Experiential Statistics: A Case Study in Favor of Using Project-Based Learning to Advance Preliminary Statistics Content Knowledge in the Algebra I and Geometry Classroom

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EXPERIENTIAL STATISTICS: A CASE STUDY IN FAVOR OF USING PROJECT-BASED LEARNING TO ADVANCE PRELIMINARY STATISTICS CONTENT KNOWLEDGE IN THE ALGEBRA I AND GEOMETRY CLASSROOM

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The School of Education

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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................... ii

LIST OF TABLES ..................................................................................................................... v

LIST OF FIGURES .................................................................................................................. vi

ABSTRACT .............................................................................................................................. viii

INTRODUCTION ...................................................................................................................... 1

REVIEW OF THE LITERATURE ............................................................................................ 6
  Interest and General Attitudes Towards Statistics ................................................................. 6
  Theoretical Frameworks ......................................................................................................... 8
  Statistical Literacy ................................................................................................................ 10
  Professional Development .................................................................................................... 13
  National Standards and Benchmarks .................................................................................... 14
  Statistics Education Across the Curriculum and Across Educational Levels .................... 16
  Project-Based Learning (General and in Statistics Education) ............................................ 18
  Collaboration Setup ............................................................................................................. 26
  Technology Use for Statistical Analysis in the Mathematics Classroom ......................... 27
  Gaps in the Literature and Research Questions ................................................................... 33

METHODS ................................................................................................................................ 36
  General Structure of the Study and Random Assignment .................................................... 38
  Topics of Study by Course ..................................................................................................... 41
  Protocol for Randomization of Student Groups for Project-Based Assessments ............ 43
  Experimental Design Used for Student Achievement Portion ........................................... 45
  Final Statement Regarding Testing Controls ......................................................................... 49
  Final Study Hypotheses for Achievement Portion ............................................................... 50
  Statistical Analyses Used for the Student Achievement Portion ......................................... 51
  General Structure for Attitudinal Portion of the Research Study .................................... 51
  Statistical Analyses Used for the Student Attitudinal Portion ............................................ 55
  Teacher Interview Protocol .................................................................................................. 58

RESULTS AND DISCUSSION .................................................................................................. 59
  Achievement Portion Results and Discussion for Algebra I Course ................................... 59
  Achievement Portion Results for Geometry Course ............................................................. 63
  Attitudinal Portion Results ................................................................................................. 66
  Participant Frequencies by Demographic/Class Variable .................................................... 67
  Internal Consistency and Reliability Analysis ....................................................................... 70
  Paired t Test Analysis on Mean Item Response Change for Each Facet ................................ 71
  Paired t Test Analysis on Changes in Item Responses Within Facet .................................... 72
LIST OF TABLES

1. Topics used in the Algebra I and Geometry Course Statistics Unit………………………….41

2. Project Requirements for Project-Based Assessments………………………………………44

3. Student Randomized Numbers for Project-Based Assessment Groups…………………….45

4. Hypotheses for the Achievement Analyses of the Research Study…………………………50

5. Table of Frequencies for the Class Variable – GPA………………………………………68

6. Table of Frequencies for the Class Variable – Math Course………………………………68

7. Table of Frequencies for the Class Variable – Expected Math Grade……………………68

8. Table of Frequencies for the Demographic – School Classification……………………..69

9. Table of Frequencies for the Demographic – Race/Ethnicity…………………………….69

10. Table of Frequencies for the Demographic – Gender……………………………………..69

11. Table of Frequencies for the Class Variable – Treatment Method………………………69

12. Cronbach’s Alpha Internal Consistency/Reliability Analysis Results……………………71
LIST OF FIGURES

1. Descriptive Statistics for Algebra I Student Achievement Portion……………………….60
2. Algebra I Student Achievement Output…………………………………………………….60
3. Distribution, Boxplots and Normal Quantile Plots for Algebra I Exam Score Differences by Treatment……………………………………………………………………………….62
4. Descriptive Statistics for Geometry Student Achievement Portion……………………..63
5. Geometry Student Achievement Output…………………………………………………….64
6. Distribution, Boxplots and Normal Quantile Plots for Geometry Exam Score Differences by Treatment……………………………………………………………………………….65
7. Paired t Testing on Means of Item Differences in Survey Results by Facet...............72
8. Paired t Test Results for Work Ethic Facet on Changes in Response…………………73
9. Paired t Test Results for General Attitude Facet on Changes in Response……………73
10. Paired t Test Results for General Opinion Facet on Changes in Response…………..73
11. Q-Q Plots for Multivariate Normality Distribution Assumption in MANOVA……..75
12. MANOVA Results on Mean Changes in Response per Item Within Facets………77
13. Mean Significant Difference in Response Change for Method by Facet……………..78
14. MANOVA on Differences in Response for Each Item within the Work Ethic Facet……79
15. Between-Subject Item Effects for Differences in Responses Among Items in Work Ethic…80
16. Symmetry Assumption Check of Work Ethic for Wilcoxon Signed Rank Test………..82
17. Significant Items in Work Ethic from Wilcoxon Signed Rank Analysis………………83
18. Symmetry Assumption Check of General Attitude for Wilcoxon Signed Rank Test………84
19. Significant Items in General Attitude from Wilcoxon Signed Rank Analysis…………87
20. Symmetry Assumption Check of General Opinion for Wilcoxon Signed Rank Test……88
21. Significant Items in General Opinion from Wilcoxon Signed Rank Analysis..........................90
ABSTRACT

Preparing secondary students for college entrance requirements and the expectations of the job market, a market which is actively seeking the employees who are most qualified to take on jobs that require data analysis skills, is becoming increasingly important. Federal, state, and local education administrators and personnel must rewrite many of the general education curricula to incorporate data organization, collection, manipulation, application, and analysis in order to better prepare students for the expectations of college entrance and an ever-changing employment market. From a purely pedagogical standpoint, while traditional educational structure has been commonplace for decades in the United States, projects used as assessment tools are a more progressive way to gauge content understanding and course achievement, especially in mathematics. Algebra I and Geometry students at a lone high school were randomly assigned to participating teachers’ classes that were assigned to one of two main treatment groups, one that used projects, the other traditional instruments, as formative assessments, in order to gauge two main goals - the growth in achievement before and after a curricular unit involving statistics and the change in attitudes towards statistics before and after the statistics unit. Using several parametric analyses (paired t testing and MANOVA) and an additional non-parametric statistical analysis on a variety of demographic and class variables and coupled with an interview of participating teachers, the results revealed that projects, from the perspective of both participating students and teachers, often are much more effective in increasing achievement and attitudes towards the science of statistics, especially in the secondary educational years. The results of this study would be useful in rewriting mathematics curriculum to incorporate more focused attention to the science of statistics.
INTRODUCTION

For some time now, the job market in the United States and around the world has been changing. Decades ago, secondary school graduates who sought employment required only a certain set of job skills, many of a clerical nature, in addition to a basic knowledge of reading, writing and arithmetic. In those days, if a secondary school student had additional trade and vocational skills and he or she had no imminent plans to attend a post-secondary institution, the student would be much more marketable than any average secondary school graduate. Nevertheless, these secondary school graduates certainly could find employment after graduation. For example, in 1973, 72% of all U.S. jobs were held by people who had a high school diploma or less, while in 2020, it is expected that nearly two-thirds (65%) of all jobs will require some form of postsecondary education (Foorahar, 2014). The required skill sets for being employed have changed, though. Today, specific skill sets geared towards the ability to analyze big data are of paramount importance, regardless of primary job discipline.

In fall 2016 LinkedIn™ published a list of the ten most important job skills that employers around the globe are actively seeking in current job applicants. All ten positions were closely related to careers that are heavily weighted towards data manipulation, data mining, and statistical analysis. The top three positions in order on the list were cloud and distributed computing, statistical analysis and data mining, and web architecture and development framework, respectively (Smith, 2016).

The curriculum in most state STEM programs do not include standards and benchmarks for data manipulation, mining and analysis. In the 1950’s a course in statistics was rarely taught in the high school classroom, but during this decade the efforts in making statistics a part of the school
curriculum began to take form (Scheaffer and Jacobbe, 2014). Sixty plus years later, state departments of education across the U.S. have begun to embed statistics into the math curriculum, and only recently into the math and science curricula (Scheaffer and Jacobbe, 2014; Ben-Zvi and Garfield, 2008). Usiskin and Hall (2015) published a powerful article that touches on the importance of statistics education across the curriculum, a stance that I, too, echo. Usiskin and Hall detail three main premises in the publication: that statistics applies to all spheres of human activity, that every student should have state-mandated access to the fundamental ideas of statistics, and that, in parallel with the GAISE (Guidelines for Assessment and Instruction in Statistics Education, 2005) report, every high school graduate should be able to understand and apply statistical reasoning as it applies to life after school. Horton and Hardin (2016) provided an expansive review of research literature focused on how well undergraduate students are being prepared for the analytics skills desired by many companies in business and industry. The authors stress the importance of students not only being able to manipulate data, but also being able to answer a statistical question.

The dilemma, then, is how to address this dire need for preparing students, secondary and higher, for the expectations of the job market, a market which is actively seeking the employees who are most qualified to take on jobs that require data analysis skills. The onus, then, falls on federal, state, and local education administrators to rewrite many of the general education curricula to incorporate data organization, collection, manipulation, application, and analysis. On the postsecondary level, this venture cannot be confined to STEM (science, technology, engineering, and mathematics) fields only; nay, it must also include social sciences courses, courses such as psychology, economics, sociology, political science, etc. However, on the secondary level, STEM courses seem to provide the most suitable and relevant curricular frameworks to embed the science
of statistics (Smith, Molinaro, Lee and Guzman-Alvarez, 2014). The National Center for Education Statistics (NCES) published a report in 2013 which showed that in 2009, 11% of high school students graduated with at least one semester of statistics, an increase from 1% in 1990. Furthermore, the NCES study shows that in 1999, approximately 25,000 U.S. high school students took the Advanced Placement (AP) Statistics exam, compared to approximately 170,000 in 2013 (NCES, 2013).

It is clear from these numbers that the value of statistics education on the secondary school level is becoming increasingly important. From a purely teaching standpoint, Cobb (1992) held a conference consisting of thirty-eight other instructors of statistics to develop critical topics for an introductory statistics course that would be useful for the next thirty years. The skills of highest priority decided upon by this panel of statistics experts included

1) critiquing statistics as given by the media and in journals
2) understanding variability (i.e., bias, sampling, systematic, and measurement errors, regression effects, etc.)
3) basic exploratory data (e.g., collecting and summarizing data through writing and explanation of results)
4) basic distributions as approximations to variation in data sets
5) elementary probability (especially Bayes’ Theorem)
6) the Central Limit Theorem and law of averages
7) correlation/regression/association modeling
8) being able to provide graphical representations of data, and in turn, interpret graphical figures.
Topics not included in this conference but of paramount importance are the use of technology in the statistics classroom, certainly not nearly as available for use in the classroom in the 1980’s and 1990’s as it is in the classroom of today, and the use of collaborative group projects. I deem both as vital tools to teach statistics in the secondary classroom, tools that will serve as the primary foci of my research study. Before these important foci can be discussed, an in-depth understanding of precursors must be established.

Until 1997, statistics training had primarily been limited to colleges and universities and employers within the workforce. In 1997, the College Board® proctored its first ever AP Statistics examination. Since that year, the College Board® has seen the number of AP Statistics exams rise significantly. It is quite possible that the reason for this significant growth in students taking the AP Statistics examination is that the College Board® recognizes that the world has moved to a need for more people who can effectively and efficiently analyze data. The AP Statistics courses, however, are relatively traditional in their assessments, despite the natural practicality that data science has in the world. For this reason, there exists a rich opportunity and a clear potential for the use of projects in courses of this type. Given a clear shortage of secondary students relatively ill-prepared to analyze data in jobs after high school, the door is now open to study how projects, as opposed to traditional assessment measures, can be used to advance statistics education, not just in the typical AP Statistics course, but in lower-level math courses. This research study aims to help in this endeavor – to prove that projects during curricular units on statistics of Algebra I and Geometry courses increase achievement and attitudes towards data science. In this research study I will delve into the following: the extent to which project-based assessments enhances student knowledge retention of basic statistics standards, how best to design statistics unit assessments to gauge understanding of statistics content, the pros and cons of using projects vs traditional
assessments in the lower-level secondary mathematics courses, the effects that these assessment types have on student attitudes towards statistics, the extent to which projects maximize learning, and the impact of statistics on students in the future and outside of the classroom. Perhaps upon conclusion of this study more mathematics classrooms will realize the impact that data has in the world and we will better prepare secondary students to meet new expectations in their ability to perform basic analytics skills.
REVIEW OF THE LITERATURE

The precursors that inform a quality statistics education, especially on the secondary school level, are multifold. The precursors that will form the foundation of my research follow in sequential order: interest and general attitudes towards statistics, relevant theoretical frameworks, statistical literacy, professional development, national standards and benchmarks, and statistics across the curriculum. These precursors will be used along with an in-depth discussion of the project-based learning instructional design framework and technology use in statistics curriculum to set up the analyses for this research endeavor.

Interest and General Attitudes Towards Statistics

No matter if the statistics course is on the secondary or post-secondary level, it is vital that instruction of statistical content be developed to increase overall interest in statistics. For example, at the highest levels of statistics education in the high school classroom, specifically the AP Statistics classroom, exposure to statistics in any format increased interest in statistics and the chance of being admitted to a college or university (Patterson, 2009). Still, there is an inherent negative attitude towards the science of statistics. On the secondary school level, this is likely due to a lack of prior exposure to standard statistics content.

It should come as no surprise that this typical negative attitude towards statistics is a feeling that has been prevalent over several decades of statistics education. In a survey of 672 students enrolled in general education statistics courses at three Mexican universities, attitudes towards the statistics course and attitudes towards the field of statistics significantly differed (Garcia-Santillan, Escalera-Chavez, Rojas-Kramer, and Pojos-Texon, 2014). Prior to the Garcia-Santillan et al. (2014) study, their research revealed that students who deeply immerse themselves
in general study behaviors tend to have a more favorable attitude towards statistics, whereas students who approach studying superficially tend to have more problematic attitudes towards statistics, resulting in lower interest levels in the course content, an increase in anxiety and a weaker understanding of the content. Regarding general student attitudes towards statistics, the more academically driven students tend to react much more positively to statistics as a science than apathetic students.

Even secondary school math teachers can have negative attitudes towards statistics, not because of the content taught but because they do not consider themselves well prepared to teach statistics content (Hannigan, Gill, and Leavy, 2013). In the Hannigan et al. (2013) study, secondary mathematics teachers were given the commonly used survey instrument, the Survey of Attitudes towards Statistics, or SATS (Schau, Stephens, Dauphine, and del Vecchio, 1995), the results of which confirmed that attitudes towards statistics were generally positive. A common stance was that statistics is not a subject that is quickly learned, thus teacher training in how to teach statistics is of critical importance.

Swanson, VanderStoep, and Tintle (2014) analyzed statistical differences in attitudes between students enrolled in traditional curriculum statistics courses and those enrolled in randomization curriculum (e.g., those that utilize simulation, bootstrapping, and permutation testing) statistics courses at post-secondary institutions. The authors did not find any significant differences between the two instructional curricula, implying that randomization methods have no real effect on the attitudes of students towards statistics. Perhaps the best method to enhance student attitudes then lies in the ability to practically apply statistics concepts through real life data and graphical representations of said data.
Mills (2004) researched undergraduate student attitudes towards statistics in introductory statistics courses that heavily utilized computer technology into the instructional design. Using the SATS survey designed by Schau et al (1995) and performing a cumulative logit analysis on a proportional odds model with regard to the results of the SATS survey, the results of the Mills study showed that student attitudes were neutral towards effect of instruction, that students like statistics, but get frustrated easily. Students generally disagreed that understanding statistics was difficult and that statistics has value in real world applications. Students who purported to being good at mathematics claimed to like statistics in general, suggesting a connection between prior success in math courses and drive to succeed in statistics courses. Finally, there was no significant difference in gender responses to positive attitudes towards statistics.

While much research has been performed towards student attitudes towards statistics, there are large gaps in the literature with regard to secondary student attitudes towards statistics, one of several ventures that my research aims to understand. Establishing secondary student feelings towards the science of statistics both before learning the content and afterwards should provide an objective lens into improvements that can be made to the design and delivery of statistics course content on the secondary level and even below. To do so, however, an objective theoretical framework is warranted and necessary.

