Spring 2017

The Effects of Using GeoGebra on Student Achievement in Secondary Mathematics

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Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Arts in Education

California State University, Monterey Bay

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Abstract

According to the National Assessment of Educational Progress (NAEP), in 2010 approximately 30% of 12th grade United States (U.S.) students were *proficient* or *advanced in mathematics,* 38% were *basic in mathematics*, and 32% were below basic (NCES, 2013). The U.S. adopted the curricula of higher performing nations through the Common Core State Standards (CCSS). The CCSS for mathematics advises teachers to integrate technology into the classroom as a manipulative to help students engage in high-level mathematical concepts. The purpose of this study was to determine if integrating GeoGebra, an iPad application, would have a positive effect on student understanding of High School Geometry. This is an experimental quantitative study with a nonequivalent pre-test and post-test design using a treatment (i.e., using GeoGebra) and a control group (i.e., not using GeoGebra). During the five-week intervention, the treatment group used GeoGebra while the control group had normal instruction. Independent and paired t-tests were conducted to determine if significant differences were found between the treatment and the control groups scores on the Module 5 math test. Based on the results, student scores improved when using the application (i.e., treatment group); however, not statistically higher than the control group. Therefore, future studies need to be conducted to continue to assess the effectiveness of using iPads during instruction.

Keywords: student achievement, mathematics, technology, iPads, GeoGebra

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Literature Review

After the release of the 1997 Third International Mathematics and Science Study (TIMSS) data, a downward trend for United States (U.S.) student performance in mathematics relative to other countries was noted. Furthermore, the 2010 TIMSS data and the Program for International Student Assessment (PISA) indicated that only approximately 30% of 12th grade U.S. students are characterized as *proficient* or above (e.g., *advance*) *in mathematics* on the National Assessment of Educational Progress (NAEP; NCES, 2013; Schmidt & Houang, 2012). In addition, of the remaining 70% of 12th grade U.S. students only 38% were characterized as *basic in mathematics*, the remaining 32% are below basic. The NAEP defines 12th grade basic in mathematics as being able to solve problems using a direct application of concepts and procedures. Proficiency in mathematics for 12th grade is defined as being able to recognize when specific concepts, procedures, and strategies are appropriate, while selecting and applying them to solve problems. The definition for advanced in mathematics for 12th grade is being able to demonstrate in-depth knowledge. Specifically, advanced students are able to integrate their knowledge into solving non-routine and challenging problems, provide mathematical justification for their solution, and make generalizations and provide mathematical justifications for their generalizations (NCES, 2013). According to Schmidt and colleagues (2001) the reason for students' low performance has to do with the way mathematical content is being taught in the classroom.

In high performing countries, students are taught fewer coherent topics at each grade level, but in greater depth (Akkus, 2016; Daro, McCallum, & Zimba, 2010; Schmidt, Hsing Chi, & McKnight, 2005). Additionally, in high performing countries, teachers spend weeks on one concept where students are learning, developing ideas, and using strategies to solve problems; whereas the U.S. curriculum would have this same concept taught in one day with teachers giving instruction on when and how to solve problems using that one concept. Exposing students to fewer new concepts could allow them time to master old ideas while they are developing new ideas (Schmidt et al., 2005). Research has been conducted with high performing countries to try and identify the standards used throughout the curricula, with the goal of adopting or adapting them into U.S. curriculum (Akkus, 2016). One way the U.S. has sought to adopt the curricula of higher performing nations was through the implementation of the Common Core State Standards (CCSS).

Common Core State Standards

The CCSS were developed to address the drop-in U.S. students' performance in mathematics. The National Governors Association (NGA) and the Council of Chief State School Officers (CCSSO) released the standards for mathematics in March of 2010 with the goal that all states would adopt the standards. The CCSS for mathematics cover fewer topics at each grade level, but students are learning the topic in depth, which leads to them having a better understanding of the material (Daro, McCullum, & Zimba, 2010). The goal for the CCSS was to make the knowledge and skills students required in order to be prepared for success in college and careers more consistent across the country.

The CCSS were constructed based on research conducted on international curriculums of high performing countries along with the input of educators from kindergarten through college, and the state departments of education. The standards for mathematics are divided into grade-by-grade specific standards and high school standards. The CCSS Initiative (2017) noted that the high school standards for mathematics were all standards students should study for college and career readiness. The high school standards are divided into conceptual categories: Number and Quantity, Algebra, Functions, Modeling, Geometry, and Statistics and Probability. For the purposes of this study, the CCSS surrounding High School Geometry (HSG) will be discussed in depth.

HSG Standards

The HSG standards cover key concepts seen in elementary and middle school, but work with more precise definitions and the development of proofs (i.e., arguments). The standards are organized to support the six key concepts students need to learn in geometry; this study will focuses on three key concepts. According to the CCSS Initiative (2017) the High School Geometry/Geometric Measurements and Dimension (HSG.GMD) are the standards for applying geometric concepts in modeling situations. The High School Geometry/Modeling with Geometry (HSG.MG) standards involve visualizing the relationship between two-dimensional (2D) and three-dimensional (3D) objects, explaining the volume formulas, and using them to solve problems involving objects. Lastly, the High School Geometry/Right Triangles, and Trigonometry (HSG.SRT) covers the standards for defining trigonometric ratios and solving problems involving right triangles, applying trigonometry to general triangles, and proving theorems involving similarity. Although the CCSS standards for mathematics were developed to improve students understanding of the content, they do not address how they are to be taught in the classroom.

Teaching Mathematical Concepts

The CCSS standards for mathematics allow teachers to change the way they approach teaching; however, this means that teachers are left to develop ways of instructing the standards on their own or through collaboration. Further, teachers still need professional development and training in order to integrate the CCSS for mathematics into their instruction (Akkus, 2016). Teachers need to use different teaching strategies to address the CCSS standard for mathematics, strategies that address the higher level of rigor while still make them accessible to students at different levels of understanding.

