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Examining the use of Spreadsheets in a High School Statistics Course as it Relates to Participant Knowledge and Attitudes

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ACCEPTANCE

This dissertation, EXAMINING THE USE OF SPREADSHEETS IN A HIGHSCHOOL STATISTICS COURSE AS IT RELATES TO PARTICIPANT KNOWLEDGE AND ATTITUDES, by AARON A. RAFTER, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education & Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

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EXAMINING THE USE OF SPREADSHEETS IN A HIGHS CHOOL STATISTICS COURSE AS IT RELATES TO PARTICIPANT KNOWLEDGE AND ATTITUDES

by

AARON RAFTER

Under the Direction of Dr. Brendan Calandra

ABSTRACT

Students who feel anxiety about and have low perceptions of their abilities in mathematics and connected fields such as statistics tend to also show low achievement, and vice versa (Foley et al., 2017; Haciomeroglu, 2017; Hembree, 1990; Sherman & Wither, 2003; Soni & Kumari, 2017; Zakaria, Zain, Ahmad, & Erlina, 2012). It has been proposed in the literature that using technology tools such as spreadsheets in a statistics class may reduce the perceived complexity of problems, reduce the load of complex calculations, make problems more manageable for students, and thus potentially reduce related anxiety (Yadav, Hong, & Stephenson, 2016).

The purpose of the study was to examine whether and how working with spreadsheets in a high school statistics course might influence a group of high school students' performance on and attitudes towards statistical functions and their levels of anxiety towards statistics and mathematics more generally. Data sources included an existing, validated attitude survey for mathematics, student artifacts, formative assessments, and semi-structured interviews. This study was guided by the following research question: How will a problem-based statistics activity using spreadsheets

in a high school mathematics course influence participant knowledge and attitudes? Results demonstrated generally that working with spreadsheets did have a positive influence on the participants' knowledge, attitudes and even efficiency (time spent on tasks).

EXAMINING THE USE OF SPREADSHEETS IN A HIGH SCHOOL STATISTICS COURSE AS IT RELATES TO PARTICIPANT ATTITUDES TOWARDS MATHEMATICS AND COMPUTING

by

AARON RAFTER

A Dissertation Presented in Partial Fulfillment of Requirements for the

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CHAPTER 1: INTRODUCTION

With the emphasis on higher educational standards in K-12 mathematics, students in Georgia are expected to learn specific topics set by the state and pass statewide tests. Many skills taught in high school mathematics courses are not always used by professionals in today's societies (Bossé, 1995; Vigdor, 2013; Wu, 1997). Mathematics is very often taught in Georgia as set of processes and skills preparing the learner from year to year for more advanced mathematics; meaning, they are only being prepared for the next mathematics course and they do not seem to make connections to transferring their knowledge to the real world. This is apparent when reading through the Georgia Standard of Excellence for Mathematics: Grades 9-12 (Woods, 2016), in which the first 24 of 27 pages of this document list standards pertaining to abstract algebra, geometry, and trigonometry, with references to solving problems or applications in only seven of the multitude of standards. However, the standards do call for rich applications in statistics in the remaining three pages where many references to real data and applications are mentioned in which this study aims to address.

Rationale

The need for STEM and Computing

The lack of employment in STEM fields for the future are not equally deficient across all fields, but there are critical fields such as healthcare, energy sustainability, and technology development that desperately need filling (Bøe, Henriksen, Lyons, & Schreiner, 2011). While the need for a mathematically literate workforce is clear, American teenagers are demonstrating lower achievement than other countries in mathematics (State Educational Technology Directors Association, 2011). The most concerning statistic is the projections for future STEM occupations before 2024. Mathematical science occupations are projected to grow at a rate of

28.2% while the rest of the fields are averaging around 6% growth rate until 2024 (Adams, Hill, Fayer, Lacey, & Watson, 2017). For example, the state in which this study was being conducted, Georgia, already had over a 15.7% increase in STEM occupations from 2009 to 2015 (Adams et al., 2017). These statistics are important for students to understand now because these vacancies also come with larger wages and salaries. The demand for STEM occupations has pushed the national average for all STEM occupations to $87,570 which is approximately twice the salary for non-STEM occupations. 93% of STEM occupations were significantly above the national average wage (Adams et al., 2017). Examples of growing fields that combine computer sciences with other disciplines are Bioinformatics, Computational Statistics, Chemometrics, and Neuroinformatics are showing a rise in demand (Bailey & Borwein, 2011; Foster, 2006; Henderson, Cortina, Hazzan, & Wing, 2007; Weintrop et al., 2016). Understanding students' perceptions toward mathematics prior to entering higher education is relevant due to the reported negative effects that some mathematics curricula have had on students, thus driving students away from declaring majors in mathematics and related fields (Vigdor, 2013). Student failure can discourage and push students away from continuing to pursue a career in a given field (Foley et al., 2017; Haciomeroglu, 2017; Hembree, 1990). Likewise, success in a subject can lead to more positive attitudes, retention and further growth within the discipline.

The Problem with the Curriculum

As America has made attempts in the past to standardize secondary mathematics education across the nation, this has come at the cost of preparing students for intense study in mathematics beyond secondary school (Vigdor, 2013). Wu (1997) found that during the "New Math" movement during the 1950's, an emphasis on empty abstraction and formalized mathematics reform was placed on K-12 mathematics. Studying algebra, geometry, trigonometry, and the calculus with proofs in an intellectual style were heavily focused on during this era. This “New Math” movement was written primarily by professional mathematicians and not by math educators (Wu, 1997), however this lead to very drastic drop in those growing up in this era to declare majors in mathematics, engineering, and physical sciences (Vigdor, 2013). Vigdor (2013) found this decline following the “New Math” era from 2009 and 2010 American Community Survey from the Census Bureau. The decline for those growing up during the “New Math” era can be seen in Figure 1 below, where they would have been entering college in the 60’s and 70’s.

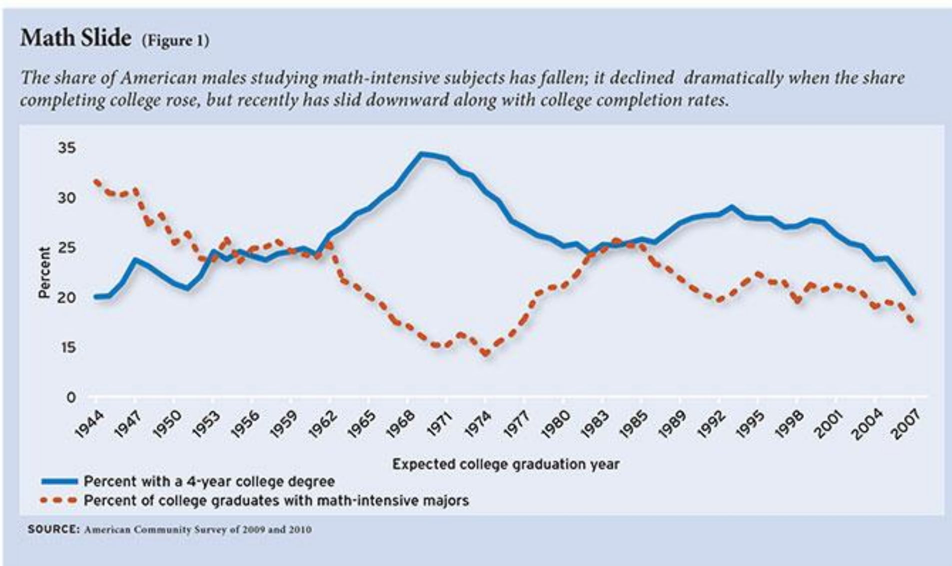

Figure 1. Vigdor, J. L. (2013). Solving America’s math problem. *Education Next*, *13*(1), 42–49.

Prior to the “New Math” era, mathematics was much more pragmatic relating to what types of mathematics would be used in careers (Vigdor, 2013) rather than extremely abstract mathematics like Calculus that was introduced during this era (Bossé, 1995). “New Math” was successful in raising the standards and increasing rigor, but what was found is many students gave up on mathematics and were declaring fewer math-intensive majors (Vigdor, 2013).

A Potential Solution

Problem based activities have been used in the past to introduce real-world applications of mathematics to high school students (Jonassen, 2010; Shute, Sun, & Asbell-Clarke, 2017; Weintrop et al., 2016; Wing, 2006). Spreadsheets are a low floor application in that users can work with having little or no prior programming knowledge or experience. Indeed, spreadsheets have also shown to increase attitudes in statistics education by reducing complex calculations into manageable steps and thus reducing anxiety (Clayton & Sankar, 2009). And when students perform well and feel comfortable in mathematics, they have better perceptions of mathematics than those that do not (Meece, Wigfield, & Eccles, 1990). Because spreadsheets are also the most widely used end user programming system (Panko, 2000), lending them a genuine sense of real-world relevance, this tool may help students see connections that mathematics and computing have to the their daily lives and the workplace.

Theoretical Framework

Dewey argued that by learning through experience, learners construct an educative experience in their minds for later use that could be used to solve problems (Dewey, 1916). Dewey’s ideas extend into Jonassen’s (2010) ideas of learning through problem solving and problem based learning. While projects are a great activity for students, they are merely an activity and do not, according to Dewey, constitute an educative experience unless there was some consequence or thinking that comes from the activity. The author of this study suggests that students need to work in such a way that they create meaningful, productive educative experiences (Dewey, 1916; Driscoll, 2012), and that this can be done via problem-based learning environments (Jonassen, 2010). These experiences may be a means by which students can improve their ability to solve mathematical problems. In turn, if students are better able to solve future problems and are comfortable with the mathematical scientific processes learned in the classroom, then their perceptions towards these topics may also increase (Meece et al., 1990).

Problem based learning is a learner-centered approach that empowers learners to research, incorporate theories and practices related to a field of study, and apply prior knowledge and skills toward the development of a solution to a well-defined problem (Savery, 2006). The success of problem-based learning relies heavily on well-defined problems and a tutor to scaffold and guide the learning process where needed. In addition, activities that incorporate real world examples that students can relate to might help them discover the usefulness of mathematics and computing, and thus increase positive perceptions (Flegg, Mallet, & Lupton, 2012; Gainsburg, 2008; Yardi & Bruckman, 2007).

For the purpose of this study, spreadsheets were used as a sort of Mindtool for students learning how to carry out complex statistical calculations. In this study, the term *Mindtools* refers to using technological programs as cognitive tools in the learning process rather than merely vehicles for delivering instruction. In this way, a student learns *with* rather than *from* the given tool. The author presents spreadsheets in the context of this study as a sort of mindtool (Jonassen, Carr, & Yueh, 1998). Spreadsheets as mindtools are included as part of the theoretical framework because the author claims that they can be used as a learning tool whose affordances may provide students who are low achieving in mathematics computing access to problem-based activities involving math and computing, thus potentially influencing their performance and reducing anxiety towards statistics and mathematics more generally.

Purpose

The purpose of this study was to examine whether and how working with spreadsheets in a high school statistics course would influence participant's performance on statistics functions and thus their level of anxiety towards statistics and mathematics more generally. Data sources included an existing, validated attitude survey, student artifacts, and semi-structured interviews. Performance measurements were required by the institutional review board and could be an indicator for improving anxiety measurements according to the literature. This study will be guided by the following research question: How will a problem-based statistics activity using spreadsheets in a high school mathematics course influence participant knowledge and attitudes?

CHAPTER 2: REVIEW OF THE LITERATURE

Defining Key Terms

Problem-Based Learning

Jonassen (2010) argued for nearly two decades that learning should be problem based. Problem-based learning is a learner centered approach that empowers learners to research, incorporate theories and practices related to the field of study, and apply prior knowledge and skills toward the development of a solution to a well-defined problem (Savery, 2006). The success of problem-based learning relies heavily on well-defined problems and a tutor to scaffold and guide the learning process when needed. Peer collaboration is essential in the learning process as well. At the end of the learning, the tutor also conducts a thorough debriefing of the learners' findings and the learning experience (Savery, 2006). In addition, mathematics and computing can intersect within problem-solving activities (Palumbo, 1990; Schoenfeld, 1992). One controlled experimental study found that using problem based learning vs. a traditional method for teaching statistics students at the secondary level showed to be equally efficient in performance measurements but show students had a positive perception towards group work, interest in mathematics, and perception towards the learning experience they experienced (Abdullah, Tarmizi, & Abu, 2010). After finding that problem based learning had been applied in other fields, one study attempted to fill the gap where mathematical fields needed to adopt more problem based learning interventions in universities (Tarmizi & Bayat, 2010). These researchers found students had increased performance based on three tests, positive effects on students' meta-cognitive awareness, and on students' motivational level among university students (Tarmizi & Bayat, 2010).

Mindtools

In this study, the term Mindtools refers to using technological programs as cognitive tools rather than merely vehicles for delivering instruction. In this way, a student learns with rather than from the given tool. The author presents spreadsheets in the context of this study as a sort of mindtool (Jonassen, Carr, & Yueh, 1998).

Jonassen (1996) claims that when learners interact with mindtools, they represent what they know through the tool and engage in critical thinking about the content being learned. Mindtools require learners to think about what they know about a subject in a different way than they might have before. For example, the subjects in this study would traditionally think about using a formula with a calculator rather than embedding these formulas into a spreadsheet. This is allowing the subjects to use analytical reasoning and to think deeply about what they are studying.