Theoretical Frameworks

The framework of my research study on improving student exposure and success on statistical concepts in early mathematics courses as they predict college readiness and success in higher-level statistics courses on the secondary and postsecondary educational levels begins with student attitudes. Many research studies have used Eccles’ Expectancy-Value Theory (EVT) as a foundational framework. Eccles’ EVT was designed to illuminate the importance of the nature of
student academic behaviors. The framework itself relates student beliefs on their potential success on an academic task with how much the student values the task itself, in an attempt to make relevant predictions on results related to student achievement (Wigfield and Eccles, 2002, 2000; Eccles, 2009, 1983). Eccles’ EVT proposes that students are more apt to choose to engage in, work towards success in, and achieve in educational tasks which the students value more and in which the students expect to be successful. Relative importance is described by subjective task value (STV) that construes the value of mathematics and science courses in terms of four dimensions: (1) the utility value as related to the student’s future goals, (2) the intrinsic value based on enjoyment, (3) the attainment value based on consistency with student identity, and (4) the cost determined by perceptions of time taken away from other activities or the potential negative responses of peers (Eccles, 2009). Ramirez, Schau and Emmioglu (2012) used Eccles’ EVT as the framework for their SATS-M survey. Additionally, Andersen and Ward (2013) examined the dynamic processes by which ninth-grade, high-ability students made STEM persistence plans within each race/ethnicity group. They found that ninth-grade, high-ability students who have a higher attainment value for science are more likely to plan to persist in STEM.

At present, ninth-grade and tenth-grade students at the STEM school where I am performing my research are primarily enrolled in Algebra I and Geometry courses, respectively. The district where this school resides requires that SpringBoard®, pre-Advanced Placement curricular resource materials published by the College Board®, are used. Unit 6 of the SpringBoard® curriculum for both Algebra I and Geometry is a unit devoted solely to probability and statistics for Algebra I and probability only for Geometry. Determining student attitudes and feelings towards statistics before and after this unit becomes important, as I believe that few, if
any, students have had experience with basic statistics. It is for this reason that Eccles’ EVT will serve as one of two relevant frameworks for my research study.

The other framework that becomes important to my research is Achievement Goal Theory (AGT), in which students value or devalue statistics based on the manner in which the value that they place on an educational task impacts their choices and behavior, in addition to the effort that they are willing to exert towards success. Influenced by and borne from social-cognitive, achievement motive and attribution theories, AGT was proposed by Dweck and Leggett (1988) as a social-cognitive approach that emphasizes the influences of personal and external factors on goal endorsements and underscores the importance of perception (Maehr and Zusho, 2009). Ramirez, Schau, and Emmioglu (2012) also used AGT, but as a secondary framework for their SATS-M survey.

Together, since student attitude, drive, focus, and commitment to success in statistics content elements embedded in lower-level mathematics courses, namely Algebra I and Geometry, are bedrocks to predicting statistics content knowledge retention and attitudes towards the importance of statistics in practical settings, Eccles’ EVT and AGT seem to be ideal foundational theoretical frameworks to predict statistics readiness in higher-level statistics courses.

Now that the foundational frameworks have been established, specifically with regard to attitudes, value, and effort towards statistics content, a deep understanding of the importance of statistical literacy becomes paramount.

*Statistical Literacy*

Statistical literacy is a multi-tiered concept which extends from general attitudes of both teachers and students towards statistics to training teachers to begin teaching statistical concepts to student engagement and assessment in statistical concepts. Statistical literacy is much more than
just a student being able to read statistical graphs and explain their meaning. More importantly, statistical literacy also comprises student ability to understand data and how analysis of data is practically applied to a variety of disciplines, within and outside of the interests of each individual student. When students gain a better appreciation for the ways in which statistical analysis can apply to hard science, social science, the arts, and business/industry/technology, the student eventually can start to appreciate the usefulness, worth, and beauty of statistical science. For some students this “epiphany” comes quickly; for others, not so quickly, likely due to apathy or fear. No matter the position, there is an inherent attitude towards statistics that exists and research shows proof.

At all educational levels, from primary school to secondary school and into the college and university settings, statistical literacy can be attributed to a multitude of factors. At the middle school level, interest development in statistics results because of a mixture of classroom influences and factors such as student knowledge of statistics, student enjoyment of statistics, and competency in learning statistics (Carmichael, Callingham, Watson, and Hay, 2009). Middle school preservice teacher self-efficacy to teach statistics has been measured using the Self-Efficacy to Teach Statistics (SETS) instrument, which also measures the ability of these teachers to teach key Common Core State Standards for Mathematics (CCSSM) concepts (Harrell-Williams, Sorto, Pierce, Lesser and Murphy, 2014). Middle school student achievement is influenced by pedagogical content knowledge in statistics (Callingham, Carmichael and Watson, 2015). Teacher self-efficacy to teach statistics, then, is vital to student statistical literacy, especially on the pre-secondary school levels.

Other research shows that there is a significant gender difference relative to statistical literacy, where female middle school students performed better on the Watson (1997) statistical
literacy tests than male students (Yolcu, 2014). Jacobbe, Foti, Case & Whitaker (2014) analyzed high school student statistical literacy through four problem solving areas in statistics: formulating questions, collecting data, analyzing data, and interpreting results by designing a series of assessments called LOCUS, assessments that gauge student understanding of statistical standards and benchmarks within recommended GAISE guideline and aligned with the Common Core State Standards (CCSS). They determined that a mixture of multiple choice and constructed response aid in advancing statistical knowledge. Additionally, Tintle, Topliff, VanderStoep, Holmes and Swanson (2012) analyzed college student statistical literacy through randomization processes (i.e., simulation of data, bootstrapping, etc.) and found that after an introductory statistics course, students who were in a randomization cohort showed higher levels of retention than students in a consensus cohort. The strongest evidence lied in the area of data collection, experimental design, and tests of significance.

Informal statistical inference is the backbone of the science of statistics. When students are able to make valid statistical inferences about populations, they show proof of their understanding of statistics. Makar (2013) researched ways for students to become more experienced in making statistical inferences. To do so, the author proposed not only the building and application of curricular strands in statistics but also statistical thinking and appreciation for the relevance of statistics to prediction, estimation, and conclusions from data. No matter the level of statistical education, statistical literacy is vital to a true understanding of statistics content.

Connecting success on the secondary school level with retention on the post-secondary level has been researched as well, specifically with regard to success in high school mathematics and success in undergraduate level introductory statistics. One such study examined the relationship between students’ high school math achievement and high school mathematics
curriculum on the difficulty level of students’ first college statistics course and on the grade earned in that course (Dupuis, Medhanie, Harwell, Lebeau, Monson, and Post, 2012). The researchers found that students with stronger mathematical backgrounds resulted in greater benefits in college introductory statistics, that STEM majors take more difficult statistics course, and that high school mathematics GPA and ACT math subscores were significant predictors of students’ grades in their first college statistics course, with high school math GPA as the most significant predictor, thus implying that prior math achievement and college statistics achievement are related.

Because math achievement appears to be a major factor in statistics content knowledge and successful application of such, it is imperative that quality statistics instruction be readily available. This can only occur if there are suitable teachers to teach the required statistics content. Professional development, then, becomes very important. Much research has been devoted to professional development of teachers with regard to statistics education. What follows is a glimpse into some of that research.

Professional Development

In order to reach optimal levels of statistical literacy among students of all educational levels, statistics professors, instructors, and teachers must be trained to teach effectively. Professional development (PD) opportunities for teachers are a key component to ensuring teacher effectiveness. A multitude of research on PD for statistics teachers has been conducted. This PD falls in line with requirements set forth in Chapter 6 of the Statistical Education of Teachers (SET) report (Franklin, Kader, Bargagliotti, Scheaffer, Case, & Spangler, 2015), as well as the Guidelines for Assessment and Instruction in Statistics Education (GAISE) report (Franklin, Kader, Mewborn, Moreno, Peck, Perry, & Scheaffer, 2007). Some of this PD research includes studies on preparing primary and middle school teachers to instruct curricular content that highlights student knowledge
retention of the type of statistics expected in the GAISE report (de Oliveira Souza, Lopes and Pfannkuch, 2015; Bargagliotti, Jacobbe, and Webb, 2014; Browning, Goss and Smith, 2014; Schmid, Blankenship, Kerby, Green, and Smith, 2014; Meletiou-Mavrotheris, Mavrotheris, & Paparistodemou, 2011; Metz, 2010). One research study proposed establishing a graduate school course designed solely to prepare future statistics teachers to teach statistics (Garfield and Everson, 2009). Another research study developed a PD program for statistics teachers that focused on implementing probabilistic simulations in elementary school classrooms (De Oliveira Souza, Lopes, & Mendonca, 2014). Professional development, then, is inherently an important element for maximizing statistical literacy.

National Standards and Benchmarks

In 2007 the American Statistical Association (ASA), working alongside the National Council of Teachers of Mathematics (NCTM), published a comprehensive framework meant to guide statistics education in pre-K-12 schools known as the Guidelines for Assessment and Instruction of Statistics Education, or GAISE. A separate college report known as the GAISE college report was written two years prior. The original secondary school GAISE report (2007) outlined specific expectations for statistics education in pre-K-12 schools, expectations that would prepare students for the prerequisite statistics skills necessary in college and in the real world. In the original pre-K-12 GAISE report and all follow-up reports since, there have been four components: formulating questions, collecting data, analyzing data, and interpreting results. The GAISE report bases a student’s statistical maturity on experience, not age.

Much prior research has been devoted to the use of recommendations made in the GAISE report and how they apply to student learning of statistics at every pre-college level (Franklin, Kader, Mewborn, Moreno, Peck, Perry & Scheaffer, 2007). The Common Core State Standards
for Mathematics (CCSSM) and GAISE have some alignment (Groth and Bargagliotti, 2012). The CCSSM expects middle-grades students to understand statistical variability, to summarize and describe distributions, to use random sampling to draw inferences about populations, and to investigate patterns of association in bivariate data. Further, the GAISE guidelines extend curricula based on CCSSM by recommending that students study how statistics are misused and misinterpreted, including how surveys are designed and written so that students understand how open-ended survey questions leads to a broader range of responses and thus more data.

GAISE encourages the use of projects to understand and interpret data. Federally funded grants through the National Science Foundation (NSF) have been awarded to researchers who redesign introductory statistics courses to meet GAISE recommendations (Hall & Rowell, 2008). Teacher discourse, planning, and collaboration in meeting GAISE recommendations, with special regard to assessment and instruction at the pre-K-12 level (Groth, 2008) and with regard to the best textbooks to use for postsecondary introductory statistics courses (Dunn, Carey, Farrar, Richardson and McDonald, 2017) and even in elementary school math classes (Jones & Jacobbe, 2014), are of paramount importance.

The professional development of teachers is vital when meeting GAISE recommendations. Franklin, Kader, Bargagliotti, Scheaffer, Case and Spangler (2007) offered rich suggestions to develop elementary, middle, and secondary teachers, respectively, to teach statistics. With regard to high school teachers in particular, Franklin et al. (2007) maintain that a major facet of statistical literacy lies in the teachers’ ability to be able to stress the importance of statistical modelling, using both real data and simulation techniques. Additionally, teachers should also be taught to train students to formulate questions, collect data, analyze data, and interpret results. Any opportunity to use real data should always be taken, but these opportunities should not be confined to STEM
courses only. Statistics education should be prevalent across the curriculum. In fact, much research has been devoted to teaching statistics across the curriculum and across varying educational levels. Statistics Education Across the Curriculum and Across Educational Levels

Teachers of mathematics should not be the only teachers who are trained. Statistics education cannot and should not be solely confined to the statistics classroom. From writing critically about statistics to practically applying statistics in secondary-level STEM and even in social science courses, using higher levels of Bloom’s taxonomy to critically synthesize, apply and evaluate complex statistical questions seems to be the ideal way to teach statistics. It is critical that statistics be encouraged across academic disciplines. Curricular strands for mathematics, science, and even social science must include content that promotes data management, data analysis, inference, and interpretation of results. Research even supports this across curricula, from mathematics, where statistics can be performed using telecollaboration projects (Staley, Moyer-Packenham and Lynch, 2005) to modelling and simulation, group comparisons, and sampling and estimation skills (Zieffler and Huberty, 2015; Scheaffer, Tabor and Hirsch, 2008).

Statistics extends to far greater expanses than mathematics alone. Usiskin and Hall (2015) stress the importance of practical application of statistics within course instruction in high school literacy, science, health, and social science courses. These authors propose four methods by which statistics can be taught in the K-12 curriculum: within mathematics, the method by which most statisticians purport to have learned statistics and where students use statistics to reinforce a mathematical idea; as applied mathematics, where the problem arises from outside of mathematics and mathematics is used to aid in solving the problem (which will be the major principal method for my research study); as an independent subject where, like physics, there is so much to physics that does not apply to mathematics that it is often studied in its own right, not as a subject within
a mathematics course; and across the curriculum, language arts, mathematics, social studies, science, and health and physical education each can encourage statistics education in its own practical way.

As it relates to restructuring high school mathematics curriculum, where statistics courses are typically intermeshed, the problem is that no matter the level of mathematics course content, teachers are so ingrained in using traditional instructional methods that a deep understanding often gets lost in the instruction. Activities like Change Agents for Teaching and Learning Statistics (CATALST), which promotes modeling and simulation, comparison of groups, and sampling and estimation (Zieffler & Huberty, 2015) should primarily replace lecture. Once the activities are completed, a student survey or questionnaire about understanding of statistical concepts should be conducted (Viali and Sebastiani, 2010). Furthermore, with the prevalence of the Common Core Standards for Science and Mathematics now in high use, key statistical foundations such as probability are no longer considered an important domain in K-8 mathematics curriculum (Langrall, 2016). As Scheaffer, Tabor, and Hirsch (2008) outlined in their research article, the key to redesigning the high school mathematics curriculum to a more central focus on statistics is to design activities in which students are required to ask statistics questions, collect and analyze appropriate data, and interpret results, and to do so through the use of simulation software, all within the context of mathematics courses like algebra and geometry.

The rich plethora of research discussed thus far with regard to statistics education has focused on six primary pillars: interest and general attitudes of students and teachers alike towards statistics, a combination of relevant theoretical frameworks that serve as the foundation of this research study, statistical literacy and the importance to analytics in an ever-changing job market, professional development for current and future instructors of statistics, national standards and
benchmarks recommended to ensure that students receive a statistics education that prepares them for the marketplace, and statistics across the curriculum, so that students realize the worth and value of statistics in multidisciplinary settings. These pillars only establish the groundwork for the primary foci of this research study and how they are used to increase statistics knowledge and encourage practical application, namely that of project-based learning and technology use to promote statistics education in the mathematics classroom.

Project-Based Learning (General and in Statistics Education)

Project-based learning (PBL) provides the kind of education that is proving most useful in maximizing student knowledge and doing so within a framework that is experiential, hands-on, and student-directed. For far too long teachers seem to overwork themselves by enforcing learning of the content of interest, yet the most practical method for learning is one in which the individual student drives his or her own learning. Through higher order cognitive thinking, students who use PBL can use creativity, investigation, interpretation and reflection to derive constructed answers to questions. According to the Buck Institute for Education (BIE), the foremost leader in the structure, framework and promotion of PBL, standards-focused projects best maximize student retention of course content knowledge. Projects within an academic discipline should be central to student learning and drive this learning though focused exploration of rigorous and challenging questions within collaborative groups, resulting in maximized performance (Markham, Larmer and Ravitz, 2003). PBL has a multitude of benefits, ranging from bridging the gap between knowledge and skill to motivating and engaging traditionally underperforming and apathetic students and finally to boosting collaboration and communication skills. PBL, then, is best used when it enhances course content through investigation and thus should not be used to teach basic skills. That said, these skills should be taught by the teacher first (i.e., teacher-centered), but once
learned, the instruction should become student-centered, where students apply prior knowledge through investigation and skill under the umbrella of inquiry and project-based learning.

In general, as projects are developed, the end result should be considered first. Long-term and short-term outcomes should be established. The instructor must be careful not to assign activities but rather to pose relevant driving questions which are widespread in scope but also rigorous and thought-provoking. For example, with regard to mathematics classroom where statistical content is likely first introduced, when I design projects, I would want to avoid giving data to the student and telling them what analyses to run. Instead, PBL fundamentals would expect me to pose to my students a research question (or in a perfect world allow the students to pose their own research questions) and have the students collect the data and run the statistical analyses that the students believe is best in answering the question. Along the way, though, feedback is given so that corrections can be made. Given that most, if not all, of my current Algebra I and Geometry students have never once been exposed to statistics course content, the challenge becomes that much more difficult, but with the right planning and a focused commitment to the end goal of statistical literacy, the results should be abundantly fruitful.