Instructional strategies used to increase learning. According to Kutluca (2013) and Van Heile (1999) created a framework for understanding the developmental process students go through while they are learning and developing an understanding of geometry. The framework for understanding geometry has five levels. The first level is the visual level where students reason with geometric figures, identify shapes, name, and compare them. The second level is the descriptive/analysis level where students reason about concepts. The third level is the relational/abstract level when students develop the properties for the concept. The fourth level is the formal deduction level, which deals with students learning to manipulate the relationship with in the mathematical context. Lastly is the mathematical rigor level when students analyze and compare systems based on different axioms (Kutluca, 2013; Liu, 2013).

The Van Hiele model for geometric understanding is also based on students doing hands-on activities (Carroll, 1998). For example, students using play dough to construct 3D object from a 2D illustration to find the volume of the object; finding the weight of the object can also be included. This simple activity allows teachers to cover a standard from HSG.GMD: identifying 3D objects made from rotating a 2D object, and HSG.MG: using the measurement of the object and describe them (e.g., the nail is a made of two cylinders and a cone), applying geometric methods for solving the problem (e.g., finding the volume of the nail using formula of cylinder and cone), and apply density based on the area and volume for the object (e.g., pounds per inch).

According to Van Hiele (1999) students' understanding of shapes and mathematical properties accrue during the visual level of thinking when students are engaged in activities that use manipulatives (e.g., paper folds, drawings, or pattern blocks). The use of manipulatives for learning mathematics has a positive effect on student learning (Boggan, Harper, & Whitmire, 2010; Couture, 2012). Students at the secondary school level also benefit when they are participating in hands-on activities where they are learning the properties and concepts versus memorizing the information and formulas (Carroll, 1998; Ernest, 1994; Garrity, 1998). Currently, there have been no recent studies involving the use of math manipulatives on high school students. These activities need to have an emphasis on the applications of geometry in everyday life, use reasoning skills, integrate problem solving, and incorporate discussion (Carroll, 1998). In accordance with the CCSS Initiative (2017) the Common Core State Standard for Mathematical Practice 5: Use appropriate tools strategically (CCSS.MP5) notes that technology can be used to make mathematical models. This allows students to visualize results of varying assumptions, explore consequences, and compare predictions. Therefore, when implementing the CCSS for mathematics teachers should seek to integrate technology into the classroom as a form of manipulative to help students engage in high-level mathematical concepts.

Teaching with technology in mathematics. Students may view technology as a toy, which is fun and engaging; however teachers must work to ensure students are using technology effectively in the classroom. Although teachers must teach students how to effectively use technology, there is little to no training and planning time given to teachers for integrating technology into their instruction (Bloemsma, 2013; Grimes & Warschauer, 2008; Vu, 2013).

Thus, teachers must continue to explore new ways of integrate technology in a meaningful way to ensure student engagement and achievement during the instruction.

Research has been conducted to determine the effects of technology use in the classroom on teachers (Beckerle, 2013; Crichton, Pegler, & White, 2012; Perry & Steck, 2015; Haydon et al., 2012; Vu, 2013). Such studies found that high school mathematics teachers were not able to successfully design activities that would successfully incorporate iPads into their instruction (Bloemsma, 2013; Crichton et al., 2012). Additionally, in a study conducted by Grimes and Warschauer in 2008, many teachers voiced frustration with technical problems and concerns that technology interfered with student learning. For example, teachers may develop a project involving students finding information on the Internet but if students do not have access then the teacher would need to formulate an alternative plan while managing students.

Teachers can spend hours developing lessons that have iPads integrated as a learning tool; however, the average time spent will vary depending on the teachers training with using iPads (Vu, 2013). Although research has demonstrated that teachers need time and training in order to successfully integrate technology in their classrooms (Beckerle, 2013; Crichton et al., 2012; Haydon et al., 2012; Kutluca, 2013); with the adoption of the CCSS, teachers are expected to be incorporating technology successfully across content areas. Furthermore, there are studies which show that the way a teacher uses technology in a lesson might have a larger impact on student learning then the technology itself (e.g., Alon, An, & Fuentes, 2015; Bloemsma, 2013; Perry & Steck, 2015; Wiest, 2001). For example, using an iPad to take notes when students can use paper and pencil is unnecessary as this is using technology just to use technology. According to Wiest, technology should be cohesive with mathematics education similar to the world outside the classroom (2001). In particular, technology should be used along with the content, such as learning with a manipulatives and not used to replace teachers. Specifically, technology is not an add-on to curriculums that teachers use, but rather a tool for the future (Wiest, 2001).

Technology use in teaching mathematics. The use of technology has become part of everyday life; thus, allowing students to use technology in the classroom can benefit their education (Bloemsm, 2013). As mentioned by the CCSS.MP5 (2017) students should use technology as a tool for expanding their understanding of mathematical concepts. There has been research conducted on what technology is best for integrating into mathematics (Bloemsma, 2013; Crichton, 2012; Haydon et al., 2012; Liu, 2013; Perry & Steck, 2015). There are several studies that focus on student engagement with mathematics and found students to be more interactive when using the technology (Haydon et al., 2012; Perry & Steck, 2015). Technology has also shown to have a positive effect when integrated into game-base instruction, manly for practice application or used in geometric activities (Haydon et al., Kutluca, 2013; 2012; Perry & Steck, 2015). Therefore, technology such as iPads have become populate tool when teaching since they have several application that can be used in education (Perry & Steck, 2015).

