secondary education (Pintrich et al., 1993). In fact, the data contained within the MSLQ manual was based upon a study of 380 college students (Pintrich et al., 1993). Although initially designed to measure motivation and learning strategies of college students, the MSLQ has also been used in elementary, middle, and high schools. Research on the MSLQ in each of these learning environments has indicated that the instrument is an effective tool to measure student motivation and learning strategies (Montalvo & Torres, 2004).

Several studies have been conducted using the MSLQ with elementary, middle, and high school students (Milner, Templin, & Czerniak, 2011; Pintrich, 2000; Pintrich, Roeser, & De Groot, 1994; Tsai, Lin, & Yuan, 2001; Wolters & Pintrich, 1998). Milner et al. (2011) used the MSLQ to examine motivation and learning strategies within a constructivist elementary science class. Pintrich (2000) used the MSLQ in a study of 8th and 9th grade students. Pintrich et al. (1994) conducted a study on the relationship between classroom experiences and individual differences on motivation and self-regulated learning strategies in 7th grade students. Tsai et al. (2001) used a modified MSLQ to assess the motivation and learning strategies of high school science students on web-based content map testing. A study facilitated by Wolters and Pintrich (1998) used a modified MSLQ to measure the contextual differences in motivation and self-regulated learning in 7th and 8th grade math, English, and social science classrooms. Kivinen (2003) used the MSLQ on secondary students.
Numerous studies conducted at the college level have included the use of the MSLQ. Haron, Shaharoun, Puteh, and Harun (2012) used the MLSQ to study motivation in a college level engineering static course. Al Khatip (2010) and Klomegah (2007) used the MSLQ to study the self-efficacy of college students. Both studies found that there was a strong correlation between student self-efficacy and academic performance (Al Khatip, 2010; Klomegah, 2007). Additionally, Alkharusi, Neisler, Al-Barwani, Clayton, Al-Sulaimani, Khan, and Al-Kalbani (2012) used the MSLQ to study college students.

An abbreviated version of the MSLQ has been used in several studies (Bye et al., 2007; Clark, Ernst, & Scales, 2009; Krupczak, VanderStoep, Wessman, Makowski, Otto, & Van Dyk, 2005; Marra & Wheeler, 2000; Matthews, 2004). Bye et al. (2007) used the abbreviated MSLQ to study motivation, interest, and positive effect on traditional and non-traditional college students. The researchers selected the abbreviated MSLQ because the instrument was context bound, applicable to all students regardless of faculty, and were only testing motivation (Bye et al., 2007). The study conducted by Clark et al. (2009) used the MSLQ to examine motivation and satisfaction of student learning in an introductory engineering graphic course. The abbreviated MSLQ was used to better gauge student motivation and student attitudes (Clark et al., 2009). Krupczak et al. (2005) used an abbreviated version of the MSLQ to evaluate student outcomes of non-engineering students in an engineering course. Marra and Wheeler (2000) used a modified version of the MSLQ to assess the impact of a student-centered engineering project on student motivation. Matthews (2004) used the MSLQ to compare attitudes between traditional and problem-based learning.
According to Gay, Mills, and Airisian (2006) the most important characteristic of an instrument is validity. Validity refers to the degree in which a test measures what it is supposed to measure. The MSLQ has been applied and validated at different education levels including the university setting (Carmen & Torres, 2004). The MSLQ is a valid measure of a student’s motivational and learning strategies (Duncan & McKeachie, 2005; Carmen & Torres, 2004). To further build upon the validity of the MSLQ, the developers of the MSLQ, Pintrich et al. (1993) provided previous validation data for the MSLQ within their MSLQ manual.

The reliability of the MSLQ has been determined through multiple studies and use of Cronbach’s alpha. The Cronbach’s alpha is a measure of internal consistency for an instrument (Frankel & Wallen, 2000). The resulting scores range from zero to 1, with a coefficient of .70 being considered acceptable and higher values being desired (Frankel & Wallen, 2000). Research conducted by Pintrich et al. (1993) suggested that the MSLQ was reliable in relation to internal consistency (see table 3). Campos (2002) obtained a Cronbach’s alpha of .85 for the MSLQ. A study by Cook, Thompson, and Thomas (2011) determined that scores on the MSLQ are predictable and reliable with an internal consistency (Cronbach’s = .93).
Table 1

*Table 1: Cronbach’s Alpha for MSLQ Motivation subscales (Pintrich et al., 1993)*

<table>
<thead>
<tr>
<th>MSLQ Motivation Subscales</th>
<th>Coefficient Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Component: Intrinsic Goal Orientation</td>
<td>.74</td>
</tr>
<tr>
<td>Task Value Component</td>
<td>.90</td>
</tr>
<tr>
<td>Control of Learning Beliefs</td>
<td>.68</td>
</tr>
<tr>
<td>Self-efficacy Learning Performance</td>
<td>.93</td>
</tr>
</tbody>
</table>

**Purdue Spatial Visualization Test – for Rotations**

Multiple instruments have been developed to measure spatial ability in engineering graphics including the Lappan Test, PSVT, Mental Rotations Test (MRT) and Metal Cutting Test (MCT). Additionally, studies conducted by (Blasko and Holliday-Darr, 2010; Blasko, Holliday-Darr, and Trich Kremer, 2009; Connolly, La Harris, and Sadowski, 2009; Medina, Gerson, and Sorby, 1998; Sorby 2009b) have included multiples spatial ability tests. The focus of each of these studies was the assessment of the spatial visualization skills of students in engineering graphics. All of these studies also included the PSVT and specifically the PSVT-R.

The PSVT is composed of three sections including: Development, rotations, and views. For the purpose of this study only the PSVT-R was used. The PSVT-R component was used due to its relevance to the study which was to assess spatial visualization skills. Blasko et al. (2009) noted that their use of PSVT-R did show a fairly robust correlation to the mental rotation tasks within their study. While, Koch and Sanders (2011) selected the PSVT-
R instrument to measure spatial visualization ability because of its high correlation with similar instruments that measure visualization ability.

The PSVT-R is commonly used in engineering and technology fields to measure spatial ability (Blasko et al., 2009; Flesig & Spence, 2011; Yue, 2006). This is especially true in the United States where the PSVT-R is more common, as compared to the MRT and MCT (Ault & John, 2010). Yue (2006) also noted that a partial reason for the popularity of the PSVT-R in engineering schools is because the test uses isometric drawings for spatial visualization. For example, since 1993 engineering students at Michigan Tech University have continued to be tested with the PSVT-R during orientation (Sorby & Veurnik, 2010).

Research conducted by Bodner and Guay on 4,800 students at Purdue University provided the following evidence in the support of the PSVT-R as a valid measure of the cognitive abilities that most frequently appear under the title of “spatial abilities” (Bodner & Guay, 1997, p. 13):

- The strong correlation between performance on Rotations (ROT) test and Shepard- Metzler tests, which have been shown to be among the spatial tests least likely to be confounded by analytic processing strategies.
- The much weaker correlation between performance on the ROT test and the Minnesota Paper Folding Board test, which has been shown to be among the spatial tests most likely to be confounded by analytic processing.
- The significant difference between the performance of males and females on the ROT test, which has been observed in other measures of the spatial visualization factor of spatial ability.
• The correlation between ROT scores and student performance on highly spatial topics in chemistry.

• The correlation between ROT scores and performance on problem-solving tasks in chemistry.

• That require cognitive restructuring/disembedding strategies.

Studies have linked success on the PSVT-R to academic success in engineering graphics course (Gimmestead, 1990; Solby, 2010). According to Sorby and Veurink (2010, p 5) a student’s “performance on the PSVT-R has been linked to success in graphics and in Michigan Tech’s first-year engineering course.” This opinion was also shared by Gimmestead (1990), who determined through research that the PSVT-R was a significant predictor of success in engineering graphics. Additionally, Maeda and Yoon (2011) reported that the PSVT-R has been used to make inference about a student’s academic success in STEM fields and as a placement test in engineering graphic courses.

Bodner and Guay (1997) identified two different methods for the PSVT-R test to be utilized as a research instrument. Both of these methods provide the rationale for the using the PSVT-R to evaluate augmented reality as it relates to student spatial visualization skills in an engineering graphics course. First, the PSVT-R test can be used to evaluate the effect of emerging technologies such as virtual reality on student performance (Bodner & Guay, 1997). As stated previously in the review of literature, there is an established relationship between virtual reality and augmented reality from a technological and implementation standpoint. The second way in which the PSVT-R can be used as a research instrument is to “probe students’ perception of computer-based learning activities that require them to
perceive three-dimensional structures from two-dimensional representations on a computer screen” (Bodner & Guay, 1997, p. 14). This is of value because the augmented reality software used in the study displayed three-dimensional images on a two-dimensional computer screen.

In order to measure a person’s spatial visualization ability Bertoline and Miller (1990) recommended the administration of the PSVT-R the pre- and post-test format. This approach allows researchers to make comparisons and analyze between pre- and post-tests. The pre- and post-test format has been supported by numerous studies that have used the PSVT-R in pre- and post-test format (Ault & John, 2010; Blasko & Holliday-Darr, 2010; Connolly et al., 2009; Fleisig, et al., 2011; Gorska et al., 2009; Gueven & Kosa, 2008; Medina et al., 1998; Sorby, 2009b; Sorby, Drummer, Hungwe, Parolini, and Molzan, 2006; Veurink, Hamlin, Kampe, Sorby, Blasko, Holliday-Darr, ... and Knott, 2009).

The Kuder-Richardson 20 (KR-20) was used to ensure the reliability of the PSVT-R instrument through the analysis of the number of items on the test, student performance on each question, and variance (Tucker, 2007). The KR-20 measures the test reliability of inner-item consistency, with a higher value indicating that there is a strong relationship between items on the test (Arizona State University, 2004). The scale has a range between zero and one. A lower value (.01) indicates a weaker relationship between test items and a higher value ranging between .80 and .85 is considered a strong relationship (Arizona State University, 2004). A study conducted by Branoff (2009) showed the PSVT to have a calculated internal consistency coefficient of .82 and .80. Sorby and Baartmans (2000) found a KR-20 score of .83 for the PSVT-R pre-test and .71 for the post-test PSVT-R. The low KR-
20 score on the post-test PSVT-R was not a concern of the researchers because previous research had generally been higher than .80 (Sorby & Baartmans, 2000). Research conducted over a five-year period by Flesig et al. (2011) using the PSVT-R had a K-R 20 measure for reliability of 0.89, 0.88, 0.86, 0.87, and 0.89 indicating the reliability of the instrument.

The Kuder-Richardson 20 (K-R 20) was used to ensure the reliability of the PSVT-R instrument. The K-R 20 measures the test reliability of inner-item consistency, with a higher value indicating that there is a strong relationship between items on the test (Arizona State University, 2004). The scale has a range between zero and one. A lower value (.01) indicates a weaker relationship between test items and a higher value ranging between .80 and .85 is considered a strong relationship (Arizona State University, 2004). A study conducted by Branoff (2009) showed the PSVT to have a calculated internal consistency coefficient of .82 and .80. Research conducted by Flesig et al. (2011) on five different studies using the PSVT-R had a K-R 20 measure for reliability of between 0.86 and 0.89.

**Student Questions**

A basic interpretive method consisting of seven questions was incorporated into the study to collect additional data from the students on their experience with augmented reality. A basic interpretive study is used to understand how participants make meaning of a situation or phenomenon and is commonly used in the field of education (Merriam, 2009). In a basic interpretive study, data is collected through interviews, observations or document analysis and then analyzed in order to identify patterns and themes (Merriam, 2009).

The seven questions used to investigate the students’ experiences with augmented reality within an engineering graphic course were initially derived by a study conducted by
(Chen et al., 2011a). In the study, Chen et al. (2011a) had students complete a post-test questionnaire to collect their opinions concerning the use of augmented reality in an engineering graphic course. The post-test questionnaire included seven questions that assessed the students’ experience with the augmented reality system used in the study. The questions used by Chen et al. (2011a) were then reinforced by several additional studies that incorporated the use of post-test surveys and questionnaires.

The questions were given to all of the students after they completed the required assignments. The questions were designed to further investigate the impact of augmented reality. Studies by (Martín-Gutiérrez et al., 2010; Rafi et al., 2008; Sin & Zaman 2010) used post-test questionnaires along with a pre- and post-test instrument. Numerous studies included a questionnaire at the conclusion of the study to further investigate the findings and participant experiences. Studies conducted by (Borrero & Márquez, 2011; Chen et al., 2011a; Leopold, Gorska, and Sorby, 2001; Park et al., 2011; Sin & Zaman, 2010) incorporated questionnaires at the conclusion of their studies for the purpose of gathering participant opinions on the learning experience. Park et al. (2011) also used the questionnaire to assess the visualization abilities of the students.

Several studies have used a post experiment questions to further investigate if there was a relationship between augmented reality and motivation. The additional instrument was needed because a student’s motivation may not always be evident through the examination of test scores (Ames, 2003). There may be several other factors that affect test scores and these need to be examined. To help determine if there was a relationship between the inclusion of a virtual environment and student motivation, a satisfaction questionnaire was given at the end
of the study (Sancho et al., 2009). Campos et al. (2011) measured the motivational attitudes of students through questionnaires, observation, and video recordings. Frietas and Campos (2008) used written questionnaires to examine the motivational impact of an augmented reality system on students. According to Kaplan (2010) a self-report is often used to assess a student’s intrinsic and extrinsic motivation level.

The inclusion of post experiment questions allowed researchers to further investigate the effectiveness of their treatment and instrument used in the study. Núñez et al. (2008) had participants complete a survey at the conclusion of the study to collect their opinions on the advantages and disadvantages of the project. The survey also assessed the usefulness of the methodology from the perspective of the student (Núñez et al., 2008). Both Lamanaukas et al. (2007) and Rafi et al. (2008) administered questionnaires at the completion of their studies in an effort to obtain feedback from participants on the effectiveness of the training they received. Studies by (Lieu, 1999; Sancho et al., 2009; Sumadio, 2010) all used questionnaires to provide insight into the usefulness of the technology used in the study. Lieu (1999) also used a questionnaire to understand how the students used the technology.

The seven questions used in the basic interpretive study were developed based upon the review of literature (see Appendix 1). All of the studies reviewed included the use of augmented reality or virtual reality in a learning environment. Although each of the studies implemented augmented reality in a different method and utilized surveys and questionnaires differently several unifying themes emerged.

Several of the questions within the studies reviewed addressed specific areas of interest for the researchers. Campos et al. (2011) used multiple measures to assess motivation
including post-test questionnaires. Di Serio et al. (2012) focused on identifying any potential barriers to the inclusion of augmented reality and addressed the role of augmented reality on student motivation. Lamanauskas (2007) had students answer two open ended questions addressing the positives and negatives associated with the usability of augmented reality. Rafi et al. (2008) used open ended questions to have students assess their own improvement of spatial visualization skills through the use of a virtual environment trainer.

Numerous studies used multiple questions to further assess the effectiveness of augmented reality (Larsen et al., 2011; Martín-Gutiérrez et al., 2010; Núñez et al., 2008; Sumadio and Rabli, 2010). Martín-Gutiérrez et al. (2010) used a survey at the completion of the study to better gauge student satisfaction on the methodology and technology used in the survey. Larsen et al. (2011) asked eight open ended questions while conducting interviews. These questions were included because each of the interviews followed the same structure to ensure reliability and was conducted at the conclusion of the study. The questions were designed to address pedagogical effectiveness and the technical acceptance of the system (Larson et al., 2011). A study by Núñez et al. (2008) had students complete a survey on their experiences using augmented reality in a chemistry course. The questions addressed the advantages, disadvantages, and usefulness of augmented reality used in the experiment. Sumadio and Rabli (2010) had students complete questions associated with the design of the augmented reality system including: system efficiency, the ability of system to help solve tasks, user control, and suitability for learning.

Studies conducted by (Borrero & Márquez, 2011; Fernandes & Sánchez, 2008; Santana-Mancilla, García-Ruiz, Acosta-Díaz, and Juárez, 2012) incorporated post-test
questionnaires. Borrero and Márquez (2011) used a questionnaire to assess the effectiveness of augmented reality in electrical engineering. Questions addressed student motivation, application, and enhanced through the inclusion of augmented reality. Santana-Mancilla et al. (2012) used a post-test questionnaire to evaluate the usability of a mobile augmented reality system. A questionnaire was included in a study by Fernandes and Sánchez (2008) to obtain insight into the learning experience.

After examining the use of questions in all of the aforementioned studies and researching the how to effectively develop question, a total of seven questions were created to assess the student’s learning experience with augmented reality. Once developed the questions were initially evaluated by Dr. Matthew Lammi. Dr. Lisa Bass further examined the questions and no changes were recommended.

**Chapter Summary**

The review of literature surveyed and synthesized the literature as it relates to understanding the role of augmented reality on learning and teaching in a beginning graphics communication course. The chapter began by analyzing mixed reality and examining the similarities and differences between augmented and virtual reality. Evidence was presented supporting the inclusion of studies on virtual reality and to the decision to choose augmented reality over virtual reality.

The review then examined the research on the use of augmented reality in education. The first step in the process was to identify and detail all pertinent studies. These studies identified the major areas of research and led to development of the research questions used for this study. The three major areas in which research was conducted were on augmented
reality’s role as a motivational tool, to improve spatial visualization skills, and positively impact learning experiences. Next, the methodologies used in these studies were detailed. The results from this were that there was no unifying theme. The examination revealed that studies have been conducted across several disciplines, included several different groups of participants, sample sizes, and assessment measurements. The conclusion drawn from this was that more research was needed to obtain a greater understanding of the effectiveness of augmented reality. Finally, the implications from these studies were disclosed. The findings were that augmented reality was an effective tool to increase student motivation, could improve spatial visualization skills, and can impact learner outcomes through manipulation, engagement, and experimentation.