There are several classifications of mindtools (Jonassen et al., 1998). Spreadsheets specifically fall under the umbrella of dynamic modeling tools. While some tools would allow learners to represent semantic relationships among concepts in mathematics, dynamic modeling tools allow learners to express dynamic relationships among mathematical concepts. For example, cells in a spreadsheet hold values, formulas, or functions that can logically change the values or expressions in other cells. The sequences created by the users of spreadsheets are dynamic and logical, thus creating a rich learning environment for the learner to interact existing knowledge with the mindtool or to create a deeper knowledge with the mindtool. Jonassen, Carr, and Yueh (1998) cite historical uses for spreadsheets as mindtools in science and mathematics classrooms by educators since spreadsheets require abstract reasoning by the learners to not only follow rules within spreadsheets but also to create new rules. They also add in that spreadsheets tie back to problem based activities because the decision making within a spreadsheet requires higher order thinking.

The concept of mindtools evolved out of the use of cognitive tools where instructional designers forfeit technology for use of communication and delivery of instruction over to the learners for representing and expressing what they know (Jonassen & Reeves, Thomas, 1996). Cognitive tools are heavily embedded in constructivism. In the context of cognitive tools, instructivism is found communicating and delivering standard information with standard assessments to follow instruction where learners attempt to match expected responses. The constructivist creates learning environments that places learning in the hands of the subjects equipped with cognitive tools to construct new knowledge through new experiences (Jonassen & Reeves, Thomas, 1996). How a learner constructs new knowledge varies with previous knowledge (Jonassen, 1996), which varies with the previous experiences we’ve had (Dewey, 1916; Jonassen, 1996). So learners may demonstrate different responses in the context of cognitive tools and mindtools or even simply reflect on prior knowledge. Even without the lacking expected responses teachers and instructivists are seeking, learning is still taking place in this context.

Spreadsheets

In keeping with Jonassen's idea of the Mindtool, some studies have shown that when teachers allow students to explore mathematical and scientific ideas using technological tools and problem solving techniques to create algorithms and abstractions, it can help learners

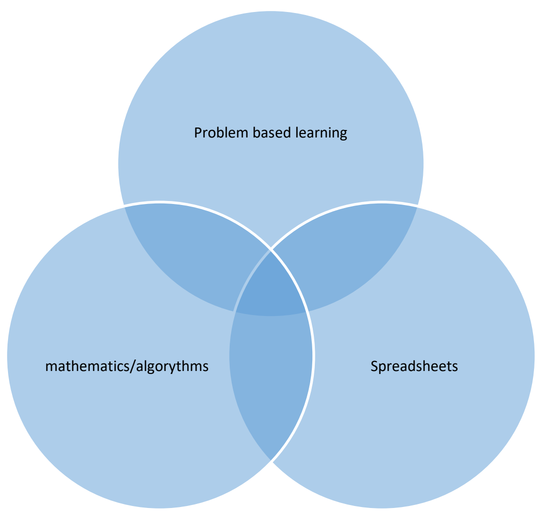

Figure 2. Theoretical frame supporting intervention

develop deeper understandings of the concepts at hand (Jackson, Stratford, Krajcik, & Soloway, 1994; Jonassen, 1996; Jonassen et al., 1998; Jonassen & Reeves, Thomas, 1996; Sherin, DiSessa, & Hammer, 1993; Taub, Armoni, Bagno, & Ben-Ari, 2015; Weintrop et al., 2016; Wilensky, 1995; Wilkerson-Jerde, 2014). In this way, using algorithmic programs to solve real world problems could add yet another layer of abstraction with input and output procedures (Yadav et al., 2016).

Spreadsheets are a software application that are found at the intersection of mathematics and computing. See Figure 2. A spreadsheet serves as a program with input and output values (Abraham, Burnett, & Erwig, 2007). Users can edit cells that might have a constant value and substitute it for another dynamic value or formula creating a new process. Spreadsheets also allow for the visualization of data through charts and graphs that can be manipulated by changing data values (Chi, Riedl, Barry, & Konstan, 1998). As mentioned earlier in this manuscript: a) spreadsheets are a low floor application in that users can work with them having little or no prior programming knowledge or experience (Abraham et al., 2007), which makes a spreadsheet a great option for this research study to use with students who have low perceptions and experience with computer science and mathematics; b) spreadsheets have been shown to increase attitudes in statistics education by reducing complex calculations into manageable steps and by reducing anxiety (Clayton & Sankar, 2009); and c) in part because spreadsheets are the most widely used end user programming system (Panko, 2000), lending them a genuine sense of real-world relevance, this tool may help students see connections that mathematics and computing have to the their daily lives and to the workplace.

Relevant Literature at the Intersection of Problem-Based Learning, Technology and the Use of Spreadsheets

Interventions for underachieving mathematics students

A common cause for underachievement in mathematics is mathematics anxiety (Foley et al., 2017; Haciomeroglu, 2017; Hembree, 1990; Sherman & Wither, 2003; Soni & Kumari, 2017; Zakaria et al., 2012). There is substantial evidence to the relationship of anxiety predicting poor mathematics achievement. Also, the inverse relationship sadly exists as well, where mathematics underachievement is also a valid predictor for math anxiety, making the two variables highly correlated (Sherman & Wither, 2003). Zakaria et al. (2012) measured secondary students' anxiety and compared it to their performance and found a significant relationship between the two with high effect. Part of the study used the same measurement tools that are used in this study, the Fenneman-Sherman ATMI (Fennema & Sherman, 1976; Zakaria et al., 2012). One positive method to increasing performance overall in mathematics is to introduce technology applications into the curriculum for scaffolding, solving problems, and minimizing computations (Cheung & Slavin, 2013). Over the decades, reviewing research and summarizing findings around performance and anxiety have been a popular type of publication among mathematics education researchers. Several researchers have written reviews and cited multiple studies that show how introducing appropriate technologies can have a positive effect on mathematics achievement (Cheung & Slavin, 2013; Li & Ma, 2010; Slavin, Lake, & Groff, 2009) and can introduce confidence and reduce anxiety (Barkatsas, Kasimatis, & Gialamas, 2009; Pierce, Stacey, & Barkatsas, 2007). Specifically, spreadsheets have been shown to increase self-efficacy even for Algebra (Topcu, 2011). The next section will discuss more details about specific technology components that benefit achievement and reduce anxiety.

Using technology to teach and learn mathematics

NCTM suggests that technology is essential in teaching and learning mathematics, and it enhances students' learning (National Council of Teacher of Mathematics, 2000). Supplementing with applications and technology in regular classroom curricula is beneficial to achievement (Kulik & Kulik, 1991). The current view is not if technology should be incorporated into learning mathematics, but rather how we should incorporate technology (Cheung & Slavin, 2013). Rich, Leatham and Wright (2013) suggest integrating computer programming and mathematics into the same classroom. The relationship between two paired subjects, like mathematics and computer programming, refers to what is called convergent cognition (Rich et al., 2013). "Computer programming [should] be considered as an effective tool … for developing specific mathematics concepts and application, and mathematical problem-solving ability" (National Mathematics Advisory Panel, 2008). Teaching programming to middle and high school students has presented a strong positive correlation between programming experience and mathematical achievement on assessments (Rich et al., 2013). Spreadsheets are a form of programming for mathematics and statistics and require a great depth of thinking (Abraham et al., 2007; Panko, 2000), which makes them a great fit for this study.

The correlations found in technology and mathematics can be attributed to several studies conducted using the Logo programming environment that was created in 1966 (Rich et al., 2013). Several studies suggested that using Logo to learn programming and mathematics simultaneously show an increase in student's performance in mathematics (Rich et al., 2013). Students who learn to program increase their problem solving abilities as well (Rich et al., 2013).

Using spreadsheets to reduce anxiety in the statistics classroom

Spreadsheets are already widely used in many educational classrooms such as business, biology, chemistry, and engineering (Bell, 2000; Carlton, Nicholls, & Ponsonby, 2004; Oke, 2004; Rubin & Abrams, 2015; Silverstein, 2008). For decades, spreadsheets have been used in statistics and algebra classrooms (Herkenhoff & Fogli, 2013; Hunt, 1996; Nash, 2008; Soper & Lee, 1985; Topcu, 2011; Warner & Meehan, 2001). However, motivating students in a statistics classroom, and getting them to enjoy learning the subject has been a major challenge (Bell, 2000; Eom, Wen, & Ashill, 2006; Kvam & Sokol, 2004). Statistics anxiety can be experience by as much as 80% of graduate students learning research methodology (Onwuegbuzie, 2004; Onwuegbuzie & Wilson, 2003). If the research is connecting that much anxiety to graduate students, then high school students are likely feeling extreme anxiety as well. Self-efficacy contributes significantly to motivation and academic achievement (Usher & Pajares, 2009). However, research to counter this anxiety does exist. The effectiveness of spreadsheets in statistics courses has been shown to improve comprehension and learning underlying principles in statistics (Pace & Barchard, 2006) and has shown to significantly increase self-efficacy in Algebra (Topcu, 2011). Additionally, when teachers show hand calculations completed with ease, they are actually further flustering students that already have math or statistics anxiety (Pace & Barchard, 2006). By using a spreadsheet instead of hand computations, this avoids adding to the frustrations the students might already have. Further research displays evidence of a positive effect on students' attitudes when spreadsheets are used in statistics classrooms (Clayton & Sankar, 2009).

CHAPTER 3: METHODOLOGY

Method

The purpose of the study was to examine whether and how working with spreadsheets in a high school statistics course might influence a group of high school students' performance on and attitudes towards statistical functions and their levels of anxiety towards statistics and mathematics more generally. The primary data source included a subscale from an existing validated attitude survey, the Attitudes Toward Mathematics Inventory (ATMI) called the Mathematics Anxiety Scales (MAS). Performance was measured through a formative assessment centered around the topic being learned at the time, correlation and regression. Semi-structured interviews and student artifacts were also examined, although the student artifacts serve as much of the treatment as it does a data source. This study was guided by the following research question: How will a problem-based statistics activity using spreadsheets in a high school mathematics course influence participant knowledge and attitudes?

Study Design

This study followed the counter balance design outlined by Allen (2017). The design applied a treatment to one group, spreadsheets, while another group learned using a traditional approach to teaching the subject matter using just scientific calculators which can be referred to as a second treatment. The study then switched the two groups, applying the experimental treatment, spreadsheets, to the calculator group and reverting the spreadsheet treatment group back to the traditional methods for teaching this subject. Measurements for anxiety and attitudes along with performance were measured before either method of learning began, after using one of the two treatments, then a third time after the groups switched treatments. This can be outlined in the diagram in Figure 3 below.

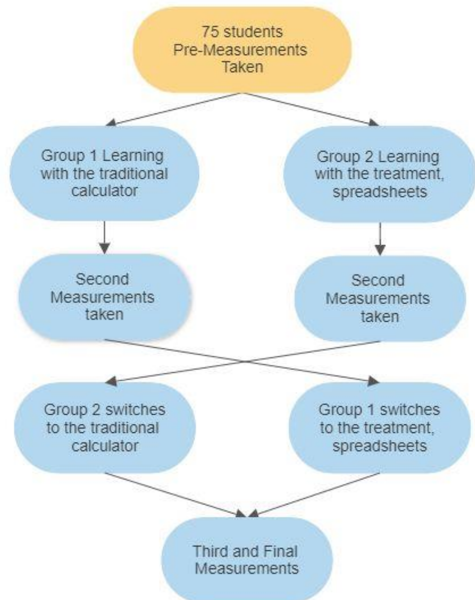

Figure 3. Counterbalancing refers to the systematic variation of the order of conditions in a study, which enhances the study's interval validity. In quasi-experimental designs, variables can be counterbalanced to control their effects on the dependent variable of interest, thus compensating for the lack of random assignment and the potential confounds due to systematic selection bias (Allen, 2017).

Treatment

The activity at the center of this study was designed to show the students the basic design of algorithms through computing and using a spreadsheet. The aid of the computer simplified the calculations which in turn increased their performance (Flegg et al., 2012; Gainsburg, 2008; Yardi & Bruckman, 2007) and efficiency in the construction of correlation and regression models with residual plots. As performance increased, their perceptions also increased (Clayton & Sankar, 2009; Singh, Granville, & Dika, 2002). The instrument that was used to measure this outcome, was the Mathematics Anxiety Scales (MAS) which had both been validated previously for reliability (Fennema & Sherman, 1976; Wiebe, Williams, Yang, & Miller, 2003). The data was analyzed as a repeated measure, pre-survey, second survey, and post-survey design. Significance was measured using a two-way repeated measure ANOVA to see if perceptions increase, decrease, or display no difference in order of the two treatments. Also, survey measurements were analyzed on the treatment level using Friedman's non-parametric test for medians with Wilcoxon Signed ranks ad-hoc tests. Student artifacts were analyzed as a third outcome to measure the students' ability to transfer their knowledge by completing a written assignment demonstrating an ability to collect data, analyze the data, and write a conclusion. Success was measured through a rubric based on state and county standards for the course topic. An additional performance measurement was a set of questions related to the subject that measured if there is a change in performance before, after, and during the treatment. This performance measure is not part of the research question, but rather a requirement for institutional review board to show that students were meeting all learning objectives for the course, and as outlined in the literature review performance is tied to anxiety in mathematics. Performance was measured using two-way repeated measure ANOVA to see if order of treatments effects performance and a one-way repeated measure ANOVA to see if there was a difference within treatments. Finally, efficient was measured using a paired t-test to see if students were able to complete the formative assessment faster with either of the two treatments.