Using iPads. The iPad, as described by Vu (2013), was designed by Apple Inc. as a line of tablet computers used as a platform for multimedia (i.e., music, books, games, and web content). There are two models of iPads; the first only has Wi-Fi data connect which allows the user to browse the Internet, load and stream media, and install software. The other model has Wi-Fi and 3G wireless data connection; this model requires a data plan through network companies (e.g., Verizon and AT&T). As the use of iPads has increased worldwide, more and more classrooms are integrating iPads into the curriculum. Moreover, as iPad use is increasing so are the number of applications (i.e., software designed to run on iPads) available for downloads.

According to Bloemsma (2013) there are over 20,000 educational applications (apps) that can be used on the iPad.

The implementation of iPads in the classroom has the potential to keep students engaged in learning mathematical concepts. Studies have shown that students are more engaged when working with iPads (Haydon et al., 2012; Kim, Chacko, Zhao, & Mantclare, 2014; Liu, 2013). However, there are some studies which show no evidence that students learn more when using iPads (Bloemsma, 2013; Perry & Steck, 2015). There are mixed results with regards to iPads being effective in kindergarten through high school classrooms. The mixed results could be due to a lack of experience using iPads, a lack of training on integrating iPads into the instruction or that teachers have no time to develop the instruction coherently.

According to some studies, students use iPads more for note taking, finding research, and reading (Alon et al., 2015; Bloemsma, 2013; Dogan, 2012; Maxwell & Banerjee, 2013). One study conducted by Liu (2013) showed that when iPads were integrated into a geometry lessons it was helpful for student understanding of the content knowledge. The study by Perry and Steck in 2015 noted that when iPads are integrated using an instructional approach to teaching (e.g., direct instruction) might have a negative effect on student comprehension of the course material; the opposite accrued when using a student-centered approach to teaching (e.g., constructive). Perry and Stack define direct instructing as a method of teaching using drill-and-practice approach and teacher-centered instruction activities; also constructive is define as a method of teaching as learning through collaborative student work and student exploration. Thus, there is a lack of information regarding which approach to teaching is best when integrating iPads into instruction. There is also a lack of information regarding how iPads are being implemented in high school classrooms; however, Wiest (2001) suggested that teachers using technology when students are learning; which is the CCSS.MP5. One way that teachers can using iPads at the high school level is by using a software program classed GeoGebra.

GeoGebra. The iPad application (app) selected for this study was GeoGebra, which is a Mathematical software that can be used for free (IGI, 2016). GeoGebra is a Dynamic Geometry Software (DGS) that has geometric and algebraic features. GeoGebra was first developed as a software for computer use only, but was later adapted into an app accessible on either the Internet or other mobile devices (e.g., smart phone or iPad). According to Kutluca (2013) when using GeoGebra in a high school Geometry class, students will have a positive effects with regards to learning and understanding geometry; based on the Van Hiele (1999) levels of understanding. Other studies noted that GeoGebra has a positive effect on students' understanding of geometry concepts; such as shapes and ways of thinking about geometry (Kutluca, 2013; Ljajko & Ibro, 2013; Saha, Ayub, & Tarmizi, 2010).

According to Saha and colleagues (2010), during the time of their study, there was limited research on the effectiveness GeoGebra has on student learning when integrated in the classroom. Studies have shown that using DGS; such as GeoGebra, has the potential in fostering students-centered and active learning (Hannafin & Scott, 2001; Hohenwarter, Hohenwarter, & Lavicza, 2009; Ljajko & Ibro, 2013; Wiest, 2001). With DGS students are able to access and process information individually, model 2D and 3D figures, explore mathematical ideas, and conduct investigations (Wiest, 2001). GeoGebra has a 3D feature that allows the user to model geometric shapes and interact with the figures. However, there is a lack of information on the effect the GeoGebra app has on students' mathematical learning. Therefore the purpose of the current study is to determine if integrating GeoGebra during instruction would have a positive effect on students understanding of high school geometry.

Method

Research Question

Does the addition of the iPad application GeoGebra into a daily lessons increase high school students understanding of high school geometry?

Hypothesis

Based on research (Bloemsma, 2013; Grimes & Warschauer, 2008; Kutluca, 2013; Liu, 2013) the researcher hypothesized that the use of the iPad application GeoGebra would increase students understanding of High School Geometry/Geometric Measurements and Dimension (HSG.GMD), High School Geometry/Modeling with Geometry (HSG.MG), and High School Geometry/Similarity, Right Triangles, and Trigonometry (HSG.SRT).

Research Design

This study used a quasi-experimental quantitative with a nonequivalent pre-test and post-test design. Two classes were analyzed during the study; one was the treatment group (i.e., using GeoGebra on the iPads) and the other was the control group (i.e., not using GeoGebra). The two groups took a pre-test before starting the Mathematics Vision Project (MVP) Secondary Mathematics 3 (Math 3) Module 5 Modeling with Geometry. The study took five weeks to complete. At the end of the five weeks the two groups took the post-test.

Independent variable. The independent variable was the implementation of GeoGebra (Hohenwarter et al., 2009; Kutluca, 2013) on the student school assigned iPads (Liu, 2013). The GeoGebra software is a popular educational tool that is free both on a computer and an iPad (IGI, 2016). The applicatio was selected for this study because it supports student learning for the lesson objectives from the Math Vision Project Math 3 curriculum (MVP, 2014c).

Dependent variable. The dependent variable was the students' Module 5 test (see Appendix A) scores (MVP, 2014a). The students' understanding of HSG.GMD, HSG.MG, and HSG.SRT was assessed and measured using the MVP Module 5 test. The Module 5 test consisted of 20 questions with four different question types. *Matching* questions consist of using a figure to match each item on the left with the information on the right, *Short Answer* questions require students to answer the questions with a short response (i.e., find the angle, find the perimeter, and label the figure), *Completing the Triangle* questions where students need to fill in the missing information for the triangle with what they are given and know, and *Real World Application*.