Next, the review of literature examined the implementation of mixed reality applications and supplementary technologies in an engineering graphic course. The literature review of mixed reality research supported the use of augmented reality, highlighted gaps in the research, and provided multiple methods of implementation. Additional technologies were then examined to further investigate the effects of technologies in engineering graphics. The research indicated that the inclusion of several different technologies were beneficial in a supportive role to assist learners in spatial development and provide visual assistance.

The chapter discussed the motivational component of the study. A working definition of motivation was provided, two motivational theories were discussed, and connections between motivation, augmented reality, and engineering graphics were detailed. The motivational component was relevant because studies showed that the ability of augmented
reality to improve spatial visualizations skills in an engineering graphic course increases motivation leading to academic success.

Lastly, the chapter discussed the rationale for the inclusion of both the MSLQ and PSVT-R and student questions. A brief description and history was provided for each instrument. Numerous studies were included to highlight how both instruments have been implemented into previous research. Finally, evidence was presented from previous research conducted on each data collection method to support the use of each in the study.
CHAPTER THREE: RESEARCH AND METHODOLOGY

In the following chapter the research design and methodology used for this study is described. The chapter describes the design of the study, the participants, the location, the instrumentation used, the method for data collection, and the statistical techniques used to analyze the data. The study incorporated three different data collection methods. The independent variable was the implementation of augmented reality. The measurable dependent variables were the student’s motivational attitude as measured by the MLSQ survey, student’s score on the PVST-R test, and student questions concerning the use of augmented reality.

Research Questions

The focus of the study was on the overarching theme: “Understanding how learner outcomes can be affected through the implementation of augmented reality in an introductory engineering graphics course.” Specific research questions included:

1. How will the implementation of augmented reality affect the motivation of students in an introductory engineering graphics course as measured by the MSLQ? If so, how?

2. How will the implementation of augmented reality affect the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R? If so, how?

3. What are the students’ learning experiences with augmented reality?
a. How does the use of augmented reality promote experimentation including: examination, comparison, and problem solving?

b. How does the use of augmented reality allow the student to manipulate the models by providing the following: multiple viewing perspectives, rotation, and scalability?

c. How does augmented reality engage students through: active participation, kinesthetic learning, and inquiry?

**Rationale for the Design of the Study**

The rationale for the design of the study was based on the review of literature and guidance from the GC 120 instructor. The findings and methodologies used in previous studies provided a blueprint in which to build this study. After evaluating previous research, the researcher presented the study to the instructor where suggestions were then made in order to improve the effectiveness of the study and ensure the inclusion of augmented reality did not alter the course (Núñez et al., 2008).

**Implementation**

The study was conducted in two different sections of the same engineering graphics course. As a result, certain issues needed to be addressed. Both courses needed to be as similar as possible. This included having the exact same structures and requirements. A study by Glick et al. (2012) conducted research in two separate courses. In the study they controlled for the effect of the teacher by following the same guidelines for each course and using the same materials (Glick et al., 2012). Di Serio et al. (2012) followed the same approach in their study where they employed the same content as in previous courses. A
study by Lewis and Litchfield (n.d.) failed to address the issue of instructor variable, which led to different methods on instruction, course projects criteria, and grading, all of which limited the results of the research.

Prior to introducing augmented reality into a classroom, one first needs to examine the current methodology of the course (Núñez et al., 2008). The intended purpose is to naturally improve the methodology through the inclusion of augmented reality (Núñez et al., 2008). If the course design is altered the results may be devalued. To accomplish this goal the research must align with the content of the course while addressing the needs of the students. To properly investigate the effect of augmented reality in an engineering graphics course, the technology should address the fundamental topics taught within the course (Chen et al., 2011b). Medicherla (2011) believed that it was necessary to take into account the curriculum and specific objectives when designing research around augmented reality. A study by Smith, Taylor, Green, Peterson, Garrety, Kemis, and Thompson (2009) accomplished this by integrating a virtual reality into a design and technical graphics course giving the models a purpose and adding to the understanding of content. The strengths associated with the use of augmented reality need to be aligned with specific content areas where the potential exist for the greatest effect.

The research conducted for this study was designed to not disrupt the engineering graphic course in which it was implemented. Several measures were taken as to not compromise the design of the course. For one, the inclusion of augmented reality focused on specific assignments. Larson et al. (2011) noted that research on the use of augmented reality should focus on learning scenarios. To insure validity, Contero et al. (2007) made sure their
research did not impact the lecture portion of the course. Instead, the research was conducted during the optional help sessions. The study by Ault & John (2010) kept the traditional lecture component of the course and conducted research during the open computer lab. During the open lab students were then able to work with the software to complete the required exercises.

When designing the study, consideration was given to the development of all required assignments. The intent was to design assignments that aligned with the content and concepts being taught in the course while highlighting the benefits of the technology. Shelton and Hedley (2002) stated that the most effective method of introducing augmented reality was through less complex content initially. Studies conducted by Chen et al. (2011a); Glick et al. (2012); Martín-Dorta et al. (2008); Martín-Gutiérrez et al. (2012); Shelton & Hedley (2002) were designed to begin with simple activities and progress to more complex models. Alias et al. (2009) indicated that their study may have been unsuccessful because the learning materials used in the study consisted of relatively simple objects. Based on these findings the study was designed to begin with a simple 3-D model and progress in difficulty each of the six weeks.

Students’ needs including; creating an engaging learning environment and addressing different learning styles, must be taken into account when implementing a new technology. The technology should assist the learner in the educational process. Larson et al. (2011) believed there must be an educational value associated with the inclusion of augmented reality for the student. For, as Di Serio et al. (2012) noted the inclusion of technology is not the panacea for education.
Augmented Reality System

There were numerous augmented reality systems that could have been suitable for this study. However, there were certain criteria that had to be met. For one, the interface needed to feel natural (Fjeld, Fredriksson, Ejdestig, Duca, Bötschi, Voegtli, and Juchli, 2007). If the students were uncomfortable using the system they were less likely to take part in the study. The system needed to be simple and easy in order for the students to learn (Di Serio et al., 2012). According to Larson et al. (2011) the most important aspect of an augmented reality system was usability. Finally, few resources were available to the researcher, and no funding was available for the study. This meant that the augmented reality software needed to be free and all components must be readily available to accommodate up to 50 students. Fortunately the study was conducted at a university and several options were available.

The augmented reality software selected for the study was Augmented®. The software was selected for several reasons. A major benefit of the software was that it was free to use. There was a paid version of the software available for use, but it was selected because there was no funding for the study. The paid version included an additional feature not present in the free version. The software was also compatible with SolidWorks files and downloadable to iPads. This was important because all of the models used in the study were created in SolidWorks. The models were created in SolidWorks and saved as STL files. The STL files were easily uploaded onto Augmented® application and could be viewed through a single account. This meant that each student did not need their own account to view the model and only one model needed to be uploaded.
There are two methods to display the augmented reality model. The model could be displayed either through a head mounted device or a monitor. A head mounted display was not considered for this study because they are too cumbersome, not practical for a large sample size, and may not deliver good image quality (Fernandes & Sánchez, 2008). A monitor based display was chosen because it was the best fit for the study and had been used effectively in several studies (Y. Chen, 2006; Fernandes & Sánchez, 2008; Núñez et al., 2008; Wu, Lee, Chang, & Liang, 2013).

An iPad was selected for multiple reasons. As Wu et al. (2013) determined, the use of a portable device was less obtrusive yet still enhanced the sense of immersion and presence. Tablets were effectively used in a study by Contero et al. (2007) to allow students to obtain multiple viewing perspectives. Students were familiar with the portable device and were comfortable interacting with it. Another reason for the selection of an iPad was the fact they were readily available and could accommodate the large sample size. Finally, an iPad was chosen because in an augmented reality system, the more the devices required, the greater the risk of device failure (Wu et al., 2013). The iPad housed the augmented reality application and included a camera for viewing.

The final piece to the augmented reality system was the marker. The marker was readily available through the Augment® website and could simply be printed out for free. The virtual models were superimposed onto the marker allowing the user to view the augmented 3-D model in the physical environment (Chen et al., 2011b). The marker could easily be manipulated by the students (Núñez et al., 2008).
Augmented Reality Implementation

An effective augmented reality system requires the implementer to provide successful integration for the technological benefit of the student (Noeth & Volkov, 2004). First, the researcher familiarized himself with and became comfortable with the software (Y. Chen, 2006). Next, the researcher ensured all of the software was properly loaded onto the iPads and tested. The augmented reality objects being modeled were preloaded onto the iPad prior to each session. During the sessions, students were presented with an iPad with the augmented reality software running and the model available for viewing. There were a total of 20 iPads and 60 augmented reality markers dispensed throughout the class, requiring students to share iPads during peak demand. The augmented reality markers were also tested. The user was required to be properly trained on how to manipulate the camera and marker and understand the spatial relationship between the two (Kato & Billinghurst, 1999; Fernandes & Sanchez, 2008). A failure in one of these areas could have limited the success of the experiment and compromised the validity of the study by causing the students to be resistant to the use of augmented reality. A study conducted by Allison and Hodge (2000) using virtual reality concluded that students should observe and model the activity during the same period instead of having students observe during one class and then model in another.

Before allowing students to interact with the augmented reality system certain procedural steps needed to be implemented to ensure all users were comfortable with and knew how to effectively use the technology. Prior to beginning a study, the augmented reality system should be modeled in front of the entire class and individually to each student who took part in the study (Chen et al., 2011a; Rosenbaum, Klopfer, & Perry, 2006). This process
was important because almost every student in the study was unfamiliar with the technology (Lamanaukas et al., 2007; Sumadio & Rambli, 2010; Woods et al., 2009; Sin & Zaman 2010). Dunleavy et al. (2008) believed it would be difficult to successfully implement an augmented reality system without significant modeling. An important component of the modeling was showing how to interact and manipulate the model effectively.

**Study Design**

Several considerations went into the design of the experiment including: duration, actual time spent working with augmented reality, and length of each session. The design of the study was based primarily off of the review of literature but also included a discussion with course instructor on where best to implement augmented reality. The study intervention was conducted over a nine-week period. A total of eight models were implemented that corresponded to the six assignments. For assignment number two students were allowed to choose from two different models or complete both. There was a total of nine hours of required time for student interaction with augmented reality. Lastly, each treatment session lasted for one and an half hours.

The review of literature provided several examples of effective durations. The duration varied from a single week to the entire length of the course, which was up to a year. An experiment by Alias et al. (2002) lasted for a total of one week. However, Alias et al. (2002) believed the short duration limited the effectiveness of their study. Cobos-Moyano, Martín-Blas, and Oñate-Gómez (2009) conducted their research over a two-week period. Rafi et al. (2008) conducted their study for four weeks. Ferguson, Ball, McDaniel, and Anderson (2008) conducted their study for a five-week period. A finding of the study was
that five weeks was not a sufficient duration to improve spatial skills through traditional methods (Ferguson et al., 2008). A study by Gueven and Kosa (2008) used 3-D software to improve spatial skills during an eight week period. While Samsudin et al. (2011) believed that an eight-week training course was not sufficient in increasing students speed when solving spatial tasks. They believed that the training needed to be longer and include additional sessions in order to be effective Samsudin et al. (2011). The study conducted by Medina et al. (1995) consisted of a year-long study and a ten-week study. Both of the studies covered the entire course. Flesig et al. (2011) lasted the entire length of the course, which was 12 weeks. Finally a study conducted by Connolly (2009) covered 16 weeks.

Specific time durations in terms of weeks were not always present in study designs but instead the authors provided the number of sessions administered. These studies consisted of between three and five sessions. A study by Martín-Dorta et al. (2008) contained a total of three sessions in their experiment. The studies by Blasko and Holliday-Darr (2010) and Turos and Ervin (2000) contained four sessions in their experiments. Turos and Ervin (2000) noted that the exact number of training sessions could not be determined because the students continued to improve in all four sessions and believed additional research was required to determine the number of sessions needed to achieve optimal performance. Finally, a total of five sessions were used in the study by Martín-Gutiérrez et al. (2010).

The other component in the determination of the duration of the study was how the research would fit into the design of the engineering graphic course. There were only so many weeks available in which the students were working with SolidWorks. After discussion, it was also determined that the implementation of augmented reality should occur
after students have been exposed to SolidWorks and were comfortable using the 3-D software.

The total number of hours students spent working with augmented reality was determined from the literature and also from how the study fit into the course. Both Blasko and Holliday-Darr (2010) and Contero et al. (2007) allowed for a total of six hours of treatment. A study by Cobos-Moyano et al. (2009) consisted of a total of eight hours of treatment. A study by Martín-Dorta et al. (2008) also had treatment time consisting of eight hours, but the study also included four hours of homework. Martín-Dorta et al. (2008) also noted that quick remedial courses consisting of between six and twelve hours can be significantly affect spatial ability. In the study conducted by Martín-Gutiérrez et al. (2010) the total amount of time was nine hours. The decision to select nine hours of treatment was based on the number of weeks in which SolidWorks was being discussed and used by the students and the amount of time available during the help sessions.

The length of each session was determined primarily based on the review of literature but consideration was given for the time allotment of the course. Studies by (Blasko & Holliday Darr, 2010; Cölln et al., 2012; Gueven & Kosa, 2008) each had treatment sessions that lasted for an hour and half. While studies by (Contero et al., 2007; Rafi et al., 2011) had treatment sessions that lasted for two hours. Finally, Martín-Gutiérrez et al. (2010) had treatment sessions that consisted of four two hour sessions and a one-hour session. Based on the session length of the studies listed above, it was determined that either an hour and a half or two hours was appropriate. The final decision to choose an hour and a half was decided upon after speaking with the instructor. Each section of the course had a help session, which
lasted for two hours. The instructor wanted to reserve half of hour in case the students had any issues unrelated to the use of augmented reality, and thus an hour and a half treatment session was chosen.

Research studies often incorporate a control group to better control extraneous variables. Studies by (Blasko & Holliday-Darr, 2010; Rafi et al., 2008; Samsudin et al., 2011) included a control group in their design when they implemented technologies into the learning environment. This study chose to not include a control group because the purpose of this study was only to investigate the effects of augmented reality in an engineering graphic course.

**Data Collection Methods**

The benefit of augmented reality on human performance is difficult to judge for several reasons. First, the majority of augmented reality software packages used in previous studies were prototypes. Secondly, there were limited evaluation systems developed to determine the effectiveness of the software. In addition, it was difficult to determine what constituted proper subject matter to assess the effectiveness of augmented reality. Finally, it could be difficult to create effective experiments around the technology, because of the limited amount of research conducted on augmented reality and because there are numerous augmented reality prototypes available for use in studies (Goldiez et al., 2004).

The study included multiple assessments. The decision to use multiple assessment instruments was supported by the research findings of Clark and Ernst (n.d.). Clark and Ernst (n.d.) recommended that specific assessment instruments were needed to address the
motivational attitudes, learning strategies and preferences, and spatial visualization ability of students in introductory engineering design graphics courses.

**Pre- and Post-Test Design**

A pre- and post-test format was used in this study for both the MSLQ survey and PSVT-R test. The use of a pre-test-intervention-post-test design is an appropriate method of investigation to determine the effects of innovations on education (Dugard & Todman, 1995). Additionally, several studies have used the pre- and post-test format to test for increased spatial ability and comprehension.

A pre-test was administered prior to the start of the study to measure spatial visualization skills and motivational attitudes. Gorska et al. (2009) stated that a standard spatial ability test should be administered to determine what are the best teaching practices and tactics to improve spatial skills. Titus and Horsman (2009) also recommended that pre-assessments should be administered to determine a baseline of the spatial visualization abilities of students enrolled in the course.

The use of a pre- and post-test format has been used in several studies to test for spatial ability and comprehension. Studies by (Alias et al., 2009; Blasko et al., 2009; Contero et al., 2007; Ferguson et al., 2008; Leopold et al., 2001; Medina et al., 1995; Sorby & Veurink, 2010) all used a pre-and post-test format to measure for an increase in spatial ability. Shelton and Hedley (2002) had students complete a pre-and post-test assessment for comprehension. This approach allowed for the testing of student knowledge acquired through the assistance of augmented reality. Studies by Medicherla (2011) and Sin and Zaman (2010) had students complete a pre- and post-test assessment using a survey as the instrument. The
survey used by Medicherla (2011) was designed to provide feedback regarding the students' level of comprehension, understanding and motivation associated with the inclusion of an augmented reality system.

Controlling the distance between the initial PSVT-R test and this final PSVT-R helped reduce the influence of extraneous variables on the results. This was important for the PSVT-R because each student had a different level of visualization skills and this needs to be taken into account when conducting research (Strong & Smith, 2002). There has been no universal time frame established when incorporating a pre-post-test format. Blasko and Holliday-Darr (2010) gave the pre-test at the beginning of the semester and post-test at the end of the semester. Medina et al. (1995) incorporated a ten-week separation between pre-post-tests. Sorby and Baartmans (2000) allowed for a three-month duration between pre-post-tests. Ben-Haim, Lappan, and Houang (1985) only allowed for three weeks between pre-post-tests because that was length of the treatment. Based on these studies and the time constraints associated with the course, 12 weeks between pre-post-tests was chosen because this limits the external effect on the results.