Context

The math course at the time of this study was called Statistical Reasoning. It was a course in the state of Georgia that students could take instead of precalculus after their third year at this high school. Before entering their senior year, teachers recommended the students on a few different categories such as grade point average, achievement scores in Algebra II, and motivation. Some students also self-selected into this course even after being recommended to take the more rigorous course, precalculus. So, this course was primarily students that were low achieving in mathematics, lacking motivation to take more challenging mathematics courses, or both. The course is much like an introductory statistics course where students learn measures of center, measures of spread, displays of data, distributions, and basic analysis methods in inferential statistics. The topics of the course in which this study took place was during gathering data and correlation and regression models.

Participants

Sample and population defined

The students were composed of 75 students, 71 seniors and 4 juniors. The gender count was 36 female and 39 male. Demographic data to describe the subjects can be seen in table ## below. There were four groups meeting at different times of day. One of the groups had three

Table ##
Demographic Data

	School	District
N	1748	19973
Ethnicity		
White	1,067 (61%)	9418 (47%)
Asian/Pacific Islander	194 (11%)	1398 (7%)
Hispanic	199 (11%)	2460 (12%)
Black	178 (10%)	5621 (28%)
Multi-racial	110 (6%)	1038 (5%)
Other Factors		
Economically Disadvantaged	74 (4%)	2173 (11%)
Students with Disability	120 (7%)	2054 (10%)

English Language Learners	78 (4%)	1149 (6%)

Note: Due to rounding totals might not be 100%

special education students with individualized education plans (IEP), but the rest in this class are no different than any other class. The course was available to seniors at this high school, but with a few juniors often mixed in the ages range from sixteen to eighteen years old. The school was located in a primarily high affluent community with some diversity, and it has existing high achievement scores on state wide testing and standardized testing such as the SAT and ACT. At least five of these students had failed mathematics every single year and were receiving some sort of credit recovery online or in summer school through the local county programs. The purpose of using this group of individuals was to begin with a group that would likely represent a population of high school students that had a lower perception toward mathematics. This group was used in hopes to reflect the views of many underachieving students that come from middle to upper class communities that are preparing to enter the work force or post-secondary education.

Special Education Accommodations

Three of the students had IEP accommodations that allowed them to be pulled out for small group testing and reviewing for all assessments. All of these students received extended time on all assessments, a quiet setting for assessments, and printed or guided notes during class time. Additional accommodations that were sometimes but not always used by these students were preferential seating, chunking of information, teacher must check for understanding, use of graphic organizers, word banks for assessments, reinforcing positive behavior, fidget manipulatives or stress ball, and giving nonverbal cues to discontinue behaviors. Twelve students had 504 accommodations, and these accommodations were sometimes related to health and a few were related to cognitive disorders that required academic accommodations. Two students were diabetic which requires that they are allowed to eat or leave class as needed, may require that they put their heads down if they are feeling ill, and at times may seem highly distracted. The other ten 504 students receive extra time on assessments and may require small group testing if the student asks in advance to do so.

Instruments

Perception measurements

Measuring mathematical affinity or attitudes towards mathematics has been a long standing practice and goes back over half a century to measuring the attitudes of small children and arithmetic (Dutton, 1954). Prior research supports the claim that students that lack a positive attitude toward mathematics will perform at a lower standard than those that portray a desire to learn mathematics (Tapia & Marsh, 2004). Knowing the value of student perceptions, attitudes, and affinity for mathematics brings an added value to this research study. Finding a reliable instrument for measuring attitudes toward mathematics was highly important, and several already existed that had been developed and tested rigorously.

One of the earlier instruments was the Fennema Sherman Mathematics Attitude Scale (FSMAS) (Fennema & Sherman, 1976). This tool was developed to measure nine different factors that contribute to the attitudes individuals have towards mathematics. Fennema and Sherman (1976) described all nine as the following:

1. *The Attitude toward Success in Mathematics Scale (AS) is designed to measure the degree to which students anticipate a positive or negative consequence as a result of success in mathematics. They demonstrate their fear by anticipating negative consequences of success as well as by lack of acceptance or responsibility for the success.*

2. *The mathematics as a Male Domain Scale (MD) is intended to measure the degree to which students see mathematics as a male, neutral, or female domain in the following ways: (a) the relative ability of the sexes to perform in mathematics; (b) the masculinity/femininity of those who achieve well in mathematics; and (c) the appropriateness of this line of study for the two sexes.*
3. *and 4. Is designed to measure students' perception of their monther's/father's interest, encouragement, and confidence in the student's ability. It also includes the student's perception of their mother's/father's example as an individual interested in, confident of, and aware of the importance of mathematics.*
5. *The teacher scale is designed to measure students' perceptions of their teacher's attitudes toward them as learners of mathematics. It includes the teacher's interest, encouragement, and confidence in the student's ability.*
6. *The confidence in Learning Mathematics Scale (C) is intended to measure confidence in one's ability to learn and to perform well on mathematical tasks. The dimension ranges from distinct lack of confidence to definite confidence. The scale is not intended to measure anxiety or mental confusion, interest, enjoyment, or zest in problem solving.*
7. *The Mathematics Anxiety Scale (A) is intedended to measure feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics. The dimension ranges from feeling at ease to feeling distinct anxienty. The scale is not intended to measure confidence in, or enjoyment of, mathematics.*
8. *The Effectance Motivation Scale in Mathematics (E) is intended to measure effectance as applied to mathematics. The dimension ranges from lack of involvement in mathematics to active enjoyment and seeking of challenge. The scale is not intended to measure interest in, or enjoyment of, mathematics.*
9. *The Mathematics Usefulness Scale (U) is designed to measure students' beliefs about the usefulness of mathematics currently, and in relationship to their future education, vocation, or other activities.*

This study aimed to have an impact on student anxiety; it did not aim to impact all of these categories. Factors five through nine could be majorly impacted by spreadsheet activities in helping students see the confidence placed in them by the teacher to complete the task, their own personal confidence in mathematics after they complete the task, a lowered anxiety with completion of the task, increased desire to do more mathematics, and an increased belief that mathematics is useful. However, the focus of this study was on scale number seven listed above since anxiety is such an integral part to students' attitudes towards mathematics according to the literature.

Since Fennema and Sherman developed their model, researchers have questioned and tested this suggesting that it does not need nine factors. It may only require eight or even six according to some previous research (Melancon, Thompson, & Becnel, 1994; Mulhern & Rae, 1998). Tapia and Marsh (2004) narrowed it down to just six factors and created the Attitudes Toward Mathematics Inventory (ATMI) (Appendix A). Together, they gave careful consideration and research to each of these six factors:

1. *Confidence. The Confidence category was designed to measure students' confidence and self-concept of their performance in mathematics.*
2. *Anxiety. The anxiety category was designed to measure feelings of anxiety and consequences of these feelings.*
3. *Value. The value of mathematics category was designed to measure students' beliefs on the usefulness, relevance and worth of mathematics in their life now and in the future.*
4. *Enjoyment. The enjoyment of mathematics category was designed to measure the degree to which students enjoy working mathematics and mathematics classes.*
5. *Motivation. The motivation category was designed to measure interest in mathematics and desire to pursue studies in mathematics.*
6. *Parent/teacher expectations. The parent/teacher expectations category was designed to measure the beliefs and expectations parents and teachers have of the students' ability and performance in mathematics.*

Their survey consisted of forty-nine Likert-scale items. Their survey was tested on 545 high school mathematics students across all grade levels. To test the consistency of the scores, the Cronbach alpha coefficient was calculated for the entire survey, and correlations were calculated for each of the forty-nine items. Any items that had weak correlations were deleted which increased the Cronbach alpha, reducing the survey down to forty items. When the calculations were finished, the Cronbach's alpha was extremely strong at 0.97 for the entire survey, and the correlations were all over 0.50 for each individual remaining item. So now, the ATMI survey consists of only forty strong items that individuals rank on a five point Likert scale.

This tool seems to bring more validity and reliability now that it has taken all the research since Fennema and Sherman and trimmed it down to a much more narrowly focused survey. It has also gone through rigorous testing with strong statistical models to prove the consistency, validity, and reliability. It has been used in studies even recently to measure students attitudes in gamification in mathematics (Ke, 2008), secondary students in mathematics (Asante, 2012), and developmental mathematics in higher education (Guy, Cornick, & Beckford, 2015) to name a few.

In two pilot studies by the author of this study, it was found that the survey length created response bias from two previous years of students. Many students would submit surveys with the first few responses appearing to be honest, but after a few the results were either very random, or very consistent marking 3's for all inventory items. This was when the entire survey was given, fortunately, since the aim of this study is show an improvement in attitudes through a reduction of mathematics anxiety, a brief survey was used that is a subset of the ATMI survey called The Mathematics Anxiety Scale (MAS). The list of items can be seen in Figure 4 below.

Table 1

Item-Total Correlation and Internal Consistency Reliability of MAS-R

Item	Affect Dimensionality	Correlation with Total	Cronbach's Alpha[a]
1. I find math interesting.	Positive	.59	.90
2. I get uptight during math tests.	Negative	.68	.90
3. I think that I will use math in the future.	Positive	.31	.91
4. Mind goes blank and I am unable to think clearly when doing my math test.	Negative	.63	.90
5. Math relates to my life.	Positive	.26	.91
6. I worry about my ability to solve math problems.	Negative	.66	.90
7. I get a sinking feeling when I try to do math problems.	Negative	.63	.90
8. I find math challenging.	Negative	.57	.90
9. Mathematics makes me feel nervous.	Negative	.73	.90
10. I would like to take more math classes.	Positive	.54	.90
11. Mathematics makes me feel uneasy.	Negative	.74	.89
12. Math is one of my favorite subjects.	Positive	.74	.89
13. I enjoy learning with mathematics.	Positive	.64	.90
14. Mathematics makes me feel confused.	Negative	.75	.89

[a]The Cronbach's alpha coefficient indicates the internal consistency reliability of the total scale if the item is deleted.

Figure 4. The Mathematics Anxiety Scale (A) is intended to measure feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics. The dimension ranges from feeling at ease to feeling distinct anxiety. The scale is not intended to measure confidence in, or enjoyment of, mathematics (Fennema & Sherman, 1976). In short, this is known as the Fennema-Sherman Mathematics Anxiety Scale (MAS). (Bai, Wang, Pan, & Frey, 2009)

Measuring Student Performance

As part of the intervention, participants built a tool used to generate responses related to correlation and regression problems. The students used this tool or a calculator to answer performance-based questions based on Georgia performance standards around correlation and regression. The tool was also used to support a hypothesis that the student comes up with in a high school classroom setting by completing a basic written assignment with a question of interest, data collection, analysis, and a simple conclusion. This was the final performance measurement also displaying transfer. For these reasons, performance and transfer was measured with a rubric on the assignment that the students completed. This rubric was generated from the Department of Mathematics and Statistics at the University of New Mexico that can be viewed in Appendix F (Erhardt, 2016). The standards are Georgia Standards for Statistical Reasoning MSRCD1, MSRCD3, MSRCD4, and MSRIR1 and they are outlined in full detail in Appendix G.

Semi-Structured Interviews

Semi-structured interviews were used upon completion of the treatment and surveys. Twelve students were selected to participate. The selection process was determined after all treatments were completed and is discussed in the results section. There were a few guiding questions to generate a dialogue.

1. For the two treatments you experienced, spreadsheet vs. handheld calculator, did you have a preference? Why?
2. What was it about the treatment that you preferred over the other? What did it afford you that the alternative did not?
3. Did you enjoy using one tool over the other? Did it make you enjoy learning this subject more than previous courses? Why?

Creswell (2007) suggests that 5 to 25 interviews be conducted as an initial starting point. More interviews could be considered for further depth and discovery. In this study, twelve students were interviewed. The selection process was completed during the data collection phase of the study, and the selection process is discussed in the results section along with how the data was coded.

Procedures

Treatment and Description of Procedures

The specific treatment applied was a computational activity that spanned the course of approximately three weeks. The students used the required previous mathematical ideas that were foundational to complete this project but expanded on previous knowledge to learn about correlation and regression throughout the project. The students were introduced to using a spreadsheet program where they built algorithms through multiple steps. Most students had not used this program in a mathematical or computational way. Some had used spreadsheets to create tables and grids with categories and numbers, but no computations. The program that was used is the web-based Google Sheets. The students all had a Chrome Book assigned to them, so typical applications that might run on other devices such as Microsoft applications and Apple applications were not an option. They built an algorithm to compute the standard deviation with minimal preprogrammed commands as an introductory lesson (See appendix D). The students had already learned about standard deviation but had not calculated it beyond a hand calculation for three to four data values. After this exercise, students moved on learning about programming a spreadsheet algorithmically to compute values related to correlation and regressions along with residual values.