Setting & Participants

This study took place at a Title 1 high school located within a rural area in Central California. The school is on a block schedule and classes meet twice a week for 90-minutes each with one 35-minute class in the middle of the week. Wi-Fi was provided throughout the high school campus; student devices (e.g., iPads) are typically connected to the student network. The high school has deployed one-to-one iPad for all students attending the high school; the devices managed by the school district only have Wi-Fi connection.

In 2015-2016, the school had 1,429 students enrolled (390 freshman, 385 sophomores, 351 juniors, and 303 seniors). Approximately 94.3% of the student's population was classified as Hispanic or Latino, 2.7% White, 1.1% Filipino, 0.5% Asian, 0.5% Black or African American, 0.4% two or more races, 0.2% American Indian or Alaska Native, and 0.1% Native Hawaiian or Pacific Islander.

The participants in this study were students enrolled in Math 3 at the high school (56 juniors and 1 senior). Two classes were selected based on the time of the day that they meet and the similarity of the average grade for the class, making it more of a purposeful sampling. The classes were selected based on similarity to each other in order to ensure there was no bias (e.g., not comparing a high performing class to a low performing class). The control group was the first group to interact with the lessons; this was to insure that the treatment group was the last to learn the lesson and would not influence their classmates.

Treatment group. There were 29 students in the treatment group (21 girls, 8 boys). Of the 29 students, 89.7% identified as Hispanic or Latino (26 students), 6.9% identified as white (2 student) and 3.4% identified as Asian (1 student). Of the 29 students, 96.6% where juniors (28 students) and 3.4% seniors (1 student).

Control group. There were 25 students in the control group (15 girls and 10 boys). Of the 25 students, 92.6% identified as Hispanic or Latino (25 students), and 3.7% identified as Other Asian (1 student). All students in the control group were juniors.

Measures

The pre-test and post-test was the Module 5 test from the MVP curriculum (Mathematic Vision Project, 2014a). The researcher reserved the right to alter the order in which the test problems were presented and changed minor details of given problems to verify that students were able to apply the learned concepts and not memorize questions (i.e., pre-test question one was question 5 on post-test). The process for solving the problems and reasoning questions from the Module 5 test did not change to insure that the validity and reliability are not affected.

Validity. The assessment used in the study came from the MVP curriculum and was purchased by the high school mathematic department to use as an assessment for teaching the CCSS (Mathematic Vision Project, 2014a). The Module test was developed by the authors of the MVP curriculum and assesses the CCSS that are covered in that Module (Mathematic Vision Project, 2014a).

Reliability. The lessons were in sequence according to the teacher's notes provided by the MVP curriculum (Mathematic Vision Project, 2014c). The pre-tests and post-test were graded according to the answer key for the Module 5 test solution manual (Mathematic Vision Project, 2014a).

Intervention

GeoGebra was downloaded onto the iPads that students from the treatment group used during class time. Students in the treatment group used GeoGebra during the *explore* phase of the lesson (i.e., a learning tool and visual aid); this was about 30 minutes during a 90 minute class period. The *explore* phase was part of the task when students begin to make conjectures, collect and record data, participate in small group discussion, and revisit or revise their thinking relative to the mathematical ideas (Mathematic Vision Project, 2014c). Students from the control group still used their iPads during the *explore* phase; but they were instructed to not use GeoGebra.

Procedures

On the first day of the study both groups took the same pre-test. During the first 35-minute lesson students from the treatment group was given a short introduction on how to use GeoGebra from the researcher (i.e., familiarize students with program). In accordance to the MVP curriculum the eight lessons for Module 5 would take a day each for each lesson to complete (Mathematic Vision Project, 2014c).

With the block schedule, it took a total of five weeks to complete the study. During the first week the students took the pre-test, and then stated the first task in Module 5 (Task 5.1).

The second week of the study students worked on Task 5.2 and Task 5.3. For the third week students worked on Task 5.4 and Task 5.5. On week four students started working on Task 5.6 and Task 5.7. The last week of the study, students completed Task 5.8 and took the post-test. Students from the treatment group were instructed to not talk about the lessons with other students about what they learned in class during the five weeks. At the end of the five weeks the results of the study were shared with the classes involved in the study.

Data collection. The researcher was the only person that was viewing the data. The data were collected from the pre-test and post-test scores from both the treatment and control group. No data were collected between the first and last day of the study. The researcher used the answer key to grade the test to insure that all the participant scores from the pre-test and the post-test were consistent.

Fidelity. All the math teachers at the high school use the same teaching curriculum. To ensure intervention fidelity, once a week during the five weeks another math teacher came to observe the lesson being taught be the researcher (i.e., 20% of the lessons were observed by a second teacher). The observing math teacher ensured the researcher was using the MVP curriculum to teach students about geometry. She also verified that the treatment group was the only group using GeoGebra during the exploring phase of the lessons (see Appendix B). Therefore, fidelity in this study was 100%.

Ethical Considerations

During the 35-minute classes once a week students learned how to use GeoGebra in preparation to the upcoming lessons. The researcher prepared files for students so time was not wasted on setting up the software. All students in the researchers Math 3 classes took the Module 5 post-test on the last day of the study; regardless of participating in the study since the test was part of their grade. To prevent students from cheating, students were not allowed to use the iPads during the test, as this was a school rule. Further, all students names were kept confidential.

Validity threats. Steps were taken to reduce the validity threat of sample bias. The researcher selected classes that were similar in class size, ratio of female to male, the times of the day they meet, and mathematical skills of the class (i.e., class grade average). It was insured that the group are similar in age, grade level, and learning the same curriculum.

Another possible threat to validity that could have occurred during this study was that students do not bring their iPads to school or they are low on power. To prevent this from happening the researcher allowed students' to use their own smart phones to access GeoGebra. Students also shared devices in class and joined the researchers group on GeoGebra, which has all the files that where used in class. The classroom also had power outlets, which students use to charge their iPads.