To compare pre-and post-test mean scores a paired t-test was used. A paired t-test was selected because it is used to determine whether there was a statistically significant difference between the means of two samples (Fraenkel & Wallen, 2000). Additionally, a paired t-test was chosen because it has been used to compare spatial gains (Connolly, 2009; Gorska et al., 2009; Gueven & Kosa, 2008; Leopold et al., 2001). A paired t-test was used by Milner et al. (2011) to compare mean scores on the MSLQ.
Participants Involved in the Study

The study was conducted within an introductory graphic communications course (GC 120) over two sections at North Carolina State University. A total of 120 students were enrolled in both sections. Of the 120 enrolled, 50 students took part in the study (N=50). The 70 students who chose not to take part in the study were excluded from all of augmented reality treatment sessions, but were still able to attend the help sessions. All of the participants involved in the study were students in an entry-level engineering course. The majority of the students were engineering majors since the course was a requirement for most engineering fields. However, the course was made available to all students regardless of major. For the bulk of students, this was their first course in graphic communications.

Students were unaware of the research that was to be conducted in each course prior to enrolling in one of the sections. This helped ensure the external validity of the experiment and contributed to a normal distribution. Any student who was enrolled in GC120 in the spring of 2013 had an equal opportunity to enroll in any one of the several section offerings. All students were considered novices in relation to their experience with augmented reality. This determination was made after asking all of the students who took part in the study if they had ever used the technology. Of the 50 students who participated in the study, none of them had ever used the augmented reality.

Several safeguards were put into place to ensure the privacy of the participants involved. To ensure the anonymity of the participants, all names were removed from all corresponding documents. The names were replaced with a numeric code only known to the researcher. The result of both the pre- and post-tests instruments and questions were kept
confidential. Only the researcher had access to this data. The electronic data collected from both pre- and post-tests of the PSVT-R tests were exported from Moodle and stored on a flash drive. Both of the MSLQ surveys were administered using a paper format. Once completed, the paper results were kept within the researcher’s office and permanently stored after the completion of the study. All paper documents were securely locked in a desk drawer in the researcher’s office and all electronic data were stored on a flash drive that was also locked in the researcher’s desk drawer.

**Demographics**

The study sample was comprised of 50 students \( (N = 50) \) from two GC 120 sections. The demographics included in the study were gender, major, and class standing. Seventy percent of the subjects in the study were male and 30 percent were female. Ninety-two percent of the students were engineering majors, while eight percent of the students were non-engineering majors. The high proportion of engineering majors in the study was expected because the course was a requirement for all engineering majors. The academic levels of students within the study were broken down as follows: 26 percent freshman, 50 percent sophomore, 18 percent junior, and six percent senior. The distribution of academic levels indicated that for the majority of the students this was their first engineering graphics course. This study drew participants from two sections, including 19 students from the morning section, and 31 students from the afternoon section.

**Procedures**

This study was conducted in the spring semester of 2013. To help ensure both sections received an equivalent level of instruction, the same instructor and teaching
assistants taught both sections. The instructor has taught the GC 120 course for 13 and a half years and has developed a uniform approach to all of his sections including identical assignments, projects, tests, book, CAD software, tutorials, and Moodle website. The courses were designed to be hybrid, including both a face-to-face and online component, which resulted in Monday being an optional help session day and Wednesday being required. The study began on during the second week of the semester and concluded on the 13th week of the semester (see table 1).

Table 2

*Research Timeline*

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Monday</th>
<th>January 7th</th>
<th>1st day of class</th>
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<tbody>
<tr>
<td>Week 2</td>
<td>Monday</td>
<td>January 14th</td>
<td>PSVT-R pre-test</td>
</tr>
<tr>
<td>Week 4</td>
<td>Monday</td>
<td>January 28th</td>
<td>IRB Approval</td>
</tr>
<tr>
<td></td>
<td>Wednesday</td>
<td>January 31st</td>
<td>Present research study to both sections, and collect informed consent forms.</td>
</tr>
<tr>
<td>Week 5</td>
<td>Monday</td>
<td>February 4th</td>
<td>1st Research Session</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Students complete MSLQ pre-test</td>
</tr>
<tr>
<td>Week 6</td>
<td>Monday</td>
<td>February 11th</td>
<td>2nd Research Session</td>
</tr>
<tr>
<td>Week 7</td>
<td>Monday</td>
<td>February 18th</td>
<td>3rd Research Session</td>
</tr>
<tr>
<td>Week 8</td>
<td>Monday</td>
<td>February 25th</td>
<td>4th Research Session</td>
</tr>
<tr>
<td>Week 9</td>
<td></td>
<td></td>
<td>No Session (Spring Break)</td>
</tr>
<tr>
<td>Week 10</td>
<td>Monday</td>
<td>March 11th</td>
<td>5th Research Session</td>
</tr>
<tr>
<td>Week 11</td>
<td>Monday</td>
<td>March 18th</td>
<td>6th Research Session</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Students completed the MSLQ post-test and</td>
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</table>
The initial step in the research process was to obtain permission to conduct research. Permission was granted on Monday, January 28, 2013 through the acceptance of a university’s Institutional Review Board (IRB). Upon IRB acceptance, the researcher presented the study to students in both sections in order to obtain participants.

Participation in the study was on a volunteer basis and each participant was provided with a written informed consent. Students were allowed to choose whether or not to participate, and were aware that they could withdraw from the study at any time without penalty. To increase student participation, compensation was offered in the form of extra credit. Students who completed the study received a total six extra credit points that were applied to their final project grade. The final project was scored on 100-point scale and accounted for 20 percent of the student’s final grade. The students only received the extra points if they completed all the requirements of the study. The student either received full credit or no credit. The requirements included meeting for a total of six Monday sessions throughout the semester and completing all required tests. These tests included the pre- and

<table>
<thead>
<tr>
<th>Week 12</th>
<th>Monday</th>
<th>March 25th</th>
<th>Make-up Session</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Students completed the MSLQ post-test and questions on their experience using augmented reality</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 14</th>
<th>Monday</th>
<th>April 8th</th>
<th>Students completed the PSVT-R post-test</th>
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</thead>
</table>
post-test of the MSLQ and PSVT-R, and questions on the effect of augmented reality on learner outcomes. There was an alternative assignment for those who chose to not take part in the study. For the alternative assignment, the researcher provided links to six prominent research articles chosen by the researcher on the application of augmented reality in education. Students were allowed to choose three articles to read, analyze, and write a short paper (not to exceed five APA, MLA etc. formatted pages plus references) discussing article content, difference, or any relevant comparison that the student considered appropriate.

Throughout the study the instructor and teaching assistants continued to teach on Wednesdays and provided optional help sessions on Mondays for those not in the study. There was no inclusion of augmented reality during the Wednesday courses. The instructor and teaching assistants were trained on how to use the augmented reality software, but not on how to solve issues associated with the technology. The researcher was only responsible for addressing all questions that arose surrounding the use of augmented reality, while all the content and SolidWorks related problems were addressed by the instructor or teaching assistants. Additionally, the instructor did not provide instruction on the use of the augmented reality software referring all questions to the researcher. During this period, the researcher did not teach content related to GC 120 and only focused on the treatment of augmented reality.

The researcher discussed the purpose of the study and demonstrated how to use the augmented reality software with the instructor and both teaching assistants present. There was a teaching assistant assigned to each section. The teaching assistants aided the researcher in preparing the iPads, loading the augmented reality software, and ensuring all technologies
were in working order prior to each session. The teaching assistants also assisted the researcher by bridging the gap between researcher, student, and assignment during the study. The teaching assistants worked with the researcher and instructor on Mondays going between the study and help session. Participants had the opportunity to receive assistance from the instructor or teaching assistants whenever necessary.

On week two students completed the PSVT-R pre-test. Students were required to complete the test regardless of whether or not they participated in the study. All students were also required to take the PSVT-R post-test. Both applications of the PSVT-R test were taken through the Moodle website. The Moodle website calculated the students’ scores and produced a grade for each student that cannot be seen by the instructor or student. Students who took part in the study were administered the MSLQ during week four. The MSLQ survey consisted of 30 questions and was available through the Moodle website with students using a corresponding sheet of paper to answer the questions. The data was exported into an excel spreadsheet and then deleted from the Moodle website. The initial MSLQ and PSVT-R results became the baseline data for the study and were used for comparison to the post-test MSLQ and PSVT-R instruments when the study concluded.

The first interaction between the researcher and students occurred during the fourth week of classes. Both of the classes began by having the instructor for the course introduce the researcher and study. The researcher then introduced himself and began to discuss the study, which included stating the purpose and rationale for the research, detailing how the study would be conducted, explaining why the study would be conducted, and detailing what would be required of the participants.
The first augmented reality session occurred during week five. This was the students’ first opportunity to interact with the augmented reality software. Before beginning the assignment, each student was individually instructed on how to use the augmented reality system. The researcher modeled the proper technique and methods for the effective use of augmented reality and provided a step-by-step demonstration. The purpose was to familiarize the students with the technology, software, models, and how they combine to create a virtual object. All of these measures were deemed critical for student understanding (Schmoker, 2006).

There were a total of six assignments and one make-up session that incorporated the use of augmented reality, with a different model being assigned each week. For week two, there were two different models to choose from. Each of the assignments built upon the previous one and required students to refine their skills in SolidWorks. Three of the assignments were required as part of the GC 120 courses, while the other three assignments were designed solely for the study. The three assignments that were not part of the course were selected based upon the suggestion of the instructor and because of their relevance to the content being taught. During each session, the students spent the allotted time creating the model in SolidWorks with the assistance of the augmented reality software and 2-D sketch in the book. A study conducted by Allison and Hodge (2000) using virtual reality concluded that students should observe and model the activity during the same period instead of having students observe during one class and then model in another. During this time, the instructor and teaching assistant provided assistance where needed. Upon completion of the assignment, the student emailed the modeled part to the researcher. This was done to ensure
that students were completing the required model during the session. Additional time could be used outside of class, but this was not a requirement.

Table 3

*Augmented Reality Assignment Schedule*

<table>
<thead>
<tr>
<th>Assignment #</th>
<th>Week #</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Problem #2 on page 337 in the <em>Fundamentals of Graphic Communications</em> book (figure 3).</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Figure 5.142 in the <em>Fundamentals of Graphic Communications</em> book (figure 4).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Figure 5.130 in the <em>Fundamentals of Graphic Communications</em> book (figure 5).</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Model #4 on page 484 in the <em>Fundamentals of Graphic Communications</em> book (figure 6).</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Figure 5.148 on page 308 in the <em>Fundamentals of Graphic Communications</em> book (figure 7).</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Figure 5.146 on page 308 in the <em>Fundamentals of Graphic Communications</em> book (figure 8).</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>Figure 5.147 on page 308 in the <em>Fundamentals of Graphic Communications</em> book (figure 9).</td>
</tr>
<tr>
<td>Make-Up</td>
<td>11</td>
<td>Figure 5.135 on page 306 in the <em>Fundamentals of Graphic Communications</em> book (figure 10).</td>
</tr>
</tbody>
</table>
**Assignment One.** The first project that incorporated augmented reality was assigned in week 3. The first assignment was problem #2, a bearing rest, found in *Fundamentals of Graphic Communications* on page 337 (Figure 3). The problem focused on developing geometric relations, commands in SolidWorks, and establishing design intent.

![Assignment 1](image1.png)

Figure 3. Assignment 1

**Assignment Two.** The second assignment that incorporated augmented reality was assigned in week 4. For the second assignment students were given the option of selecting figure 5.142 a bearing block (Figure 4) or figure 5.130 a motor plate (Figure 5). Both assignments were found in *Fundamentals of Graphic Communications* book. Figure 5.142 focused on utilizing the fillet command, concentric relations to align three sets of circle and
arc combinations. The assignment also focused on center-to-center distance between holes.

Figure 5.130 focused on tangential relations, the fillet command, and symmetry.

Figure 4. Assignment 2a
Assignment Three. The third assignment was assigned in week five. The model was number four on page 484 in *Fundamentals of Graphic Communications* book (Figure 6). The model presented multiple methods to accomplish the same design and allowed students to illustrate design intent to determine how one would complete the model. Students were also asked to analyze the model from left to right and front to back identifying corresponding extrusion heights on different features.
Assignment Four. The fourth assignment was assigned during week 8. The assignment was figure 5.148 a anchor base found on page 308 in the Fundamentals of Graphic Communications book (Figure 7). The assignment allowed students to refine their knowledge of geometric relations, such as tangent, concentric, and symmetrical, and addressed the reoccurring theme of design intent. Students were also required to analyze the model from left to right and front to back to align features presented at different heights.
Assignment Five. The fifth assignment was assigned during week 11. The assignment was figure 5.146 a retaining cap located on page 308 in the *Fundamentals of Graphic Communications* book (figure 8). The model forced students to incorporate concentric relations, angled cuts, and use multiple cut-extrude commands. Students dealt with radially aligned features such as cutouts and holes.
Assignment Six. The sixth assignment was assigned during week 12. The assignment was figure 5.147 a locating base, on page 308 in the Fundamentals of Graphic Communications book (figure 9). In the assignment students used the centrally aligned feature on a flat base, created concentric holes, and used tangential features.
Figure 9. Assignment 6

**Make-up Assignment.** The make-up assignment was given during week 13. The option was given to those students who had completed five of the previous six assignments and had a valid excuse for missing a session. The assignment was figure 5.135 a shaft support, located on page 306 in the *Fundamentals of Graphic Communications* book (figure 10). The model required students to use non-tangent lines, rounded corners, fillets, and address variable heights.
The final component of the study was the completion of the MSLQ and PSVT-R post-tests and student questions on the effectiveness of augmented reality in an introductory engineering graphics course. The MSLQ post-test and student survey on their experience using augmented reality were completed during week 12, after the completion of assignment #6 or the make-up assignment. The PSVT-R post-test was then completed during week 14. For consistency and accuracy, the same format was followed for both tests. The MSLQ survey was again given in a paper format and the PSVT-R test was again taken through the Moodle website. The completion of both post-test and seven questions concluded the data collection portion of the study.
Data Collection Methods

A total of three data collection methods were used in the study to determine the effects of augmented reality in an introductory engineering graphics course. The MSLQ was included to assess the motivational attitudes of students. The PSVT-R was included to assess the students’ spatial visualization ability. Finally, a basic interpretive method that consisted of seven questions was included to assess the students experience with augmented reality.

MSLQ Survey

A major research question proposed within this study was whether augmented reality affected the motivational attitudes of students in an engineering graphics course. The instrument that was administered in an attempt to answer this question was the MSLQ. The MSLQ contains 81 questions and addresses both motivation orientation and learning strategies. The learning strategies section was excluded because it was not pertinent to the research question. This resulted in the use of a condensed version of the MSLQ containing only 26 of the motivation orientation questions (Matthews, 2004). Due to copyright regulations the MSLQ was not included in the appendix.

PSVT-R Test

The PSVT-R instrument contains 30 multiple-choice questions. Each of the 30 questions follows the same formatting. The test is also designed to have each question increase in difficulty. The test is scored as a percentage correct. For example, a student who correctly answers 24 out of 30 questions correctly would score an 80 percent. According to research conducted by Ault and John (2010) the average score on the PSVT-R is 75 percent.
Additionally, in studies conducted by Sorby and Veurink (2010) a score of less than 60 percent was considered failing.

Students were given instructions on how to complete the PSVT-R prior to beginning the test. For each question, students were presented with a three-dimensional model that had been rotated. The model served as the example for the question and required students to mentally rotate the image. Once the student had determined how the model was mentally rotated, he/she was required to mentally rotate the problem model and select the answer from five possible rotations. The rotations were labeled with A, B, C, D, or E. The student was asked to determine which of the solutions presented best compared to the initial example (figure 11). In order to choose the correct answer the student had to visualize the proper rotation and direction of the initial example and then compare this rotation to the selections listed below. All students enrolled in both sections of GC 120 were required to take both the pre- and post-test PSVT-R regardless of whether or not they took part in the study.

There was a 20-minute time limit imposed upon students when taking the PSVT-R. After 20 minutes the Moodle site would close the test and not allow students to complete the PSVT-R. The time restriction was imposed in order to restrict the analytical processing of students (Bodner & Guay, 1997).
Student Questions

The questions addressing the students’ experience with augmented reality in an engineering graphic course consisted of seven questions. Students had the option to complete any number of the seven questions and write as much or little as they chose. The purpose of the questions was to assess the students’ perceptions and opinions of the effectiveness of augmented reality to assist them with their assignments. This was accomplished by having students describe how augmented reality affected their motivation, engagement, learning experiences, and visualization ability.
Data Collection

Data were collected from all three assessments through different methods. For the MSLQ, this was collecting the student completed paper answer sheets for both the pre- and post-tests. For the PSVT-R, this was the retrieving of student responses from the Moodle website for both the pre-test and post-tests. Finally, for the student questions this was collecting the paper answer sheets.

Both the MSLQ and PSVT-R used a pre- and post-test test format. This method was selected because this is an effective method to assess student outcomes on a particular activity (Baylor & Ritchie, 2002). For both the MSLQ and PSVT-R, data were collected prior to starting the augmented reality treatment. Additionally, data were collected after the completion of all treatment sessions. For the MSLQ, the difference between the pre- and post-tests was seven weeks, and for the PSVT-R the difference was 12 weeks. The additional length between the pre- and post-test PSVT-R was because the pre-test was given two weeks before the treatment and the post-test was given three weeks after the students’ last exposure to augmented reality.