Learning how to use a spreadsheet algorithmically

Before beginning with the spread sheet, the students were required to complete a simple task on paper on how to calculate the mean and standard deviation by hand (Appendix C). This began the algorithmic thinking process that would transfer to the computer (Aho, 2012; Guzdial, 2008; Papert, 1980; Weintrop et al., 2016; Wing, 2006). The assignment is organized as a grid much like a spreadsheet, and the students followed a similar process when using a Google Sheet to create this algorithm. The students went through a simple guided tutorial with the teacher-researcher to create a simple sheet to do some basic operations such as "=sum( )" and how to add and connect cells to other computations. For example, calculating a mean will first be completed by telling the sheet to add up all the numbers using addition or the sum command, then dividing. The focus of this was to teach the students algorithmic thinking through computing before using the built in commands such as "=average( )". The second example was to do the same with standard deviation which requires more steps using operations in the sheet such as addition, squaring, and dividing throughout many different cells. Then the students were introduced to the "=stdev( )" command (Appendix D). Once the students understood how the spreadsheet program works on a very basic level, they then designed a sheet that would calculate values related to correlation and regression along with residual values. They were also able to use this spread sheet on their assessment at the end of the learning period rather than using a calculator and paper and they saw how much easier it was to use a preprogrammed algorithm. The purpose of this part of the procedure ties back in to increasing the perceptions of mathematics by reducing anxiety and simplifying calculations. The students also saw that they are capable of performing basic computing with a spreadsheet.

Controlling the experiment

The experiment established a baseline for comparison in two ways. One way was through pre-survey for the student's attitudes using the subset survey of the ATMI, the MAS. The students took the survey before treatment, and then again after each level of treatment depending on which group they were assigned. The same type of pre-measurement was done for performance since this was a required measurement by IRB, and since research suggests that performance is tied to anxiety.

The two groups switched treatments, meaning the computing group switched to calculators while those that started with calculators switched to computers after the second measurement is made. Then the experiment continued and the students were given the survey and performance measurement a third time. This allowed both groups to see both treatments. This was to maintain fairness between the two groups. Both groups had to be taught the same thing according to the school system IRB.

Performance Measurements in Detail

Participants constructed a basic question to poll fellow students around the school that would return two quantitative answers (Appendix E). They collected data using whatever sampling method they decided to use. The data that they collected was entered into their spreadsheet to generate the Pearson Correlation Coefficient, coefficient of variation, a slope, a y-intercept, and predicted values about the model as well as residuals. The students wrote up four paragraphs presenting a description of their mini research, their data and sampling method, their results and tables, and a short conclusion. The description included a one sentence purpose and a one sentence rationale along with a single research question. The data was presented in a table or extended table with a description of how the data was collected. The conclusion summarized their findings and what they learned from the experience. The purpose of this part of the procedure was to showcase how statistics and mathematics are used in a real world problem that they derived.

Students also answered performance based questions based on the Georgia Standards of Excellence for Mathematics 9-12 (Woods, 2016) in a formative assessment. These questions were questions designed to test students' knowledge about correlation and regression. These performance-based questions were given before students began treatment, after the first treatment group used spreadsheets, and then again after the groups switch treatments as outlined in the counterbalance design. The performance measurement is to maintain the integrity of the study to ensure no learning of the standards were lost.

Hypothesis

The hypothesis of these procedures was that the students would have a better understanding of how mathematics and statistics transfers to the real world and how computing is a valuable skill for all to have even if they are not a computer scientist. Once students saw how valuable coding was in their lives, they had a better understanding how mathematics is used in the technology they experience daily and have a greater appreciation for mathematics.

The primary objective here was to reduce anxiety towards statistics and mathematics more generally. For this reason, participants completed the survey discussed. The hypothesis was that the survey would show an increase in positive attitudes toward mathematics as students use spreadsheets to complete learning objectives. This survey was given to all subjects before and after the treatment and analyzed. A comparison of the mean and median scores was analyzed as well as each individual question was analyzed. The more the students agree with each inventory item, the more positive their affinity for mathematics was. The aim was that the survey after treatment would have a higher score on this inventory than before the treatment.

Assumptions and Limitations

Population and sample limitations

This research drew conclusions regarding the perceptions of low achieving, affluent, high school mathematics students from 75 students from one high school in Georgia. The community is very affluent as a whole, however the students had some diversity within the population. Some had grown up in this community their entire lives, while others were transfers from other cities as well as other states. These students have either self-selected into this course or were recommended by their previous teacher due to low performance or low motivation, so the perceptions of mathematics and computing are assumed to be low entering into this study. Since this is such a small group of students, generalizations are not expected to much larger populations.

Personal positioning and bias

The classroom teacher and the researcher were one in the same in this study. The surveying was being controlled by the classroom teacher that was organizing the activities for the students. While subjects knew the teacher-researcher, all bias is attempted to be removed by having a focused survey of mathematical perceptions prior to treatment with an emphasis that this is not a survey about the class or teacher-researcher. To avoid other perceived biases, the researcher will use anonymous surveys for all surveys. Another source of bias was the partial voluntary response selection of exit interviews used on twelve subjects. These subjects could have had bias strong for and strong against the treatment.

CHAPTER 4: RESULTS

The results were broken into three primary parts from three primary data collections. The first is the participant’s responses to the Mathematics Anxiety Scales (MAS), which as described before is a separate sub scales of the full Attitudes Toward Mathematics Inventory (ATMI). The second was the results related to student performance to ensure all learning objectives were met through a basic set of standard questions and a basic written assignment. The third part of the results section is the semi-structured interviews. Two groups are described throughout these results sections. One group used calculators first and then switched to spreadsheets. This group was referred to as the calculator/spreadsheet group, while the group that experienced spreadsheets first and then calculators second was be referred to as the spreadsheet/calculator group.

Mathematics Anxiety Scales Survey

The survey was administered at three different points throughout the study. First, as an initial benchmark prior to any treatment technology use. Second, it was given after one group learned a unit of statistics using scientific calculators and after another group was taught the same unit using a spreadsheet. The third survey was given after the two groups switched technology, and were taught how to use the opposite technology during the same unit. The hypothesis was after using the primary treatment, spreadsheets, the students would show positive

Table 1
Attitudes Towards Mathematics Inventory, Mathematics Anxiety Scales

Item
I find mathematics interesting.
I get uptight during math tests.
I think I will use math in the future.
Mind goes blank and am unable to think clearly when doing my math test.
Math relates to my life.
I worry about my ability to solve math problems.
I get a sinking feeling when I try to do math problems.
I find math challenging.
Mathematics makes me feel nervous.
I would like to take more math classes.
Mathematics makes me feel uneasy.
Math is one of my favorite subjects.
I enjoy learning mathematics.
Mathematics makes me feel confused.

(Bai et al., 2009)

changes on survey items formed in the positive, and negative changes for survey items formed in the negative. The survey items can be seen in Table 1 above. Each survey item was measured for significance using matched pairs t-tests for each of the three different measurements within the groups during the study. These tables labeled in Appendix H and are for reference only. These tables display changes in the positive and negative appropriately. For the purposes of analysis, all descriptive statistics and procedures were conducted with all negative inventory items reversed to positive and recoded. Table 1 above displays all inventory items for which students were surveyed.

Table 2
Descriptive Statistics: Survey Scale

Group	*Mean*	*Std. Deviation*	*N*
Pre-Survey			
calculator/spreadsheet	2.582	0.732	41
spreadsheet/calculator	2.750	0.989	34
Total	2.658	0.856	75
Second Survey			
calculator/spreadsheet	2.632	0.758	41
spreadsheet/calculator	2.981	0.935	34
Total	2.790	0.855	75
Third Survey			
calculator/spreadsheet	3.178	0.798	41
spreadsheet/calculator	2.761	0.980	34
Total	2.989	0.903	75

After reverse coding the survey data, descriptive statistics were calculated and presented in Table 2 below. Note that the total means include more than one treatment. Note that the two highest descriptive mean scales (M = 2.98, M = 3.18) occurred immediately following activities with spreadsheets.

Table 3 is the result of a two-way repeated measures ANOVA. While this table shows a significant main effect $F(2,73) = 10.63$, $p < 0.001$ among pre-survey, second survey, and third

Table 3

Tests of Within-Subjects Effects: Survey 1st 2nd and 3rd by Group (treatments mixed)

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*	*Noncent. Parameter*	*Observed Power**
Survey								
Huynh-Feldt	3.424	1.951	1.755	10.632	0.000	0.127	20.746	0.987
Survey * Group								
Huynh-Feldt	5.960	1.951	3.055	18.510	0.000	0.202	36.117	1.000
Error(Survey)								
Huynh-Feldt	23.507	142.440	0.165					

Note: Survey is designated for Survey 1, 2 or 3 while Group is designated as Calculator/Spreadsheet or Spreadsheet/Calculator group. Treatments within Survey are mixed.

**Computed using alpha = .05*

survey, it should be noted that these columns are mixed treatments due to counterbalancing. Within measures will be analyzed further in a different procedure. Table 3 also displays a significant interaction between groups ($F(2,73) = 18.51$, $p < 0.001$). This parametric test was run to test between groups factors. Table 4 displays the marginal means and confidence intervals to narrow the search for the dependent groups that are significantly different. It can be seen here that the confidence intervals for the calculator/spreadsheet group have a significant measure in

Table 4
Group by Survey based on Marginal Means

			95% Confidence Interval	
	Mean	*Std. Error*	*Lower Bound*	*Upper Bound*
Calculator then Spreadsheet				
Pre-Survey	2.582	0.134	2.315	2.849
Second Survey	2.632	0.132	2.370	2.895
Third Survey*	3.178	0.138	2.902	3.453
Spreadsheet then Calculator				
Pre-Survey	2.750	0.147	2.457	3.043
Second Survey	2.981	0.145	2.693	3.269
Third Survey	2.761	0.152	2.458	3.063

Note: These are parametric comparisons from ordinal data
**significant difference based on Bonferroni Adjustment*

the third survey CI[2.902, 3.453] after spreadsheets were applied as an activity over both previous measurements CI[2.315, 2.849] and CI[2.370, 2.985]. This can also be visually seen in the marginal means plots in figure 6 below.

The marginal means plots also showed the spreadsheet/calculator group improving on anxiety measures after using the spreadsheets and going back down subsequently returning to traditional calculator procedures. The calculator/spreadsheet group spiked after going through the calculator procedures and then switching to spreadsheets in the final measure.

To measure within treatments, Friedman's test was used. Friedman's test is a non-parametric test used to measure ordinal data. Friedman's test uses ranked means rather than weighted means to account for ordinals. Table 6 displays the significance within the three levels of treatments for each survey. One level is all pre-survey measurements (*Mdn* = 2.64) with no treatment, second level is all student's survey measurements after using calculator procedures

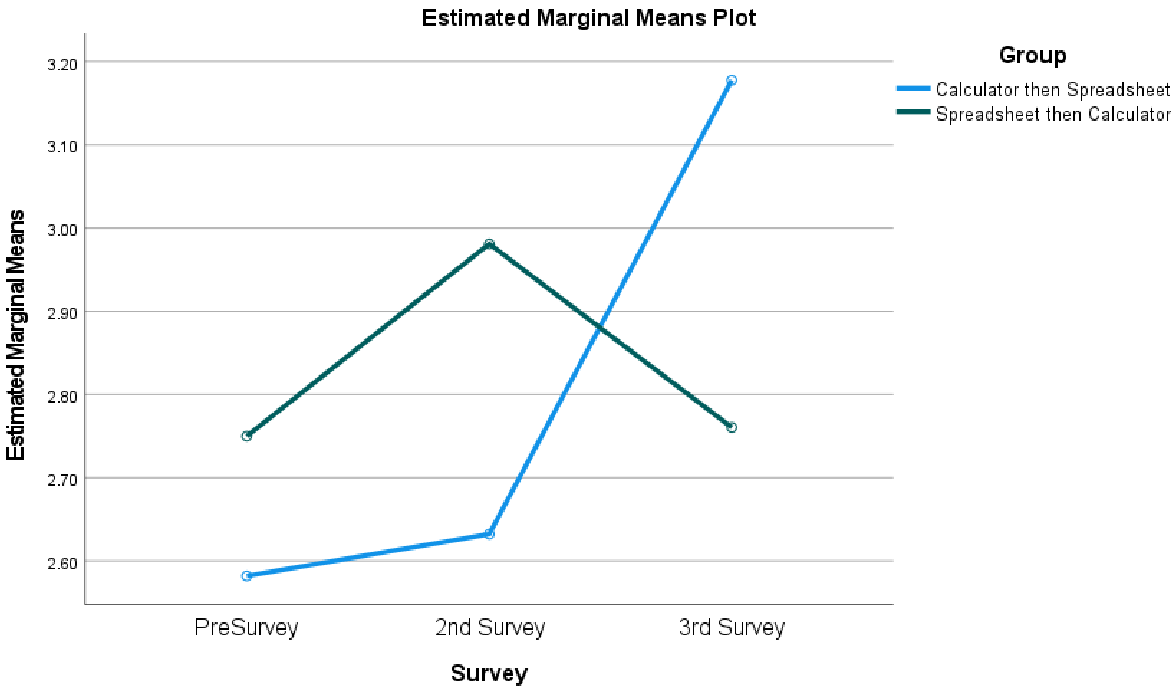

Figure 5.