Under guidelines set forth by BIE, when driving questions within a PBL framework are created, these questions must be rigorous and challenging, sustain student interest, engage students in higher-order thinking skills so that they can critically evaluate information, and align with curricular standards. Driving questions always require to some extent a reframing of the question so that students can attack challenging tasks. For decades in the introductory Statistics classroom, instruction was always teacher-centered, yet upon completion of the course, few students are exposed to enough real data and analysis opportunities, thus they are limited in practical skill for
future Statistics courses and even the expectations of the job market. The following are examples of driving questions that I would use in my introductory Statistics course:

- How can the probability that a minority or underrepresented student will become accepted into their first choice of college or their ideal first job out of high school best be predicted?
- How are traffic-related deaths of varying age groups and genders preventable by seat belt usage?

The next step to establishing a quality PBL framework is to create assessments that culminate into the desired result of the overarching course theme. These assessments begin with formative assessments in which the instructor provides feedback and ends with a summative assessment, also called culminating products. These summative assessments can vary from research papers to multimedia presentations to exhibitions outside of the school (e.g., at a place of business, academic conference, etc.). Artifacts detailing the process of PBL, specifically planning, questioning, and problem solving, should be sought within each project. BIE maintains that rubrics should be established for every culminating product and these rubrics should share three distinguishing features: *elements*, which frame the rubric itself; *scales*, which categorize success on each element of the rubric; and *criteria*, which describe the degree of success in meeting the project goal (BIE Handbook).

When *elements* of the rubric are established, consideration should be given to higher levels of Bloom’s taxonomy and the quality of the procedures in the project, in addition to rigor, complexity of knowledge displayed, and validity of ideas and skills used. When *scales* for each element of the rubric are set, scaling should be differentiated so that differences in success are clear and scale labels should reflect performance on course content standards. When *criteria* for the
rubric are developed, applications of criteria to performance also must be clear. The rubric is best developed when the expectations for exemplary work are first established and then sub-category expectations are developed in sequence (BIE Handbook).

Traditionally, introductory Statistics courses have been filled with assessments that are common to other science and mathematics courses, assessments such as time-filling activities (i.e., “busy work”), quizzes and tests. This is a common practice in the mathematics classroom, where the focus of this research study will take place. In each of these assessments, the framework is teacher-centered. Rubrics are generic in nature and don’t always adhere to the three components that were just discussed. In my Algebra I and Geometry courses, the statistics and probability unit of which would be framed using PBL, I would require projects that encourage collaboration with experts and professionals in the field, in addition to fellow students. I am a big proponent of presentation skills and “lab”-like reports, even on the freshman and sophomore secondary school level, as I believe presentations and write-ups are both great measures for assessing student knowledge of course content. With each Statistics project, I also require a prospectus that details exactly the research question posed, the experimentation or observational study to be conducted to answer the research question, the type of sampling to be performed, the hypotheses for the study, and the types of analyses needed. However, since the Algebra I and Geometry courses that will be used for this study are not full statistics courses, thus only basic descriptive statistics and probability analyses and no hypothesis testing will be covered, the prospectuses will be more on the generic side. However, the culminating results will serve to begin to advance statistical literacy. I do not submit my own opinions on the directions that these items proceed, as I want the onus to fall solely on the individual student. Instead the student will drive the direction of his or her own project.
Research shows that teacher-developed projects that highlight the most important aspects of general statistics content knowledge have numerous advantages including allowing students to determine the best ways to manage, enter and analyze given data (du Feu, 2011), increasing student attitudes towards statistics at a younger age (Koparan and Guven, 2014), and encouraging statistical analysis in multi-linguistic settings (Sisto, 2009).

The best method for advancing statistical literacy, however, may be student-centered and student-developed projects. Much research addresses the benefits to inquiry-based and project-based learning that is both student-centered and collaborative. From online simulation projects (Baglin, Bedford and Bulmer, 2013) to projects that highlight statistics from a multidisciplinary scope (Dierker, Alexander, Cooper, Selya, Rose, and Dasgupta, 2016; Dierker, Kaparakis, Rose, Selya, and Beveridge, 2012), the statistics projects that promote discovery (Bailey, Spence, and Sinn, 2013) and focus on data summary and analysis as it applies to business and industry (Moreira da Silva, Porciuncula and Pinto, 2014) become ideal, both on the high school level (Groth and Powell, 2004; Smith, 1998) and the undergraduate level (Melton, Reed and Kasturiarachi, 1999), even in more focused disciplines like psychology (Marek, Christopher, and Walker, 2004).

Scaffolding in PBL, according to the BIE, is the step-by-step process by which students learn. Commencing with direct instruction and continuing until the final culminating product (e.g., presentation, research report, etc.), scaffolding provides the instructor with a sequential method for evaluating student learning (BIE Handbook). In the introductory Statistics classroom, because the course content standards are rich in theory and analyses, some direct instruction is necessary. The challenge is that there is not an abundance of time available to make practical the standards and benchmarks in Statistics, so efficient use of class time is mandatory. An example of scaffolding
that was used for the basic descriptive statistics and probability unit in both my Algebra I and Geometry courses was as follows:
direct instruction → rubrics for presentations and research reports → advanced organizers → peer review

Along the way, there were several opportunities not only for me to provide feedback to students, but for students themselves to self-evaluate their own progress. I also encouraged reciprocal teaching, whereby students took on the role of teacher. Community members often participate in the collaborative learning group and, in conjunction with the teacher and administration, become the audience for each project presentation. A timeline for each scaffold in each project was detailed beforehand.

At the end of each project was an evaluation period where students could evaluate what they learned, if group collaboration was effective, what skills needed additional practice, limitations in the project, and by extension, what improvements could be made for future studies. Teachers and instructors participated in the self-evaluation as well. Doing so resulted in improvements that could be made for future projects, culminating products and formative assessments.

Numerous chapters in the Capraro, Capraro and Morgan (Eds., 2013) book, *STEM Project Based Learning*, encourage most of the suggestions made by the Buck Institute for Education. As Scott W. Slough and John O. Milam write in Chapter 3, “…Scaffolding students to make their thinking visible provides opportunities for students to explicitly monitor their own learning, which encourages reflection and more accurately models the scientific process…” (Capraro, Capraro, and Morgan, p. 16). Slough and Milam in *STEM Project Based Learning* touch on something that I also deem as a personal goal in my statistics unit of my Algebra I and Geometry courses: the
learner is in control of his or her learning, and do so by choosing their own topics of interest. Also, in *STEM Project Based Learning*, Capraro and Jones write in Chapter 6 that PBL projects should be interdisciplinary and multidisciplinary. In the structure of my introductory Statistics course that utilizes PBL, the projects chosen by the students to answer a given research question are cross-curricular. Since research papers are required, the student must be able to write effectively and analyze data from a multitude of career-oriented dimensions, both in STEM and outside of STEM. Furthermore, the beauty of PBL use in the statistics unit of my Algebra I and Geometry courses is that it is consistent across learning styles and disabilities, as is suggested by Soares and Vannest in Chapter 9 of *STEM Project Based Learning*. Exceptional and diverse learners can guide their own instruction through the experiments or observational studies that they choose to conduct.

PBL in the statistics unit of my Algebra I and Geometry courses is not free from pitfalls. The expanse of the course content necessary before commencement of each project is vast, thus sufficient class time must be spent in teaching prerequisite statistics content skills. Given that the statistics unit of both the Algebra I and Geometry curricula are limited to a few weeks, heavy consideration must be given to efficient and focused planning. Instructors must adhere to this plan. Additionally, because of this shortened time frame, students in my Algebra I and Geometry courses may have to be allowed access to previously collected open data. The inherent problem is that in this manner, students are merely replicating a previous study. In these previous studies, the data are not always accompanied by the original study paper, so students are left to guess at the sampling technique, experimental design, etc. This takes the creativity, originality, and focus of the paper away from the thinking process and placed into the “direction following” process, which is not a hallmark of PBL. It is for this reason that I prefer and would heavily reward students who challenge
themselves by designing an experiment that each deems to be worthwhile to the scope of the course content. They would then perform the statistical analyses that best answer their research questions.

The common instrument to gauge the effectiveness of PBL use is twofold. First, a smaller unit exam will compare sections of all Algebra I and Geometry teachers at my school in their respective Algebra I and Geometry courses. Participating Algebra I and Geometry teachers will be randomly assigned to either the PBL framework or traditional sections, with standard instructional design, delivery, and pedagogy. Second, pre-unit and post-unit examinations, regarding statistics content and in line with curricular standards and benchmark requirements on both the state and national levels, will be comprised of statistics curricular-aligned questions tested on each exam. For my research, I hypothesize that students who are enrolled in one of my Algebra I and Geometry courses that utilizes PBL as the vehicle for assessing knowledge retention of Statistics course content will show higher growth from pre-unitexam to post-unit exam than students who are enrolled in traditional introductory Statistics courses, ones that use standard homework, quizzes, and mid-term examinations as formative and summative assessments.

These methods, however, are useless unless there is already a standard set of general math skills, including the ability to learn statistics by interpreting graphs, including from simple descriptive statistics graphs (e.g., pie charts, Pareto graphs, bar graphs, histograms, ogives, etc.). The goal, then, of this research paper is to create a first step – a best practices framework in line with Cobb (1992), which also advances statistical literacy through project-based learning and collaboration amongst students to correctly analyze graphics used in the statistics classroom. To effectively answer these questions, a thorough understanding of graphics usage in the statistics classroom must be understood.
Statistical graphs, tables and charts can be frightening to the average student, regardless of school level. There are numerous factors that come into play when establishing the best practices for interpreting graphics to teach statistics, factors such as the ability for students to collaborate to arrive at valid solutions, the use of technology in the classroom in both teacher-centered instruction and student-centered learning, a deeper understanding of just how data works (i.e., how data is collected, manipulated, transformed, managed, organized and analyzed), and finally, a deeper understanding of sampling variability and how it affects understanding of distributions.

**Collaboration Set-up**

Collaboration between peers or between teachers and students, and now, between members of the workforce/industry and students, is becoming more and more a practical method of learning. Bebermeier and Reiss (2015) reported on a workshop that the authors held in which college students in an introductory statistics course reviewed descriptive statistics and created exercises for their fellow students. Student participation and commitment to high quality work was commonplace. The authors concluded that despite being costly to run, the workshop produced positive results, ones that helped predict success on final course assessments. Roseth, Garfield, and Ben-Zvi (2008) addressed concerns of statistics instructors who were reluctant to encourage student-centered teaching strategies, relying instead on traditional teaching practices. The authors suggested that, in regards to student-centered projects within a cooperative learning framework, group size, individual accountability, and explicit, positive interdependence are key elements. They suggest using the GIG procedure of assessments (Group preparation, Individual assessment, Group assessment). First, student show proof that the group can answer questions or solve a project problem correctly. Then, each student within a group take an individual assessment aimed at
gauging just how much each individual student understands the content strand. Finally, the entire group collaborates and a final group grade is given.

Technology Use for Statistical Analysis in the Mathematics Classroom

Technology use is an essential element of statistics projects. It should come as no surprise that we live in a world of technology, but that technology must be applied correctly. Considering that big data is traditionally extensive, technology software in addition to hand-held technology aids must be embedded in statistics instruction. Research shows that various programs can help advance statistics education. Christensen and Stephens (2002) compared success on summative statistics assessments between high school statistics classes that used Microsoft Excel® to create graphs and provide descriptive statistics as opposed to similar classes that performed all graphics and descriptive statistics by hand. Francis, Hudson, Vesperman, and Perez (2014) researched relevant differences between pre-service teachers (PST) in schools whose classes incorporated one of three instructional styles: project-based learning (PBL), problem-solving (PS) activities, and model-eliciting activities (MEA). A statistical program known as Tinkerplots™, a data exploration software package designed for students in grades 4-9, was used to support statistics education. The authors found that as students become more knowledgeable and competent with the software, student proficiency in statistics significantly increased. Tinkerplots™ is a great organizational tool which allows students to overlay statistical plots upon one another (e.g. dotplots over boxplots, error bars over time series graphs, etc.) and which allows students to see statistics from an interactive perspective. English and Watson (2016) also analyzed student use of Tinkerplots™ and determined that the most distinguishable information learned by using the software was that random samples could be collected with technology. This opens the door to simulations as a relevant method for performing statistical analysis. A similar statistical software that has shown
great progress in teaching graphically how to analyze data is GeoGebra (Prodromou, 2014). On the collegiate level, use of statistical programs like SAS®, R®, SPSS®, Minitab®, Stata® and Fathom® or Java applets (Everson, Zieffler and Garfield, 2008) are preferable to using tables or hand-written calculations. No matter the level of education, technology use in the classroom aimed at graphically applying statistics serves two purposes according to Eichler and Zapata-Cardona (2016). The first aspect involves enhancing statistical investigation and reasoning. The second aspect includes supporting conceptual learning through simulation. Technology, however, is just a start. Students working with data is of utmost importance.

Data collection through projects and activities are imperative to success in the statistics classroom. When students can collect their own data, analyze it, and finally present results, they learn to value the experimentation process. Students who can sequentially take basic statistics content and then practically apply what they learned in numerous activities and projects have a decided advantage over those who do not. For example, in the research study performed by Smith, Molinaro, Lee and Guzman-Alvarez (2014), the authors proposed a sequence of lectures, activities and case studies that focus on the collection, management and analysis of data. The sequence generally starts with a lecture, continues to a student activity and ends in a case study before the process is repeated. The sequences can be as few as a single process for specific content benchmarks and as many as 3-4 repetitions, each sequence repetition building on the previous one, yet becoming more and more challenging over the entirety of the content benchmark.

Lovett and Lee (2016) researched middle school students and their use of technology to make valid and reasonable conclusions on an activity where students completed a personal information survey and a question from the survey was taped to the back of each participating student. Students asked their peers to respond to the given question and from those responses
students were tasked with deducing the question from the survey taped to their respective backs. Once all students had made a decision on the question taped to their backs, the data was analyzed and discussed. The beauty of an activity of this type was that students learned that it was less important to be right or wrong in a statistical analysis and much more important to provide relevant, justifiable claims using evidence.

Even elementary school students can use graphics to understand statistics. Sales (2008) offers a statistical activity that primary school students can perform that promotes data collection and graphing. Students measured each other’s height and foot size and then performed a simple correlation analysis and plotted attained data in scatterplots. Learning statistics, then, can start a very young age.

Blagdanic and Chinnapan (2013) inspected student practical application of statistics through real-life data. Using nutrition information on cereal boxes, students were charged with drawing what they thought were relevant graphs (e.g. boxplots, histograms, etc.) for the given information. The authors concluded that middle school students can draw graphs (often times more than one type of graph that represented the given data), but they tended to start drawing graphs without truly understanding the nature of the graph nor the data they were graphing. Finally, students primarily were able to tabulate and draw clustered graphs. This research proves that starting with given data and creating graphs or starting with graphs and extracting data, practical application of real-world statistics can be learned.

Sampling variability might be the most difficult to explain. Students in Algebra I and Geometry courses will almost assuredly have difficulty grasping variability and its worth to data science. The challenge, then, will be how to present variability in unique, innovative, and from a multitude of educational delivery designs. Bargagliotti and Groth (2016) gave several sample
assessment tasks that stress variability of data and encourage students to provide both statistical and mathematical explanations as to the reasons why distributions of data differ. Pfannkuch, Arnold and Wild (2014) analyzed students’ understanding of sampling variability through three mental processes: visualization of the distribution of data, analysis of said data, and verbally describing the data. The authors wanted students to visualize various graphs of data distributions as sample sizes change and then make comments about these graphs.

Teaching statistics using graphics is a fantastic way to get future statisticians and non-statisticians to understand the practical importance of statistics. Bradstreet (1996) reported that a majority of students enrolled in a statistics course deemed graphics used as an instructional tool in their statistics course as highly important to conceptualizing and designing experiments, to communicating efficiently and effectively, to understanding data, and to appreciating statistical analyses more. Horton, Baumer and Wickham (2015) maintain that incorporating real-world big data, statistical software computer coding and a variety of graphics that explain data results is the best way to teach introductory statistics. I imagine that the same will hold true for students in Algebra I and Geometry.

There is an abundance of research that focuses on different graphics types. Traditionally, the first types of graphics discussed in an introductory statistics classes are the Venn diagram, the boxplot and the bar graph. Since Venn diagrams are already embedded in the Louisiana state standards for both Algebra I and Geometry, students should have few difficulties with the use of Venn diagrams in statistics. In fact, when teaching Venn diagrams, there are natural ties to mathematics, specifically in the organization of data, that math and statistics instructors can make. Waddell, Jr. and Quinn (2011) assert that Venn diagrams are perfectly sensible if relative frequencies of compound events are unknown. They maintain that differing sizes of the circles in
a Venn diagram can aid in showing frequency data of a categorical group. These circles reveal areas that are proportional to the frequency of the categorical data.

Instructors of mathematics and statistics who provide lectures about boxplots, and specifically, the comparison of two or more boxplots, should focus on reasoning elements such as hypothesis generation, summary information, shifts between the boxplots, overlap of the boxplots, variability and spread of all boxplots, sample sizes for each boxplot and its effects on the boxplot, contextualizing boxplots, and determining potential outliers in a boxplot and their effect on the distribution of data as depicted in the boxplot (Pfannkuch, 2006).