In order to address the potential issue of student apathy or a lack interest on the PSVT-R, the instrument was graded and appeared on each student’s Moodle page (Sorby & Baartmans, 1996). The test was taken by all students in the courses. Students were made aware that the PSVT-R was an important component of the course. This gave a value to the test scores for the students and allowed them to take it seriously.

The student questions were completed on the final day of the treatment. Students were given the questions after completing the final assignment and post-test MSLQ. The
seven questions were given in a paper format and were completed by the students at their desk. Once the students had completed their questions, the papers were returned to the researcher and were free to leave.

**Data Analysis**

Once collected, data from all three of the assessments were analyzed. The analysis of data began during week 12 and after every student had completed all of treatment sessions and assessments. For both the MSLQ and PSVT-R, the analysis began by calculating the mean and standard deviation for the pre- and post-test results. For the MSLQ, this also included determining the mean and standard deviation of the five subscales and overall summary. These descriptive statistics were calculated and presented to describe and summarize the data.

A paired t-test was used to compare the pre- and post-test mean scores for both the MSLQ and PSVT-R. The resulting scores of the overall MSLQ and five subscales were then compared. The purpose was to determine if there was a significant difference in motivational attitudes of the participants prior to the treatment as compared to after the treatment was received. The resulting scores of the PSVT-R tests were gathered and compared. The purpose was to determine if there was an improvement in spatial visualization skills after the students worked with augmented reality.

A Pearson Correlation was included to measure the linear relationship between the post-test scores of the MSLQ and post-test scores of the PSVT-R. The purpose of the correlation was to assess the relationship between student motivation and spatial visualization skills. A Pearson correlation was used because it is the most commonly used
correlation that “measures the degree and direction of linear relationships between two
variables” (Gravetter & Wallnau, 2000, p. 531). The stronger the association between the two
variables the closer $r$ will be to +1 or -1 (Wallen & Frankel, 2000).

The seven questions on the students experience with augmented reality were collected
and analyzed. The first step in the process was to read all of the responses. Next, all of the
responses were typed into an Excel spreadsheet. Then the researcher analyzed the results
looking for emerging themes from each question. This was accomplished by highlighting
phrases and specific words. The themes that emerged were categorized and coded. Once the
major themes were identified, categorized, and coded the researcher re-read all of the
responses and placed them into the corresponding category. After reading all responses each
category was totaled and calculated. Finally, the researcher re-examined each category and
set of responses to ensure that all were related to the category.

Chapter Summary

The chapter detailed the steps the researcher took in administrating all phases of the
study. This began with the rationale for the design of the study and concluded with the
collection of data. To support the methodology, evidence from previous studies was
presented. The study began with the acceptance of the IRB. Upon acceptance of IRB, the
study was presented to students in two sections of a GC 120 at North Carolina State
University. The sample size consisted of 50 students (N=50). The format of the study was
pre-test-intervention-post-test. Students were required to attend six treatment sessions
consisting of 90 minutes each, for a total of nine hours. In each session, students used an
augmented reality system to assist them visually in the creation of a 3-D model in
SolidWorks. The three data collection methods used in the study to attempt to measure the effectiveness of augmented reality were the MSLQ, PSVT-R, and questions on the students’ experience using augmented reality. Both the MSLQ and PSVT-R used a pre- and post-test format while the student questions were completed at the conclusion of the study. The results of the MSLQ and PSVT-R were compared using a paired t-test and the results of the student questions were coded and emerging themes were described. In the next chapter, the data and results from the three assessments will be analyzed and detailed.
CHAPTER FOUR: FINDINGS

The purpose of this study was to understand how learner outcomes could be affected through the implementation of augmented reality in a beginning engineering graphic communication course. To determine this, three data collection methods were implemented: the MSLQ, PSVT-R, and student questions. The MSLQ was used to determine student motivation from using augmented reality. The PSVT-R was used to assess if student visualization skills were improved through the implementation of augmented reality. The final instrument consisted of seven questions regarding the students’ experiences using augmented reality. The questions were included to elucidate the students’ perceptions of augmented reality and to fill any gaps from the MSLQ and PSVT-R instruments.

This chapter describes the statistical results from the MSLQ and PSVT-R as well as the data collected from the student questions on their use with augmented reality. The first section details the demographic findings of the participants in the study. The second section describes the analysis of the statistical data relating to the two hypotheses. For both quantitative instruments an alpha level of .05, which is commonly used in statistics, was used to test for any level of significance.

Demographic Data

Subject Gender and Academic Levels

The demographic data was analyzed based on gender and academic levels of participants in the study. Table 4 refers to both gender and the academic level of students and Table 5 refers to the academic majors of participants in the study. The gender count in Table
4 highlights the fact that 70 percent of the subjects \((N = 50)\) in the study were male and 30 percent were female. The high percentage of male students was to be expected in an engineering graphics course. The academic levels of students within the study were broken down as follows, 26 percent freshman, 50 percent sophomore, 18 percent junior, and 6 percent senior (see Table 4). The academic levels presented in Table 4 indicated that for the majority of students in the study this was their first engineering graphics course.

Table 4

*Gender and Academic Level of Subjects in Study Sample*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Students</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>35</td>
<td>70</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Academic level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>Sophomore</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Junior</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Senior</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
**Academic Majors in Study**

The academic majors of the students were broken down into either engineering or non-engineering majors (see table 5). The demographic analyses indicated that the students’ academic major were primarily engineering (92 percent). In fact, only 8 percent of the students were non-engineering majors. These numbers were to be expected because the course was a requirement for engineering majors, but was open to all majors.

Table 5

*Academic Majors in Study*

<table>
<thead>
<tr>
<th>Academic Major</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>46</td>
<td>92</td>
</tr>
<tr>
<td>Non-Undesignated engineering</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

*Note. N = 50*

**Data Analysis**

Next, the researcher analyzed the motivational attitude and spatial visualization performance hypotheses relating to the inclusion of augmented reality. Pre- and post-test scores of the MSLQ survey and PSVT-R were then analyzed and compared. The results of the questions assessing the students’ experiences with augmented reality were also examined and recurring themes were established.
Research Question #1

Will the implementation of augmented reality affect the motivational attitude of students in an introductory engineering graphics course as measured by the MSLQ? If so, how?

HO1: The implementation of augmented reality will not have a statistically significant effect on the motivational attitudes of students in an introductory engineering graphics course as measured by the MSLQ.

The variations between the MSLQ subscales 1, 2, 3, 4, 5 and condensed version were used to test the subjects’ attitude in the study and are explained in this section (subscale 6 was not utilized). Subscale summaries and results for each of the subscale analyses are presented in Table 6 and 7. Table 6 displays and allows for the numerical comparison of the mean and standard deviation for the pre- to post-test scores on MSLQ subscales (1, 2, 3, 4 and 5) and condensed MSLQ. Table 7 displays the results from the paired t-test for each of the five MSLQ subscales and condensed MSLQ. The paired t-test was used because it is an appropriate method for the comparison of two related group’s scores before and after an intervention (Frankel and Wallen, 2000; Mowery, 2011).

A condensed version of the MSLQ was used and included the following subscales: Intrinsic goal, extrinsic goal, task value, and self-efficacy. Table 6 lists the means and standard deviations of the scores for subscales (1, 2, 3, 4, and 5) used in the MSLQ, and Table 7 summarizes the paired t-test results.
Table 6

Comparison of Scores for MSLQ Subscales by Test

<table>
<thead>
<tr>
<th>MSLQ Subscale</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value component: Intrinsic goal orientation (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test value</td>
<td>50</td>
<td>5.08</td>
<td>.43</td>
</tr>
<tr>
<td>Post test value</td>
<td>50</td>
<td>5.31</td>
<td>.41</td>
</tr>
<tr>
<td>Value component: Extrinsic goal orientation (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test value</td>
<td>50</td>
<td>5.59</td>
<td>.28</td>
</tr>
<tr>
<td>Post test value</td>
<td>50</td>
<td>5.53</td>
<td>.43</td>
</tr>
<tr>
<td>Task value component (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test value</td>
<td>50</td>
<td>5.57</td>
<td>.21</td>
</tr>
<tr>
<td>Post test value</td>
<td>50</td>
<td>5.54</td>
<td>.28</td>
</tr>
<tr>
<td>Control of learning beliefs (4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test value</td>
<td>50</td>
<td>5.81</td>
<td>.43</td>
</tr>
<tr>
<td>Post test value</td>
<td>50</td>
<td>5.76</td>
<td>.36</td>
</tr>
<tr>
<td>Self-efficacy – Learning Performance (5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test value</td>
<td>50</td>
<td>5.59</td>
<td>.32</td>
</tr>
<tr>
<td>Post test value</td>
<td>50</td>
<td>5.57</td>
<td>.26</td>
</tr>
<tr>
<td>Overall MSLQ summary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total MSLQ: pre-test</td>
<td>1297</td>
<td>5.53</td>
<td>1.19</td>
</tr>
<tr>
<td>Total MSLQ: post-test</td>
<td>1297</td>
<td>5.57</td>
<td>1.16</td>
</tr>
</tbody>
</table>
**Subscale 1 - Value component: Intrinsic goal orientation.** The subscale intrinsic goal orientation included a total of four questions. The subscale was included to assess whether students considered augmented reality to be a tool affecting their intrinsic motivational by arousing curiosity and interest in the subject matter (Pintrich et al., 1991). The mean value scores on the intrinsic goal orientation subscale revealed a pre-test score of (5.08) and a post test score of (5.31) (see table 6). The p-value of .014 indicated that there was statistical difference between the students’ pre-post test scores (see table 7).

**Subscale 2 - Value component: Extrinsic goal orientation.** The subscale extrinsic goal orientation included a total of four questions. The scale was included to assess whether students viewed the inclusion of augmented reality as an extrinsic motivational tool to improve their grade (Pintrich et al., 1991). The mean value scores on extrinsic goal orientation revealed a pre-test score of (5.59) and a post-test score of (5.53) (see table 6). The p-value of .708 indicated no significant difference between the students’ pre-post test scores (see table 7).

**Subscale 3 – Task value component.** The subscale task value contained a total of six questions. The scale was included to assess whether students viewed the inclusion of augmented reality as interesting and of importance to success in the course (Pintrich et al., 1991). The mean value scores on the comparable task value subscale revealed a pre-test score of (5.57) and a posttest score of (5.54) (see table 6). The p-value of .888 indicated no significant difference between the students’ pre-post test scores (see table 7).

**Subscale 4 – Control of learning beliefs.** The subscale included a total of four questions. The scale was included to assess whether students viewed the inclusion of
augmented reality as a tool that would increase their success in the understanding of engineering graphic concepts (Pintrich et al., 1991). The mean value scores on the control of learning beliefs subscale revealed a pre-test score of (5.81) and posttest score of (5.76) (see table 6). The p-value of .60 indicated no significant difference between the students’ pre-post test scores (see table 7).

**Subscale 5 – Self-efficacy learning performance.** The subscale included a total of eight questions. The scale was included to assess whether the inclusion of augmented reality increased the students confidence to succeed and receive a good grade in the course (Pintrich et al., 1991). The mean value scores on the self-efficacy learning performance subscale revealed a pre-test score of (5.59) and post-test score of (5.57) (see table 6). The p-value of .32 indicated no significant difference between the students’ pre- and post-test scores (see table 7).

**Overall MSLQ summary.** The overall MSLQ summary included all 31 questions administered. This provided a combined score for all 26 questions. The results revealed a mean value on the pre-test score of (5.53) and posttest score mean value score of (5.57) (see table 6). The p-value of .27 indicated no significant difference between the students’ pre- and post-test scores on the MSLQ (see table 7).
Table 7  
*Paired Samples Test for MSLQ Subscales and Overall Summary*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Lower</th>
<th>Upper</th>
<th>T</th>
<th>Df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Goal Orientation</td>
<td>-0.22</td>
<td>1.26</td>
<td>0.09</td>
<td>-0.4</td>
<td>-0.05</td>
<td>-2.48</td>
<td>198</td>
<td>0.01</td>
</tr>
<tr>
<td>Extrinsic Goal Orientation</td>
<td>0.04</td>
<td>1.32</td>
<td>0.09</td>
<td>-0.15</td>
<td>0.22</td>
<td>0.38</td>
<td>199</td>
<td>0.71</td>
</tr>
<tr>
<td>Task Value</td>
<td>0.01</td>
<td>1.23</td>
<td>0.07</td>
<td>-0.13</td>
<td>0.15</td>
<td>0.14</td>
<td>298</td>
<td>0.89</td>
</tr>
<tr>
<td>Control of Learning Beliefs</td>
<td>0.05</td>
<td>1.22</td>
<td>0.09</td>
<td>-0.16</td>
<td>0.22</td>
<td>0.52</td>
<td>197</td>
<td>0.60</td>
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<tr>
<td>Self-efficacy – Learning Performance</td>
<td>-0.06</td>
<td>1.22</td>
<td>0.06</td>
<td>-0.18</td>
<td>0.06</td>
<td>-0.99</td>
<td>398</td>
<td>0.32</td>
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<tr>
<td>Overall Pre – Post</td>
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<td>0.03</td>
<td>-0.11</td>
<td>0.03</td>
<td>-1.1</td>
<td>1299</td>
<td>0.27</td>
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</table>

Note. $p < 0.05$
Research Question #2

Will the implementation of augmented reality improve the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R? If so, how?

HO2: The implementation of augmented reality will not have a statistically significant improvement on the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R.

The differences between the pre-post test score results from the PSVT-R are displayed below in tables 8 through 10. Table 8 displays the results from the pre-post tests of the PSVT-R including the minimum, maximum, mean, and standard deviation. Table 9 displays the results from the paired t-tests. Table 10 displays the frequency distribution of scores on the pre-post tests.

The PSVT-R consisted of 30 multiple choice questions (Bodner & Guay, 1997). Each question was worth one point for a total of 30. Students completed the pre-test two weeks prior to the study and post-test two weeks after the completion of the study. The minimum score on the pre-test was 13 and the minimum score on the post-test was 12. The maximum score on both the pre-post tests was 30. Four students scored a 30 on the pre-test and seven students scored a 30 on the post-test. The pre-test mean score was 24.6 and the post-test mean score was 25.9. The standard deviation on the pre-test was 4.13 and 4.09 on the post-test. The results of paired t-test showed a p-value (.001) indicating a significant difference between students pre-post test scores on the PSVT-R (table 9).
The results of the pre-test scores on the PSVT-R revealed that the students who participated in the study possessed high spatial skills prior to the start of the study as compared to studies by Blasko and Holliday-Darr (2010) and Sorby (2009a). The mean score on the PSVT-R test from this study was 24.6 out of 30, which would equate to 82 percent. Forty-five out of the 50 or 90 percent of students scored at least a 19 out of 30 or 63 percent. These results were important because studies by Blasko and Holliday-Darr (2010) and Sorby (2009a) considered a score of less than sixty percent as failing. Additionally, in the research conducted by Sorby (2009a) 20 percent of the students scored less than 60 percent on the pre-test of the PSVT-R. That percent is certainly higher than the 10 percent found in this study.

The results of the post-test PSVT-R indicated that 48 out of 50 or 98 percent of the students scored at least 60 percent on the post-test. Both of the students who had a score of less than 60 percent on the post-test actually had their scores decline when compared to their pre-test scores. This potentially could be explained through student apathy. Although the PSVT-R was part of the course it was not graded and may not have seemed important to those two students.

Table 8

*Results of the PSVT-R*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>M</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>50</td>
<td>13</td>
<td>30(4)</td>
<td>24.6</td>
<td>4.13</td>
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<tr>
<td>Post-test</td>
<td>50</td>
<td>12</td>
<td>30(7)</td>
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Table 9

*Paired Samples Test for PSVT-R*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>Sig. (2-tailed)</th>
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<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Pre – Post PSVT-R</td>
<td>1.280</td>
<td>.8826</td>
<td>.125</td>
<td>1.53</td>
<td>1.036</td>
</tr>
</tbody>
</table>

Table 10

*Frequency Comparison between Pre-post Scores on the PSVT-R*

---

**Frequency of Pre-Post Test PSVT-R Scores**

![Bar chart showing frequency of Pre-Post Test PSVT-R Scores](chart.png)
Correlation

A Pearson correlation was computed to assess the relationship between the post-test scores on the PSVT-R and MSLQ. This measurement was included to determine if there was a relationship between levels of spatial visualization ability and students motivation. The Pearson correlation showed an \( r = .318, p < .024 \) indicating there was a weak positive relationship between post-test scores on the PSVT-R and MSLQ (Table 11). Based upon these results, increases in post-test MSLQ scores were weakly correlated with increases in post-test PSVT-R scores. The scatter plot diagram (figure 12) was examined and provides a visual description of the weak positive correlation between MSLQ scores and PSVT-R. Additionally, the scatter plot diagram revealed no outliers that might have influenced the results were identified.

Table 11

*Post-test MSLQ and PSVT-R Relationships*

<table>
<thead>
<tr>
<th></th>
<th>Post-test PSVT-R</th>
<th>Post-test MSLQ</th>
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<tr>
<td>Post-test PSVT-R</td>
<td></td>
<td></td>
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<tr>
<td>Pearson Correlation</td>
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<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.024</td>
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<tr>
<td>N</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Post-test MSLQ</td>
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<td>Pearson Correlation</td>
<td>.318*</td>
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<td>Sig. (2-tailed)</td>
<td></td>
<td>.024</td>
</tr>
<tr>
<td>N</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (2-tailed).
Research Question #3

What are the students learning experiences with augmented reality?

a. How does the use of augmented reality promote experimentation including: examination, comparison, and problem solving?

b. How does the use of augmented reality allow the student to manipulate the models by providing the following: multiple viewing perspectives, rotation, and scalability?

c. How does augmented reality engage students through; active participation, kinesthetic learning, and inquiry?