To prevent researcher bias, the control group was taught the lessons before the treatment group. This prevented the researcher from having any influence on the control group with regards to using the application during the lesson. The researcher presented the findings as they are and had no influence on the results of the study.

Data Analyses

All data were entered into the Statistical Package for the Social Sciences (SPSS) for Windows, version 24.0.0 (SPSS, 2016). No names or identifying information were included in the data analysis. Before analysis was conducted all data were cleaned to ensure no outliers were present (Dimitrov, 2012). After cleaning the data, the final sample size was 28 participants for the treatment group and 22 participants for the control group. Independent (control and treatment groups) and paired (pre-test and post-test) samples t-test were conducted to determine the significant differences in mean scores on the Module 5 test. Further, before interpreting the analytical output, Levene's Homogeneity of Variance was examined to see if the assumption of equivalence had been violated (Levene, 1960). If Levene's Homogeneity of Variance was not violated (i.e., the variances were equal across groups), data were interpreted for the assumption of equivalence; however, if the variances were not equal across groups the corrected output was used for interpretation.

Results

Two independent samples t-tests were conducted on the whole sample ($n = 50$) for both the pre-test and post-test scores. Results for the pre-test were: Levene's Homogeneity of Variance was violated ($p < .05$) meaning the variance between groups was statistically different and the second line of data was used, and the t-test showed significant differences between the mean scores on the pre-tests between the two groups $t(32) = 3.17$, $p < .01$. This means that there was a statistically significant difference in the two groups to start; although this was not expected, the two groups were still considered comparable based on demographics (see Table 1).

Results for the post-test were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed, and the t-test showed non-significant differences between the mean scores on the post-tests between the two groups $t(46) = 1.45$, $p > .05$. This indicates that students from both groups scored similarly on post-test, which indicated that using GeoGebra on the iPads during class instruction may not have an effect on students learning (see Table 1).

Table 1

Results of Independent Samples T-Tests

	Mean	SD
Pre Test		
Treatment	1.68	1.54
Control	3.68	2.62
Post Test		
Treatment	11.81	7.10
Control	15.01	8.33

Note. SD = Standard Deviation.

After determining the differences between pre-test and post-test scores between groups, two paired t-tests were conducted for both groups (i.e., treatment and control) to determine if participants mean scores from pre-test to post-test were significantly different within each group (see Table 2). Results for each group were as follows: treatment group, $t(26) = -7.30$, $p < .001$; control group, $t(20) = -7.22$, $p < .001$, meaning that both groups saw a statically significant difference between the pre-test and post-tests. Based on the results and the negative t values, both the control and treatment groups showed an increase in scores on their Module 5 test. This indicated that students from both the control and treatment groups learned and improved upon their scores. Although both groups increased their scores, the control group performed better and improved more than the treatment group (see Table 2). These findings contradict the hypothesis that using the iPad application GeoGebra would increase students understanding of HSG.

Table 2

Results of Paired T-Tests

	Mean	SD
Treatment Group		
Pre	1.70	1.56
Post	11.81	7.10
Control Group		
Pre	3.62	2.67
Post	15.05	8.33

Note. SD = Standard Deviation.

Discussion

The purpose of this study was to determine if integrating iPads; specifically the GeoGebra application, would have a positive influence on students understanding of HSG standards. The design for the study was a quasi-experimental quantitative with a nonequivalent pre-test and post-test on two Math 3 classes. There were 50 students in total, the treatment group had 28 students and control had 22 students. The groups were assessed using the same pre-test and post-test, which was graded by the researcher using the answer key provided by the MVP curriculum used in the study (Mathematic Vision Project, 2014c). With the MVP curriculum and the schools block schedule, the intervention took five weeks to complete.

The CCSS Initiative (2017) developed the standards for mathematics with the goal of preparing students for college and career readiness when they graduate from high school. The CCSS.MP5 recommends that teachers use technology as a hands-on tool (i.e., manipulative). Since technology has become a popular hands-on tool outside the classroom (Bloemsm, 2013), students need to learn how to use it within the CCSS for mathematics. Technology such as GeoGebra can be used as a hands-on tool, which is important since students comprehend more with hands-on learning (Carroll, 1998; Ernest, 1994; Garrity, 1998) and manipulatives (Boggan et al., 2010; Couture, 2012). GeoGebra has been shown to help students' understanding geometric concepts (Hannafin & Scott, 2001; Kutlucs, 2013).

Based on the results of the independent t-tests for the two groups (i.e., treatment and control) pre-test scores showed that there was a significant difference between them, with the control group having the better scores then the treatment group (see Table 1). This phenomenon is not uncommon (Carroll, 1998; Kutluca, 2013) who documented a difference between the group's pre-test scores. This may be an indicator that not all students are being taught the standards or have the same prior knowledge. This lack of prior knowledge can lead to gaps in students' levels of geometric understanding (Van Hiele, 1999).

Within the CCSS for mathematics the MVP is a form of *spiraled curriculum.* According to Schmidt and Huang (2012) a *spiral curriculum* is when topics are introduced in a very elementary form and build up in conceptual complexity over the grades. Therefore, before students can prove the Laws of Sine and Cosine and use them to solve problems (i.e., standard HSG.SRT.10), students need to know what and how to use basic tragicomic ratios on right triangles. In this study, there were six questions asking for students to match the trigonometric ratios according to the triangle given. Looking over the data only a few students from the treatment group knew these during pre-test. This could be why the groups in these study were not similar at the beginning.

Based on the results of the paired t-test, there was an indication that both groups learned during the time of the study. This supports the studies of Kutluca (2013), Ljajko and Ibro (2013), and Saha and colleagues (2010), which state that GeoGebra had a positive effect on students learning. However, when comparing the two groups in the current study there was no statistical difference in post-test scores between using GeoGebra on the iPads during instruction and using normal direction instruction. This means that students from both groups performed at the same level when taking the post-test. Therefore, the researcher is not rejecting the hypothesis because using the application showed to help students learn geometry; however more research is needed to see how much integrating iPads into a teacher's lesson has an effect on student learning.