Other research looks at bar graphs, specifically in representing categorical and qualitative data. Miller (2007) states that bar graphs are a great way to teach students how to order information empirically, group data theoretically, and organize data to develop a clearer picture of the data frequencies. The author also encourages statistics instructors to have students write narratives to accompany any table or chart, but especially bar graphs. Humphrey, Taylor and Mittag (2013) conducted research aimed at helping students know when to display a bar graph and when to display a histogram. The authors determined that after an extensive review of textbooks, online tutorials, and other informational tools, there rarely has been one common reason given as to why students have difficulty deciphering between when to depict data through box plots and when to depict data through histograms. The authors made clear that bin widths of either graphical type is of paramount importance and maintain that students must realize what happens to frequencies as bin widths change. Similar research has been done with regards to the power of other graphics such as frequency polygons (Callaert, 2000) and pie charts (Hunt and Mashhoudy, 2008).

Research on the use of scatterplots as graphics is abundant as well. This, perhaps more than any other graphing type, will be the most understandable to Algebra I and Geometry students.
Considering that a vast majority of the Algebra I content standards pertain to linear functions, graphing and analysis, scatterplots will be practical and a fantastic way to bridge statistics standards with algebra standards. Regression, then, becomes one of the central content strands of statistics. Before students can effectively find a regression line, they must first fully understand how the line explains data and predicts future observations. This is done by first understanding correlation. Kozak (2009) showed two techniques, one graphical and the other based on simulation, for explaining the relationship between frequency distributions of correlation coefficients between small sample size data of two Normal variables. Sorto, White, and Lesser (2011) presented tasks that incorporate graphics to help students fit lines to data through the least squares method, a commonly misunderstood method. Bradstreet and Palcza (2011) analyzed real data on various coughing medications and determining which are best. They used regression analysis pepper extract concentration and number of coughs over a set period of time. Varying residual analyses in the study best assisted students in making practical statistical inferences.

Research shows that graphics presented by hand-held and computer technology instruments are now commonplace. Kulp and Sprechini (2016) presented an activity to teach statistics through graphics of real world, large generated data sets. To analyze plots of any type, the hand-held graphing calculator has proven to be a wonderful tool for leaning about the normal distribution. Jackman (2001) and Graham (2000) both give detailed descriptions on how the graphing calculator can be used to depict a multitude of graphics. Simulation graphics are also useful in advancing learned statistical concepts (Marasinghe, Meeker, Cook and Shin, 1996).

One powerful research study was performed by Orris (2011) who showed how variance and standard deviation can be represented graphically by looking at standard deviations as graphical objects. Standard deviations are represented by the size of the average square.
Gaps in the Literature and Research Questions

Despite the rich array of research now discussed, the focus turns to my particular research study and how effectively best to teach basic descriptive statistics and probability in secondary schools, a venture which little research exists. The current gaps in the literature are numerous. Based on recommendations supplied by GAISE, little research has focused on student achievement and student attitudes towards statistics, particularly on the secondary school level. For decades, the only exposure to basic statistics that many students had received came in the form of measures of central tendency in the junior high/middle school grades, and only then, briefly (i.e., a daily lesson or two). Until the College Board® published a series of mathematical courses aligned to advance students towards AP Calculus AB and BC, and only recently, AP Statistics, courses, the science of statistics being taught in high schools was a rare occurrence. Algebra I, Geometry, and Algebra II curricular content through the SpringBoard© curriculum, published by the College Board®, each now contains an entire unit, albeit brief, focused on the science of statistics and how it relates to typical course content in each of the respective courses. Given standard teaching practices whereby traditional formative assessments (e.g. homework, quizzes, worksheets, etc.) are commonplace, will students exhibit typical behaviors towards these types of assessments, behaviors such as late submission, minimal efforts, etc.? Would student interest, commitment and work ethic be increased if formative assessments were, instead, project-based rather than traditional. How would students view the science of statistics before and again after initial exposure and would their attitudes and perceptions change over the course of said exposure?

Because of these gaps in the literature and given new curricular standards in the Common Core State Standards for Mathematics, in addition to advances made by national education
companies such as the College Board®, I developed a research study focused on filling these literature gaps. My primary research questions, then, are as follows:

1. To what extent does project-based learning (PBL) improve student knowledge of basic statistics curricular standards as opposed to more conventional (i.e. traditional) methods when the content is first introduced in an Algebra I or Geometry course?

2. To what extent are student attitudes towards statistics affected when students are first exposed to basic descriptive statistics and probability in Algebra I and Geometry courses?

3. To what extent do student attitudes towards statistics change after learning introductory statistics within Algebra I and Geometry courses that uses varying instructional delivery methods (e.g., traditional vs. PBL)?

4. To what extent is the instructional design and delivery of introductory statistics standards that highlights the use of projects within Algebra I and Geometry courses beneficial for both teachers and students?

5. What are the pros and cons for introducing statistics in an Algebra I or Geometry course that is strictly assessed through the use of projects? Fully traditional?

To answer research question 1, a detailed general linear model analysis was performed. To answer research questions 2 and 3, respectively, variations of two popular survey instruments, the Student Attitudes towards Statistics (SATS) pre-course and post-course surveys, were used to gather rich information from permitted, participating Algebra I and Geometry students regarding the impacts that formative assessment styles have on their attitudes towards the statistics content delivered in their Algebra I or Geometry course. Several follow-up quantitative analyses served to provide the answers to research questions 2 and 3. Research questions 4 and 5, respectively, were answered using detailed teacher interviews after the statistics unit was completed. The results
necessary to answer all five of these research questions have been expounded upon and summarized later in this paper.

It should come as no surprise that a course like Statistics already has a negative stigma associated with it. In my discussions with fellow teaching colleagues over the last eighteen years, I have surmised that the reason for this behavior is likely due to the notion that for many students, their first exposure to Statistics occurred on the post-secondary level. Given the expansive science of statistics, it is clear that actively educating students at a younger age is vital, especially given the importance of data analytics in the world of today. The worth and value of this research study, then, becomes that much more important, given that the informational attained from it could open the door to more advanced research studies that will actively advance statistics education in the mathematics classroom and across the curriculum, thereby preparing students for the expectations of post-secondary institutions and the job market.
METHODS

This research study was separated into two facets. The first portion of the study involved student achievement. The aim of the student achievement portion of the study was to evaluate growth in scores, pre-unit test and post-unit test, on a common curricular examination across two levels of a formative assessment factor (project-based assessments vs traditional assessments) and across teachers who were eventually used as a blocking factor. The second portion of the study evaluated changes in student attitudes towards work ethic, general attitudes/perceptions, opinions, and speculations before and after a SpringBoard© Algebra I and Geometry statistics unit across the same formative assessment factor levels (project-based assessments vs traditional assessments) and across varying demographics and class variables.

For the student achievement portion of the study, two math courses were used: Algebra I and Geometry. Within the Geometry course, two teachers agreed and were authorized by local school administration to participate in the study. For Algebra I, I and one other teacher initially participated in the study, but unfortunately, the other Algebra I teacher had to leave the study approximately 75% through its completion. Because this teacher left the study, the teacher blocking factor was eliminated. A generalized linear model analysis was performed for each math course type, the purpose of which was to evaluate the treatment effect of formative assessment type (project-based assessment use vs traditional assessment use) within each course and across teachers who used a common instructional platform (Geometry only), with interaction analysis following. The expectation of the student achievement portion of this study was that, ignoring any relevant teacher effect, the average growth in achievement for students randomly assigned to Geometry or Algebra I math course sections using project-based assessments should be higher than
for those students randomly assigned to Geometry and Algebra I math course sections using traditional assessments.

For the student attitudinal portion of this study, I was graciously authorized to use and make warranted edits to the original Student Attitudes Towards Statistics (SATS) survey (Schau, 1995), a survey used by Schau et al. to gauge post-secondary and university student attitudes towards statistics before and after a course involving statistical analysis. The surveys used for my research study were altered from the original SATS surveys by Schau et al. (1995) and subsequently targeted to gather valuable information on secondary students, a venture which very few, if any, previous research studies had done. The purpose of the surveys used in this research study were to gauge student attitudes toward statistics when they are introduced to statistics content for the first time in the Algebra I and Geometry SpringBoard© curricula. For many students participating in this research study, the statistics unit proved to be the first exposure many of these students had to the science of statistics. Participating students were administered a pre-unit survey prior to the commencement of the curricular unit in statistics, a survey that gauged student stances towards statistics based on four main criteria: work ethic, general attitude/perception, general opinion, and speculations. Once the statistics unit in the respective courses was completed, participating students were administered a similar post-unit survey, a survey which also gauged student stances towards statistics based on the same four main criteria. The aim of the student attitudinal portion of this research study was to evaluate if attitudes had changed over the course of the unit for those randomly assigned to an Algebra I or Geometry course that used either projects as formative assessments or traditional assessments. The expectation was that those students in an Algebra I or Geometry classroom that utilized projects as formative assessments would should the
most positive change in attitude towards statistics than those students assigned to an Algebra I or Geometry classroom that utilized traditional assessments.

**General Structure of the Study and Random Assignment**

This research study incorporated several statistical analyses on two different populations. The two populations of interest were students enrolled in Algebra I and students enrolled in Geometry. The students within each population had naturally been assigned to pre-established Algebra I and Geometry teachers at the school where this research study was held. These students were randomly assigned to these classes in summer 2018, thus no Algebra I and Geometry teacher participating in this research study had a say in choosing select students - only guidance counselors and school administrative personnel made these enrollment decisions.

Initially, three Algebra I teachers were authorized and agreed to participate in this research study, however two of these teachers were removed from the study, one due to resignation, the other due to personal decision not to participate. For this reason, the achievement portion of this research study still compared changes in achievement growth across the treatment effects, but only for myself, the one participating Algebra I teacher. Two of my regular Algebra I courses were randomly selected and assigned to be either a “project-based assessment” section or a “traditional assessment” section. Honors sections of Algebra I under my lead were omitted from the study so as not to create a nested student “ability” effect that may potentially cause bias in the results.

I created and administered the instructional materials (i.e. lecture slides) and formative assessments that the students used within my traditional, formative assessment classroom. For my Algebra I section assigned to use projects as formative assessments, the projects were developed by randomly assigned student groups and each group project required my approval using a prospectus (see Appendix B). A sample completed group project prospectus has been provided in
Appendix C. The projects had to meet SpringBoard© and Common Core State Standards©. Each Algebra I group project prospectus was required to highlight a study of the student group’s choosing that met the expected curricular topics outlined in Table 2. The grading rubric used to grade projects for the statistics unit in both Algebra I and Geometry is supplied in Appendix D. The pre-unit exam and post-unit exam were also based on SpringBoard© and Common Core State Standards©. The growth in exam score then was evaluated statistically. All students enrolled in my two randomly assigned Algebra I course sections were required to participate in the achievement portion of this research study because the content taught was mandatory and a required part of the Algebra I curriculum for the state, as well as in the Common Core State Standards©.

There were two (2) Geometry teachers who were authorized and agreed to participate in this research study – myself and one other teacher. Two of our respective Geometry courses were randomly selected and assigned to using project-based assessments or traditional assessments, in the same manner used for Algebra I. Honors sections of Geometry under our respective directions, like for Algebra I, were omitted from the study so as not to create a nested student “ability” effect that may cause bias in the results.

Like the Algebra I courses, I created the instructional materials and formative assessments that the traditional students used. For sections of our Geometry courses assigned to use projects as formative assessments, the project requirements had to meet SpringBoard© and Common Core State Standards© requirements, yet were developed by the participating students and approved by each participating Geometry teacher alone through the same prospectus in Appendix B. Each Geometry group project prospectus was required to highlight a study of the student group’s choosing that met the expected curricular topics outlined in Table 2. The pre-unit exam and post-
unit exam were also based on SpringBoard© and Common Core State Standards©. The growth in exam score was evaluated statistically, but because there were natural expected variations in teacher delivery, the two teachers were used as blocks. As was the case with Algebra I students, all students enrolled in these Geometry course sections were required to participate in the achievement portion of this research study because the content taught was mandatory and a required part of the Geometry curriculum.

I developed all instructional materials for the basic lecture content that were used in the statistics unit for both Algebra I and Geometry. These pre-developed instructional materials included Powerpoint presentations and other supplemental documents. I trained the other participating Geometry teacher prior to instruction on the expectations of the delivery of curricular content in the study, however the methods by which each teacher delivered the course content to their own students was left solely up to that participating teacher, provided that all of the curricular content instruction required by the state and the Common Core State Standards© were met. It was expected that, outside of natural teaching differences, instructional delivery practices would be the same across all teachers and over each respective course, for both project-based and traditional-based courses. There were potential outside classroom factors that may have affected instructional and assessment protocols, factors such as school-wide assemblies, required end-of-year state examinations (e.g. End-of-Course assessment requirements), etc., but steps were taken to minimize these reductions to instructional time and content lessons, as best as possible.

It is important to note that the other participating Geometry teacher had assigned simple projects to students in prior courses under his direction, but at no time had he ever used the elements of a true project-based learning framework. For this reason, I educated him prior to this research study on the elements of a project-based learning framework, as outlined, suggested and
encouraged by the Buck Institute for Education. I personally, had used the project-based learning framework in many of my prior mathematics and statistics courses.

Topics of Study by Course

The statistics unit topics for Algebra I and Geometry are detailed in Table 1 below. Sections of the Algebra I and Geometry courses assigned to a traditional-based assessment structure used homework assignments and a mid-unit quiz as formative assessments. The summative assessments used included the following: one pre-unit examination and one post-unit examination, the questions of which were comprised of multiple-choice and constructed response questions in line with state and Common Core State Standard© requirements. Sections of the Algebra I and Geometry courses assigned to a project-based structure used student-developed and teacher-approved group projects only as formative assessments. The project-base structured course sections were not assigned homework nor quizzes. These project-based structured courses, however, took the exact same overarching pre-unit and post-unit examinations as the traditional-based structured courses. These examinations were used as the primary instruments to evaluate if a project-based structured statistics unit in Algebra I or Geometry was more successful in advancing basic statistics content knowledge than a comparable Algebra I and Geometry course that used traditional assessments to advance basic statistics content knowledge.

Table 1. Topics used in the Algebra I and Geometry Course Statistics Unit

<table>
<thead>
<tr>
<th>ALGEBRA I STATISTICS UNIT TOPIC</th>
<th>GEOMETRY STATISTICS UNIT TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures of Center and Spread</td>
<td>Sample Spaces, Venn Diagrams and Probability Notation</td>
</tr>
<tr>
<td>Dot and Box Plot and the Normal Distribution</td>
<td>Addition Rule of Probability and Mutually Exclusive Events</td>
</tr>
<tr>
<td>Correlation and Simple Linear Regression</td>
<td>Dependent Events</td>
</tr>
<tr>
<td>Bivariate Data</td>
<td>Independent Events</td>
</tr>
</tbody>
</table>
For Algebra I and Geometry courses randomly assigned a project-based structure, certain project topics were required. A description of the requirements for projects, as well as the mandatory topics to be addressed, were as follows:

Outside of a required common pre-unit and post-unit examination for all instructional structures, for students in a section randomly assigned to use projects as assessments, each student and three (3) classmates were randomly assigned to previously set groups based on a common random number assignment and using a course roster alphabetized by last name. The purpose behind the randomization of groups was to reduce the number of natural “cliques” that might have formed had students been allowed to choose their own groups. Furthermore, doing so also revealed to students the importance of learning how to collaborate with other students that each may have never chosen otherwise, a good skill to have given expectations in higher educational levels and the work force.

Each group was required to design simple project experiments (preferable) or retrieve open data (possible, but groups can contact me or their participating teacher for open data repositories) that would seek answers to research questions that groups developed related to the projects that each group chose to meet curricular requirements. Algebra I student groups were required to choose two (2) of the three (3) project analyses below. Geometry students were required to complete both projects detailed in Table 2 below. A sample of an Algebra I presentation has been provided in Appendix E, while a sample of a Geometry project has been provided in Appendix F. All group projects had to adhere to the project analysis requirements below, but also had to be based on topics covered in the Statistics unit of their Algebra I or Geometry course. NO group was allowed to be larger than four (4) members, in order to avoid small clusters of students not participating.
For each group project, a project prospectus was required that met the curricular topics outlined in Table 2. When completed, this prospectus gave a full description of the project itself, from target populations sought, research questions posed, sampling methods used, types of data used, statistical analyses performed, and if any community partners/experts/advisors were used in the study. The purpose of this prospectus is to give this researcher and the classroom teacher a full understanding of what each project entails, so that in the event of any potential risky project study proposals (i.e., risks to human or animal subjects), this researcher and/or the classroom teacher can deny the project. This is done to protect the school, the students, all participants in the proposed project study, and all researchers, including this researcher. Appendix B details the prospectus template that will be used for all group projects.