The participants completed the questions at the conclusion of the treatment. There were a total of seven open-ended questions that addressed the student’s experience using
augmented reality to assist with the six assignments in an introductory engineering course. The results from all 50 participants were collected and analyzed to identify themes that emerged (appendix 2).

1. *How did the use of augmented reality affect your learning experience?*

There were two major themes and two minor themes for this population from the researcher’s perspective that emerged from the students’ responses as to how augmented reality affected their learning experience. The two major themes that emerged were that augmented reality improved the students’ visualization skills and that students were better able to understand and conceptualize the assignments. The two minor themes to emerge were: the ability to manipulate models during each assignment positively affected the learning experience and the learning experience was enhanced through the inclusion of augmented reality.

The most prevalent theme to emerge from the students’ responses was the influence augmented reality had as a visualization tool to affect the learning experience. A total of 68 percent (n=34) students wrote about the positive impact of augmented reality as a visualization tool to assist them in understanding the assignments. Several students stated that augmented reality “helped me” visualize the drawing. One student stated that augmented reality “really helped me visualize what I was doing in SolidWorks and simplified geometry.” Other students indicated that augmented reality improved their visualization skills. Another student stated, “it helped my visualization abilities.”

Forty percent (n=20) of the participants believed that augmented reality allowed them to greater understand the assignment by enabling them to clarify dimensions and
conceptualize models. This was noted in a student’s response “it helped me understand general layouts of complicated structures.” Students also noted that augmented reality helped clarify issues. Finally, students discussed how augmented reality allowed them to conceptualize the models. Another student commented on how augmented reality “helped me learn to visualize and rotate objects in my head better.”

The two minor themes to emerge from the question were the possibilities presented through being able to manipulate the model and the ability of augmented to enhance the learning process. Eight students talked about how they were able to manipulate the object in order to gain a greater understanding. One student pointed out that “the augmented reality simulated a hands-on experience with the model so I could rotate it and zoom in and out to see the finer details.” Students also wrote about how augmented reality “enhanced” the learning experience and they “really liked working with the software,” and the software “made it easier.”

2. How has the use of augmented reality influenced your motivation in GC 120?

There were several themes that emerged from the students’ responses. The majority of students believed augmented reality influenced their motivation in GC 120, while some believed augmented reality provided no motivational effect. Students pointed out that augmented reality influenced their motivation to spend additional time working with SolidWorks and on assignments, improved their confidence within the course, and increased their interest within the course.

The inclusion of augmented reality allowed students to spend additional time working in SolidWorks. The additional time allowed students to develop and hone their skills. The
increased capabilities and success provided motivation and was noted by 12 of the students. This belief was exemplified by one student who stated “I think it has helped me become a lot better with SolidWorks” and he added, “I am a lot quicker and know how to use the tools in which before I did not.”

Twenty percent (n=40) of the students believed augmented reality did not impact their motivation in the course. These students believed they were already motivated to succeed in the course and did not need any additional motivation. This was evident by a student who said augmented reality “has not motivated me any more than before” and student number seventeen who stated “I was motivated before so I do not think it has changed that much.”

Several students indicated that augmented reality increased their motivation and interest in the course. Nine students talked about how augmented reality motivated them as noted by a student number who wrote that augmented reality “has made GC 120 a greater part of my week and has increased my motivation.” An additional five students talked about how their interest to learn was enhanced through the use of augmented reality. Student number 22 stated that “the augmented reality has increased my interest in the GC 120 course material significantly.”

Students became more confident with the coursework through using augmented reality. Eight students believed augmented reality improved their confidence within the course and with using SolidWorks. One student said that “I would say it has improved my motivation by improving my confidence in understanding of the course material.” Students also concluded that augmented reality improved their confidence with software as evidenced
by a student stating that augmented reality “has improved my confidence in using
SolidWorks.”

3. **Please describe how the use of augmented reality affected your ability to
   manipulate the assigned models.**

Several themes emerged from the students’ responses to how the use of augmented
reality affected their ability to manipulate the assigned models. Because of augmented reality
students were able to manipulate models through rotation and by zooming in and out. The
ability to manually manipulate the models allowed students to gain an additional perspective
which showed hidden features and allowed them to view the model from many angles.
Because of this ability students were able to conceptualize the models prior to starting. This
experience was noted by a student who wrote that “augmented reality made it easier for me
to manipulate the assigned models as I had a better visualization of the model.”

Sixteen percent (n=8) of the students identified rotation as an effective means to
manipulate models. One student believed that “having a piece you can rotate is very helpful”
because “you can’t see every side in a drawing but you can in augmented reality.” The ability
to manipulate the models helped them complete the assignments in less time and with less
difficulty. A student noted that “augmented reality let me rotate the parts and zoom in on all
features,” while another student stated that “I was able to model more accurately and faster
than had I not used augmented reality.”

By manipulating models students were able to obtain an additional perspective. Forty
six percent (n=23) of the students believed that augmented reality allowed them to
manipulate models to gain additional perspectives. A student highlighted this belief when he
wrote that augmented reality “helped understand how the object looked, so once I knew the dimensions it helped know where to put them.” This provided students the opportunity to view all of the features, holes, and sides of an object. Another student wrote about how he could “check for the locations of rounds easier, and inspect the model to check for potential shortcuts.” Augmented reality also “made it a lot easier to visualize the parts from all angles” when “isometric pictures did not show holes or lines” and “you can’t see every side in a drawing.”

Finally, 12 percent (n=24) of the students believed that the ability to manipulate the model allowed them to conceptualize the assignment prior to starting. One student believed augmented reality made it “easier to find a starting point for some of the more difficult sketches.” This view was shared by student number 28 who said that augmented reality “allowed me to think through and more easily breakdown the models so I could simplify them.”

4. How were you able to examine and compare the assigned models through augmented reality?

Two themes emerged from the students’ responses as to how they were able to examine and compare the assigned models through augmented reality. First, students stated that they were able to examine the assigned models through manipulation. Secondly, students used the augmented reality software to check and compare the assigned models.

A total of fifty four percent (n=27) of the students indicated that the ability to manipulate models allowed them to examine and compare their model to the augmented model and 2-D sketch. This was evident by one student’s response that “manipulating both
the on screen tools and the AR itself made it easy to examine every aspect of the model.” The manipulation of models occurred by rotating the object, zooming in and out to examine specific features, and from viewing the model from different perspectives.

Almost half of the students wrote about using rotation to manipulate the assignment. For example, one student noted that he “was able to spin the views to help figure out where to start on the part.” This allowed students to manually assist with their visual understanding of the model. Another student added that he “was able to rotate the part, which is something I could not do with the paper sketch I had.”

To clarify uncertainties students were able to zoom in on a specific area. Students combined this with the ability to rotate models. This was evident in one student’s response that “by rotating and zooming in the augmented reality program, I could see the model more clearly and understood what I had to do to create it in SolidWorks.”

The ability to manipulate models allowed students to view hidden features and obtain alternate views. Fourteen percent (n=7) of the students believed the ability to view hidden features improved their performance. A Student noted that he “could see areas of the model that were not shown in the book to get a better, more full view of the model.” The augmented model also allowed students to “see things that in the book are not clear, like extruded cuts for example some in the book are not clear how deep the cut is while in augmented reality you can see clearly,” as pointed out by another student.

Augmented reality allowed the students to compare and confirm the augmented model to the 2-D drawing in the book. Thirty six percent (n=18) of the students believed this allowed them to better examine and compare their work to that portrayed in the book. One
student stated, “I compared models with other students using iPads and textbooks to see what we did not understand” while another student was “able to compare what I saw on paper (in the book) to a 3-D model.” For some students the ability to compare models made the process easier as described by one student who pointed out that “augmented reality made it a lot easier to compare the models.” The augmented model also allowed students to check their work throughout the process. Another student stated that he “would try to picture the whole item by myself then double check with the application” and that “it helped me avoid mistakes and helped me learn.”

5. *How did augmented reality help you to engage in the GC 120 course?*

There were three themes that emerged from the data collected associated with student engagement and the use of augmented reality in a GC 120 course. The first theme to emerge was that augmented reality provided an additional opportunity for students to practice and enhance their 3-D modeling skills. The next theme to emerge was that student engagement increased because augmented reality afforded an additional visualization tool. Finally, students’ engagement increased in the course because augmented reality increased interest in the content.

A total of forty four percent (n=22) of the students noted that the inclusion of augmented reality provided an additional opportunity to improve performance. The opportunity allowed students to receive additional practice working with 3-D modeling and SolidWorks. A student noted that by “participating in the augmented reality experiment I got more exposure to SolidWorks and the graphic design process.” The study also required students to attend the optional help sessions, which was noted by a student who wrote that
augmented reality “convinced me to go to the help sessions and work with SolidWorks more.” This view was shared by a couple of students who both stated that the opportunity made them attend the help sessions which led to increased engagement.

A total of forty eight percent (n=24) of the students believed the augmented reality experience increased engagement because it aided in their visualization ability. Two students believed augmented reality “made it easier to visualize the parts.” Students were able to obtain a greater understanding of the visual relationship between the assignment and finished model. One student stated that he “was able to keep up and understand better during the modeling tutorials where before I was lost.” The additional resource assisted students when working with SolidWorks as noted by a student who “was able to understand SolidWorks better which helped him learn sketching in general better.”

Thirty percent (n=15) of the students responded that augmented reality increased their interest in the course and engineering graphics as a whole which led to a higher level of engagement. This belief was highlighted by one student who noted that “augmented reality helped me engage myself in this course because it sparked my interest when I could see the final product before I had done anything in SolidWorks.” Another student wrote that “after using it, I became more interested in 3-D modeling by gaining another perspective into models on how they look.” Student interest was garnered through the provision of augmented reality as an additional resource. The additional resource allowed students to obtain a greater understanding of course concepts. This was evident by one student who stated augmented reality “offered a different kind of experience other than staring at the book.” One of the students talked about how augmented reality “gave me the opportunity to see the finished
product before I had started,” while another student became more interested in the course because he “could see the final report before I had done anything in SolidWorks.”

6. How was your visual understanding of the assigned models affected by augmented reality?

The overwhelming theme that emerged from the student’s responses was that augmented reality aided in the student’s visual understanding. Ninety-two percent (n=46) of the students believed their visual understanding of the assigned models was positively affected by augmented reality. Students believed augmented reality provided an additional resource as noted by one student who stated that his “visual understanding was improved since it gave me an additional way to examine the models.” This allowed students to view hidden features and conceptualize the assignment before they began to create models in SolidWorks.

Twenty eight percent (n=14) of the students who believed augmented reality assisted in visual ability also believed it allowed them to view hidden features. Students believed that these features were difficult to view or unclear in the book. One particular student noted that augmented reality allowed him to “see objects that were hidden in the drawing in the book.” There were also instances where the 2-D drawings were difficult to understand. One student added this when he noted that “augmented reality helped me understand how 2-D models that have all their dimensions written out transfer into a 3-D model.” Another student added that “augmented reality showed parts of the model that were not clear or hard to understand.”

Ten percent (n=5) of the students believed augmented reality aided their visualization ability also believed that it allowed them to conceptualize the model before creating it. One
student believed augmented reality “helped me construct the model in my head when looking at a multi-view of the model.” This view was shared by another student who stated he was “able to compare what I saw on paper (in the book) to a 3-D model.”

7. *Are there any other thoughts you would like to share relating to your experience with augmented reality?*

There were two themes that emerged from the students’ responses relating to any additional thoughts. The first theme was that the students enjoyed the experience and believed it was beneficial. The second theme that emerged was related to issues and limitations the students had with the software and overall experience.

Forty six percent (n=23) of the students believed the opportunity to work with augmented reality was beneficial and assisted in their understanding of the course. This was evident in one student’s response that “it has helped me understand how to model objects in SolidWorks much better” and another student added to this belief with “I got a lot of work done and I learned a lot about SolidWorks and visualization improved.” Students also gave their opinion on how best to incorporate the software. A student said “I like augmented reality and think it would be used most effectively as an aid to the textbook sketches when modeling.” Finally another student said “I think that the augmented reality portion of the class should be required for GC 120.”

Several students wrote about the limitations of the software. One issue students identified was with proper lighting. A student pointed out that the “lighting” effect made it hard at times to differentiate between different faces. The coloring of the models was also a factor as noted by one student who believed the “the color or shadowing occasionally made it
difficult to fully understand the models.” The augmented models had no dimensions forcing the students to reference the books. Another student wrote that “I think it would be helpful to be able to see the dimensions on the augmented reality model.”

From the entire collection of responses several themes emerged. To obtain these themes students’ responses to each question were initially sorted into categories. The creation of categories occurred once there were two responses related to a specific theme. After thoroughly analyzing the responses to each question numerous themes were identified. The themes of all seven questions were collected and organized according to response rate. Several themes transcended more than one question and were merged together to create a final list of themes that can be concluded from the students’ responses. First, students believed working with the augmented reality software was enjoyable and fun. Second, student thought that augmented reality improved their visualization ability. Third, the inclusion of augmented reality aided students in their ability to understand and conceptualize assignments. Fourth, augmented reality allowed them to examine the assigned models through manipulation. Fifth, the students believed augmented reality provided an additional perspective which showed hidden features, allowed them to view the model from many angles, and check and compare the assigned models. Sixth, students associated the used of augmented reality with increased interest in the content. Seventh, students noted that augmented reality served as a motivational tool. Finally, the student responses stated that additional refinement of the augmented reality system was necessary in order to increase the effectiveness of the application.
Chapter Summary

This chapter described the demographics of the study and presented the data from all three measurements including MSLQ, PSVT-R, and questions regarding the students’ experience with augmented reality. The demographics showed that 70 percent of the students were male, included students from all education levels, and was almost exclusively composed of engineering majors. The MSLQ data that was presented compared the pre-post test mean scores from five subscales and a detailed summary of the findings. The results of the PSVT-R were reported and compared the pre-post test mean scores and frequency. The responses from the questions on the students’ experience with augmented reality were analyzed, categorized, and the emerging themes were identified. A Pearson correlation was calculated and showed a weak relationship between the students’ post-test scores on the MSLQ and PSVT-R. The following chapter will draw conclusions from all three measurements, analyze the implications from the results, and identify future opportunities for the inclusion of augmented reality.
CHAPTER FIVE: FINDINGS, CONCLUSIONS, AND IMPLICATIONS

Chapter five includes the findings for the three data collection methods, conclusions drawn from the findings, and implication of these findings. A summary of the study, including major research questions and subsequent questions is presented. Each of the first two research questions is accompanied with its corresponding hypothesis. Next, the findings from all of three of the research questions are detailed. From these findings, conclusions are drawn and utilized to reveal further implications and potential areas for future research. The implications section will address the issues that are raised, provide suggestions for what should be done, and how this should be accomplished. In addition, future research options will be presented to advance the study.

Research Questions

The major research question addressed in this study was to investigate how augmented reality as a pedagogical tool in an introductory engineering graphics course influenced motivation, affected the learning experience, or affected the spatial visualization ability of students. The research questions were broken down as follows:

1. Will the implementation of augmented reality affect the motivational attitude of students in an introductory engineering graphics course as measured by the MSLQ? If so, how?
2. Will the implementation of augmented reality improve the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R? If so, how?
3. What are the students learning experiences with augmented reality?
   a. How does the use of augmented reality promote experimentation including:
      examination, comparison, and problem solving?
   b. How does the use of augmented reality allow the student to manipulate the models by providing the following: multiple viewing perspectives, rotation, and scalability?
   c. How does augmented reality engage students through: active participation, kinesthetic learning, and inquiry?

**Analysis of Research Questions and Hypotheses**

The purpose of this study was to further the understanding of how augmented reality could impact an introductory engineering graphic course. Data was collected through the three different methods including: a pre- and post-test MSLQ, pre- and post-test PSVT-R, and student questions on their experience with augmented reality. The results of the MSLQ were analyzed to answer hypothesis #1, the results of the PSVT-R were analyzed to answer hypothesis #2, and the students’ responses from the seven questions were analyzed to answer research question #3.

**Research Question #1**

Will the implementation of augmented reality affect the motivational attitude of students in an introductory engineering graphics course as measured by the MSLQ? If so, how?
HO1: The implementation of augmented reality will not have a statistically significant effect on the motivational attitudes of students in an introductory engineering graphics course as measured by the MSLQ.

The research findings consisted of five MSLQ subscales and an overall MSLQ score. The first subscale, intrinsic goal orientation, was the only subscale to show a statistical difference between the pre- and post-test scores. Subscales of extrinsic goal orientation, task value component, control of learning beliefs, and self-efficacy showed no statistical difference between pre- and post-test scores. In addition, there was no statistical difference between the pre- and post-tests scores on the overall MSLQ survey. Based on these findings, the null hypothesis that augmented reality will have no significant impact on the motivational attitudes of students was not rejected.