Although the post-test indicated that there was no statistical difference between the treatment and control groups test scores, there was a difference on the pre-test scores. The control group (i.e., not using GeoGebra) had better scores compared to the treatment group (i.e., using GeoGebra) on the pre-test. Saha and colleges (2010) noted that during their study the control and treatment group had no statistical difference with the pre-test and post-tests; however, the group that used GeoGebra in their study had slight higher score then the control group with regards to their visual-spatial ability. This could mean that GeoGebra helped with closing the gap between the treatment and the control scores in this study. Further, using GeoGebra on the iPads during instruction as a hands-on learning tool could have a positive effect on student learning the HSG standards. However, more research would need to be done to determine if integrating iPads into the tasks truly have a greater impact on students understanding when compared to no using technology during instruction. There were limitations within this study that should be taken into consideration during future studies.

Limitations and Future Research

One limitation that accrued during the study was when students did not have the prior knowledge needed to access a task from Module 5. In this study, the researcher had to change the lesson plan for the one task (i.e., Task 5.7) and did not complete the final task (i.e., Task 5.8). Therefore, the GeoGebra on the iPads was not used during the last week of the study, since the researcher was not able to make interactive resources in time and no pre-existing resources were applicable for what the students needed. By changing the intervention in such a way, students could focus and build on their existing knowledge while using or not using the iPad. In other words, having the prior knowledge was needed before students could access the new information found in the last two tasks. Therefore, future studies should have a review lesson on the knowledge they should already know before taking the pre-test.

Another limitation was that the researcher had no formal training in the use of the iPad with the MVP curriculum (Akkus, 2016; Beckerle, 2013; Ljajko & Ibro, 2013). The researcher needed to make or edit pre-existing resources, which are found on the GeoGebra website, to fit within the task and student's needs as recommended by Ljajko and Ibro (2013). Having some form of training on using GeoGebra and developing GeoGebra based resources, which could then be used to aid students during the learning process would be beneficial. Developing the resources were difficult even though the researcher has had some training with using GeoGebra (i.e., less than two hours) and with integrating iPads in to the classroom (e.g., nothing specific to the content). If an instructor was trained on using GeoGebra, more time could be spent on developing resources that can be used as Wiest (2001) and Ljajko and Ibro (2013) mentioned. These resources for discovering and experimenting with the mathematical ideas that students develop would be extremely valuable.

The final limitation to discuss in this study surrounds the sampling method and sample size used. This study used a convenience sample with small group sizes; which could be a reason for why the independent t-test for the pre-test scores were statistically different. With the independent t-test showing that there was a difference with the groups before the intervention. This makes it difficult to determine if the iPads had an effect on student understanding of the material. In addition, this study had two classes, one control and one treatment. In order to strengthen the results for the independent t-test and paired t-test, a larger sample size is needed. Future studies should look at having four or more classes and consider using a criteria sample.

This study found that when the iPad application GeoGebra was integrated into the Module task there was a positive effective on students understanding of the HSG standards being taught. This means that when technology is integrated into a task or lesson as a learning tool, students can benefit. However, more research would need to be conducted in order to determine whether the extent of the effect is significantly greater than traditional instruction.

References

Akkus, M. (2016). The common core state standards for Mathematics. *International Journal of Research in Education and Science, 2*(1), 49-54.

Alon, S., An, H, & Fuentes, D. (2015). The iPad: A Mathematics classroom tool for implementing the common core state standards technology vision. *Tablets in K-12 Education: Integrated Experiences and Implications*. *IGI Global*, *12,* 128-135. doi: 10.4018/978-1-4666-6300-8.ch009.

Beckerle, A. L. (2013). *A mixed method study measuring the perceptions of administrators, classroom teachers and professional staff on the use of iPads in the Midwest school district.* (Doctoral Dissertation). Retrieved from ProQuest, UMI Dissertation Publishing. (Accession: 3605242).

Bloemsma, M. S. (2013). *Student engagement, 21st century skills, and how the iPad is…* (Doctoral Dissertation). Retrieved from ProQuest, UMI Dissertation Publishing. (Accession: 3566043).

Boggan, M., Harper, S., & Whitmire, A. (2010). Using manipulatives to teach elementary mathematics. *Journal of Instructional Pedagogies, 3*, 1-6.

Carroll, W. M. (1998). Geometric knowledge of middle school students in a reform-based mathematics curriculum. *School Science and Mathematics, 98*(4), 188-197.

Common Core State Standards Initiative. (2017). St*andards for Mathematical Practice*. Retrieved from http://www.corestandards.org/Math/Practice/

Couture, K. (2012) Math manipulatives to increase 4th grade student achievement. Retrieved from http://www.eric.ed.gov.

Crichton, S., Pegler, K., & White, D. (2012). Personal devices in public settings: Lessons learned from iPod touch/iPad project. *Electronic Journal of e-Learning, 10*(1), 23-31.

Daro, P., McCallum, W., & Zimba, J. (2010). Common US math standards. *Science, 328*(5976), 285-285.

Dimitrov, D. M. (2012). *Statistical methods for validation of assessment scale data in counseling and related fields*. Alexandria, VA: American Counseling Association.

Dogan, B. (2012). Integration of iPad in higher education: A pilot project. *Proceedings of Global TIME 2012*, 27-30.

Ernest, P. S. (1994). Evaluation of the effectiveness and implementation of a Math manipulative project. Paper presented at the Annual Meeting Mid-South Educational Research Association Nashville, TN. Retrieved from http://www.eric.ed.org.