Students in the project-based sections were held to a specific rubric developed specifically for the group project presentations. Appendix D details the rubric that the participating Algebra I and Geometry teachers of the project-based sections will use to evaluate success on group projects.

Protocol for Randomization of Student Groups for Project-Based Assessments

A TI-84™ graphing calculator was used to randomize students by the ordered, alphabetical list provided electronically by the participating school. Students with last names starting with the letter “A,” and continuing alphabetically by last name, were listed as “Student 1,” “Student 2,” etc. This process continued until all students ordered 1 – 32 (since no classes were larger than 32 students) were randomly assigned to a student project group by using the Random Integer function of the TI-84™ graphing calculator. Once assigned to a group, that student remained in his or her assigned group throughout the entirety of the Statistics unit in his or her Algebra I or Geometry class. Only I, all participating Algebra I and Geometry teachers at the participating school, and the administration at said school knew the identities of the students in each randomly assigned group.
Table 2. Project Requirements for Project-Based Assessments

<table>
<thead>
<tr>
<th>ALGEBRA I</th>
<th>GEOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive Statistics Project that Incorporates the Use of Measures of</td>
<td>Project that Incorporates the Use of a Two-Way Table to Set up a</td>
</tr>
<tr>
<td>Central Tendency, Measures of Variation, Dot Plots, and Box Plots</td>
<td>Probability Distribution and Detail Relevant Probabilities (FOCUS:</td>
</tr>
<tr>
<td></td>
<td>Addition Rule and Multiplication Rule Required)</td>
</tr>
<tr>
<td>Project that Incorporates the Use of Scatterplots, along with</td>
<td>Project that Incorporates the Use of a Two-Way Table to Set up a</td>
</tr>
<tr>
<td>Correlation Coefficient and Simple Linear Regression (Line of Best Fit)</td>
<td>Probability Distribution and Detail Relevant Probabilities (FOCUS:</td>
</tr>
<tr>
<td>Analyses</td>
<td>Conditional Probabilities and Independence of Events Required)</td>
</tr>
<tr>
<td>Bivariate Categorical Data Study</td>
<td></td>
</tr>
</tbody>
</table>

All identities were hidden for all portions of this research study. The specified naming convention used to identify students participating in the study was a conglomeration consisting of the hour of the day that a student took an Algebra I or Geometry course, followed by the first letter of the last name of the participating teacher of that student’s Algebra I or Geometry course, and ending with the roster number of the student in alphabetical order within that participating Algebra I or Geometry teacher’s class. For example, the 29th student on Mr. Earle’s 1st hour Geometry alphabetized class roster would have been assigned the pseudonym, 01E29. This naming convention was used throughout this entire research study, in both the student achievement portion of the study and the attitudinal portion.

Table 3 below details the TI-84™ randomly generated roster numbers to assign students in Algebra I or Geometry sections that used projects as formative assessments. In the event that participating classes had fewer than 32 students, the cooperating teacher used this student group random assignment protocol above but filled in any number gaps so that no student group contained fewer than three (3) students. Groups were expected to be four (4) students in size, but could not exceed four (4) students, nor be fewer than three (3) students.
Table 3. Student Randomized Numbers for Project-Based Assessment Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>TI-84™ Randomly Generated Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13, 16, 27, 32</td>
</tr>
<tr>
<td>2</td>
<td>8, 20, 21, 26</td>
</tr>
<tr>
<td>3</td>
<td>11, 15, 25, 30</td>
</tr>
<tr>
<td>4</td>
<td>7, 9, 23, 28</td>
</tr>
<tr>
<td>5</td>
<td>4, 5, 12, 22</td>
</tr>
<tr>
<td>6</td>
<td>1, 6, 24, 31</td>
</tr>
<tr>
<td>7</td>
<td>14, 17, 19, 29</td>
</tr>
<tr>
<td>8</td>
<td>2, 3, 10, 18</td>
</tr>
</tbody>
</table>

*Experimental Design Used for Student Achievement Portion*

For the student achievement portion in the Algebra I sections of this research study, two Algebra I classrooms under the direction of only one participating teacher were randomly assigned, one section using project-based formative assessments, the other using traditional formative assessments. All students within either of these Algebra I sections were required to take a pre-unit examination covering basic statistics content that was directly related to other Algebra I course content within state and Common Core State Standards™ guidelines. Following a unit on the basic statistics analysis content outlined in Table 3, students were required to take a post-unit examination covering the same basic statistics content. The time frame allotted to conduct this study was minimized to less than three weeks due to several external factors (End-of-Course testing, required final exam “dead” periods, etc.), the same pre-unit and post-unit exam was not administered to avoid potential memorization of answers across examinations. Similar examinations, however, were administered, exams that covered the same content standards outlined in the unit. In this way, growth from pre-unit examination score to post-unit examination...
score could be analyzed using paired *t* test analysis with project-based formative assessment class structure and traditional formative assessment class structure serving as treatments. Both the pre-unit and post-unit Algebra I exams had high internal validity, as each was developed by the College Board® to assess student understanding of the curricular standards embedded within the statistics unit in the SpringBoard© Algebra I course. Paired differences in post-unit exam and pre-unit exam scores among students in the project-based assessments Algebra I section were compared to differences in post-unit exam and pre-unit exam scores among students in the traditional assessments Algebra I section.

Descriptive statistics were also taken on the pre-unit examination assessment scores, the post-unit examination assessment scores, and the paired differences to ascertain overall growth across each of the treatment types. In commonality with similar studies performed in educational research studies using a single teacher, a generalized linear model analysis was performed for main treatment effects. Difference (i.e. growth) in examination score was used as the dependent variable. The model used for this generalized linear model is shown in Equation 1,

\[ Y_{ij} = \mu + \tau_i + \varepsilon_{ij}, \]

Eq. 1

where \( \tau_i = 1 \) or 2 (treatment type) and \( \varepsilon_{ij} \) is the student difference in exam score. Effect size then was analyzed using Cohen’s D statistic. The choice of 1/2 coding of treatment effects was preferred over a typical 0/1 “dummy” code of the treatments to avoid any potential risks of more “0” values (e.g. “project-based student”) in the original data than “1” values (e.g. “traditional assessment student”), thereby resulting in potential zero inflation. All analyses in the student achievement portion of this research study were performed using SAS® 9.4 software.
For the student achievement portion in the Geometry sections of this research study, two Geometry classrooms under the direction of both participating teachers were randomly assigned, one section using project-based formative assessments, the other using traditional formative assessments. Like for the Algebra I sections, all students within either of these Geometry sections were required to take a pre-unit examination covering basic statistics content that was directly related to other Geometry course content within state and Common Core State Standards™ guidelines. Following a unit on the basic statistics analysis content outlined in Table 3.1, students were required to take a post-unit examination covering the same basic statistics content. The time frame allotted to conduct this study was around five weeks, so restrictions to course content delivery and assessments (e.g. End-of-Course testing, required final exam “dead” periods, etc.), were minimized, unlike that of Algebra I. Despite having additional time to complete the statistics unit, the same pre-unit and post-unit exam was not administered to avoid potential memorization of answers across examinations. Instead, similar examinations were administered, exams that covered the same content standards outlined in the unit. In this way, growth from pre-unit examination score to post-unit examination score could be analyzed using paired $t$ test analysis with project-based formative assessment class structure and traditional formative assessment class structure serving as treatments. Both the pre-unit and post-unit Geometry exams had high internal validity, as each was developed by the College Board® to assess student understanding of the curricular standards embedded within the statistics unit in the SpringBoard© Geometry course. Paired differences in post-unit exam and pre-unit exam scores among students in the project-based assessments Geometry section were compared to differences in post-unit exam and pre-unit exam scores among students in the traditional assessments Geometry section.
Analysis of Covariance (ANCOVA) was originally considered for both the Algebra I and Geometry analyses, but preliminary results showed no significance. Furthermore, had a common covariate (e.g. a separate pre-test, such as a mid-term exam or the previous year’s statewide standardized exam results) been available for use, thus allowing for inclusion of other potential factors such as inherent student ability, success on prior exams, or testing behavior, this research study may have been able to inspect more deeply other main effects and interactions, but since these other covariates were not readily available, the ANCOVA was omitted from consideration for this research study. Future extensions of this study, though, should strongly consider an ANCOVA on any available covariate instrument results.

Descriptive statistics were also taken on the pre-unit examination assessment scores, the post-unit examination assessment scores, and the paired differences to ascertain overall growth across each of the treatment types. In commonality with similar studies performed in educational research studies using more than one teacher, a generalized linear model analysis was performed for main treatment effects. Due to the natural variation in instructional delivery methods inherent across teachers, this generalized linear model analysis was performed for treatment effects, but teachers were used as fixed blocks. Difference (i.e. growth) in examination score was used as the dependent variable. The model used for this analysis with teachers used as blocks is shown in Equation 2,

\[ Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \quad \text{Eq. 2} \]

where \( \tau_i = 1 \) or 2 (treatment type) and \( \beta_j = 1 \) or 2 (teacher block), and \( \varepsilon_{ij} \) is the student difference in exam score within treatment type and within teacher block. The choice of 1/2 coding of treatment effects was preferred over a typical 0/1 “dummy” code of the treatments to avoid any
potential risks of more “0” values (e.g. “project-based student” or “Teacher 1”) in the original data than “1” values (e.g. “traditional assessment student” or “Teacher 2”), thereby resulting in potential zero inflation for treatment effect or within blocks. Effect size then was analyzed using Cohen’s D statistic for all elements of the model, including the teacher block. All results have been supplied.

**Final Statement Regarding Testing Controls**

All measures to control for expected effects were taken for this research study. Honors Algebra I and Geometry classes were not allowed to be considered in this study, since there was only one section of each course. Comparing an Honors section to a regular section would have created natural student effects. The purpose of this research study was not to consider the effect that student ability had on achievement within a treatment, although a future extension of this study may certainly warrant this consideration. That said, the only classes allowed to be included in this study were regular Algebra I and Geometry courses. Within each regular Algebra I and Geometry course section using projects or traditional assessments, there were inherent natural student ability differences. Students who had high achievement and ability were often placed into regular classes due to scheduling conflicts and class size restrictions, so controlling for students who may have already been considered high-achieving, which would warrant their inclusion in Honors courses, proved nearly impossible because omitting these previous high-achieving students within the randomly selected courses would have reduced the sample sizes and put the participating teacher at risk for insubordination for not including every student assigned to the course. This research study, then, was forced to include high-achieving students who were enrolled in one of the participating course sections. Future studies, however, certainly warrant the consideration of natural variations in student ability using some measuring instrument prior to study commencement.
The potential effects of the teacher were controlled by every teacher using common lesson plans, instructional delivery tools (PowerPoint slides), instructional delivery dates, and formative and summative assessments. Only projects across student groups differed across groups. The projects were never used as a primary instructional tool; nay, they were only designed and developed by student groups, and used by the participating teacher as formative assessments to gauge preliminary understanding of the curricular content within the statistics unit. This, though, was the purpose of project-based learning – the value of student-centered investigation and the practical application of what was taught in the common lessons. Since all instruments were common, sans projects, there was no instrument effect to consider. Overall, this research study was designed to be as free of any potential effects that would have marred or skewed results as possible.

**Final Study Hypotheses for Achievement Portion**

The hypothesis for this study is that those students who were in a project-based learning Algebra I or Geometry course will show statistically significant higher growth than students who were in a traditional-base Algebra I or Geometry course. The analyses for the achievement portion of the study were conducted using the hypotheses outlined in Table 3.4 below. All analyses conducted in the student achievement portion of this research study were performed using a 5% significance level.

<table>
<thead>
<tr>
<th></th>
<th>ALGEBRA I</th>
<th>GEOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_{0_{AlgebraI}}$; $\mu_{PBL} = \mu_{Traditional}$</td>
<td>$H_{0_{Geometry}}$; $\mu_{PBL} = \mu_{Traditional}$</td>
<td></td>
</tr>
<tr>
<td>$H_{A_{AlgebraI}}$; $\mu_{PBL} &gt; \mu_{Traditional}$</td>
<td>$H_{A_{Geometry}}$; $\mu_{PBL} &gt; \mu_{Traditional}$</td>
<td></td>
</tr>
</tbody>
</table>
Statistical Analyses Used for the Student Achievement Portion

For the student achievement portion of this research study, one participating Algebra I teacher had two of his Algebra I sections randomly assigned to use either projects as formative assessments or traditional formative assessments, one for each treatment type. Using the SAS© 9.4 code supplied in Appendix L, descriptive statistics on the pre-unit statistics examination score, the post-unit examination score, as well as the difference in those exam scores, have been supplied. A generalized linear model (GLM) analysis was conducted using treatment type as the only factor and the difference in post-unit and pre-unit exam score as the dependent variable.

For the Geometry part of the achievement portion of this research study, two Geometry sections each for two participating teachers were randomly assigned to use either projects as formative assessments or traditional formative assessments. Like for the Algebra I analysis in this achievement portion of the research study, the descriptive statistics on the pre-unit statistics examination score, the post-unit examination score, as well as the difference in those exam scores, have been supplied. Because there were expected variations in teaching delivery across both teachers, another generalized linear model analysis was conducted, but this time using teachers as blocks, the treatment type as the main factor, and the difference in pre-unit exam score and post-unit exam score as the dependent variable. An analysis of significance on main effects and interactions have been provided, followed by an analysis of effect size using Cohen’s D statistic.

General Structure for Attitudinal Portion of the Research Study

The overall research design for the attitudinal portion of this proposed study was a sequential explanatory mixed methods design. Based on the popular instrument, the Student Attitudes towards Statistics (SATS) survey developed and published by Schau (1995), a pre-unit survey was conducted on willing student participants who were permitted by their parents to take
the surveys. At the end of the statistics unit assessments, a separate but related post-unit survey was conducted on these same willing and permitted students. Unlike the achievement portion of this research study where every student was required to participate due to curricular course content, the attitudinal portion of this research study was optional, thus students or their parents could opt out of the study at any time without penalty.

The original SATS instruments developed by Schau (1995) were chosen because of their relevance to the attitudinal portion of this research study. The original SATS survey has been published in multiple, edited formats, the most popular being the SATS-36 instrument. The original SATS (1995) instrument was administered before and after an undergraduate introductory statistics course to students enrolled in varying cohorts of the course. The surveys were broken into four main scales: Affect, Cognitive Competence, Value and Difficulty. Later, the SATS-36 instrument was published and contained two additional scales beyond the four scales in the original SATS. These new added scales were Interest and Effort.

Validity analysis of the SATS-36 instrument, along with other surveys involving student attitudes towards statistics, was evaluated by Nolan, Beran, & Hecker (2012). In the Nolan et al. (2012) article, the authors revealed results of internal consistency and validity analyses on both pre-course and post-course SATS-36 surveys. Content validity in both surveys was evident due to the two additional scales. Substantive validity was evident due to the increased structural fidelity within an expectancy-value theory (EVT) framework, a key framework for this research study as well. Structural validity was evaluated using between-factor correlation analysis. It was determined that Affect/Cognitive Competence (pre and post), Affect/Difficulty (post only), Cognitive Competence/Difficulty (post only), and Value/Interest (post only) showed significant strong positive correlation (Nolan, Beran & Hecker, 2012).
Reliability analysis of the SATS-36 pre-course and post-course survey instruments (and other surveys involving student attitudes towards statistics) were also evaluated by Nolan et al. (2012). According to these authors, Cronbach’s $\alpha$ reliability analysis revealed the following statistics for the SATS-36 pre/post survey instruments: Affect (0.82/0.88), Cognitive Competence (0.78/0.93), Value (0.78/0.93), Difficulty (0.68/0.91), Interest (0.80/0.89), and Effort (0.76/0.83). Furthermore, content validity measures in SATS-36 were deemed acceptable (Nolan, Beran & Hecker, 2012). Based on these significant reliability and content validity measures, this research study used subtle variations of and edits to these instruments.

The goal of the pre-unit and post-unit surveys for this research was to retrieve valuable information about student experiences, understanding, and feelings about statistics in general, including expectations (before the unit) and impressions (after the unit) with regard to statistics in general for secondary students, which has yet to be analyzed in research. To meet this endeavor, two separate LSU Qualtrics surveys were conducted, one prior to conducting the statistics unit, the other after the statistics unit. These surveys can be found in Appendices G and H, respectively.