Table 5

Descriptive Statistics (Ordinal) for within treatment measurements

					Percentiles		
	N	*Ordinal Ranks*	*Minimum*	*Maximum*	*25th*	*Mdn.*	*75th*
Pre-Survey	75	1.60	1.07	4.93	2.07	2.64	3.29
Calculator	75	1.74	1.00	4.79	2.07	2.79	3.29
Spreadsheet	75	2.65	1.07	4.79	2.57	3.14	3.71

(*Mdn* = 2.79), and the third level is the student's survey measurement after using spreadsheets (*Mdn* = 3.14). Additional descriptive statistics can be seen in Table 5. The results of the

Friedman's test was significant, $\chi^2_F(2) = 51.17$, $p < 0.001$. Post-hoc tests using a Wilcoxon signed-rank test with a Bonferroni adjusted alpha level of 0.017 (0.05/3) showed that the scaled survey score after spreadsheets (*Mdn* = 3.14) were higher than the pre-survey (*Mdn* = 2.64) and after using calculator procedures (*Mdn* = 2.79). This survey scale difference was significant and can be seen in Table 7, however, calculator treatment appears to have had no effect compared to pre-survey scales.

Table 6
Friedman's Test for Within Subjects Treatments

	N	*df*	*χ 2*	*Asymp. Sig.*	*Kendall's W**
Treatments	75	2	51.17	0.000	0.34

* Kendall's Coefficient of Concordance

Table 7
Wilcoxon Signed Ranks Test - Comparing within treatments

	N	*Mean Rank*	*Sum of Ranks*	*Z**	*Asymp. Sig. (2-Tailed)*
Calculator vs Pre-Survey	75		2278.00	-1.10	0.272
Negative Ranks	31	31.08	963.50		
Positive Ranks	36	36.51	1314.50		
Ties	8				
Spreadsheet vs Pre-Survey	75		2556.00	-6.09	0.000
Negative Ranks	8	26.88	215.00		
Positive Ranks	63	37.16	2341.00		
Ties	4				
Spreadsheet vs Calculator	75		2485.00	-5.44	0.000
Negative Ranks	14	22.43	314.00		
Positive Ranks	56	38.77	2171.00		
Ties	5				

** Based on negative ranks*

Performance Measurements

Performance measurements were measured through a ten question formative assessment based on state standards as a requirement for the Institutional Review Board (IRB) for the school district and because the literature states that anxiety and performance are tied together. The requirement was that the treatment must have shown that the groups were able to achieve the

Table 8

Performance Test Scores, Descriptive Statistics

	Calculator/Spreadsheet Group			Spreadsheet/Calculator Group		
Item	*N*	*M*	*SD*	*N*	*M*	*SD*
Pretest	41	5.61	12.66	34	*5.00*	*12.85*
2nd Test	41	91.22	15.03	34	89.12	20.80
3rd Test	41	96.10	11.59	34	88.82	21.71

Table 9

Tests of Between-Subjects Effects: No Difference in Performance between groups

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*p*	*partial* η^2	*Observed Power*
Intercept	875288	1	875288	2272.406	0.000	0.969	1.000
CS or SC (Group)	617.78	1	617.78	1.604	0.209	0.021	0.239
Error	28118.22	73	385.18				

Note: alpha = 0.05

same or better performance with the new treatment, spreadsheets. So it is important to note that performance is not part of the primary research question, but measuring performance might tell something about anxiety measures since the two can correlate (Meece et al., 1990). Measuring performance also points toward future research all while fulfilling the IRB requirement. The formative assessments were specific to calculating statistical values using technology that are usually unattainable calculations by hand such as Pearson's correlation coefficient and regression equations for linear, quadratic, logarithmic and exponential models. Students were measured before treatment, after one treatment, either calculator or spreadsheet depending on group assignment, and then a third time after switching treatments in the counterbalance design. Descriptive statistics can be seen above in Table 8.

The original hypothesis was met in Table 9 above for between subjects effects shows no significant difference between groups using a Two-Way Repeated Measures ANOVA $F(1, 73) = 1.60$, $p = 0.21$ and when observing within measurements in Table 11 there is no significant difference $F(2,73) = 1.19$, $p = 0.31$. Levene's Test for equality of variances is also below in Table 10 which shows no significance in all but the third measure, however, since the means for the spreadsheet groups were descriptively higher, this was enough to meet the requirement for IRB, and since a non-parametric test does not appear present for repeated measures between groups, these results were accepted since the researcher was not seeking significant performance increases. However, since the calculator/spreadsheet group was the highest in comparing means ($M = 96.10$), more research should be done measuring performance based on learning with different treatment orders. It is possible, based on interviews, to be discussed later, that learning with a calculator first and then a spreadsheet made the process of using a spreadsheet easier. For now, this mean was not significantly different.

Table 10
Levene's Test of Equality of Error Variances

Test	Levene Statistic	df1	df2	Sig.
Pretest				
Based on Mean	0.138	1	73	0.711
Based on Median	0.043	1	73	0.837
Based on Median and with adjusted df	0.043	1	72.984	0.837
Based on trimmed mean	0.176	1	73	0.676
Second Test				
Based on Mean	1.074	1	73	0.304
Based on Median	0.257	1	73	0.614
Based on Median and with adjusted df	0.257	1	66.146	0.614
Based on trimmed mean	0.640	1	73	0.426
Third Test				
Based on Mean	7.483	1	73	0.008
Based on Median	3.430	1	73	0.068
Based on Median and with adjusted df	3.430	1	54.393	0.069
Based on trimmed mean	6.191	1	73	0.015

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + CS_or_SC, Within Subjects Design: Test

Traditionally, students have been able to perform these calculations using a simple scientific calculator with stat features built in, so the hypothesis was that that using spreadsheets would be no different between the two technologies. Obviously, the descriptive statistics displayed a large increase from pretest to the second test in both groups since the groups appeared to have little knowledge about finding values related to correlation and regression. This was highly anticipated, and was not extremely relevant to the research question, but is relevant for IRB standards. There was expected to be no difference in performance between treatments. However, in the third and final measurement after the two groups switched, the calculator/spreadsheet group appeared to be significantly higher than the calculator/spreadsheet group appeared to be significantly higher than the spreadsheet/calculator group (*M = 96.10 SD = 11.59, M = 88.82 SD = 21.71 respectively).* However, looking deeper into the pairwise comparisons and using a Bonferroni correction to adjust for the multiple comparisons and between variables in this data set, the difference between groups is not significant. See Table 12 below for the pairwise comparisons and Figure 6 for Marginal Means Plots for comparisons.

This is an unexpected finding that the means were descriptively different, and perhaps with a larger sample size that reveals similar means the test might show a significant difference indicating that performance could depend on the order of treatments. For now, we do not have sufficient evidence to support this claim.

Table 11
Tests of Within-Subjects Effects: Performance Treatments Mixed

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*	*Noncent. Parameter*	*Observed Power**
Test								
Huynh-Feldt	366856.47	1.21	302599.05	957.04	0.00	0.93	1160.27	1.00
Test * CS_or_SC								
Huynh-Feldt	454.69	1.21	375.05	1.19	0.29	0.02	1.44	0.20
Error(Test)								
Huynh-Feldt	27982.64	88.50	316.18					

Note: Within categories had mixed treatments, this table should be for observed interactions between groups only
** Computed using α = .05*

Table 12

Pairwise Comparisons for Performance

A	*B*	*Mean Difference (A-B)*	*Std. Error*	*Sig. **	*95% Confidence Interval for Difference* Lower Bound*	*Upper Bound*
					Test Measure	
1	2	-84.864	2.756	0.000	-91.618	-78.110
	3	-87.156	2.639	0.000	-93.622	-80.689
2	1	84.864	2.756	0.000	78.110	91.618
	3	-2.292	0.952	0.056	-4.625	0.041
3	1	87.156	2.639	0.000	80.689	93.622
	2	2.292	0.952	0.056	-0.041	4.625

*Notes: * Based on estimated marginal means*
Adjustment for multiple comparisons: Bonferroni.

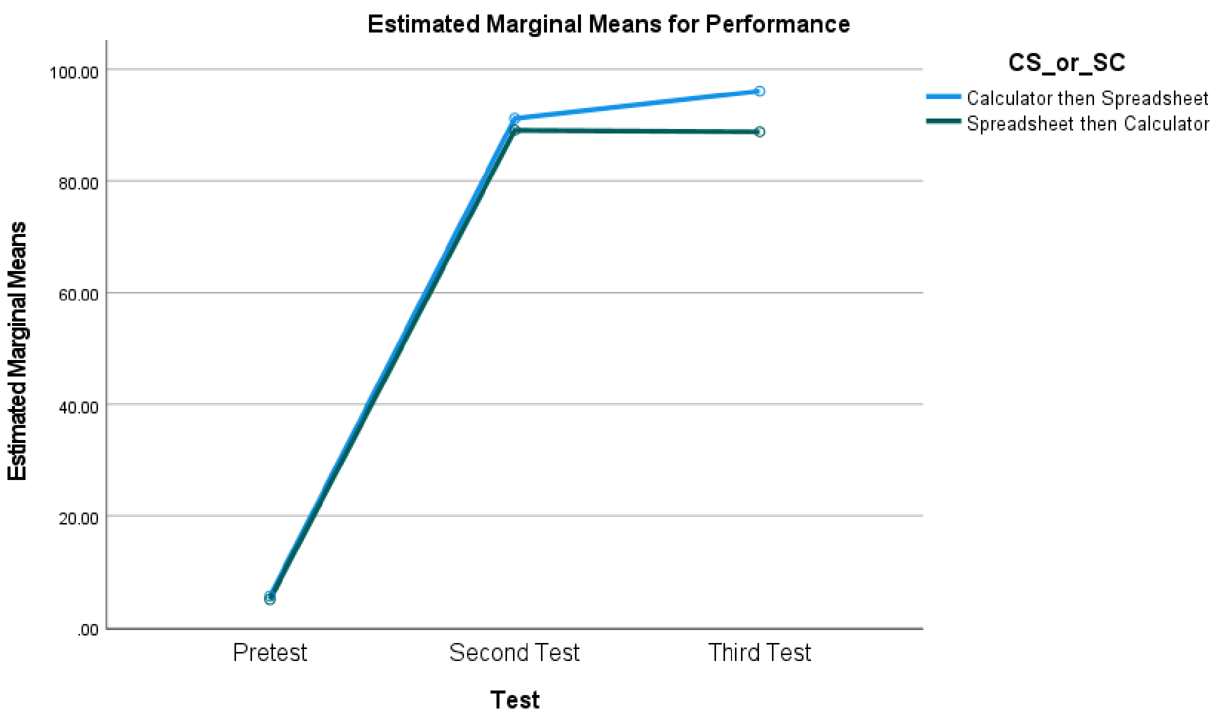

Figure 6.

One final analysis of the performance scores was conducted within treatments rather than between groups. The difference is to ensure that the actual treatments had no effect or that the spreadsheet group had a positive effect on performance. To answer this, a one-way ANOVA was run within just the three treatments pretest (no treatment), calculator procedures, and spreadsheet procedures. Order of treatments is not considered in this analysis. Results can be seen in table 13 below. As expected, the results were significant with moderate to high effect $F(2,148) = 969.36$, $p < 0.001$, $\eta^2 = 0.93$. This large test statistic is due to the large difference between the pretest and two posttest scores. So, some pairwise effects are displayed in table 14. In this table, it can be seen that there isn't just significant difference against pretest scores, but also comparing the two treatments calculator and spreadsheet procedures were significant.

Beyond measuring performance scores, the learning management system allowed the researcher to further investigate one more variable. Time was recorded for each test, and while this was not originally planned, the data was present and analyzed in Table 15. Even though there were not large differences in scores between all treatment groups, time seemed to be significantly different when looking between different treatment levels. The tests completed with calculators took significantly longer according to the results. The initial calculator group performed slower on testing, but when given a spreadsheet, the time spent on task decreased significantly (*M = 8.98 SD = 1.65, M = 7.95 SD = 1.34 respectively)*. Conversely, the group that started with spreadsheets spent less time on task with a spreadsheet than when they did the same activities with a calculator (*M = 7.76 SD = 1.78, M = 9.86 SD = 1.91 respectively)*.

Table 13

Tests of Within-Subjects Effects: Comparing within Treatment Effects

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*	*Noncent. Parameter*	*Observed Power**
TestTreatments								
Huynh-Feldt	371816.00	1.20	308858.45	969.36	0.000	0.93	1166.96	1.00
Error(TestTreatments)								
Huynh-Feldt	28384.00	89.08	318.62					

* Computed using alpha = .05

Table 14

Pairwise Comparisons: Comparing within Treatments

Treatment Comparisons	*Mean Difference*	*Std. Error*	*Sig.**	95% Confidence Interval for Difference*	
				Lower Bound	*Upper Bound*
Calculator - No Treatment	84.80	2.77	0.0000	78.01	91.59
Spreadsheet - No Treatment	87.60	2.59	0.0000	81.26	93.94
Spreadsheet - Calculator	2.80	0.98	0.0164	0.40	5.20

Notes: Based on estimated marginal means

** Adjustment for multiple comparisons: Bonferroni α = 0.167 (0.05/3)*

Table 15

Performance Test Time (minutes), Calculator/Spreadsheet vs Spreadsheet/Calculator

	Calculator/Spreadsheet Group			Spreadsheet/Calculator Group				
Item	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p*
2nd Test	41	8.98	1.65	34	7.76	1.78	3.055	0.002
3rd Test	41	7.95	1.34	34	9.86	1.91	-4.929	0.000

Written Assignments

Students were assigned a written assignment related to the unit as part of the spreadsheet treatment. This section was meant to present evidence that students created an artifact that met the standards of the course as well as demonstrate an ability to transfer their knowledge to a more relatable setting. Students were attempting to find two variables that correlate based on a basic question of interest as it relates to the course. They then had to calculate the correlation coefficient, coefficient of determination, a linear regression equation that best fits their data, and a scatterplot with the regression line presented in their document. This allowed students to explore real world situations of their own interest. Some opted to go and find data that interests them, others went for easier to obtain data such as conveniently asking friends to report their study habits and grade point average. Regardless of topics chosen, the assignment goal was to increase the student's perceptions on inventory items such as *I find math interesting, math relates to my life, I would like to take more math classes*, and *I enjoy learning mathematics*. Students were given several examples and non-examples along with a detailed explanation of each paragraph requirements and recommendations. Each assignment was assessed with a rubric. The results are in Table 16 below.