The only subscale in which a significant statistical difference was evident was the first subscale, intrinsic goal orientation. This finding was supported by a study conducted by Lamanauskas et al. (2007) that highlighted the ability of augmented reality to promote intrinsic motivation. An intrinsically motivated student has an internal desire to learn. This may include learning for the enjoyment it provides or the feeling of accomplishment one experiences from completing a task (Deci et al., 1991; Lepper, 1998). These results were encouraging because they indicated that the use of augmented reality affected the students’ intrinsic motivation to learn. The results were also encouraging because according to Eccles et al. (1998) and Wigfield et al. (2006) interests, intrinsic motivation, and intrinsic value were all predictors of increased academic engagement and learning.
The conclusion that can be drawn from subscales of extrinsic goal orientation, task value component, control of learning beliefs, self efficacy, and MSLQ summary was that the implementation of augmented reality into an introductory engineering graphics course did not statistically affect the motivational attitudes of the students. The finding that augmented reality did not increase student motivation contradicted the research conducted by (Campos, et al., 2011; Di Serio et al., 2012; Frietas & Campos, 2008) who determined that augmented reality had a positive influence on the motivational attitudes of students. It should be noted that various measurements were used in these studies. Campos et al. (2011) used observations, Di Serio et al. (2012) used the Instructional Materials Motivation Survey, and Frietas and Campos (2008) used questionnaires.

There were several possible reasons to explain the failure to reject the hypothesis. For one, the lack of difference could be associated to the length of the study. If the study had been extended the impact of augmented reality might have been greater and made a more significant difference in students’ attitude. Secondly, as noted by Frietas and Campos (2008), augmented reality’s impact on motivation might have a greater impact on students with weaker visualization skills. Since students in the course possessed higher levels of visualization skills as measured by the PSVT-R, the motivational impact of augmented reality may have been reduced as a result. Finally, as evident in the studies conducted by Campos et al. (2011) and Larson et al. (2011), student motivation might be easier to measure through qualitative analysis. Although the results of the MSLQ showed no statistical significance, there were several findings from the student questions attributing the use of
augmented reality to increased motivation. This may indicate that the MSLQ might not have been the most effective method to measure the attitudes of the participants.

The lack of a statistically significant result on the extrinsic component could be attributed to the idea that the use of extrinsic factors will only work on students as long as they are under the influence of extrinsic factors (Huitt, 2011). In the study, the only extrinsic factor available to students was an extra six points on their final project. Additionally, the use of extrinsic rewards often does not last and can be detrimental to intrinsic rewards. However, it should be noted that Ryan and Deci (2000) contended that extrinsic motivation can be transformed into intrinsic motivation if the assignment is of interest to the student and the teacher supports the feeling of student autonomy.

The lack of a significantly significant difference on the aforementioned subscales could be associated to the approach students’ took in their responses. Students may have answered the items of the questionnaire with what they desire their motivational attitude to be (Al Khatib, 2010), rather than what it actually was. This could have led to students rating themselves higher on their motivational beliefs in their initial MSLQ survey, which in turn could have masked the results of the post-test scores.

**Research Question #2**

Will the implementation of augmented reality improve the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R? If so, how?
HO2: The implementation of augmented reality will not have a statistically significant improvement on the spatial visualization skills of students in an introductory engineering graphics course as measured by the PSVT-R.

The research findings from the PSVT-R consisted of 30 multiple choice questions that were given in a pre- and post-test format. The paired t-test showed a significant statistical ($p = .001$) difference between the pre- and post-test scores. Based on these findings the null hypothesis that augmented reality will not improve the spatial visualization skills as measured by the PSVT-R was rejected. The conclusion that can be drawn from this finding was that there was a relationship between the use of augmented reality and improved spatial visualization skills. Since there was no control group used in the study the researcher could not associate gains on the post-test PSVT-R solely to the use of augmented reality. It needs to be noted that there could be other reasons for the increase in post-test PSVT-R test scores.

The implementation of augmented reality may have been responsible for the increase in post-test scores. The augmented reality software provided students with an additional tool to visualize models. Students were also able to manipulate the models to obtain a greater understanding of each assignment. Studies conducted by (Allen, et al., 2011; Y. Chen, 2006; Kaufmann & Schmalstieg, 2002; Martín-gutiérrez et al., 2010; Medicherla et al., 2010; Núñez, et al., 2008; Shelton & Hedley, 2002) highlighted the ability of augmented reality to impact spatial visualizations skills.

All of the assignments required students to view, visualize, and recreate 2-D models presented in the engineering graphic textbook. The process of visualizing and recreating 2-D models into 3-D models was assisted by augmented reality. Anytime a student had an issue
with or did not understand the 2-D model they were able to view the completed augmented model. Numerous students reported errors and inconsistencies with the 2-D models after viewing the augmented models. The additional visual tool may have served as a training aid allowing students to develop a greater understanding of how to comprehend 2-D models. This process was similar to the process students followed when completing the PSVT-R.

Another possibility is that the students’ spatial ability improved simply by taking the engineering graphic course. The increase in students’ spatial scores on the PSVT-R could have been associated with the instruction received in the course. Studies by (Alias et al., 2009; Connolly, 2009; Sorby & Baartmans, 1996) found that students’ spatial skills were improved through curriculum content. The study by Connolly (2009) also found that students who initially possessed lower spatial ability showed high levels of improvement throughout the course. Contradicting those findings was a study by Ferguson et al. (2009) that found no difference in spatial ability from a five-week study.

The experiment required students to spend an additional nine hours modeling on six different assignments. The additional time spent modeling may have allowed them to further develop their visualization skills. During the sessions students were also able to get help from the teaching assistants and instructor. Several students noted in their responses that the experiment allotted them additional time to spend on assignments.

The six assignments required the students to recreate the models in SolidWorks. The additional time spent working with SolidWorks may have also led to improved scores. The opportunity to spend additional time working in SolidWorks was noted by several students in their responses.
Research Question #3

What are the students learning experiences with augmented reality?

There are three sub-questions related to this question. How does the use of augmented reality promote experimentation including: examination, comparison, and problem solving? How does the use of augmented reality allow the student to manipulate the models by providing the following: multiple viewing perspectives, rotation, and scalability? How does augmented reality engage students through: active participation, “hands-on-learning,” and inquiry?

To address research question three, seven questions were created. The questions were developed based on the review of literature and reflected the results of previous studies. The questions were completed by the students at the conclusion of the study and students were not required to answer any of the questions.

The responses from the student questions revealed several positive findings. Multiple students believed their learning experience was enhanced through the inclusion of augmented reality. Students noted that the opportunity to work with augmented reality was beneficial and aided in their understanding of the course. Students also believed augmented reality allowed them to spend additional time developing their skills. This was accomplished through the use of augmented reality as a motivational tool, as a means to increase spatial visualization ability, and by allowing students to manipulate the models during the assignments.

The responses indicated that augmented reality had a positive influence on the students’ motivation in the course. Students noted that through the use of augmented reality
they were motivated to spend additional time working with SolidWorks and on assignments, they displayed improved confidence within the course, and their interest within the course was increased. These findings were evident in the students’ responses to both question number two and five. It does need to be noted that a few students believed augmented reality had no impact on their motivational attitudes.

The responses revealed that the students believed the assistance provided from the use of augmented reality improved their spatial visualization ability. The vast majority of students responded that augmented reality positively impacted their visual understanding of the assignments. In fact, 46 out of the 50 students noted that augmented reality assisted their visualization ability. The students noted that their improved visualization ability increased their engagement levels in the course.

The ability to manipulate the models to assist in understanding was reported throughout the seven questions. Students stated that they were able to manually manipulate the models through rotation and by zooming in and out. This was important because the ability to manipulate models during each assignment positively affected the learning experience. Students also reported that this ability allowed them to obtain additional perspectives which showed hidden features. This allowed them to view the model from every angle and conceptualize the assignments prior to starting. In addition, it allowed students to use the augmented reality software to check and compare the assigned models throughout the sessions. These responses were present in questions one, three, and four.

Based upon the students’ results from the questions, the use of augmented reality could allow students to interact with models through kinesthetic means. A study by Dunleavy
et al. (2009) found that the ability to manipulate tangible markers and virtual models provided through the use of augmented reality appealed to kinesthetic learners. Lamanaukas et al. (2007) noted that the use of augmented reality allowed students to learn by doing and physically manipulating objects with their hands. These findings promote the potential of augmented reality to serve as a kinesthetic learning tool in engineering graphics. An analysis of eight studies conducted by (Clark & Ernst, n. d.) in an introduction engineering design graphics course concluded that students predominately prefer kinesthetic learning, although students also rely on their visual and mental rotation capabilities.

There were several comments made by students to question seven regarding their experiences using the augmented reality system. In their responses, students mentioned some additional features they believed would be beneficial and noted some of the limitations of the software. These responses showcased some of the limitations of the augmented reality system used in the study and provided guidelines to increase the effectiveness of future systems. These limitations were also evident in a study by Dunleavy et al. (2008) noted that there difficulties associated in managing and debugging the technical components of an augmented reality system. Although I do not believe these limitations dramatically impacted the study, I do believe would have enhanced the system.

I believe it needs to be noted that the positive responses to the questions could be related to the Hawthorne Effect. Fraenkel and Wallen (2000, p. 665) define the Hawthorne Effect as “a positive effect of an intervention resulting from the subjects’ knowledge that they are involved in the study or feeling that they are in some way receiving ‘special’ attention.” Based upon the definition it was possible that the students may have responded
positively to the questions because they believed the use of augmented reality was beneficial when in fact it had no effect on their performance.

The inclusion of interviews and observations would have been beneficial to further delve into the benefits of the technology. I believe an opportunity to further analyze the students’ experience with augmented reality was missed because no formal interviews or observations were conducted. The addition of these two assessments would have provided additional support to the questions. After the completion of the study, I had the opportunity to discuss the study with several students and was able to gather additional information regarding their experiences. These informal interviews were insightful and shed additional light to the study. I would have also liked the opportunity to video tape each of the treatment sessions. Often I was busy assisting a student and was unable to fully capture the student experience.

**Implications**

Several implications can be drawn from the results of all three assessments. The results of the MLSQ implied that augmented reality did not serve as a motivational tool. As previously noted, there were several possible explanations for this. The results of the PSVT-R implied that something occurred in the study that increased the students’ spatial visualization ability. Based upon this, additional research on the use of augmented reality in an engineering classroom is needed. Lastly, the results of the student questions implied that the inclusion of augmented reality into an engineering graphic course was beneficial to the students’ success.
The results of the MLSQ indicated that no motivational change occurred in the students’ attitudes. The results of the post-test showed no significant difference from the pre-test results. To further investigate the role of augmented reality as a motivational tool a different motivational test should be used.

An implication from the results on the PSVT-R was that additional research on the use of augmented reality to improve spatial visualization skills is needed that includes the use of a control group. The results of the PSVT-R showed that the students’ spatial visualization skills did improve throughout the study. A limitation of the results is that this cannot be solely attributed to the use of augmented reality. A control group or design study would assist in the determination of whether or not the gain in student scores was associated with another variable. This belief was shared by Kaufmann and Schmalstieg (2002) who believed in order to truly understand the value a new technology brings to a classroom there needs to be a controlled set of evaluations.

The implication that can be drawn from the student questions were that the students enjoyed the technology and believed it was beneficial to success in the course. This was evident in the fact that students attended six optional help sessions so that they could use the technology. The students did receive extra credit for participating in the study, but I do not believe this alone motivated them to attend the optional help sessions. These findings are promising and highlight some of the benefits associated with the implementation of augmented reality.

The findings from this study can be applied to multiple disciplines. The affordances provided through the inclusion of augmented reality could be applied to science, math, and
engineering courses. The visual and manipulation capabilities of the technology align well with each of these content areas.

Within science, augmented reality could serve as a visual tool to further investigate concepts that may be difficult to visually conceptualize otherwise. Many concepts discussed in science are too large or too small to view properly. Through augmented reality concepts could be scaled to any desired size. This would allow students to interact with these concepts on a scale in which they could understand. For example, a study conducted by Shelton and Hedley (2002) used augmented reality to examine the relationship between the earth and sun. At the opposite end of the spectrum, augmented reality would allow students to visually comprehend microscopic concepts like atoms. Additionally, students would be able to manually manipulate the models to further investigate the concepts. Another advantage of the use of augmented reality within science is the ability for students to conduct interactive virtual experiments without fear of accidents or mistakes. If a mistake occurs the experiment can simply be restarted. This would also reduce the cost associated with conducting experiments because no supplies would be required.

Augmented reality could assist students in mathematic courses. The technology could benefit students who have a difficulty visually comprehending concepts by providing an alternative perspective. Student could manually manipulate the mathematical models in order to obtain a greater understanding. Studies conducted by Banu (2012) and Kaufmann (2000) used augmented reality to assist students in a geometry course.

In this study, augmented reality was used in an engineering graphic course. The findings of this study could easily be applied to other engineering courses. The visual
assistance provided by augmented reality could be used in any course that emphasized visual understanding. The technology is another tool educators can use to visually display models. Augmented reality could be used individually are collectively to teach principles and allow students to have a visual representation of the concepts.

**Future Research**

Based on the findings from the study, I believe there are several opportunities in which to investigate the use of augmented reality within engineering graphics. For one, more research needs to be conducted on the use of augmented reality as a visual tool to assist lectures and reduce instructional time. Additionally, research should be conducted on the use of augmented reality to assist students in engineering graphics that possess weak spatial visualization skills. In order to better understand the potential of augmented reality, content could be developed that specifically addresses the strengths of the technology. Exploratory research is needed to analyze the potential benefits provided through the use of mobile devices to deliver augmented reality. Finally, additional research should be conducted on the use of augmented reality as a tool to promote collaboration.

One method to increase student exposure to augmented reality in an engineering graphics course would be to have the teacher integrate augmented reality into instruction to display models and provide visual assistance in front of the entire class. Di Serio et al. (2012) found that teaching with the assistance of augmented reality promoted student engagement. Glick et al. (2012) found that the addition of a visual technology, Google SketchUp, to lectures allowed students to view objects from multiple perspectives and provided viewpoints inaccessible through the use of just the traditional textbook. In a study conducted by
Fernandes (2008), students stated that the addition of augmented reality to the lecture portion of class helped them better understand the forms and volumes of the object, as well as more easily comprehend the location of the object and its relation to other objects. During lecture, the instructor could display the augmented model and use it as a learning tool to teach engineering graphic concepts. Both Y. Chen (2006) and Lamanaukas et al. (2007) believed augmented reality was best utilized as a supplementary tool to showcase visual images. Future studies could examine the role of augmented reality to reduce instruction time allowing students additional time to work through problems. According to Larson et al. (2011), the inclusion of augmented reality crosscuts the boundaries between formal and informal learning. Chen (2011a) noted that augmented reality was able to reduce the time instructors spent in a classroom and that augmented reality based learning brings flexibility, a self-paced instruction, and provides immediate feedback.

For years Michigan Tech has successfully been providing low performing students with additional spatial visualization training through the use of remediation courses (Sorby & Baartmans, 2000). This additional training could include the use of augmented reality. Frietas and Campos (2008) and Medicherla (2011) noted that augmented reality had a positive impact on the students’ learning experience, especially among the weaker students. Titus and Horsman (2009) suggested that spatial abilities are not static and that major gains can be achieved from students with poorly developed spatial skills.

A potential application for augmented reality with engineering graphics could be as a visual tool to assist learners in a remediation course. Both Black et al. (2009) and Titus and Horsman (2009) believe remediation courses should be made available to students who
struggle with spatial visualization skills. Schools, such as Michigan Tech University, have been offering a remediation course for students who struggle with spatial skills since 1993 (Sorby, 2007). Two studies that effectively used technology to assist students in remediation courses were Martín-Dorta et al. (2008) who tested Google SketchUp and Contero et al. (2007) who incorporated web-based graphics.

Numerous studies have identified that significant differences exist in the spatial visualization ability between men and women and that women possess lower spatial skills (Blasko et al., 2009; Gorska et al., 2009; Medina, et al., 1995; Sorby & Veurink, 2010). The need to close this gap creates an opportunity to research the use of an augmented reality system to assist in the development of women’s visualization ability in an engineering graphic course. Several studies have already identified methods to improve the spatial visualization ability of women including; training Turos and Ervin (2000), digital games Yang and Chen (2010), and multimedia software (Sorby, 2007). The lack of a large female population in this study made it impossible to compare the results between males and females.

For this study, the curriculum had already been created and augmented reality only served as an additional visual tool. This approach might have limited the effectiveness of the technology. Additional studies should design learning activities to highlight the features and affordances of augmented reality (Di Serio et al., 2012; Wu, 2013). The design of specific content for augmented reality could allow for a clearer understanding of what makes the technology engaging, attractive, and able to grab the attention of users (Dunleavy et al., 2008; Martín-gutiérrez et al., 2010).
Augmented reality could be analyzed as a tool to promote digital and hybrid based courses. Dunleavy et al. (2008) believes augmented reality promotes a digital/hybrid environment. Borrero and Márquez (2011) and Kaufman and Schmalstieg (2002) both highlighted the ability of augmented reality to allow teachers and students to work remotely. In fact, Borrero and Márquez (2011) believed the affordance of augmented reality to do so present more possibilities than traditional classrooms. These are important findings because education continues to move towards online learning.

The increasing use of mobile devices including cell phones and tablets has created several new options for augmented reality. Dunleavy et al. (2008) and Shea et al. (2009) noted that the most likely platform for augmented reality will be through GPS-enabled cell phones. Both Dunleavy et al. (2008) and Shea et al. (2009) also believed the use of augmented reality on cell phones was a natural fit because students already own and know how to use these devices. Augmented reality is no longer limited to static situations and can be used in multiple mobile environments. A portable device with a camera, Global Positioning System (GPS), wireless internet access, and augmented reality application can bring augmented reality to any user through the augmentation of the real environment with an overlay of visual information (Poonsri, 2011; Shah & Agrawal, 2010).