For the attitudinal portion of this research study, survey questions were assigned to one of four main facets (i.e. “scales”): Work Ethic, General Attitude, General Opinion, and Speculation. Each were extensions of the original SATS instruments, except that the surveys were conducted before and after a statistics unit in the Algebra I or Geometry course, not before and after an entire course in introductory statistics, as was the case with the original SATS instruments. Because reliability statistics were high for the SATS (Schau, 1995) and SATS-36 instruments (Nolan, Beran & Hecker, 2012) and content validity measures were deemed in acceptable ranges for both, small variations to the wording of the surveys were changed from “course” to “unit” for most of the survey statements in both the pre-unit and post-unit surveys in this research study. A change in
simple verbiage was not expected to significantly change content validity measures. For reliability analysis, however, moderate changes to some full statements were made to focus on secondary student respondents rather than postsecondary students, the latter of which were the targets of much of the research involving SATS and SATS-36.

As will be described later in the results, due to a very low reliability statistic, all analyses involving items within the Speculation facet were subsequently omitted from the remainder of this research study. The attitudinal questions over the remaining three of these facets on both the pre-unit survey and the post-unit survey used a five-level Likert scale, with one (1) denoting Strongly Disagree and five (5) denoting Strongly Agree. In the event that attitudinal statements appeared “negative,” reverse coding was conducted prior to analysis. With regard to the behavioral statements, the same few behavioral statements were posed before and after the statistics unit. Finally, seven statements involving categorical demographic/class variable questions, most nominal, but one ordinal and one interval in nature, were posed, namely the following: Cumulative Grade Point Average (interval), Math Course Taken (nominal), Expected Grade in that Math Course (ordinal), Classification in School (nominal), Race/Ethnicity (nominal), Gender (nominal), and Treatment Method (nominal). Appendix J details the facets and their accompanying embedded items.

Due to time constraints and students opting out of the study after initially agreeing to and being authorized to participate, focus group interviews of students regarding attitudes towards statistics had to be omitted from this research study, however individual interviews were held with two of the participating teachers. The interview questions posed to teachers can be found in Appendix M. Rich information was collected as to the individual teacher perspective regarding the plan, structure, delivery and analysis of the study as each witnessed with his or her own students.
who participated in the study. Thematic elements from these teacher interviews were coded from responses. These thematic elements better explain feedback from the teacher point of view.

**Statistical Analyses Used for the Student Attitudinal Portion**

All statistical analyses for the student attitudinal portion of this research study were performed using IBM SPSS® 25 software. Forty-seven (47) Likert scale items, six (6) behavioral-related statements (non-Likert), and seven (7) demographic/class variable statements/questions were posed. Only students who completed both pre-unit and post-unit surveys were kept for the final analysis of the student attitudinal portion of this research study. Any student who completed only one of the two surveys had their responses tossed out. In total, twenty-eight (28) students participated in the final analyses for the attitudinal portion of this research study. Since the teacher to which a participating student was enrolled was not used as a demographic/class variable statement, only the math course that the student took and the method of assessment (i.e. project-based vs traditional) were the most commonly analyzed. Of the 28 participating students, thirteen (13) were enrolled in an Algebra I course with the remaining fifteen (15) in a Geometry course. Of the twenty-eight respondents, seventeen (17) were enrolled in an Algebra I or Geometry course that utilized projects as formative assessments, with the remaining eleven (11) enrolled in an Algebra I or Geometry course that utilized traditional assessments.

New variables called question “differences” were created for each item within each facet using IBM SPSS™ 25. These new variables were calculated by taking the difference between the post-unit survey Likert-scale result and the pre-unit Likert-scale result for each student. These new variables used the naming convention “Q1Diff,” “Q2Diff,” “Q3Diff,” etc. for each of the 47 Likert-scale items within the four facets. Once these new difference variables were created for each item within a facet, four additional variables were created. These four new variables took the average
“change” in difference score for each student across all items within each facet of the attitudinal portion of the study. For example, the average “change” in attitude score (i.e. post-unit survey score less pre-unit survey score) for each of the five items in, say, the Work Ethic facet would be averaged for Student A, Student B, and using all students participating in the study. These four additional variables were labeled MeanWorkEthic, MeanGeneralAttitude, MeanGeneralOpinion, and MeanSpeculation.

Many of the major statistical analyses for the student attitudinal portion of this research study were performed using the mean differences in post-unit and pre-unit survey results, as well as the mean changes in differences in response, strictly to gauge commonalities in average “growth” in student attitudinal feedback towards work ethic, general attitude, general opinion, and speculation, as each relates to the science of statistics and its use in the Algebra I or Geometry classroom and in general. Initial analyses included Cronbach’s alpha reliability analysis to gauge internal consistency and reliability of the surveys within each facet, descriptive statistics analyses across each demographic/class variable, and crosstab analyses within each facet and across demographics/class variables to ascertain differences across levels within varying demographics. The primary statistical analyses conducted were as follows:

1.) Participant frequencies within demographic and class variables
2.) Cronbach’s alpha analysis of internal consistency and reliability on pre-unit items and post-unit items
3.) T testing on the mean average changes (i.e. differences) in attitude across all items within a facet
4.) Paired samples $t$ testing between pre-unit result and post-unit results across students and within each of the four facets
5.) Multivariate Analysis of Variance (MANOVA) using the means of mean item differences for each of the four facets as the dependent variables with each of the demographic/class variables used as the independent variable. Wilks’ Lambda analysis, using partial eta squared and including a power analysis were evaluated for each facet across all demographics. Afterwards, Box’s test for equality of covariance matrices and Levene’s test for equality of error variances (the latter to check for violations to homogeneity of variances assumptions) were conducted. Only significant overall means of items would be used for a follow-up MANOVA (see #6).

6.) Multivariate Analysis of Variance (MANOVA) on mean differences on items within each significant facet were used as dependent variables with each of the demographic/class variables used as the independent variable. Wilks’ Lambda analysis, using partial eta squared and including a power analysis were evaluated for each facet across all demographic/class variables. Afterwards, Box’s test for equality of covariance matrices and Levene’s test for equality of error variances (the latter to check for violations to homogeneity of variances assumptions) were also conducted.

7.) A confirmational Wilcoxon Signed Rank test analysis (nonparametric) on post-unit vs pre-unit items within a facet to confirm results of previous analyses and to show the percentage of “growth” vs “decay” in attitude towards statistics for significant items within each facet. To avoid inflation of Type I error rate, Bonferroni adjustment was used.

All analyses in the student attitudinal portion of this research study were conducted at the 5% experimentwise significance level and adjusted to yield individual Type I error rates by using
a Bonferroni adjustment. This Bonferroni adjustment was primarily used during both MANOVA and the Wilcoxon Signed Rank analyses.

**Teacher Interview Protocol**

Follow-up post statistics unit interviews of two individual participating teachers were conducted and thematic elements were determined and discussed. The two participating teacher interviewees included the other participating Geometry teacher, as well as an Algebra I teacher who participated in over 75% of the research study but was forced to leave the study prior to its completion due to a personal matter which required this teacher to be omitted from the remainder of the study. Since this Algebra I teacher was able to see both projects embedded in the Algebra I unit and only had to miss the final post-unit exam assessment.

The questions posed in the teacher interviews were not based on any prior research but rather developed to answer several of the research study questions. The aim of the teacher interview questions was to capture the teacher perspectives on their observations and interpretations of their respective students’ overall attitude, effort, and commitment to success in their Algebra I and Geometry courses that used projects as formative assessments compared to traditional assessment instruments, as well as potential usage of projects in future courses under their direction, in statistics units or otherwise. Based on their responses, themes have been developed.
RESULTS AND DISCUSSION

The analyses for both the student achievement and student attitudinal portions of this research study were conducted at the 5% significance level. To begin, the student achievement results are revealed first.

Achievement Portion Results and Discussion for Algebra I Course

Using SAS® 9.4 software for analysis, descriptive statistics were run on pre-unit exam scores, post-unit exam scores, and the difference in exam scores (post - pre) across treatments (project-based vs traditional, denoted PB and T, respectively) on a common summative assessment for fifty-nine (59) students enrolled in either an Algebra I course assigned to deliver traditional formative assessments or an Algebra I course assigned to use student projects as formative assessments. Both courses were led by a single participating Algebra I teacher. Figure 1 details these descriptive statistics. Based on the descriptive statistics revealed in this table, the mean pre-unit exam percentage was higher for students before the statistics unit was taught by the participating teacher than the mean post-unit exam percentage. For both treatment types, there was a reduction in mean score, although clearly less of an average reduction in exam score existed for students in the project-based assigned section of the Algebra I course. The code used to retrieve the results in SAS is supplied in Appendix L.

A generalized linear model (GLM) analysis was performed using assessment type (projects vs traditional assessments) as treatments. Since there was only one participating Algebra I teacher, there was no block effect nor interaction analysis performed. The GLM basically reduced down to
one model factor, assessment type. Figure 2 shows the results of the GLM analysis according to SAS® 9.4 output.

**Method=PB**

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre_Unit_Exam_Percentage</td>
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<td>0.2591354</td>
<td>0.233333</td>
<td>0.0937891</td>
<td>0.1000000</td>
<td>0.4333333</td>
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<td>0.1000052</td>
<td>0.0689655</td>
<td>0.5517241</td>
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<td>-0.0484195</td>
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<td>-0.3310345</td>
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**Method=T**

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</thead>
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</tbody>
</table>

Figure 1. Descriptive Statistics for Algebra I Student Achievement Portion

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<th>Source</th>
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<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
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<td>0.01737447</td>
<td>1.03</td>
<td>0.3155</td>
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<tr>
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<td>0.01693937</td>
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<td></td>
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<tr>
<td>Corrected Total</td>
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<td>0.01737447</td>
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<table>
<thead>
<tr>
<th>Method</th>
<th>Method</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Std Err</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>PB</td>
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<td>0.0340</td>
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<td></td>
<td></td>
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<td>Diff (1-2)</td>
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<td>0.0335</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Algebra I Student Achievement Output

As evidenced by the GLM output, there was no significant difference in growth (or in this case, decay) between the two treatment types (F = 1.03, p = 0.3155). While there was no real, empirical proof as to the exact reasons why this phenomenon may have occurred, it is possible that
this happened because students assigned to all Algebra I courses at the school were required to take between seven and ten days of instructional time for these students to complete mandatory, statewide end-of-course exams, in addition to being restricted from new content during a mandatory school “dead period” days just before final examinations were to be held. Because of these external factors, the statistics unit of the Algebra I curriculum could not commence until the last week of April. The unit had been slated to commence the first week of April and be allotted five full weeks of instruction, including time for formative and summative assessments, but instead the teacher was allotted a total of thirteen instructional days (2.5 weeks or half the allotted time) to complete all of the Algebra I content standards. Furthermore, Algebra I students enrolled in the Algebra I class using projects as formative assessments could only fully complete one of the two required projects. These are likely the reasons why growth in achievement scores for Algebra I students was insignificant for both treatment types.

Cohen’s D analysis for effect size, despite decay in common exam scores, was calculated by dividing the difference in group means by the pooled standard deviation. For the Algebra I part of the achievement portion of this research study, it was revealed an effect size of 0.2650, implying that there may be a small treatment effect in favor of projects, but in the context of the negative decays, this simply suggests that the projects resulted in less loss of knowledge retention on statistics course content standards than traditional assessments.

Figure 3 details the distribution of differences in pre-unit and post-unit exam scores. The differences in scores appear Normally distributed for the Algebra I students assigned projects as formative assessments but more negatively skewed for those students assigned traditional
formative assessments. The Normal Quantile plot reveals random scattering about the line, implying a relative Normal distribution.

Figure 3. Distribution, Boxplots and Normal Quantile Plots for Algebra I Exam Score Differences by Treatment
Achievement Portion Results and Discussion for Geometry Course

The structure of the Geometry student achievement portion of this research study differed from the Algebra I student achievement design because of one major factor, namely that two (2) instructors participated in the study. Because of inherent differences in instructional delivery of pre-established instructional instruments and tools, thus likely elevating variation in exam scores among students and across treatment type (projects vs traditional formative assessments), teachers were treated as fixed blocks. Analyses were conducted in the same manner as with the Algebra I student achievement analyses except that teacher and treatment main effects and teacher by treatment interactions were the primary foci of the analyses. Descriptive statistics analysis was conducted on pre-unit exam score, post-unit exam score and on the paired differences for each student. Figure 4 details the descriptive statistics for the Geometry student achievement.

Method=PB

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<tr>
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Method=T

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<th>Mean</th>
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</table>

Figure 4. Descriptive Statistics for Geometry Student Achievement Portion

A generalized linear model (GLM) analysis was performed using assessment type (projects vs traditional assessments) as treatments and teacher as a fixed block. The dependent
variable was mean growth (i.e. difference) from pre-unit exam score to post-unit exam score. Figure 5 shows the results of the GLM analysis according to SAS® 9.4 output. Using Type III sum of squares for the GLM analysis, the output in Figure 5 shows that there was no teacher effect in differences in growth in exam scores (F = 0.07, p = 0.7924) nor a teacher by treatment interaction (F = 0.88, p = 0.3511), but there was a treatment main effect (F = 4.69, p = 0.0325), implying that the use of student-developed projects as formative assessments significantly improved statistics content knowledge and higher growth on a common statistics unit summative assessment than traditional formative assessments (e.g. homework and small mid-unit quizzes). The effect size for this analysis was 0.4034, indicating a moderate effect size, in favor of the use of projects over traditional instruments as formative assessments.

For the normality assumption for this analysis, Figure 6 shows the distribution of difference in exam scores by treatment type, ignoring teacher. The histogram reveals relative Normal symmetry, but the boxplots reveal a few outlying values. The Normal Quantile plot reveals random scattering about the line, implying a relative Normal distribution with possible outliers on the upper tail for the traditional assessments.

<table>
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<tr>
<th>Source</th>
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<table>
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Figure 5. Geometry Student Achievement Output (Cont’d)
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<th>Method</th>
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</tr>
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</table>

Figure 6. Distribution, Boxplots and Normal Quantile Plots for Geometry Exam Score Differences by Treatment
(cont’d)
Attitudinal Portion Results

All analyses for the student attitudinal portion of this research study used IBM SPSS® 25 software. The attitudinal portion of the study was broken up into two main surveys, one before the statistics unit in the Algebra I or Geometry course was taught, and a similar survey after the statistics unit was taught in those math courses. Each survey consisted of four (4) main facets: Work Ethic, General Attitude, General Opinion and Speculation. In each survey, forty-three (43) statements were embedded within these four facets. Also included in each survey were seven (7) behavioral statements and seven (7) demographic/class variable questions: cumulative GPA, current math course, expected final spring semester grade in current math course, classification in school, race/ethnicity, gender, and formative assessment method used in current math class. Appendix J details brief descriptions of the statements embedded within each facet, as well as the behavioral and demographic/class variable questions/statements posed.

The variables used for the attitudinal portion of this research study included a pre-unit and post-unit question (e.g. “Q2Pre,” “Q2Post,” “Q18Pre”, “Q18Post,” etc.). Several new variables
were also created. New variables that reflected differences in common post-unit and pre-unit survey items were created using the nomenclature “Q1Diff,” for example. In all, 50 new “difference” variables were created, each one revealing the change in individual student response for the item before and after the statistics unit. Values for these “difference” variables were discrete, naturally, taking on the values of -4 through 4 only, since each item on both surveys were on the five-point Likert scale. Four (4) additional variables were created to reflect these mean “changes” from pre-unit survey to post-unit survey over items within a facet. These four new variables were labeled as follows: MeanWorkEthic, MeanGeneralAttitude, MeanGeneralOpinion, and MeanSpeculation. Most of the analyses on the attitudinal portion of this research study were conducted on the individual item “differences” within a facet or on the mean “change” in survey responses by facet. Appendix K gives a summary of the variables used for the attitudinal portion of this research study.

Participant Frequencies by Demographic/Class Variable

Tables 5 through 11 show the participant frequencies by demographic/class variable. The distribution of GPA (Table 5) was trimodal with peaks clustered around ranges 2.251-2.500, 2.751 – 3.250, and 3.501-3.750. The distribution of Math Course and School Classification (Tables 6 and 8, respectively) were both relatively uniform for participating students enrolled in an Algebra I and Geometry course. The distribution of Expected Math Grade for the Spring semester only (Table 7) was unimodal with highest frequency for “B” grade. Three times as many females participated in the attitudinal portion of this research study as males (Table 10), while sixty (60) percent of participants were enrolled in an Algebra I or Geometry course that utilized projects as formative assessments with the remaining 40% enrolled in an Algebra I or Geometry course that utilized
traditional formative assessments (Table 11). Finally, approximately 57% of respondents identified as Black or African American with roughly 32% identifying as White or Caucasian (Table 9).