Table 16
Written Assignment Ratings

Rating	*n*	*Proportion*
Excellent	12	0.16
Very Good	34	0.45
Satisfactory	29	0.39
Questionable	0	0.00
Unacceptable	0	0.00

No separate group measurements are reported. This assignment was performed after all subjects had learned how to use a spreadsheet but before their final survey measurement about spreadsheets. So the spreadsheet/calculator group performed this activity before the calculator/spreadsheet group. This was a large contributor in the groups for some anxiety measurements since they had never had a written assignment like this in a mathematics course before. This is indicated in the interviews conducted to be discussed below. All students were able to get a satisfactory or higher achievement on this assignment.

Semi structured interviews

Semi structured interviews were conducted among twelve students. Some students were chosen from a group that volunteered, and a few were requested by the research. Three students in particular indicated throughout the unit that "they hate spreadsheets," so these students were intentionally asked to participate in the interviews, and they agreed. Since many students indicated throughout the treatment their appreciation for spreadsheets, it was easy to find students to talk openly about the positive feelings toward the treatment, which was why specifically selecting these three students that appeared to have negative reactions was so important. After having students fill out a survey on whether they would or would not be comfortable talking about their experience one on one with an interviewer, 55 out of 75 said they would be willing to participate. Of these 55, three were selected by the researcher based on their ability to carry a conversation and the fact that they had indicated that they enjoyed using spreadsheets. This compliments the other three that were selected for not enjoying spreadsheets. The remaining six were randomly selected from the 55 that said they were willing to participate. The interviews were centered around three questions or discussion starters, but dialogue continued beyond these questions and common themes were noted throughout the interviews.

1. Describe and compare your experience with using spreadsheets and calculators while learning statistics during this unit.
2. Describe details that might have made one stand out to you over the other.
3. Did it make you enjoy learning this subject more than previous courses? Why or why not?

The data was coded using descriptive coding (Miles, Huberman, & Saldana, 2014) to identify commons ideas at first, and later these codes were cross-listed to create the themes presented in Table 17. Many students were much more positive about their experience with using spreadsheets for the first time. The most common themes were that spreadsheets are *fun*, *easier to use*, *interesting* or *less boring*, and *useful* for their futures. One student pointed out "using my spreadsheet was way more enjoyable than anything we have done in any of my math classes since I came to this school as a freshman" while another added, "Math is usually so

Table 17
Semi Structured Interview Themes

	Spreadsheets		Calculators	
Themes and Keywords	Frequency	Proportion	Frequency	Proportion
Fun	8	0.67	0	0.00
Interesting / Less Boring	9	0.75	0	0.00
Engaging	6	0.50	0	0.00
Easier	12	1.00	0	0.00
Learning Curve	7	0.58	4	0.33
Cumbersome	3	0.25	9	0.75
Similar performance	4	0.33	4	0.33
Worth the work	6	0.50	0	0.00
Useful	10	0.83	0	0.00
New	9	0.75	0	0.00

n=12 for each theme

boring and it's just about figuring out what x is and using a spreadsheet just wasn't about that kind of boring stuff." Many interviews also converged on a common theme of a challenging *learning curve*, which was always referred to as a positive or neutral challenge rather than indicating it was too difficult to manipulate and learn. In regards to the learning curve one student said, "Even though it was new and hard, it felt like I actually was interested in what we were doing," and another reiterated, "The difficulty was actually kind of fun; it was kind of like doing a 1000 piece jigsaw puzzle, frustrating but with a reward at the end…you know because we got to use it on the test." Table 17 above outlines the frequency of specifically recurring themes and if they were indicated toward a certain treatment. It should be noted that *similar performance* is noted as four for both categories. This is to indicate that 4 students specifically had a conversation that lead to them realizing that neither method got them a better score on a test. All four of these students did say they felt the spreadsheet was *easier* to use, meaning more efficient, but produced the same results for them.

The three students that continuously commented out loud about hating spreadsheets turned out to be students that preferred spreadsheets over calculators. However, it is interesting to note that they never at any point indicated during the unit to hate calculators. It seems that the negative comments were driven from the spreadsheets containing a steep *learning curve*, and the three students felt the construction of formulas in a cell were extremely *cumbersome* with one saying “making the spreadsheet was awful and complicated putting formulas into the boxes, but it was definitely better than trying to remember what buttons to push on the calculator once the spreadsheet was all set up.” Their demeanor changed when they indicated that their dislike for spreadsheets was primarily because spreadsheets were just something *new* and foreign to them in a high school classroom, and that the spreadsheets were *worth the work* in the end because the spreadsheet was *easier* to use than a calculator once it was set up. Two of these students had nearly the same quote, but to quote only one, “I hated making the spreadsheet; it would be better if it was just given to us already set up so we could just use it.” After all was said, they all three indicated that they preferred the spreadsheet over a handheld calculator, but would like it more if a spreadsheet was already set up and shared with them directly for use. This could indicate that they might also be satisfied using a popular statistics program that’s already set up like SPSS, JMP, MiniTab, (etc.). Additionally, it should be noted that all three of these students were female, which will be mentioned later for a possible area of future research.

The most notable combination of themes was those found in the positive. Every student interviewed unanimously mentioned at least one of the three positive, common themes *fun*, *interesting* or *engaging*. This indicates that the overall experience of using spreadsheets could be described as more enjoyable over traditional calculator use in the classroom. Other overlapping themes that stood out were those relating to that of a *learning curve*. The learning curve theme was usually a positive leaning, neutral comment. Students were not indicating that a *learning curve* existed that they genuinely enjoyed or disliked, just that there was a general *learning curve* to spreadsheets since they were a new experience for nearly all students. Half the students interviewed described the activity as *fun* and also attached the theme of a *learning curve* to their discussion with the researcher. So while there was a steep and challenging *learning curve*,

Table 18
Semi Structured Interview Overlaps

Themes or Keywords	Frequency	Proportion
Fun and Learning Curve	6	0.50
Fun, Interesting, or Engaging	12	1.00
Fun given Learning Curve	6	0.86 *
Useful given Learning Curve	5	0.71 *
Worth the Work given Learning Curve	5	0.71 *
Worth the Work given Cumbersome	2	0.67 **
Useful given Cumbersome	3	1.00 **

** n = 7, ** n = 3 otherwise n = 12*

students generally still found the experience enjoyable. To look a little closer at the group of students that described spreadsheets as having a learning curve, Table 18 pulls these students out as a subgroup. Of those that used a *learning curve* to describe spreadsheets, a vast majority (86%) also described spreadsheets as *fun*. Slightly smaller, given that a student described spreadsheets as having a *learning curve*, a large majority (71%) described spreadsheets as being *worth the work* and/or *useful*. It is noteworthy that students reported using spreadsheets as a *challenging learning experience* coupled with words like *fun*, *interesting*, *engaging*, *useful*, and *worth the extra work* it takes to create statistical tools.

The last quality to come out of the interviews not outlined in any table was related to the counterbalance design. All students interviewed that started with calculators and later switched to spreadsheets (n = 5) indicated that using calculators first really made spreadsheets stand out as the preferred technology for this unit. Being able to go through the process first with a calculator gave them an accurate comparison to showcase how *boring* and *less efficient* the traditional method of learning mathematics and statistics can be. One student from the spreadsheet/calculator group worded it as though they may have "[taken] spreadsheet(s) for granted" not having experienced how much more *cumbersome* calculators can be when performing statistical calculations.

CHAPTER 5: DISCUSSION

Conclusions

Using spreadsheets as mind tools appears to have had an impact on reducing student's mathematics anxiety in this study (Clayton & Sankar, 2009; Jonassen et al., 1998). This was the goal of the study based on the hypothesis and research questions. Also, incorporating real world examples and having students complete an open ended, written assignment along with using a spreadsheet to organize and analyze their own data also had an impact on the student's attitudes and anxiety towards mathematics (Flegg et al., 2012; Gainsburg, 2008; Jonassen, 2010; Jonassen et al., 1998; Yardi & Bruckman, 2007). Unexpectedly, the group that started with a calculator and ended with a spreadsheet made the largest gains in performance, although it was not significant, and their perceptions were significantly impacted with the measured anxiety scales (Clayton & Sankar, 2009). Without considering order, the treatments were significantly different when measuring performance. The counter balance design helped to reveal this when the students were required to switch roles (Allen, 2017), and students reported that it allowed them to appreciate the spreadsheets even more having had to first go through the *boring* traditional method with a calculator. This allowed the students in the calculator group to have a fair comparison first before using the spreadsheets, where the spreadsheet group may have "[taken] the spreadsheet(s) for granted" not knowing that the calculator usage to complete the same task was a bit more *cumbersome*. The students also indicated that setting up the spreadsheet presented a *difficult learning curve* but was well *worth the work* in the end.

In context, this could be a possible solution for educators of students who exhibit signs of mathematics anxiety. Since students indicated the learning curve was worth working for, other students may find that using spreadsheets in other courses to be a means to relieve anxiety. Anxiety was noted in several areas of the current body of research as a barrier to student learning, performance, and perceptions (Barkatsas et al., 2009; Cheung & Slavin, 2013; Foley et al., 2017; Haciomeroglu, 2017; Hembree, 1990; Kulik & Kulik, 1991; Li & Ma, 2010; Meece et al., 1990; Pierce et al., 2007; Sherman & Wither, 2003; Slavin et al., 2009; Soni & Kumari, 2017; Yadav et al., 2016; Zakaria et al., 2012), and this study demonstrated the ability to lower that anxiety in this population of students. With the lowered anxiety, it is possible students could be encouraged to explore more mathematics fields in secondary or higher education settings (Foley et al., 2017; Haciomeroglu, 2017; Hembree, 1990; Vigdor, 2013). Any recommendations in this research are not generalizations about all students, as the sample sizes are quite small. However, plenty of room for future research can be listed.

Implications

Having found success in a general high school statistics course with low achieving seniors, these results might suggest that other statistics courses in the local community could benefit from incorporating computing or spreadsheets into the curriculum. The school system where this study was conducted has five high schools including this one. The other four use graphing calculators or scientific calculators for this course to fulfill the state technology standards. The district has two schools with very similar demographics to the one used in this study, so this method and treatment would match those two very closely, while the remaining two schools belong to communities with a more diverse population. So using a method like this could differ from school to school with the different demographics. This should be explored further in the different settings.

On a larger and more broad scale, College Board could adopt a more relevant technology for Advanced Placement Statistics courses in high schools such as statistical software or spreadsheets rather than having handheld calculators as the standard as relevant technology has many benefits towards achievement (Cheung & Slavin, 2013; Li & Ma, 2010; Slavin et al., 2009). The topics covered in this study are topics that are covered in AP Statistics courses. At a minimum, College Board could recommend different statistical computing methods for teachers to introduce or even embed computing in the curriculum.

Suggestions for Further Research

This research was limited to a single group of students that fit a limited description. Performing repeated measures on groups of students that fit different demographics would be an important place to explore future research. While this was typically an affluent population for this study, economically disadvantaged students and student populations with greater diversity could reveal different results. This classroom had only three students with special education needs, and populations with a larger number of students with learning disabilities, or even students diagnosed with mathematics anxiety could also have this treatment applied to see if similar changes could be found with students that have an even greater need for anxiety relief. On the other end of the spectrum, students that excel in mathematics or statistics or students that are taking an advanced placement statistics course in high school should also be measured to see if students that appear to have no anxiety might improve in other areas of the study. A few areas that could be explored for this type of learner could be to improve performance or to even see if students who use computing in the classroom are encouraged more to pursue STEM fields.

Spreadsheets do not have to be limited to just statistics courses, although it seems to be a very fitting place to explore the use of spreadsheets. Spreadsheets can be used in algebra courses for solving equations, writing formulas to simplify calculations, or to show equivalence in expressions. Other courses should be explored to see if replacing calculators as the primary technology tool could reduce anxiety rather than waiting for a senior level course to introduce any computing tools. This could potentially encourage younger students to explore computing classes offered at their school prior to entering higher education institutions.

Mentioned in the results section, three females specifically were noted as *hating* spreadsheets and expressed disdain for the process of setting up a spreadsheet. Gender was not explored in any specific measurement as it was not part of the initial hypothesis. However, gender could be a major lurking variable if measured in a separate study using the same anxiety scales or perhaps by using some of the other scales in the Attitudes Toward Mathematics Inventory. The ATMI does have measurements and inventory items directly related to gender.

An additional limitation of this study is that it only explored student's anxiety measurements and performance for a single unit of statistics. A longer study that explores a semester long or yearlong course in statistics could further support these existing findings or show even stronger changes in anxiety and perceptions. A longitudinal study that follows a cohort of students through high school using a computing tool like spreadsheets could also generate data for longer exposure of this treatment.