Garrity, C. (1998). *Does the use of hands-on learning, with manipulatives, improve the test scores of secondary education geometry standards?.* (Master's Thesis). Retrieved from http://www.eric.ed.org.

Grimes, D., & Warschauer, M. (2008). Learning with laptops: A multi-method case study. *Journal of Educational Computing Research*, *38*, 305–332. doi:10.2190/EC.38.3.d

Hannafin, R., & Scott, B. (2001). Teaching and learning with dynamic geometry programs in student-centered learning environment: A mixed method inquiry. *Using Information Technology in Mathematics Education*, *11*, 121-141.

Haydon, T., Hawkins, R., Denune, H., Kimener, L., McCoy, D., & Basham, J. (2012). A comparison of iPads and worksheets on math skills of high school students with emotional disturbance. *Behavioral Disorders*, *37*(4), 232-243.

Hohenwarter, J., Hohenwarter, M., & Lavicza, Z. (2009). Introducing dynamic mathematics software to secondary school teachers: The case of GeoGebra. *Journal of Computers in Mathematics and Science Teaching*, *28*(2), 135-146.

IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

International GeoGebra Institute (IGI). (May 2016). GeoGebra (Version 5.0.232) [Mobile application software]. Retrieved from https://itunes.apple.com/us/app/geogebra/id687678494?mt=8

Kim, H., Chacko, P., Zhao, J., & Montclare, J. K. (2014). Using touch-screen technology, apps, and blogs to engage and sustain high school students' in chemistry topics. *Journal of Chemical Education*, *91*, 1818-1822.

Kutluca, T. (2013). The effect of geometry instruction with dynamic geometry software; GeoGebra on Van Hiele geometry understanding levels of students. *Educational Research and Reviews*, *8*, 1509-1518.

Levene, H. (1960). *Contributions to probability and statistics; essays in honor of Harold Hotelling*. Stanford, CA: Stanford University Press.

Liu, N. (2013). iPad infuse creativity in solid geometry teaching. *The Turkish Online Journal of Educational Technology - TOJET*, *12*(2), 177-192.

Ljajko, E., & Ibro, V. (2013). Development of ideas on a GeoGebra-aided mathematics instruction. *Online Submission*, *3*(3), 1-7.

Mathematics Vision Project. (2014a). *Ready, Set, Go Answer key and Sample Assessments.* Secondary Mathematics III: An Integrated Approach.

Mathematics Vision Project. (2014b). *Module 5 Modeling with Geometry.* Secondary Mathematics III: An Integrated Approach. Retrieved from http://www.mathematicsvisionproject.org/uploads/1/1/6/3/11636986/sec3_mod5_modgeo_se_041114.pdf

Mathematics Vision Project. (2014c). *Module 5 Modeling with Geometry.* Secondary Mathematics III: An Integrated Approach. Retrieved from http://www.mathematicsvisionproject.org/uploads/1/1/6/3/11636986/sec3_mod5_modgeo_te_041114.pdf

Maxwell, P., & Banerjee, P. (2013). Nature and extent of iPad use among freshmen honors students. *Journal of Educational Technology Systems*, *42*(1), 21-38.

National Center for Education Statistics (2010). The Nation's Report Card: Grade 12 Reading and Mathematics 2009 National and Pilot State Results (NCES 2011-455). Washington, DC: Institute of Educational Sciences, U.S. Department of Education.

Perry, D. R., & Steck, A. K. (2015). Increasing student engagement, self-efficacy, and meta-cognitive self-regulation in the high school geometry classroom: Do iPads help?. *Computers in the Schools*, *32*(2), 122-143.

Saha, R. A., Ayub, A. F. M., & Tarmizi, R. A. (2010). The effects of GeoGebra on mathematics achievement: Enlightening coordinate geometry learning. *Procedia-Social and Behavioral Sciences*, *8*, 686-693.

Schmidt, W. H., & Houang, R. T. (2012). Curricular coherence and the common core state standards for mathematics. *Educational Researcher*, *41*(8), 294-308.

Schmidt, W. H., Hsing Chi, W., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematical and science content standards from an international perspective. *Journal of Curriculum Studies, 37*(5), 525-559.

Schmidt, W. H., McKnight, C. C., Houang, R. T., Wang, H., Wiley, D. E., Cogan, L. S., & Wolfe, R. G. (2001). *Why schools matter: A cross-national comparison of curriculum and learning. The Jossey-Bass Education Series*. Jossey-Bass: San Francisco, CA.

Van Hiele, P. (1999). Developing geometric thinking through activities that begin with play. *Teaching Children Mathematics, 5*(6), 310-316.

Vu, P. H. (2013). *An inquiry into how iPads are used in classrooms.* (Doctoral Dissertation) Retrieved from htt://www.eric.ed.org.

Wiest, L. R. (2001). The role of computers in mathematics teaching and learning. *Using Information Technology in Mathematics Education*, *11*, 41-55.

Appendix A

Module 5 Pre-Test
(Modeling With Geometry 5.1 – 5.8)

Part I: *Matching*

Use Figure 1 to match each item on the left with the ratios on the right.
(It is possible for one of the answers to be used more than once or not at all)