Technological advances provide an opportunity to research the use of a mobile augmented reality system to assist learners in an engineering graphic course. Studies by Allen et al. (2011) and Dunleavy et al. (2009) effectively used a mobile augmented reality system to promote engagement. Santana-Mancilla et al. (2012) noted that the employment of mobile phones to distribute augmented reality applications is an effective method in order to
deliver up-to-date educational content. The use of wireless mobile devices allowed students to work in open environments, receive content from multiple locations, and connect players (Rosenbaum et al., 2006). While Martin et al. (2008) believed further research should examine the development of educational strategies that integrates mobile devices to deliver content in short remedial courses. The augmented reality software used in the study was also available through an application that could be downloaded on most smart phones. Through this, students would be able to work outside of the classroom and have the augmented model available to assist them with all assignments and homework.

One area where augmented reality could assist in the learning process is through collaboration. Studies conducted by (Fernandes & Sánchez, 2008; Frietas & Campos, 2008; Matcha & Rambli, 2011) highlighted the ability of augmented reality to promote collaboration among students. Dunleavy et al. (2009) believed the opportunity to leverage augmented reality affordances to create rich collaborative inquiry via technology-mediated narrative holds great potential. Núñez et al. (2008) added that the flexibility provided by an augmented reality system created a collaborative environment that can support group work. Rosenbaum et al. (2006) further refined this concept by using groups of three and assigning each member a defined role. Di Serio et al. (2012) found that social learning occurred through the formation of social groups to discuss the content explored. Similar views were also disclosed by a few students in the study who believed augmented reality allowed them to collaborate on the assignments with their peers in order to answer questions and clarify issues.
Conclusion

The rationale for the selection of augmented reality as the educational tool and an engineering graphic classroom as the learning environment was based on the review of literature provided. The literature highlighted the use of augmented reality to impact student motivation, increase spatial visualization ability, and enhance students’ learning experiences. To assess improvement in these areas the literature identified the MSLQ and PSVT-R as two effective instruments. Additionally, the literature identified the importance of spatial abilities in engineering graphics and the continuous desire to improve these skills through the use of different technologies.

The intent of the study was to investigate the impact of augmented reality on students within an engineering graphic classroom. Multiple data collection methods were used to investigate the impact of augmented reality. The multiple data collection methods included the use of three assessments: MSLQ, PSVT-R, and student questions addressing their experience with augmented reality. The results from all three data collection methods were promising and built upon previous research. The results of the MSLQ indicated that augmented reality had a positive impact on the intrinsic motivation of the students in the study. The results of the PSVT-R indicated that the spatial visualization ability of the students in the course increased. The responses from the student questions revealed that the students enjoyed the experience and believed that it was beneficial to their success in the course.

Individually, the results from each of the data collection methods were inconclusive, but collectively the results of the three highlight the potential of augmented reality within
education. From the combination of these results a few themes emerged. For one, the results from the collection of assessments indicated that augmented reality has the potential to influence the motivational attitudes of students. The results of the MSLQ indicated that a student’s intrinsic motivation was positively impacted through the use of augmented reality. The student questions add to these findings by allowing the participants to describe how augmented reality impacted their motivation in the course. Next, the results of the PSVT-R and student questions indicated that augmented reality improved the spatial visualization skills of students. The results of the PSVT-R showed an increase in visualization skills between the pre- and post-test scores. However it was noted that the results could not be solely attributed to the inclusion of augmented reality. The student questions added to these findings by supporting the use of augmented reality to improve spatial visualization ability. The findings from the student questions found that the vast majority of students believed their abilities were improved through the use of augmented reality. Lastly, the collection of assessments indicated that augmented reality positively impact the learning experiences. The student questions provided several examples of how augmented reality aided in the learning process, which was supported by the increase in intrinsic motivation evident in the MSLQ and increased spatial visual skills found in the PSVT-R. Additional research is required to further investigate the findings of this study, but the results obtained in this study highlight the benefits of augmented reality in education and add to the growing wealth of knowledge.

The findings from this study are relevant because technological advancements and research continue to bring augmented reality to the forefront of education. A search on
Google or through YouTube will bring up numerous results relating to augmented reality. Browsing theses sites reveals that there are now several different free augmented reality software packages available for use, and YouTube provides video showcases of several different augmented reality systems. An example of the future of augmented reality is represented by Google Glasses. This technology augments an individual’s existing world through the use of glasses and could completely change the way we teach. From a technology standpoint, I believe that we are just beginning to touch the surface on the use of augmented reality in education and I believe this is truly a technology that could transform the way students learn.

I believe there will be a continued infusion of augmented reality applications into technology education. Research associated with the technology will continue to expand. The number of studies published in the last few years hints at the advances the technology is making in the field of education. The amount of research linking augmented reality to technology education continues to grow. The benefit that augmented reality brings into the classroom aligns well with technology education and has the potential to greatly impact our classrooms.

Both the MSLQ and PSVT-R instruments have been used numerous times within the field of technology education. Both of the instruments have also proven to be valid and reliable. The MSLQ will continue to be used in technology education to assist researchers in understanding the motivational attitudes of students. The ability of the instrument to be modified to fit the need of the study allows for a wide range of applications. The use of the MSLQ in engineering graphic courses will continue as researchers examine new methods to
positively affect the motivation and learning strategies of students. The PSVT-R is commonly used to assess the spatial visualization skills in introductory engineering graphic courses, with it being a requirement in some instructor’s courses. Improving students’ visualization ability will be an ongoing area of active research and the PSVT-R will continue to be a valuable instrument in which to measure this.
REFERENCES


Augmentedev.com. Augment is an augmented reality app. Retrieved from:

http://augmentedev.com/#home


http://www.cs.unc.edu/~azuma/ARpresence.pdf


Clark, A. C., Ernst, J. V. (n.d.). A learner profile thematic review of introductory engineering design graphics students, 106–110.


doi:10.1207/s15326985ep4002_6


Huffman, K. L, Miller, C. L. (January, 2012). The effectiveness of real & augmented models to advance the spatial abilities of visual/haptic engineering students. 66th Mid-year Conference of ASEE Engineering Design Graphics Division Galveston, Texas, 64-75.


Engineering Design Graphics Journal, 73(2).


Appendix A

STUDENT SURVEY
Augmented Reality Survey

The purpose of this survey is to understand the affect of augmented reality on student learning in an introductory engineering graphics course.

1. How did the use of augmented reality affect your learning experience?

2. How has the use of augmented reality influenced your motivation in GC 120?

3. Please describe how the use of augmented reality affected your ability to manipulate the assigned models.
4. How were you able to examine and compare the assigned models through augmented reality?