While many of the significant differences in this study had p-values extremely small and the results were all one-tail tests, the best way to increase power in this study would be to find larger groups of students to measure. Further decreasing the standard error of the mean would really make these results more admirable. Limiting the groups to being just over thirty students in each group was acceptable, but larger groups always yield more powerful results when testing significance.

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APPENDICES

Appendix A – Attitudes Toward Mathematics Inventory

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Darken the circle that most closely corresponds to how the statements best describes your feelings. Use the following response scale to respond to each item.

PLEASE USE THESE RESPONSE CODES:

A – Strongly Disagree
B – Disagree
C – Neutral
D – Agree
E – Strongly Agree

1. Mathematics is a very worthwhile and necessary subject.
2. I want to develop my mathematical skills.
3. I get a great deal of satisfaction out of solving a mathematics problem.
4. Mathematics helps develop the mind and teaches a person to think.
5. Mathematics is important in everyday life.
6. Mathematics is one of the most important subjects for people to study.
7. High school math courses would be very helpful no matter what I decide to study.
8. I can think of many ways that I use math outside of school.
9. Mathematics is one of my most dreaded subjects.
10. My mind goes blank and I am unable to think clearly when working with mathematics.
11. Studying mathematics makes me feel nervous.
12. Mathematics makes me feel uncomfortable.
13. I am always under a terrible strain in a math class.
14. When I hear the word mathematics, I have a feeling of dislike.
15. It makes me nervous to even think about having to do a mathematics problem.
16. Mathematics does not scare me at all.
17. I have a lot of self-confidence when it comes to mathematics
18. I am able to solve mathematics problems without too much difficulty.
19. I expect to do fairly well in any math class I take.
20. I am always confused in my mathematics class.
21. I feel a sense of insecurity when attempting mathematics.
22. I learn mathematics easily.
23. I am confident that I could learn advanced mathematics.
24. I have usually enjoyed studying mathematics in school.
25. Mathematics is dull and boring.
26. I like to solve new problems in mathematics.
27. I would prefer to do an assignment in math than to write an essay.
28. I would like to avoid using mathematics in college.
29. I really like mathematics.
30. I am happier in a math class than in any other class.
31. Mathematics is a very interesting subject.
32. I am willing to take more than the required amount of mathematics.
33. I plan to take as much mathematics as I can during my education.
34. The challenge of math appeals to me.
35. I think studying advanced mathematics is useful.
36. I believe studying math helps me with problem solving in other areas.
37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.
38. I am comfortable answering questions in math class.
39. A strong math background could help me in my professional life.
40. I believe I am good at solving math problems.

Appendix B – Computer Science Attitude Survey

Directions

Enter your student ID number onto the answer sheet. Please note that your answers will be kept confidential.

On the following pages are a series of statements.

1. Read each statement.
2. Think of the extent to which you agree or disagree with each statement
3. Mark your response on the answer sheet

Please remember:

- There are no right or wrong answers. Don't be afraid to put down what you really think.
- Don't spend a lot of time on any one item. Move quickly!
- Complete all of the items.

Respond to the following questions on the answer sheet, using the following scale:

a) strongly agree
b) agree, but with reservations
c) neutral, neither agree nor disagree
d) disagree, but with reservations
e) strongly disagree

Appendix C – Computer Science Attitude Survey

1. I plan to major in computer science.
2. Generally I have felt secure about attempting computer programming problems.
3. I am sure I could do advanced work in computer science.
4. I am sure that I can learn programming.
5. I think I could handle more difficult programming problems.
6. I can get good grades in computer science.
7. I have a lot of self-confidence when it comes to programming.
8. I'm no good at programming.
9. I don't think I could do advanced computer science.
10. I'm not the type to do well in computer programming.
11. For some reason even though I work hard at it, programming seems unusually hard for me.
12. Most subjects I can handle O.K., but I have a knack for flubbing up programming problems.
13. Computer science has been my worst subject.
14. It would make me happy to be recognized as an excellent student in computer science.
15. I'd be proud to be the outstanding student in computer science.
16. I'd be happy to get top grades in computer science.
17. It would be really great to win a prize in computer science.
18. Being first in a programming competition would make me pleased.
19. Being regarded as smart in computer science would be a great thing.
20. Winning a prize in computer science would make me feel unpleasantly conspicuous.
21. People would think I was some kind of a nerd if I got A's in computer science.
22. If I had good grades in computer science, I would try to hide it.
23. If I got the highest grade in computer science I'd prefer no one knew.
24. It would make people like me less if I were a really good computer science student.
25. I don't like people to think I'm smart in computer science.
26. Females are as good as males at programming.
27. Studying computer science is just as appropriate for women as for men.
28. I would trust a woman just as much as I would trust a man to figure out important programming problems.
29. Women certainly are logical enough to do well in computer science.
30. It's hard to believe a female could be a genius in computer science.
31. It makes sense that there are more men than women in computer science.

Appendix C – Computer Science Attitude Survey (cont)

32. I would have more faith in the answer for a programming problem solved by a man than a woman.
33. Women who enjoy studying computer science are a bit peculiar.
34. I'll need programming for my future work.
35. I study programming because I know how useful it is.
36. Knowing programming will help me earn a living.
37. Computer science is a worthwhile and necessary subject.
38. I'll need a firm mastery of programming for my future work.
39. I will use programming in many ways throughout my life.
40. Programming is of no relevance to my life.
41. Programming will not be important to me in my life's work.
42. I see computer science as a subject I will rarely use in my daily life.
43. Taking computer science courses is a waste of time.
44. In terms of my adult life it is not important for me to do well in computer science in college.
45. I expect to have little use for programming when I get out of school.
46. I like writing computer programs.
47. Programming is enjoyable and stimulating to me.
48. When a programming problem arises that I can't immediately solve, I stick with it until I have the solution.
49. Once I start trying to work on a program, I find it hard to stop.
50. When a question is left unanswered in computer science class, I continue to think about it afterward.
51. I am challenged by programming problems I can't understand immediately.
52. Figuring out programming problems does not appeal to me.
53. The challenge of programming problems does not appeal to me.
54. Programming boring.
55. I don't understand how some people can spend so such time on writing programs and seem to enjoy it.
56. I would rather have someone give me the solution to a difficult programming problem than to have to work it out for myself.
57. I do as little work in computer science courses as possible.

Appendix D – Hand Calculated Values

A0208 **Name** ____

Metabolism, I A person's metabolic rate is the rate at which the body consumes energy. Metabolic rate is important in studies of weight gain, dieting, and exercise. Here are the metabolic rates of seven men who took part in a study of dieting. (The units are calories per 24 hours. These are the same calories used to describe the energy content of foods.)

1792 1666 1362 1614 1460 1867 1439

(a) Use the formula to $\bar{x} = \frac{\sum x}{n}$ calculate the mean, showing work.

$\bar{x} = \frac{\qquad}{\qquad} = \boxed{\qquad}$

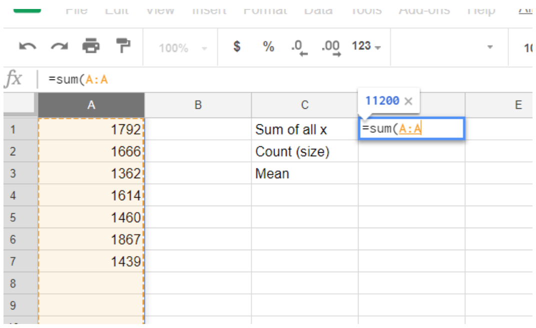
(b) Interpret this value in context.

Metabolism, II Refer to the previous exercise.

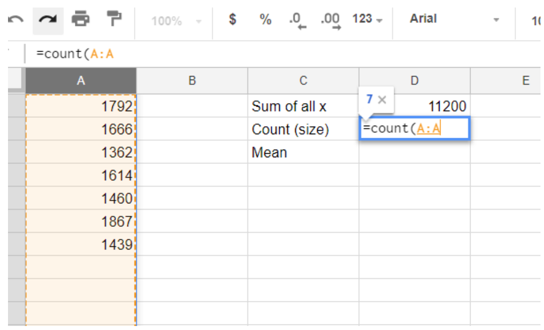
(a) Calculate the deviation of each observation from the mean. Calculate the sum of the deviations.		(b) Calculate the standard deviation. Show your work.	
Value x	Deviation $(x-\bar{x})$	Squared Deviation $(x-\bar{x})^2$	Standard Deviation s
1792			$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} =$
1666			$s = \sqrt{\frac{\qquad}{\qquad}}$
1362			
1614			$= \sqrt{\qquad}$
1460			
1867			$= \boxed{\qquad}$
1439			
Sums	$\sum(x-\bar{x}) =$	$\sum(x-\bar{x})^2 =$	

Appendix E – Spread Sheet Introduction

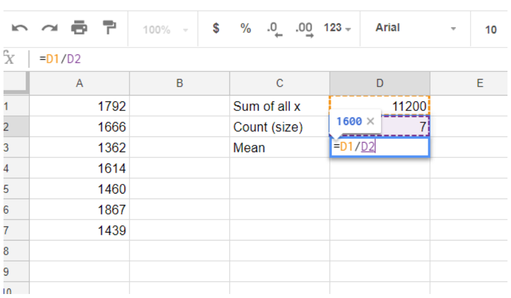
Mean Step 1



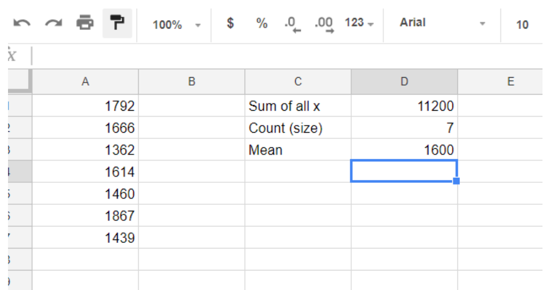
Mean Step 2



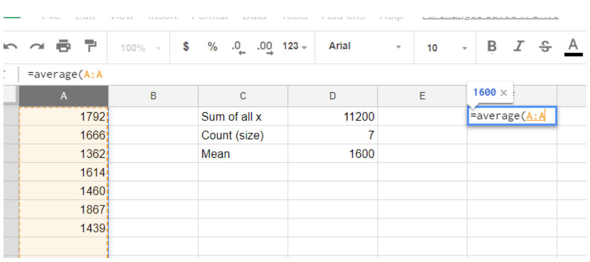
Mean Step 3



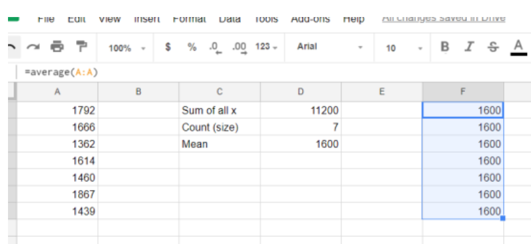
Mean Step 4



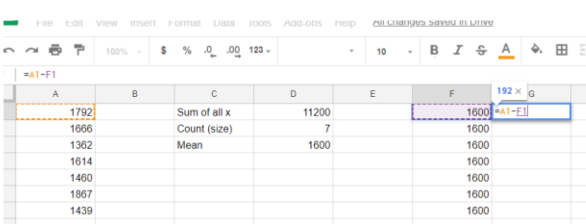
Standard Deviation Step 1



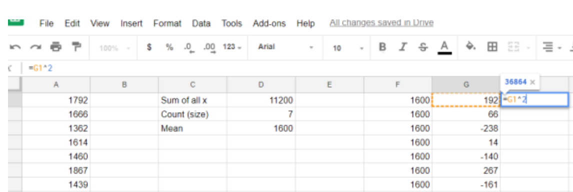
Standard Deviation Step 2



Standard Deviation Step 3



Standard Deviation Step 4



Appendix F – Student Sample of Work (first page only)

Description

This observational study is to look at if height affects how much a high school basketball player can score. The reason for this specifically is to see if being taller can help a highschool player score more than if they were shorter. The hypothesis is that the taller the player is, the more they will score.

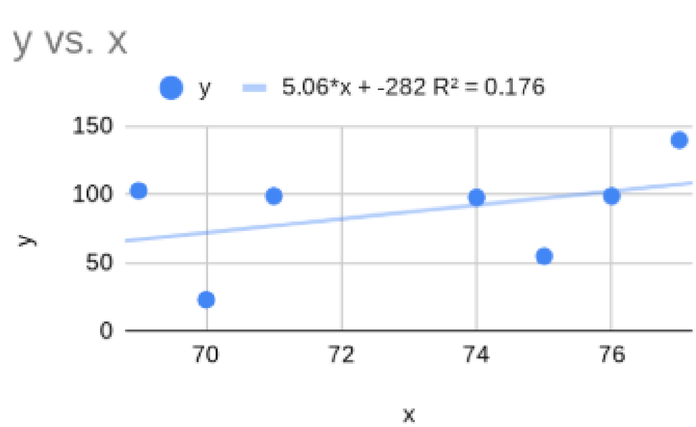
Data

Data was collected from MaxPreps stats for McIntosh Highschool. The two variables to be collected are the players heights in inches and the amount of points scored in the 10 games they have played.

Height(inches)	Points scored
74	98
69	103
75	55
76	99
77	140
71	99
70	23

Results

The table below displays a scatter plot of all of the data where the X-axis(independent) is the height of the players in inches and the Y-axis(dependent).