_______ 1. SIN A A. $\frac{a}{b}$

_______ 2. SIN C B. $\frac{a}{c}$

_______ 3. COS A C. $\frac{b}{a}$

_______ 4. COS C D. $\frac{b}{c}$

_______ 5. TAN A E. $\frac{c}{a}$

_______ 6. TAN C F. $\frac{c}{b}$

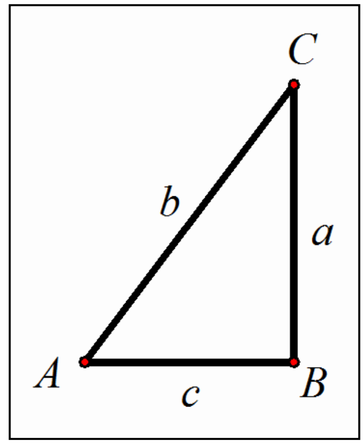


Figure 1

Part II: *Short Answer*

7. Find ∠BDE from Figure 2

8. Find ∠DBE from Figure 2

9. Find the perimeter of ΔADE. Round your answer to the nearest hundredth.

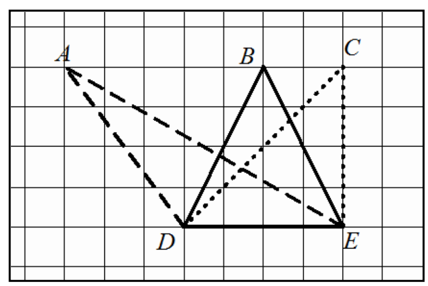
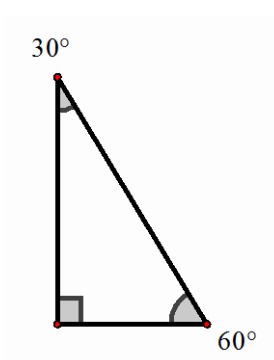


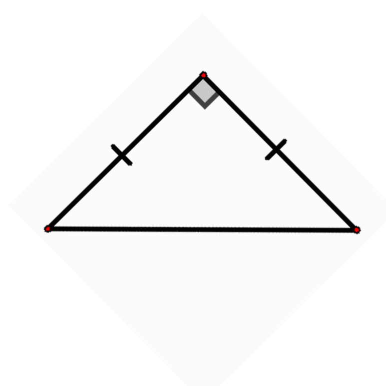
Figure 2

10. Which two line segments are equal in length, but not equal to $\overline{DE}$?

11. Label possible side-lengths for the triangle below.



12. Label possible side-lengths for the triangle below.



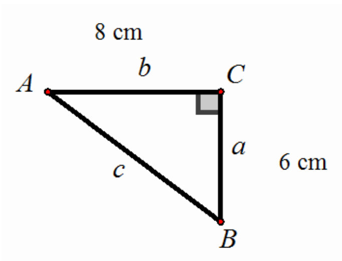
Appendix A Continued

Part III: *Complete the Triangles*

Law of Sines: If *ABC* is a triangle with sides *a*, *b*, and *c*, then $$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$ or it can be written as: $$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$	**Law of Cosines:** If *ABC* is a triangle with sides *a*, *b*, and *c*, then $$a^2 = b^2 + c^2 - 2bc\cos A$$ $$b^2 = a^2 + c^2 - 2ac\cos B$$ $$c^2 = a^2 + b^2 - 2ab\cos C$$
Heron's Area Formula: If a triangle has sides *a*, *b,* and *c*, then $Area = \sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{(a+b+c)}{2}$	

Complete the triangles below. Make sure to label your units correctly!

13.



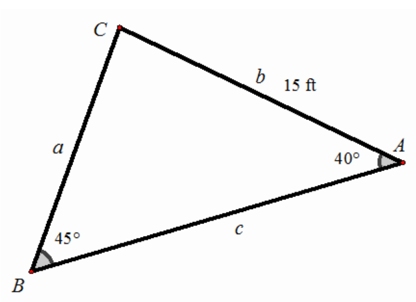
A = 　　　　a =

B = 　　　　b =

C = 　　　　c =

Area = 　　　　Perimeter =

14.



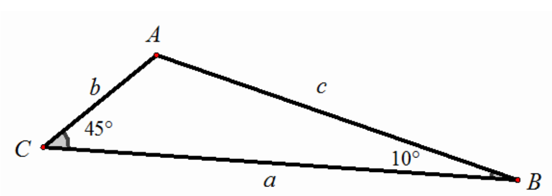
A = 　　　　a =

B = 　　　　b =

C = 　　　　c =

Area = 　　　　Perimeter =

15.



A = 　　　　a =

B = 　　　　b =

C = 　　　　c =

Area = 　　　　Perimeter =

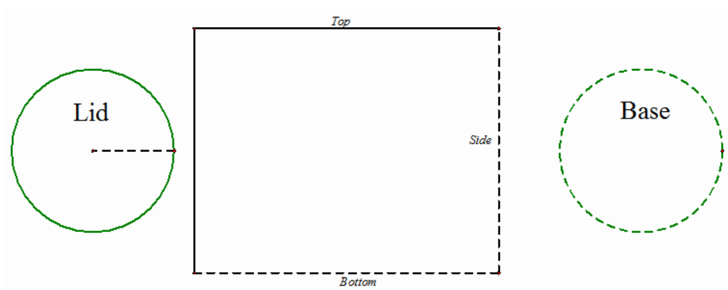
Appendix A Continued

Part IV: *Real World Application*

A can of soda is 4.8 inches tall and 2.5 inches in diameter. Use this information to answer the questions below.

16. Draw a two-dimensional shape that would need to be revolved around the x-axis to create the can of soda you see on the right.

17. Think of a perfect cylinder as the model for the actual soda can. If you took the can apart you would have a lid, a base, and the tin used for the sides. Find the lengths of all of the dotted lines below



18. Using the perfect cylinder model from number 17 above to find how much tin is used to make each soda can. (In other words, what is the surface area of the can?)

19. Using the perfect cylinder model from number 17 above find how much volume would be held in the soda can?

20. When you open a can of soda, you'll notice that they always leave it a little bit empty. About ¼ inch of the can is air at the top. Find the *actual* volume (in inches^3) of soda you get when you buy a can.

Appendix B

Fidelity Checklist

Date	Treatment/ Control	Signature/Initial
Friday, February 24, 2017	Treatment	
Monday, February 27, 2017	Control	
Tuesday, March 7, 2017	Treatment	
Thursday, March 16, 2017	Control	
Tuesday, March 21, 2017	Treatment	