Table 5. Table of Frequencies for the Class Variable – GPA

<table>
<thead>
<tr>
<th>GPA</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
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</thead>
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<td>3.6</td>
<td>3.6</td>
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<td>14.3</td>
<td>14.3</td>
<td>64.3</td>
</tr>
<tr>
<td>3.251 - 3.500</td>
<td>3</td>
<td>10.7</td>
<td>10.7</td>
<td>75.0</td>
</tr>
<tr>
<td>3.501 - 3.750</td>
<td>5</td>
<td>17.9</td>
<td>17.9</td>
<td>92.9</td>
</tr>
<tr>
<td>Greater than 4.000</td>
<td>2</td>
<td>7.1</td>
<td>7.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Table of Frequencies for the Class Variable – Math Course

<table>
<thead>
<tr>
<th>Math_Course</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Algebra I</td>
<td>13</td>
<td>46.4</td>
<td>46.4</td>
</tr>
<tr>
<td></td>
<td>Geometry</td>
<td>15</td>
<td>53.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 7. Table of Frequencies for the Class Variable – Expected Math Grade (Spring Semester)

<table>
<thead>
<tr>
<th>Expected_Math_Grade</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid A</td>
<td>8</td>
<td>28.6</td>
<td>28.6</td>
<td>28.6</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>35.7</td>
<td>35.7</td>
<td>64.3</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>28.6</td>
<td>28.6</td>
<td>92.9</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>7.1</td>
<td>7.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Table of Frequencies for the Demographic – School Classification

<table>
<thead>
<tr>
<th>School_Classification</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>15</td>
<td>53.6</td>
<td>53.6</td>
<td>53.6</td>
</tr>
<tr>
<td>Sophomore</td>
<td>13</td>
<td>46.4</td>
<td>46.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Table of Frequencies for the Demographic – Race/Ethnicity

<table>
<thead>
<tr>
<th>Race-Ethnicity</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian or Alaska Native</td>
<td>1</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Black or African American</td>
<td>16</td>
<td>57.1</td>
<td>57.1</td>
<td>60.7</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>2</td>
<td>7.1</td>
<td>7.1</td>
<td>67.9</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>32.1</td>
<td>32.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 10. Table of Frequencies for the Demographic – Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>21</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
</tr>
<tr>
<td>M</td>
<td>7</td>
<td>25.0</td>
<td>25.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 11. Table of Frequencies for the Class Variable – Treatment Method

<table>
<thead>
<tr>
<th>Method</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB</td>
<td>17</td>
<td>60.7</td>
<td>60.7</td>
<td>60.7</td>
</tr>
<tr>
<td>T</td>
<td>11</td>
<td>39.3</td>
<td>39.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Internal Consistency and Reliability Analysis

To gauge internal consistency (reliability) across survey items, Cronbach’s alpha analysis was performed on two collections of variables within each facet: pre-unit items and post-unit items, to gauge if the internal consistency remained relatively the same before and after the statistics unit. Items within each facet and across pre-unit and post-unit surveys were written in future tense and past tense. The results in Table 12 show the Cronbach’s alpha analysis. A Cronbach’s alpha value of 0.70 or higher interprets as items having good reliability within the facet for the given survey. Reliability in the Work Ethic facet was good for the pre-unit survey (0.730), but moderate for the post-unit survey (0.660). Removing question 23 from the pre-unit survey would have improved the reliability statistic to 0.816, but this question was kept as an item in the Work Ethic facet because the item was critical to the integrity of the facet. Reliability was in the good range for both pre-unit and post-unit survey items with the General Attitude facet (0.828 and 0.890, respectively). Removing items would not have improved the reliability statistic.

Reliability in the General Opinion facet was moderate for the pre-unit survey (0.636) and the post-unit survey (0.562). Removing question 10 from the pre-unit survey would have improved the reliability statistic to 0.708, but this question was kept as an item in the General Opinion facet because the item was critical to the integrity of the facet. Removing item 10 from the post-unit survey would have improved reliability to 0.619, yet doing so would have still yielded a moderate reliability result.

As evidenced in Table 12, the reliability for the Speculation facet was very poor, with post-unit survey reliability as a negative statistic (despite negative coding when necessary). In many ways, this facet was “left-over” survey items that primarily asked students to speculate on the importance of statistics to the general public and the world, both within school instruction and
beyond. This would likely be a difficult task for anyone to do, much less a teenage student. The items within the facet do seem to have worth, but given the number of items and the vast, inherent differences in the item statements alone, it is not surprising to see these results. Because of this very weak reliability, all subsequent analyses for the Speculation facet have been omitted for the remainder of the analyses in this research study. Overall, however, reliability analysis appears to show moderate to good internal consistency, except for the speculation facet.

Table 12. Cronbach’s Alpha Internal Consistency/Reliability Analysis Results

<table>
<thead>
<tr>
<th>Facet</th>
<th>Pre-Unit / Post-Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Ethic</td>
<td>0.730 / 0.660</td>
</tr>
<tr>
<td>General Attitude</td>
<td>0.828 / 0.890</td>
</tr>
<tr>
<td>General Opinion</td>
<td>0.636 / 0.562</td>
</tr>
<tr>
<td>Speculation</td>
<td>0.045 / -0.420</td>
</tr>
</tbody>
</table>

Paired t Test Analysis on Mean Item Response Change for Each Facet

Means were taken on the mean changes in responses (i.e. differences) from pre-unit survey to post-unit survey for items within the four facets. These means were expressed using the variables MeanWorkEthic, MeanGeneralAttitude, MeanGeneralOpinion, and MeanSpeculation. Figure 7 reveals that the means of differences for items in the MeanWorkEthic and MeanGeneralOpinion variables were statistically significant than 0. For MeanWorkEthic (t = -2.360, p=0.026), with a t-value of -2.360, this suggests that the average change in response on items in the facet dropped on average from pre-unit to post-unit (e.g. from more agreement to more disagreement). For MeanGeneralOpinion (t = 3.603, p = 0.001), with a t-value of 3.603, this suggests that the average
change in response on items in the facet increased on average from pre-unit to post-unit (e.g. from more disagreement to more agreement).

Figure 7. Paired t Testing on Means of Item Differences in Survey Results by facet

Paired t Test Analysis on Changes in Item Responses Within Facet

The fourth analysis conducted in the attitudinal portion was a paired samples $t$ test between pre-unit results and post-unit results across participating students and within each of the four facets. For descriptions on each item, see Appendix F. Figure 8 reveals the items within the Work Ethic facet that resulted in significant changes in results from pre-unit survey to post-unit survey. Differences on items Q16 ($t = 2.728, p = 0.011$), “Plan to Prepare Fully for Statistics Assessments,” and Q33 ($t = 3.198, p = 0.004$), “Pay Close Attention to Statistics Lessons,” showed significant differences in response within the Work Ethic facet.

Figure 9 reveals the items within the General Attitude facet that resulted in significant changes in results from pre-unit survey to post-unit survey. Differences for items Q5 ($t = 2.360, p = 0.026$), “Feel Insecure Doing Statistics Problems,” Q19 ($t = 2.870, p = 0.008$), “No Problem Presenting Statistics Projects to Non-Peer Students (Outsiders),” and Q37 ($t = -6.715, p = 0.000$),
“Ability to Learn Statistics” showed significant differences in response for the General Attitude facet.

**Paired Samples Test**

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval Lower</th>
<th>95% Confidence Interval Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q16Post - Q16Pre</td>
<td>.786</td>
<td>1.524</td>
<td>.288</td>
<td>.195</td>
<td>1.377</td>
<td>2.728</td>
<td>27</td>
<td>.011</td>
</tr>
<tr>
<td>Q33Post - Q33Pre</td>
<td>.714</td>
<td>1.182</td>
<td>.223</td>
<td>.256</td>
<td>1.173</td>
<td>3.198</td>
<td>27</td>
<td>.004</td>
</tr>
</tbody>
</table>

Figure 8. Paired t Test Results for Work Ethic Facet on Changes in Response

**Paired Samples Test**

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval Lower</th>
<th>95% Confidence Interval Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5Post - Q5Pre</td>
<td>.536</td>
<td>1.201</td>
<td>.227</td>
<td>0.070</td>
<td>1.002</td>
<td>2.360</td>
<td>27</td>
<td>.026</td>
</tr>
<tr>
<td>Q19Post - Q19Pre</td>
<td>.857</td>
<td>1.580</td>
<td>.299</td>
<td>0.244</td>
<td>1.470</td>
<td>2.870</td>
<td>27</td>
<td>.008</td>
</tr>
<tr>
<td>Q37Post - Q37Pre</td>
<td>-1.286</td>
<td>1.013</td>
<td>.191</td>
<td>-1.679</td>
<td>-0.893</td>
<td>-6.715</td>
<td>27</td>
<td>.000</td>
</tr>
</tbody>
</table>

Figure 9. Paired t Test Results for General Attitude Facet on Changes in Response

**Paired Samples Test**

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval Lower</th>
<th>95% Confidence Interval Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q13Post - Q13Pre</td>
<td>-1.393</td>
<td>1.548</td>
<td>.292</td>
<td>-1.993</td>
<td>-.793</td>
<td>-4.762</td>
<td>27</td>
<td>.000</td>
</tr>
<tr>
<td>Q22Post - Q22Pre</td>
<td>.464</td>
<td>1.170</td>
<td>.221</td>
<td>.011</td>
<td>.918</td>
<td>2.100</td>
<td>27</td>
<td>.045</td>
</tr>
<tr>
<td>Q24Post - Q24Pre</td>
<td>.500</td>
<td>.745</td>
<td>.141</td>
<td>.211</td>
<td>.789</td>
<td>3.550</td>
<td>27</td>
<td>.001</td>
</tr>
</tbody>
</table>

Figure 10. Paired t Test Results for General Opinion Facet on Changes in Response

Figure 10 reveals the items within the General Opinion facet that resulted in significant changes in results from pre-unit survey to post-unit survey. Differences for items Q13 (t = -4.762, p = 0.000), “Understanding Statistics in Lower Level Math Class will be Easy,” Q22 (t = 2.100, p

**MANOVA on Mean Item Differences for Facets by Demographic/Class Variable**

Using the four main facets in the attitudinal portion of this research study, a multivariate analysis of variance (MANOVA) was performed using each of the seven demographic/class variable questions/statements posed in both the pre-unit and post-unit surveys as the respective independent variables and the means of difference scores for items within each facet as dependent variables. The assumptions for a MANOVA include randomly and independently sampled observations, equal population covariance matrices, dependent variables that are at the interval level of measurement, and all dependent variables are multivariate normally distributed. For this study, assumption 1 is presumed random based on the random placement of students into sections of Algebra I and Geometry courses by guidance and administration departments and without the input of participating students nor teachers.

For the second assumption, Box’s tests of equality of covariance matrices were analyzed for homogeneity of covariance matrices across the dependent variables within a facet. A significant result on the Box test implied that at least one of the dependent variable covariance matrices were significantly different than the other covariance matrices. For the third assumption, the scales used in the survey are indeed Likert scales, and while these scales are “technically” ordinal, many of the scaled surveys used in social science research treat these scales as interval instead of ordinal for research and publishing purposes, even at the suggestions of many social science journal peer reviewers. Finally, for the fourth assumption, the dependent variables are multivariate normally distributed. Figure 11 details the multivariate normality distribution for the Work Ethic, General
Attitude and General Opinion facets. Based on the distributions in Figure 12, there do not appear to be any clear patterns, only random scattering of the residuals about the line.

**Mean Work Ethic**

![Normal Q-Q Plot of MeanWorkEthic](image1)

![Detrended Normal Q-Q Plot of MeanWorkEthic](image2)

**Mean General Attitude**

![Normal Q-Q Plot of MeanGeneralAttitude](image3)

![Detrended Normal Q-Q Plot of MeanGeneralAttitude](image4)

**Mean General Opinion**

![Normal Q-Q Plot of MeanGeneralOpinion](image5)

![Detrended Normal Q-Q Plot of MeanGeneralOpinion](image6)

Figure 11. Q-Q Plots for Multivariate Normality Distribution Assumption in MANOVA

Wilks’ lambda statistic, a measure of the percent variance in dependent variables not explained by differences in levels of the independent variable (in this case, each particular demographic/class variable), were analyzed using partial eta squared values, along with the observed power for the analysis. A significant p-value in Wilks’ lambda analysis suggests that there
is a significant effect that varying levels of the independent variable have on the three mean changes in responses for all three facets (recall Speculation facet has been omitted).

Finally, a Levene’s test of equality of error variances was performed to check homogeneity of variances assumption. A significant Levene’s test results suggests that one or many of the dependent variables (here, the mean changes in response for the, now, three facets) have a different variance than the other dependent variables. Figure 12 gives the results for these analyses above for each demographic/class variable and across each of the four mean changes in response per facet.

Based on the MANOVA results shown in Figure 12, Box’s test reveals that the only demographic/class variables with common covariance matrices across the four mean changes in response per facet were cumulative GPA, Expected Math Grade (in the Spring semester only), Gender, and Treatment Method. Since the other three demographic/class variables (Math Course, School Classification, and Race/Ethnicity) violated the third MANOVA assumption, they were disregarded for this analysis. For the remaining four demographic/class variables, partial eta squared of Wilks’ lambda analysis revealed insignificance effects that the varying levels of GPA, Expected Math Grade (in Spring semester only), and Gender; however, significance was revealed with regard to Treatment Method (projects vs traditional formative assessments), the latter being the primary focus of this entire research study.

Also shown in Figure 12, the Levene’s test of homogeneity of variance revealed that for all four mean changes in response as it relates to the class variable Treatment Method, the variances across levels of the treatment method class variable (two total) were non-significant, thereby adhering to the homogeneity of variances across the three facets (i.e. dependent variables). In summary, this MANOVA revealed that the demographic/class variable with the most significant
change in response across all items within each of the four facets was Treatment Method, which had equal covariance matrices across all levels (Box analysis), equal variances among the four dependent variables collectively, and a significant partial eta squared for the Wilks’ lambda analysis.

<table>
<thead>
<tr>
<th>Demographic/Class Variable</th>
<th>Box’s Test for Equality of Covariance Matrices</th>
<th>Wilks’ Lambda Partial Eta Squared (P-value)</th>
<th>Observed Power</th>
<th>Levene’s Test Significant Means (Facet)</th>
<th>Levene’s Test Significant Means P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPA</td>
<td>0.422</td>
<td>0.364 (p = 0.266)</td>
<td>0.800</td>
<td>MeanGeneralOpinion</td>
<td>0.026*</td>
</tr>
<tr>
<td>Expected Math Grade</td>
<td>0.477</td>
<td>0.154 (p = 0.266)</td>
<td>0.429</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Gender</td>
<td>0.069</td>
<td>0.063 (p = 0.969)</td>
<td>0.073</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Method</td>
<td>0.100</td>
<td>0.425 (p = 0.010*)</td>
<td>0.862</td>
<td>None</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Figure 12. MANOVA Results on Mean Changes in Response per Item Within Facets (* = significance at 0.05 level)

Figure 13 shows a more focused attention on the Treatment Method class variable and on which facets the varying levels of the Treatment Method class variable had on significant mean changes in collective item responses from pre-unit survey to post-unit survey. Figure 13 revealed that for the Treatment Method class variable, after Bonferroni adjustment, there is a mean significant difference in average response change (pre-unit survey to post-unit survey) for the Work Ethic category/scale items only, as evidence by the p-value of 0.001 (partial eta squared was 0.372 with observed power of 0.965). Post hoc analyses on these individual differences using Fisher’s LSD analyses also were not possible due to one race/ethnicity having fewer than two individuals, thereby creating an issue with degrees of freedom within the analysis.
This MANOVA analysis highlighted the significance of varying demographic/class variables on mean changes in response differences across all items collectively within a facet.

**MANOVA on Item Differences Within the Facets by Demographic/Class Variable**

Using the items within each of the four main facets in the attitudinal portion of this research study, a follow-up multiple analysis of variance (MANOVA) was performed using each of the seven demographic/class variable questions/statements posed in both the pre-unit and post-unit surveys as the respective independent variables and the actual difference scores for each items
within each facet as the dependent variables. Like for the MANOVA on means of differences across facets, this MANOVA also analyzed Wilks’ lambda (using partial eta squared and observed power), Levene’s test for homogeneity of variance, and if a demographic/class variable revealed a significant partial eta squared within Wilks’ lambda, a follow-up between-subjects analysis on the items within a facet are supplied. Box’s tests of equality of covariance matrices were omitted because many had non-singular covariance matrices, so these statistics were not supplied by the SPSS® 25 software. The results of this MANOVA has been supplied for only those demographic/class variables which met all of the MANOVA assumptions and had significant results.