Appendix G – Rubric to measure each standard for student assignments (Erhardt, 2016)

Rating	Description
Excellent	• Exemplary solution which demonstrates full comprehension of the skill. • The strategy follows directly from theoretical results. • No errors. • Student has clearly interpreted solution in highly articulate Statistical and English language.
Very Good	• Cogent solution which demonstrates good comprehension of the skill. • The strategy was apparent and effective. • Errors are insignificant. • Student has interpreted solution in understandable Statistical and English language.
Satisfactory	• Understandable solution which demonstrates reasonable comprehension of the skill. • The strategy was recognizable and mostly effective. • Errors are minor. • Student has interpreted solution in decipherable Statistical and English language.
Questionable	• Incomplete solution which demonstrates partial comprehension of the skill. • The strategy was potential effective. • Errors are significant. • Student has interpreted solution incompletely or misused in Statistical and English language.
Unacceptable	• Poor solution which demonstrates little to no comprehension of the skill. • The strategy was unclear or ineffective. • Errors are striking. • Student has misinterpreted solution completely or used unclear Statistical and English language.

Appendix H – Standards chosen to measure transfer and student performance of assignments

MSRCD1. Students will distinguish between a population distribution, a sample data distribution, and a sampling distribution.

a. Students will identify the three types of distributions.

i. Recognize a population distribution has fixed values of its parameters that are usually unknown.

ii. Recognize a sample data distribution is taken from a population distribution and the data distribution is what is seen in practice hoping it approximates the population distribution.

iii. Recognize a sampling distribution is the distribution of a sample statistic (such as a sample mean or a sample proportion) obtained from repeated samples. The sampling distribution provides the key for determining how close to expect a sample statistic approximates the population parameter.

b. Students will create sample data distributions and a sampling distribution.

ii. Create a sampling distribution of a statistic by taking repeated samples from a population (either hands-on or by simulation with technology).

MSRCD3. Students will distinguish between the three types of study designs for collecting data (sample survey, experiment, and observational study) and will know the scope of the interpretation for each design type. Students will be able to distinguish between the three types of study designs for collecting data (sample survey, experiment, and observational study) and know the scope of the interpretation for each design type.

MSRCD4. Students will distinguish between the role of randomness and the role of sample size. Students will be able to distinguish the roles of randomization and sample size with designing studies with respect to using a statistic from a sample to estimate a population parameter.

c. Recognize that sample size impacts the precision with which estimates of the population parameters can be made (larger the sample size the more precision).

MSRIR1. Students will ask if the difference between two sample proportions or two sample means is due to random variation or if the difference is significant. Students will be able to determine if there are differences between two population parameters or treatment effects.

a. Using simulation, determine the appropriate model to decide if there is a difference between two population parameters.

b. Using simulation, determine the appropriate model to decide if there is a difference between two treatment effects.

Appendix I Additional Tables for Survey Analysis

Table 1

Mathematics Anxiety Scales, Calculator/Spreadsheet Group, Survey 1 vs. 2

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	41	0.20	0.71	1.748	0.044
I get uptight during math tests	41	0.07	0.93	0.502	0.309
I think I will use math in the future	41	0.17	1.12	0.980	0.167
Mind goes blank and am unable to think clearly when doing my math test.	41	0.00	0.95	0.000	0.500
Math relates to my life.	41	0.20	1.14	1.091	0.141
I worry about my ability to solve math problems.	41	0.00	1.12	0.000	0.500
I get a sinking feeling when I try to do math problems.	41	-0.20	1.03	-1.213	0.116
I find math challenging.	41	0.02	0.91	0.172	0.432
Mathematics makes me feel nervous.	41	-0.12	1.05	-0.741	0.231
I would like to take more math classes.	41	0.10	1.00	0.628	0.267
Mathematics makes me feel uneasy.	41	-0.12	0.90	-0.868	0.195
Math is one of my favorite subjects.	41	0.07	0.88	0.534	0.298
I enjoy learning mathematics.	41	0.24	1.36	1.152	0.128
Mathematics makes me feel confused.	41	-0.15	0.96	-0.973	0.168

Table 2

Mathematics Anxiety Scales, Calculator/Spreadsheet Group, Survey 1 vs. 3

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	41	1.07	0.75	9.106	0.000
I get uptight during math tests	41	-0.46	0.67	-4.400	0.000
I think I will use math in the future	41	1.00	1.02	6.249	0.000
Mind goes blank and am unable to think clearly when doing my math test.	41	-0.29	1.03	-1.818	0.038
Math relates to my life.	41	0.88	0.98	5.739	0.000
I worry about my ability to solve math problems.	41	-0.49	1.12	-2.787	0.004
I get a sinking feeling when I try to do math problems.	41	-0.15	0.48	-1.962	0.028
I find math challenging.	41	-0.39	0.92	-2.720	0.005
Mathematics makes me feel nervous.	41	-0.54	0.78	-4.418	0.000
I would like to take more math classes.	41	0.78	1.11	4.514	0.000
Mathematics makes me feel uneasy.	41	-0.24	0.73	-2.127	0.020
Math is one of my favorite subjects.	41	0.39	0.95	2.643	0.006
I enjoy learning mathematics.	41	1.95	1.26	9.885	0.000
Mathematics makes me feel confused.	41	-0.12	1.19	-0.658	0.257

Appendix I Additional Tables for Survey Analysis (cont)

Table 3

Mathematics Anxiety Scales, Calculator/Spreadsheet Group, Survey 2 vs. 3

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	41	1.00	0.89	7.159	0.000
I get uptight during math tests	41	-0.34	0.85	-2.558	0.007
I think I will use math in the future	41	1.07	1.10	6.223	0.000
Mind goes blank and am unable to think clearly when doing my math test.	41	-0.39	1.00	-2.506	0.008
Math relates to my life.	41	0.83	1.07	4.962	0.000
I worry about my ability to solve math problems.	41	-0.32	1.44	-1.410	0.083
I get a sinking feeling when I try to do math problems.	41	0.07	0.61	0.771	0.223
I find math challenging.	41	-0.22	0.94	-1.502	0.070
Mathematics makes me feel nervous.	41	-0.39	0.92	-2.720	0.005
I would like to take more math classes.	41	0.71	1.10	4.114	0.000
Mathematics makes me feel uneasy.	41	-0.12	0.81	-0.961	0.171
Math is one of my favorite subjects.	41	0.24	0.66	2.357	0.012
I enjoy learning mathematics.	41	1.78	1.52	7.476	0.000
Mathematics makes me feel confused.	41	-0.27	0.95	-1.810	0.039

Table 4

Mathematics Anxiety Scales, Spreadsheet/Calculator Group, Survey 1 vs. 2

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	34	0.35	0.81	2.534	0.008
I get uptight during math tests	34	-0.21	1.15	-1.045	0.152
I think I will use math in the future	34	0.18	1.24	0.828	0.207
Mind goes blank and am unable to think clearly when doing my math test.	34	-0.35	1.18	-1.748	0.045
Math relates to my life.	34	0.41	1.26	1.908	0.033
I worry about my ability to solve math problems.	34	-0.44	1.26	-2.042	0.025
I get a sinking feeling when I try to do math problems.	34	-0.29	1.34	-1.282	0.104
I find math challenging.	34	-0.24	1.21	-1.136	0.132
Mathematics makes me feel nervous.	34	-0.26	1.33	-1.158	0.128
I would like to take more math classes.	34	0.29	1.12	1.537	0.067
Mathematics makes me feel uneasy.	34	-0.18	1.31	-0.783	0.220
Math is one of my favorite subjects.	34	0.24	0.99	1.391	0.087
I enjoy learning mathematics.	34	0.62	1.58	2.284	0.014
Mathematics makes me feel confused.	34	-0.65	1.23	-3.072	0.002

Appendix I Additional Tables for Survey Analysis (cont)

Table 5

Mathematics Anxiety Scales, Spreadsheet/Calculator Group, Survey 1 vs. 3

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	34	-0.06	0.78	-0.442	0.331
I get uptight during math tests	34	0.00	0.95	0.000	0.500
I think I will use math in the future	34	0.09	1.08	0.475	0.319
Mind goes blank and am unable to think clearly when doing my math test.	34	0.03	1.11	0.154	0.439
Math relates to my life.	34	-0.06	0.95	-0.360	0.360
I worry about my ability to solve math problems.	34	0.03	1.22	0.141	0.444
I get a sinking feeling when I try to do math problems.	34	-0.03	1.11	-0.154	0.439
I find math challenging.	34	0.09	0.97	0.533	0.299
Mathematics makes me feel nervous.	34	-0.21	1.12	-1.070	0.146
I would like to take more math classes.	34	0.03	1.14	0.150	0.441
Mathematics makes me feel uneasy.	34	-0.03	1.11	-0.154	0.439
Math is one of my favorite subjects.	34	-0.06	0.92	-0.373	0.356
I enjoy learning mathematics.	34	-0.03	1.09	-0.158	0.438
Mathematics makes me feel confused.	34	-0.12	1.07	-0.643	0.262

Table 6

Mathematics Anxiety Scales, Spreadsheet/Calculator Group, Survey 2 vs. 3

Item	*N*	*M*	*SD*	*t*	*p*
I find mathematics interesting.	34	-0.41	0.99	-2.429	0.010
I get uptight during math tests	34	0.03	0.94	0.183	0.428
I think I will use math in the future	34	-0.09	1.46	-0.351	0.364
Mind goes blank and am unable to think clearly when doing my math test.	34	0.15	0.78	1.094	0.141
Math relates to my life.	34	-0.41	0.74	-3.230	0.001
I worry about my ability to solve math problems.	34	0.35	1.07	1.924	0.032
I get a sinking feeling when I try to do math problems.	34	0.32	1.04	1.820	0.039
I find math challenging.	34	0.09	0.71	0.722	0.238
Mathematics makes me feel nervous.	34	0.12	0.84	0.812	0.211
I would like to take more math classes.	34	-0.09	0.71	-0.722	0.238
Mathematics makes me feel uneasy.	34	0.15	0.86	1.000	0.162
Math is one of my favorite subjects.	34	-0.06	0.49	-0.702	0.244
I enjoy learning mathematics.	34	-0.71	1.55	-2.659	0.006
Mathematics makes me feel confused.	34	0.29	0.84	2.052	0.024

Appendix J Sample Formative Questions

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

Find the value of the linear correlation coefficient r.

1)

x	26.7	22.6	27.2	47.7	10.2
y	8	7	2	3	4

A) −0.222
B) −.223
C) 0.25
D) −0.25
E) I don't know

1) ______

2)

x	57	53	59	61	53	56	60
y	156	164	163	177	159	175	151

A) 0.109
B) −0.078
C) −0.054
D) 0.214
E) I don't know

2) ______

Use the given data to find the equation of the regression line. Round the final values to three significant digits, if necessary.

3)

x	2	4	5	6
y	7	11	13	20

A) $\hat{y} = 3.0x$
B) $\hat{y} = 0.15 + 2.8x$
C) $\hat{y} = 0.15 + 3.0x$
D) $\hat{y} = 2.8x$
E) I don't know

3) ______

4)

x	0	3	4	5	12
y	8	2	6	9	12

A) $\hat{y} = 4.98 + 0.725x$
B) $\hat{y} = 4.88 + 0.625x$
C) $\hat{y} = 4.98 + 0.425x$
D) $\hat{y} = 4.88 + 0.525x$
E) I don't know

4) ______

Find a quadratic function that best fits the data. Give answers to the nearest hundredth.

5)

x	−2	5	8
y	5	7	14

A) $y = 0.21 - 1.28x + 6.44$
B) $y = -0.13x^2 - 0.67x + 6.86$
C) $y = 0.20x^2 - 0.33x + 3.52$
D) $y = 0.20x^2 + 0.33x + 3.52$
E) I don't know

5) ______

Appendix K Sample of Interview Coding (First page only)

1. Describe and compare your experience with using spreadsheets and calculators learning statistics during this unit.
2. Describe details that might have made one stand out to you over the other.
3. Did it make you enjoy learning this subject more than previous courses? If so, Why?

Answer: Using spreadsheets made everything simpler. It was like, easier to use once we got it set up. I didn't have to remember what buttons to push or what menu to use. Sometimes I got lost in the calculator for a minute, and it would take a minute to remember how to find the r value or something. Ya know?

question: yeah, so was it just that it made it easier that made the spreadsheet your preference?

answer: no, it was fresh. Like, we've done basically the same thing in every other math class. We get a handout, take notes, do homework, repeat. Quiz on Friday, test on Tuesday, whatever. And we have done a little bit in calculator menus before, but the spreadsheet was just really a new thing that we've never done before. I bet if I had taken the other math class (precalculus?) then I would just be taking notes, doing homework, and quiz on Friday like usual.

question: how did you handle the set up process of the spreadsheet? Positive or negative experience? What do you think?

answer: well you made it easy, stopping when we were lost. I don't know that I could do it on my own since you seem to know a lot of commands that we clearly don't know.

question: how could you overcome that?

answer: oh yeah, you showed us the help menu. I guess we could Google a lot of the stuff, right? I imaging spreadsheets are popular. You said they were old. Maybe I could figure it out. I don't' know that I would want to though, I'd rather just you tell us how to do it.

question: easy way out is always the most satisfying, no?!

answer: absolutely!

Question: what would you do different if you were me?

answer: More of this. Like, could we have used these when we did, umm… last semester we did a lot of calculations with those tables, and uhh…

question: probability?

answer: yes. would that have worked?

question: yes