5. How did augmented reality help you to engage in the GC 120 course?

6. How was your visual understanding of the assigned models affected by augmented reality?

7. Are there any other thoughts you would like to share relating to your experience with augmented reality?
Appendix B

STUDENT SURVEY RESPONSES
<table>
<thead>
<tr>
<th>Student</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It helped me to visualize the drawing</td>
<td>I have been motivated to try harder when drawing</td>
<td>The AR let me rotate the parts and zoom in on all features</td>
<td>AR helped me to see all the hidden features</td>
<td>AR got me to come to the help session every Monday</td>
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<td></td>
<td>It gave me an advantage by being able to rotate the part</td>
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<td>2</td>
<td>I enjoyed it</td>
<td>It has helped me get assignments completed way before the deadlines</td>
<td>If there were circumscribed holes within the holes that were hard to see in the book, the augmented reality helped me visualize it</td>
<td>I was able to rotate the augmented reality screen, and match it with the different views on my CPU</td>
<td>It challenged me to get in extra practice, but also to learn to visualize better</td>
<td>It helped a little</td>
<td>Most of the drawings we had to do were not that challenging, so I could visualize them already But, once the models got more difficult, augmented reality really helped</td>
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<td></td>
<td>I really liked working with the software</td>
<td>It has also enriched my passion for graphics</td>
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<td></td>
<td>That was the first time I've worked with it, so it was very interesting and helpful with visualization</td>
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<td>3</td>
<td>It helped me visualize 3D space</td>
<td>It made me want to practice more with SolidWorks</td>
<td>It helped me see the different sides of the models</td>
<td>I was able to double check my work</td>
<td>It let me see what I was doing easier</td>
<td>I visualize better now</td>
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<td>4</td>
<td>It helped me visualize certain areas of a part that were hard to see</td>
<td>It has not influenced it too much at all Always been high</td>
<td>It was easy to spin the part to look at it from different views</td>
<td>I was able to spin the views to help figure out where to start on the part</td>
<td>Yes it has helped me even more</td>
<td>I have always had a good visual understanding but it did make it easier</td>
<td>Maybe have the option to change the color because it was hard to see against the desktop sometimes</td>
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<td>5</td>
<td>AR allowed me to see a visual model of the final product as I planned how I would go about building the piece. It gave me a better sense of how to decide this without a model as well. It gave me a better sense of how to decide this without a model as well.</td>
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<tr>
<td>6</td>
<td>It helped me understand general layouts of complicated structures. It has intrigued me about the field. It lets you hold them in your hand opposite to looking at it. It could rotate, flip, and zoom into the section. It let me have a complete understanding of the objects. It was an additional tool to understand how the object was positioned. For it to fulfill its purpose of simulating a 3D object it needs higher resolution, more shadowing, and better user friendliness.</td>
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<td>7</td>
<td>Augmented reality helped me better see object's parts and how they are related to each other. I was more motivated to finish my assignments early with the assistance of augmented reality. The ability to rotate the models and see them from different perspectives helped me understand how to build the models. Augmented reality allowed me to examine the models from different perspectives and angles. I was able to better visualize and construct the models given in the course. Augmented reality showed parts of the model that were not clear or hard to understand. Sometimes the augmented reality models were upside down or oriented wrong which caused confusion.</td>
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<td>8</td>
<td>It affected my learning experience by helping me visualize objects on paper in 3D form. It gave me a head start on assignments due for GC 120. I could learn how to do different actions in SolidWorks before we learned it in class. It motivated me to come to the help sessions.</td>
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<td>9</td>
<td>I think it enhanced it. I would say it has improved my motivation by improving my confidence in understanding of the course material. Augmented reality essentially put the object in my hand, so it gave an easy way to manipulate the assigned models. I used the AR model first to look for asymmetries in the models or unusual feature, and once I had a general grasp of the shape I would look to the book for quantitative details. It helped exercise my 3D visualization skills.</td>
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<td>10</td>
<td>There were times when what was seen through AR supplemented what could not be seen in the book drawings alone. It allowed me to develop more 3D spatial skills because I was able to use it when I could not visualize a feature on my own. I enjoyed it as an aid to modeling figures and was more confident with my ability to model in SolidWorks. I was able to model more accurately and faster than had I not used augmented reality. I compared models with other students using iPads and textbooks to see what we did not understand. I became more engaged because I was able to become more experienced with SolidWorks and 3D modeling in general. I was able to better conceptualize the models with this aid. I like augmented reality and think it would be used most effectively as an aid to the textbook sketches when modeling.</td>
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<td>11</td>
<td>It greatly helped in visualizing the assignments given.</td>
<td>It has given me a better grasp on the materials helping my confidence some.</td>
<td>It made it much easier to view a complicated looking spot on the models by zooming in and having a more hands-on feel to the model, rather than just looking at it on a flat piece of paper in the book.</td>
<td>Through zooming in and rotating at your leisure.</td>
<td>It made the models/material more interesting and it was definitely a cool experience to get to work with the new technology.</td>
<td>It enhanced it many times over.</td>
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<td>12</td>
<td>Being able to rotate the object to see all angles helped a lot. It offered an additional reference when trying to make a mental image of the object.</td>
<td>It was exciting to use something different and made the assignments more interesting.</td>
<td>It made it easier to make connections between the image seen in the book and the 3D model.</td>
<td>The augmented reality made it possible to position the model at an angle where I could better understand how to draw it in SolidWorks.</td>
<td>It offered different kind of experience other than staring at the book so it was more interesting.</td>
<td>It helped especially to be able to see objects that were hidden in the drawing in the book. I think it would be helpful to be able to see the dimensions on the augmented reality model.</td>
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<td>13</td>
<td>Using the iPad helped me visualize what I was creating in SolidWorks. I am more motivated to work on my homework because augmented reality helps me visualize it.</td>
<td>The models made more sense to me when using augmented reality.</td>
<td>The images on the iPad gave me another resource on how to create my final product.</td>
<td>It made me better at visualization in three dimensions and it gave me practice with SolidWorks.</td>
<td>Positively.</td>
<td>I had a great experience.</td>
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<td>14</td>
<td>It made it easier to complete my work. It allowed me to see all sides of the object and made it easier to visualize the steps of construction in my head.</td>
<td>It has motivated me to work hard in the sessions because it usually means I get a homework assignment done.</td>
<td>Again, I could see what I was creating. I could spin the objects around to see sides not visible in the isometric sketch.</td>
<td>Seeing the product in three dimensions and it gave me practice with SolidWorks. I could find faults in the sketches that would be rectified by the VR model.</td>
<td>It allowed me to see what my final objective needed to be.</td>
<td>It did not give me a higher level of understanding but it allowed me to form my understanding more easily.</td>
<td>I got a lot of work done and I learned a lot about SolidWorks and visualization improved. Black is probably not the best color to use.</td>
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<td>15</td>
<td>the augmented reality helped me visualize the 3D parts in the different figures</td>
<td>many of the figures we made in augmented reality were assignments in GC 120, so I had more time to focus on other aspects</td>
<td>I was able to see which order the figures needed to be built in</td>
<td>it was easy to use augmented reality</td>
<td>augmented reality helped me practice for GC 120 and get used to SolidWorks</td>
<td>augmented reality enhanced my visual understanding of the models</td>
<td>some of the models seemed to be slightly inaccurate compared to the book</td>
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<td>16</td>
<td>it helped to clarify drawings if they were not clear enough</td>
<td>it has not motivated me any more than before</td>
<td>I did not use the augmented reality very much, just to clarify some confusion with things like if holes went all the way through or not</td>
<td>I used the iPad that would allow me to rotate view of the object manually and with a card</td>
<td>it helped very little</td>
<td>it helped visually by being more easy to visualize</td>
<td>I do not think it was necessary to succeed</td>
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<td>17</td>
<td>it was a good tool when I had a hard time visualizing the sketch</td>
<td>I was motivated before so I do not think it has changed that</td>
<td>it did not me deter, however it allowed for me to see details in the object that were confusing or unclear from the sketch</td>
<td>by rotating and seeing the object from different angles you could see what the sketch was trying to describe</td>
<td>helped me get through assignments much quicker</td>
<td>it helped me see the objects better before having to check with the augmented reality figure</td>
<td>it was very beneficial to have the augmented reality when doing assignments</td>
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<td>18</td>
<td>the augmented reality helped me complete assignments by helping me visualize things that I could not initially visualize while also helping me analyze the objects to determine the approach I should take when creating it in SolidWorks. It has been helpful in completing assignments as well as confidence. The sketch and the augmented reality together made the assignments easier. The augmented reality helped me visualize things from different perspectives as if it were a physical object to help determine my construction process in SolidWorks. It helped me to visualize aspects of the model that I could not initially visualize while also providing an “answer key” for me to be able to check the work I had done. It helped make the process of creating models much more smooth, understandable, and assuring than it previously was which helped make my engagement in the GC 120 course much more enjoyable. None</td>
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<td>19</td>
<td>It helped me to learn to visualize and rotate objects in my head better. It allows me to visualize things I could not initially understand while giving me positive conformation when I did visualize something correctly. This confidence then rolled over into my GC 120 course as positive motivation. It has improved my confidence in using SolidWorks. It helped me when I could not tell what exactly something looked like in a drawing so I could understand how similar shapes look in the future. It was able to look at dimensions and nomenclature on the drawings I had not seen before and figure out what they meant with the augment tool ex. A screw hole can be hard to see on a drawing but easy in 3D. It helped me practice my skills better and challenge myself. It helps me quickly determine when I am visualizing something wrong.</td>
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<td>20</td>
<td>I was able to see more of the object than was presented in the book. I got some extra practice with SolidWorks. 3D to 3D was easier than 2D to 3D, and it enabled me to see hidden parts of the object. You could use the app to manipulate objects. Practice with SolidWorks could see hidden parts of models.</td>
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<td>21</td>
<td>it helped me to visualize the parts better and gave me more experience working with SolidWorks which I appreciate greatly.</td>
<td>it made me more excited about the course material and gave relevance to the actual industry.</td>
<td>I like to put the book and augmented reality side by side so I could see what the model would look like it was holding it in my hands as well as see all the dimensions clearly.</td>
<td>I can now take 2D models and visualize them in 3D much better now.</td>
<td>I think that the augmented reality portion of the class should be required for GC 120.</td>
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<td>22</td>
<td>augmented reality enhanced my learning experience because I could understand the structure of the object I was building.</td>
<td>the augmented reality has increased my interest in the GC 120 course material significantly. I now enjoy doing SolidWorks whereas before I was just confused.</td>
<td>augmented reality helped me engage myself in this course because it sparked my interest when I could see the final product before I had done anything in SolidWorks.</td>
<td>augmented reality helped me understand how 2D models that have all their dimensions written out transfer into a 3D model.</td>
<td>I enjoyed using augmented reality and it helped me enjoy this subject more.</td>
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<td>23</td>
<td>augmented reality made it easier for me to visualize and understand several of the solids I was modeling.</td>
<td>augmented reality really did not affect my motivation as I was already motivated to get a good grade in GC 120 and still am.</td>
<td>I was able to use the augmented reality to clarify some questions I had about the model after just looking at the picture in the book.</td>
<td>the augmented reality increased my visual understanding by enabling me to view the model from several different angles.</td>
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<td>24</td>
<td>it did make understanding some of the models easier, although in most cases I did not need it well, it has not really changed that any, but it gave me a reason to do the assignments way ahead of time it made it so I could check for the locations of rounds easier, and inspect the model to check for potential shortcuts by manipulating them with the iPad? it ensured that I did the homework, and that I did it correctly minimally, I have been doing this for a while, so my ability to visualize the object and manipulate that visualization has been present throughout some of the models, particularly 5.147 aided with interpretation of miss-prints in the book</td>
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<td>25</td>
<td>the use of augmented reality really helped me to visualize the different parts from all angles I really enjoyed using the software, it is fun to move the parts around using the card the augmented reality software made it a lot easier to visualize the parts from all angles, when the isometric pictures did not show holes or lines or what not the augmented reality made it a lot easier to compare the models with gestures on the iPad the augmented reality made it easier to visualize the parts the augmented reality served as a check for that ability though I feel like after using the software, I had a better understanding of how certain models are supposed to look I really enjoyed using augmented reality, it was informative and fun</td>
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<td>it helped for more complex models, when a 2D picture is not enough by making it a little more &quot;hands-on&quot; I am more engaged and motivated it helped when thinking of the objects in 3D, also since I can view at different angles it made it easier to decide how to build the figure no trouble by being a &quot;hands-on&quot; tool improved, by being able to visually see it</td>
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<td>27</td>
<td>it helped having a object you could move around as it was a solid helped a lot with visualizing the object and seeing parts that may be unclear from the drawing seeing how advanced this technology is very interesting like I said, having a piece you can rotate is very helpful well having a drawing with the dimensions and the solid on a screen that you can rotate made it easier to model the objects it gave me the opportunity to see the finished product before I had to build it and got me much more interested in graphics it helped a lot I think just showing how this program works and what it can do would get a lot of peoples attention</td>
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<td>28</td>
<td>allowed me to work on my visualization of 3D objects</td>
<td>it is definitely not something you see everyday so that is engaging to get further into graphics and to do well in GC 120</td>
<td>made more motivational because I am more confident in my SolidWorks abilities</td>
<td>it is definitely not something you see everyday so that is engaging to get further into graphics and to do well in GC 120</td>
<td>made more motivational because I am more confident in my SolidWorks abilities</td>
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<td>29</td>
<td>easier to practice the objects in SolidWorks using the augmented reality</td>
<td>I'm a little more ambitious in taking on harder challenged in SolidWorks because I am more confident in my abilities to use SolidWorks</td>
<td>using the augmented reality tools allowed me to physically adjust the object in real time as opposed to being limited to turning a 2D image</td>
<td>participating in the augmented reality experiment I got more exposure to SolidWorks and the graphic design process</td>
<td>the ability to manipulate an object in 3D greatly increased my understanding of the geometry of the assigned models</td>
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<td>30</td>
<td>this mental picture allowed me to break the object into primitives to be built up in SolidWorks it was helpful to visualize the object while creating it on SolidWorks</td>
<td>I like the class better</td>
<td>being able to more freely adjust and rotate an object in SolidWorks as easily as manipulating the image on the iPad would be a huge help for engineers and students of engineering helps me visualize and see what I need to do to create the object</td>
<td>the insight gained by looking over an object at different angles negated the need to agonize over how to piece together geometric values and relations by looking at the book and then manipulating the size of the object in the 3D version</td>
<td>this helped me build confidence and familiarity, as well as provided a base to expand my knowledge helped to visualize and learn better</td>
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<td>31</td>
<td>I found it helpful to visualize what was required of the course work gives it more of a 3D aspect not much, I have the same desire to perform in this class as before by viewing the work piece through the iPads, zooming in/out, physically rotating yes, it gave me more practice using SolidWorks it helped me construct the model in my head when looking at a multi-view of the model</td>
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<td>it helped a lot at first, but as time went on I needed it less and less well, it has not really changed that any, but it gave me a reason to do the assignments way ahead of time it helped a lot figuring out parts that were not clearly visible on a sheet of paper it made it easier to tell how things connected and whether or not holes went all the way through, etc. it made it much more &quot;hands-on&quot; course which I really enjoyed I understand them a lot better, though at times it was unnecessary not really, very cool tool though, just to play around with</td>
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<td>it helped me visualize the part I was modeling augmented reality really did not affect my motivation for GC 120 much I was able to see a 3D version of the part I was making in SolidWorks instead of just viewing the sketch iso it gave me a structured time to work on parts that would be assigned later it helped me understand how the parts worked, how they were put together it is great that it can be implemented in a classroom setting some of the augmented reality sketches/part s did not match the book</td>
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<td>it made it much easier to visualize the objects that I was drawing and see all sides of the object it helps with the drawings so I am more motivated to get them finished because I know it will make them easier without augmented reality I could only see the assignment from the isometric view perspective, but with it I can see from all angles while I am designing it with the iPad I was able to rotate the part, which is something I could not do with the paper sketch I had I could rotate the models around and view from all sides to compare with my drawings to see if they matched up it gave me a better understanding of SolidWorks it helped me get all of my homework assignments done faster I had a better understanding of what I had to model it was a lot easier to visualize the model since it can be seen from all sides the &quot;lighting&quot; effect made it hard to differentiate between different faces AR helps to visualize assignments in class, but I'm not sure how useful it would be in real world applications because you would have to first design the model before it could be viewed in AR</td>
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<td>35</td>
<td>Augmented reality helped me visualize the intended outcome. It helped me have a set time to complete and practice SolidWorks problems. I was able to move the object around on the iPad to view different perspectives and help me create the object on SolidWorks. I was able to clarify things I was unsure of on the drawing with the augmented reality object. It helped me make friends and communicate with others in my section. It helped me a lot to be able to visualize the 3D object. No, very interesting.</td>
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<td>36</td>
<td>I am a very visual person so I liked being able to look at the object. It helped me quickly visualize the project instead of having to stare at a picture for an extra 5 minutes. It has definitely helped my motivation. It helped me better understand correlating faces and features which quickened my time spent working on the project. The augmented reality always added a second view allowing myself to imagine a complete 3D picture. It forced me to add a structure time in my day that I could easily complete my work before the due date. It helped, like I said it added that second view to fill in the missing visuals left out of the picture. Ipad are cool.</td>
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<td>37</td>
<td>It allowed me to get a understanding of the drawing. The technology is fun to play with. It has made GC 120 a greater part of my week and has increased my motivation. I did not have much difficulty manipulating the assigned problems, but it does allow you to observe the entire object, and figure out which steps you can build the object. I used the augmented reality to determine how I would sketch the object and the book to sketch the model. It made me come to the Monday help sessions and allowed me to ask questions. I looked at the augmented reality model to outline how I would model the object (steps). Thank you for your time.</td>
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<td>38</td>
<td>It did not help as much as I thought because the most difficult part of the sketches are finding the correct dimensions when they are not given, but it was helpful. It really helped me visualize what I was doing in SolidWorks and simplified geometry. Also, I find the sketches fun and challenging; it has made me more motivated to make a good grade. Viewing the finished product really allowed me to simplify the object into its geometrical shapes. I was able to double check my work and break down the geometry of the model better. It sparked even more interest because it was challenging. It has helped me understand how to model objects in SolidWorks much better. Thornton is extremely nice.</td>
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<td>39</td>
<td>I was able to visualize my products better and move them around to get a 3D feel. I am a whole lot better in SolidWorks because of all of the visualization practice. The biggest thing for me was being able to move the figure around. Since we both the picture and the augmented reality I was able to compare them to make my figures. I was able to understand SolidWorks better which helped me learn sketching in general better. Since I could see and move the object, I was able to understand the models better. Having TA’s present was also helpful. I am glad that I did this, it was beneficial to me learning SolidWorks better.</td>
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<td>I am glad I got the chance to use it. It helped me visualize the object especially when the drawing is more difficult to understand. It definitely made my life easier. It made it easier for me to manipulate the assigned models. Augmented reality helped me see the different angles and views of each object which made more sense to me. It helped me work with my peers around the table. It was affected greatly, now I am able to visualize and completely understand a model.</td>
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<td>41</td>
<td>It helped visualize a little. I actually look forward to showing up to class even though it is optional. I learned more about SolidWorks and became more confident. It was hard for dimensions, but it helped understand how the object looked. I used the iPad and compared to the book picture. It over all enhanced the learning environment. It made it more interesting. It became more clear. It would be perfect if the dimensions were on the screen.</td>
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<td>42</td>
<td>ar was a great asset to have while modeling the various figures we did it makes me more excited as a aspiring TED Ed. Major to think that AR could soon be seen in classrooms so once I knew the dimensions it helped know where to put them the accessibility to get &quot;hands-on&quot;, in a sense, with the object made it easy to find and identify the figure's features manipulating both the on screen tools and the AR itself made it easy to examine every aspect of the model as a future drafting teacher, AR has allowed me to personally engage in GC 120 while becoming familiar with a program that I could be using in other GC courses or my job later AR greatly strengthened my visual understanding of the models AR is a wonderful learning tool and I am very grateful for the opportunity to learn about it and its use while helping myself and you</td>
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<td>43</td>
<td>the ability to maneuver the object to get a better understanding of it made it both easier to complete the model and gave me more security that I understand it satisfactorily it was also fun just to rotate and zoom the figure, which sometimes resulted in finding fillets or other features I missed in the book it made it easier to pay attention in class without worrying about how to use SolidWorks the opportunity to use AR was thus very profitable for me, not only for GC 120, but potentially the rest of my career it made me more eager to work on sketches and 3D models Rotation and zooming in or out of the object gave me a much better model to go by than just the the 2D book instructions with the use of AR, the only reason I ever used the book was for dimensions it's easier to find a starting point for some of the more difficult sketches I could see areas of the model that were not shown in the book to get a better, more full view of the model I was able to keep up and understand better during the modeling tutorials where before I was lost AR allows me to take an object originally seen as a 2D isometric model and render it into a fully manipulate 3D object, just like if I had the model in my hands but can also zoom in and out of it was easier to understand dimensions and relationships by manipulating the model through AR for pieces that seemed vague or confusing thanks for doing this, and good luck it helped my proficiency in SolidWorks through these weekly exercises</td>
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| Page | It also made it easier to learn about multiview and isometric sketches since AR gave me more comprehensive practice. It allowed me to be able to visualize the 3D view of an object I was sketching which was a tremendous help. Augmented reality makes sketching easier and more fun in SolidWorks. Transferring over to GC 120 by helping me spend more time on the class creating objects. It was especially beneficial when extruding cuts because you could easily tell how deep each cut was.

- **44**
  - By spending more time on SolidWorks with augmented reality, I was able to enhance my sketching capabilities; thereby making the sketches for GC 120 quicker and easier.
  - Having the figure in a 3D view is certainly helpful because sometimes the sketches in the book are hard to visualize.
  - It was a great help in creating much more accurate figures on SolidWorks.

| Page | I think it has helped me become a lot better with SolidWorks. It also helped display little cuts such as fillets in the book you are given one view, while using the augmented reality you can spin the image or solid to see what it looks like from almost any angle. By using the augmented reality you can see things that in the book are not clear.

- **45**
  - It was a great learning experience I would recommend using it again for future classes.

| Page | Now when I see an image on a page I am almost automatically visualize what the plane sketches would look like. It was able to clear up misconceptions created by angled perceptions. I am a lot quicker and know how to use the tools in which before I did not.

- **46**
  - It helped me see front, top, side, and even occasionally bottom views of a model, allowing me to correctly recreate areas. I originally had trouble understanding.
  - Like extruded cuts for example some in the book are not clear how deep the cut is while in augmented reality you can see clearly.
  - I was able to get a clearer picture and visualize what needed to be done.
  - I feel like after augmented reality I could reverse engineer just about anything and put it in the computer.
  - It forced me to get the models done early and not procrastinate.
  - By seeing it from different views I could decide the best way to approach a solid based of the extruding and planes it was improved as stated earlier.

- It was worthwhile.
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<td>47</td>
<td>I used it to better visualize the parts that we modeled</td>
<td>it has motivated me in the fashion that I can better visualize the part which in turn makes the coursework simpler</td>
<td>being able to see the part from different perspectives and from there interpret it into SolidWorks</td>
<td>Again through better visualization to better understand each part</td>
<td>better engagement by being able to comprehend parts and their interpretation into SolidWorks</td>
<td>it was dramatically increased by thorough comprehension of the part</td>
<td>these questions are slightly redundant</td>
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<td>48</td>
<td>it really helped me get a better understanding of the 3D picture</td>
<td>it helped me come to the classroom more and be more active</td>
<td>it really helped me a lot because you are able to turn the image to see different parts, like hole depth</td>
<td>I would try to picture the whole item by myself then double check with the application</td>
<td>I was more active with class work and had assignments completed early</td>
<td>it really has helped me visualize better because I have more examples (full) to practice with</td>
<td>I really enjoyed this</td>
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<td>49</td>
<td>it helped my visualization abilities</td>
<td>it has motivated me because I like to play with the app at home</td>
<td>this has helped a lot it enhanced my ability by providing a bigger picture (more views) in order to fully group the whole model</td>
<td>it helped me avoid mistakes and helped me learn</td>
<td>I was able to be more precise by having multiple views of an object instead of basing a model off one view</td>
<td>after using it, I became more interested in 3D modeling by gaining another perspective into models on how they look</td>
<td>I think it should be used with all CAD classes</td>
<td>No</td>
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<td>it really helped to see some of these objects in 3D so that I could draw them better.</td>
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<td>I think it is a fantastic opportunity to be a part of augmented reality study.</td>
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<td>I feel as though I am getting to participate in &quot;the future.&quot;</td>
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<td>I found that I was more motivated to come to the Monday sessions because I was going to get to use augmented reality software.</td>
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<td>It allowed me to visualize them easier (with very little effort).</td>
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<td>I like the ability to rotate the model so I could see hidden features.</td>
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<td>I like the lighting and color of the model sometimes made this tricky, but it is still better than 2D.</td>
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<td>I was excited to come and use the software.</td>
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<td>made visualization effortless.</td>
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<td>changing the color/lighting of the model would help some or highlighting the edges with a different color would help.</td>
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<td>I really enjoyed being able to use such cutting edge developing technology and it really imparted a sense of significance to what we are doing in GC 120 greater than just the class.</td>
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Appendix C

INFORMED CONSENT FORM
North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: The implementation of augmented reality in an engineering graphics course: Visualization skills and student motivation

Principal Investigator: Timothy Thornton    Faculty Sponsor: Dr. Matthew Lammi

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?
The significance of the study is that learner outcomes could be enhanced through the implementation of augmented reality in an introductory engineering graphics course. Because augmented reality is a relatively new technology there has been little empirical research conducted on the application of augmented reality in an educational environment. There has been even less research of augmented reality within the field of education and in graphic communication courses. Augmented reality is a technology with potentially multiple uses in the classroom that could affect the motivational attitudes of students. Through augmented reality learners could be provided with an interactive three dimensional model allowing for a greater manipulation, experimentation, and engagement of objects by creating an additional augmented point of view and perspective.

What will happen if you take part in the study?
If you agree to participate in this study, you will be asked to:
- Review, sign and turn in this informed consent form (approximately 10 minutes)
- Take the Motivational Strategies Learning Questionnaire (MSLQ) (Approximately 30 minutes)
- Take the Purdue Spatial Visualization Test for Rotations (PSVT-R) on Moodle (Approximately 30 minutes)
- Take part in the use of augmented reality for six separate courses (approximately 9 hours)
- Re-take the Motivational Strategies Learning Questionnaire (MSLQ) (Approximately 30 minutes)
Re-take the Purdue Spatial Visualization Test for Rotations (PSVT-R) on Moodle for the second time (Approximately 30 minutes)
Take the survey on the use of augmented reality (Approximately 30 minutes)
It is anticipated that the total amount of time to accomplish all of these tasks will not exceed 12 hours.

Risks
There will be no risks associated with your participation in this study. There will be no interruption or discomfort associated with your out of class homework. Your normal GC 120 course homework requirements will not be impaired or impeded by participating in this study.

Benefits
By participating in this study you will be contributing the growing body of knowledge of the understanding of augmented reality in an introductory engineering graphics course. The results of this study will help improve the development of GC 120 instruction for future semesters at NCSU. The student participants will provide data for the possible improvement of future GC 120 sections but there will be no immediate benefit to the study participants other than becoming aware of the use of augmented reality in a GC 120 course.

Confidentiality
The information in the study records will be kept confidential. Each participant will be assigned a code number and this code number will be linked to a master list containing participants’ names. Data will be stored securely on the researcher’s personal computer. No one other than the principle researcher and faculty sponsor will have access to this data. No reference will be made in oral or written reports that could link you to the study. The material will be kept securely for three (3) years for further analysis. Once the three years are over the master list will be destroyed i.e., deleted from the researcher’s computer.

Compensation
For participating in this study you will receive no compensation.

What if you are a NCSU student?- Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you are a NCSU employee?- Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.
What if you have questions about this study?
If you have questions at any time about the study or the procedures, you may contact the researcher, Timothy Thornton, at Poe Hall 510G, or 813-352-9062.

What if you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

This study is for those 18 years of age or older.

Consent To Participate
“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”

Subject's signature______________________________ Date _________________

Investigator's signature__________________________ Date _________________