<table>
<thead>
<tr>
<th>Class Variable</th>
<th>Partial Eta Squared Value (P-value)</th>
<th>Observed Power</th>
<th>Levene’s Test Significant Item Differences (within Facet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>0.570 (p = 0.001*)</td>
<td>0.974</td>
<td>Q23Diff (p = 0.044*)</td>
</tr>
</tbody>
</table>

Figure 14. MANOVA on Differences in Response for Each Item within the Work Ethic Facet (* = significance at 0.05 level)

Figure 14 shows that only the Treatment Method class variable for the Work Ethic facet items revealed significant Wilks’ lambda results (partial eta squared = 0.570 with p = 0.001) across all items within the Work Ethic facet. Item Q23 did have a variance significantly different that the other four items in the Work Ethic facet. The results of Table 14 confirm that there is a positive difference (i.e. “growth”) between pre-unit and post-unit responses for the Treatment Method class variable. Once again, diving deeper into the actual item differences within the Work Ethic facet, the Treatment Method class variable is proving to show the most significant changes in student attitude.

Figure 15 shows the between-subjects significant items within the Work Ethic facet. Q16Diff shows a partial eta squared value of 0.209 (p = 0.014) and an observed power of 0.713,
while Q23Diff shows a partial eta squared value of 0.463 (p = 0.000) and an observed power of 0.995, suggesting that there is a significant improvement in attitude based on the method used.

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent Variable</th>
<th>Type III Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Noncent. Parameter</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Q2Diff</td>
<td>.734</td>
<td>1</td>
<td>.734</td>
<td>3.726</td>
<td>.065</td>
<td>.125</td>
<td>3.726</td>
<td>.460</td>
</tr>
<tr>
<td></td>
<td>Q3Diff</td>
<td>.497</td>
<td>1</td>
<td>.497</td>
<td>2.089</td>
<td>.160</td>
<td>.074</td>
<td>2.089</td>
<td>.286</td>
</tr>
<tr>
<td></td>
<td>Q16Diff</td>
<td>13.110</td>
<td>1</td>
<td>13.110</td>
<td>6.872</td>
<td>.014</td>
<td>.209</td>
<td>6.872</td>
<td>.713</td>
</tr>
<tr>
<td></td>
<td>Q23Diff</td>
<td>16.062</td>
<td>1</td>
<td>16.062</td>
<td>22.389</td>
<td>.000</td>
<td>.463</td>
<td>22.389</td>
<td>.995</td>
</tr>
<tr>
<td></td>
<td>Q33Diff</td>
<td>1.479</td>
<td>1</td>
<td>1.479</td>
<td>1.061</td>
<td>.312</td>
<td>.039</td>
<td>1.061</td>
<td>.168</td>
</tr>
</tbody>
</table>

Figure 15. Between-Subject Item Effects for Differences in Responses in Treatment Method Class Variable Among Items in Work Ethic

With regard to the new MANOVA information for the General Attitude facet, none of the demographic/class variable independent variables yielded significant partial eta squared statistics in Wilks’ lambda analysis of the MANOVA on the items within the General Attitude and General Opinion facets of the attitudinal portion of the research study. Furthermore, several of the items within the General Attitude facet had unequal variances, violating the required homogeneity of variances assumption.

In summary, the only significant predictor for the MANOVA analysis across items within facets was the Treatment Method class variable (projects as formative assessments vs traditional formative assessments). The reason for this minimal amount of significance across most demographics within both MANOVAs was most likely due to the number of students who participated in the pre-unit survey and post-survey (28). Often when situations involving small sample sizes arise, parametric analysis often yields insignificant results. Instead, nonparametric analysis usually assists in taking a closer inspection at any expected differences. Because the attitudinal portion of this research study had a minimal number of participants, and the goal of the
study was to gain more understanding on “growth” in student attitudes towards statistics, I performed a Wilcoxon Signed-Rank nonparametric analysis.

*Wilcoxon Signed Rank Test Analysis Results*

Generally used with matched or paired data, the Wilcoxon Signed Rank nonparametric test is based on difference scores and analyzes the signs of the differences, considering also the magnitude of the observed differences. For the attitudinal portion of this research study, I chose to confirm results from paired *t* test analysis on mean changes in response for each of the four facets by also performing a Wilcoxon signed rank test within each of the facets. The purpose of this test was to gauge the items within each facet to understand which items revealed significant positive or negative growth in attitude before the statistics unit and after the statistics unit. Generally, nonparametric analysis is performed on non-normally distributed data. The added benefit of performing a Wilcoxon signed rank test is that it does not require multivariate normality nor homoscedasticity and thus is more robust than a paired *t* test.

Three assumptions must hold true in order to perform the Wilcoxon Signed Rank test. First, the dependent variable must be ordinal or continuous. Second, the independent variable must consist of two categorical or matched pairs groups. Finally, the distribution of the differences of these matched pairs must be symmetrical in shape. The dependent and independent variables used in this analysis of this research study meet the first two assumptions. To check the third assumption, distributions were taken on each of the items within the Work Ethic, General Attitude, and General Opinion facets, respectively, as well as on the distribution of the mean difference in responses across all items within these facets (i.e. on MeanWorkEthic, MeanGeneralAttitude, etc.). Figure 16 shows the distributions of the differences in pre-unit survey and post-unit survey responses for each item within the Work Ethic facet, as well as the mean difference in response across all of
these items within the Work Ethic facet, collectively. With the exception of Q23Diff, all of the other item differences and the mean difference of all five items appeared to be relatively symmetric in shape, so the Wilcoxon Signed Rank Test was performed on the Work Ethic items.

Figure 17 reflects the significance of attitudinal changes for the five items within the Work Ethic facet. Specifically, items Q16 (“Plan to Prepare Fully for Statistics Assessments”) and Q33 (“Pay Close Attention to Statistics Lessons”) had test statistics of $z = -2.360$ ($p = 0.017$) and $z = -2.722$ ($p = 0.006$), respectively, but after Bonferroni adjustment, the individual Type I error rate used was $0.05/5 = 0.01$, thus Q33 was the only significant result in the General Attitude facet. This is troubling because given the nature of the item statements (see Appendices D and E), perhaps student work ethic subsided rather than increased. Considering the students assigned to the varying

![Figure 16. Symmetry Assumption Check of Work Ethic for Wilcoxon Signed Rank Test (cont’d)](image)
assessments within the Algebra I and Geometry classes, the method of assessment was not shown.

**Test Statistics**

<table>
<thead>
<tr>
<th></th>
<th>Q2Post - Q2Pre</th>
<th>Q3Post - Q3Pre</th>
<th>Q16Post - Q16Pre</th>
<th>Q23P - Q23Pre</th>
<th>t - Q33Pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Z )</td>
<td>.816(^{b})</td>
<td>1.134(^{b})</td>
<td>2.380(^{b})</td>
<td>.983(^{c})</td>
<td>2.722(^{b})</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.414</td>
<td>.257</td>
<td>.017</td>
<td>.325</td>
<td>.006</td>
</tr>
<tr>
<td>(2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

a. Wilcoxon Signed Ranks Test  
b. Based on positive ranks.

g. Q16Post < Q16Pre  
h. Q16Post > Q16Pre  
m. Q33Post < Q33Pre  
n. Q33Post > Q33Pre  
o. Q33Post = Q33Pre  

<table>
<thead>
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<th></th>
<th>( N )</th>
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<tbody>
<tr>
<td>Q16Post - Q16Pre</td>
<td>Negative Ranks</td>
<td>15(^{a})</td>
<td>10.20</td>
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<tr>
<td></td>
<td>Positive Ranks</td>
<td>4(^{b})</td>
<td>9.25</td>
</tr>
<tr>
<td></td>
<td>Ties</td>
<td>9(^{b})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Q33Post - Q33Pre</td>
<td>Negative Ranks</td>
<td>15(^{m})</td>
<td>9.77</td>
</tr>
<tr>
<td></td>
<td>Positive Ranks</td>
<td>3(^{m})</td>
<td>8.17</td>
</tr>
<tr>
<td></td>
<td>Ties</td>
<td>10(^{m})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

g. Q16Post < Q16Pre  
h. Q16Post > Q16Pre  
m. Q33Post < Q33Pre  
n. Q33Post > Q33Pre  
o. Q33Post = Q33Pre  

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<th>Sum of Ranks</th>
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<td>8.17</td>
</tr>
<tr>
<td></td>
<td>Ties</td>
<td>10(^{m})</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

c. Based on negative ranks.

Figure 17. Significant Items in Work Ethic from Wilcoxon Signed Rank Analysis

Figure 18 shows the distributions of the differences in pre-unit survey and post-unit survey responses for each item within the General Attitude facet, as well as the mean difference in
response across all items within the General Attitude facet, collectively. Except for Q14Diff and Q19Diff, all of the other item differences and the mean difference of all five items appeared to be relatively symmetric in shape, so the Wilcoxon Signed Rank Test was performed on the General Attitude items.

In Figure 19, involving items from the General Attitude facet, items Q5 (“Feel Insecure Doing Statistics Problems”), Q19 (“Problem Presenting Statistics Projects to Non-Peer Students (Outsiders)”), and Q37 (“Ability to Learn Statistics”) had test statistics of \( z = -2.204 \) (\( p = 0.027 \)), \( z = -2.679 \) (\( p = 0.007 \)), and \( z = -4.413 \) (\( p = 0.000 \)), respectively, but after Bonferroni adjustment, the individual Type I error rate used was \( 0.05/19 = 0.0026 \), thus Q37 was the only significant result in the General Attitude facet. Given the nature of the statements (see Appendices D and E), this is much more enlightening than was the case with the Work Ethic facet significant items because the statistics suggest that, on average, student general attitudes towards statistics increased after exposure to statistics in the Algebra I or Geometry courses.

![General Attitudes](image)

Figure 18. Symmetry Assumption Check of General Attitude for Wilcoxon Signed Rank Test (cont’d)
(cont’d)
### Test Statistics

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<th>Q37Post - Q37Pre</th>
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<td>-2.679&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-4.413&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>Asymp. Sig. (2-tailed)</td>
<td>.027</td>
<td>.007</td>
<td>.000</td>
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a. Wilcoxon Signed Ranks Test  
b. Based on negative ranks.  
c. Based on positive ranks.

### Ranks

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<td>13.64</td>
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<td>Total</td>
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</tbody>
</table>

Figure 19. Significant Items in General Attitude from Wilcoxon Signed Rank Analysis

Figure 20 shows the distributions of the differences in pre-unit survey and post-unit survey responses for each item within the General Opinion facet, as well as the mean difference in response across all items within the General Opinion facet, collectively. With the exception of Q24Diff, all of the other item differences and the mean difference of all five items appeared to be relatively symmetric in shape, so the Wilcoxon Signed Rank Test was performed on the General Opinion items.
Figure 20. Symmetry Assumption Check of General Opinion for Wilcoxon Signed Rank Test (cont’d)
In Figure 21, involving items from the General Opinion facet, items Q13 (“Understanding Statistics in Lower Level Math Class will be Easy”), Q22 (“Expect to Use Statistics in Daily Life”), and Q24 (“Enjoy Learning Statistics in Math Class”) had test statistics of $z = -3.497$ ($p = 0.000$),
z = -1.998 (p = 0.046), and z = -2.985 (p = 0.003), respectively, but after Bonferroni adjustment, the individual Type I error rate used was 0.05/13 = 0.0038, thus Q13 was the only significant result in the General Opinion facet. Student general opinions subsided rather than increased, which is consistent with the typical worldwide opinion towards statistics – that many people fear statistics and still do not realize the importance of analytics in the world today. This just strengthens the argument that it is vital that school systems continue to teach statistics at earlier years in school.

### Test Statistics

<table>
<thead>
<tr>
<th></th>
<th>Q13Post - Q13Pre</th>
<th>Q22Post - Q22Pre</th>
<th>Q24Post - Q24Pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Z )</td>
<td>-3.497&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.998&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-2.985&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.000</td>
<td>.046</td>
<td>.003</td>
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</table>

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

### Ranks

<table>
<thead>
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<th></th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
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<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
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<td>29.00</td>
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</tr>
<tr>
<td>Total</td>
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<tr>
<td>Q22Post - Q22Pre</td>
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<td></td>
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<td>Total</td>
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<tr>
<td>Q24Post - Q24Pre</td>
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<td>Negative Ranks</td>
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<td>28.50</td>
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<tr>
<td>Positive Ranks</td>
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<td>10.09</td>
<td>161.50</td>
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<tr>
<td>Ties</td>
<td>9</td>
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<tr>
<td>Total</td>
<td>28</td>
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<td></td>
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</tbody>
</table>

Figure 21. Significant Items in General Opinion from Wilcoxon Signed Rank Analysis

Thus far, all analyses have focused on the student perspective. What about from the teacher perspective? Were there certain elements of the unit troublesome to students from the teacher
perspective? Were projects indeed better formative assessment instruments than traditional ones? An interview was conducted on two of the participating teachers involved in this study. Appendix J details the questions posed in the interviews held with these two teachers. The themes established from their responses have been supplied.

Teacher Interview Results

Two individual interviews were conducted on teachers who participated in this research study using the questions posed in Appendix J. Participating teachers first were asked if their students’ interest in and statistics were increased after the statistics unit was taught. Both teacher respondents stated that their students were able to make connections to real-world applications and that projects, specifically, piqued student curiosity and interest. When asked if the statistics unit increased student confidence in statistics, one teacher claimed that her students had never been exposed to statistics, but after the statistics unit, the students seemed much more confident. The other teacher stated that the basics of descriptive statistics was the only topic about which his students felt confident.

The two teachers then were asked about the elements of the statistics unit that was liked and disliked most by their respective students. Both teachers stated that the students assigned projects much more enjoyed the statistics unit, however the lectures were considered “lengthy, boring, and very time-consuming.” When asked if presentation slides were helpful, both teachers said that they were informative, but students had a hard time paying attention due to the number of lecture slides required to cover the content material in the statistics unit and the “wordiness” of the slides.

The next series of questions posed to both participating teachers involved their respective classes that used traditional formative assessments. When asked how students seemed to respond
to quizzes and homework as formative assessments, teachers claimed that, as expected, students who completed assigned homework seemed to do significantly better on quizzes than those who did not complete assigned homework. However, quizzes were deemed as tedious and “extra work.” Regarding the assigned homework itself, teachers maintained that students are used to this type of formative assessment, so students seemed to do very well.

When asked her personal opinion about students using traditional assessments to learn statistics in her Algebra I course, she stated the following:

I think the assessment structure for learning statistics was cumbersome. To be successful students had to commit various formulas (some quite complex) and new concepts to memory without ample time and accessibility to practice thoroughly. I think due to these reasons students in the traditional structure tended to be more stressed by assessments because they had quizzes, homework, and a test. I think this took out the more fun and relatable aspects that statistics has the potential to benefit from.

The above quotation seems to capture what I believe makes projects as formative assessments so powerful – traditional assessments inundate students with task after task after task. The students, then, grow tired and, eventually, apathetic.

When asked if their students liked the traditional assessments, both teachers stated that the amount of work was “too much” and that the students are always taking tests throughout the year. The quiz and homework supplied within the traditional assessment treatment just added to the stress that students had been experiencing all year. As the other teacher so eloquently stated,

…students don’t enjoy any type of traditional formative assessment. Homework is tedious, and quizzes/exams are stressful. They are willing to work hard during class but trying to get them to complete homework or study outside of the classroom is challenging. They very much dislike traditional formative assessments and resist them as much as possible.

When asked if he prefers to assign traditional formative assessments in his course, this teacher asserted that traditional formative assessments are a necessary evil, and when given the opportunity to assign small group activities and projects and interactive competitions and games, he does so. This teacher also stated that the lecture materials were well-aligned with the assigned traditional formative assessments and both the pre-unit and post-unit examinations. Timing of the
statistics unit in the school year was also problematic, as both teachers felt as if they were “cramming” to get all of the lecture content taught in the few weeks left in the school year (two to five weeks, depending on the course). State and district standardized exams indeed jeopardized the successful completion of the unit in timely fashion.

The next series of questions posed to the two participating teachers involved their respective Algebra I and Geometry class sections that were randomly assigned to use projects as formative assessments. One teacher stated that projects assigned as formative assessments were innovative and student-centered in nature, which increased student motivation and learning of the content, since they could learn at their own pace. Regarding collaborations in group projects, students were afforded the opportunity to encourage and to challenge each other which, in turn, assisted in increasing learning and participation.

The most powerful question posed to both participating teachers resulted in the most powerful responses. When asked about their personal feelings about the use of projects as formative assessments in their class, the responses truly reflect the power of practical application of content. The individual, participating teachers stated the following, respectively:

My students loved the project-based structure. Many students in this group were uninterested in the lectures and did not pay attention. They didn't learn much in class. Once they began their projects, they understood what they needed to learn and why. That is when the real learning began. I think this is a much better way of teaching. There was less stress for the students, they enjoyed themselves more, and they learned more this way than the students did in the traditional structure.

I enjoyed this [project] structure because it gave the students the ability to go out into the real-world with a topic of their own interest and apply the statistics directly. Many times as a math teacher you are asked "When will I ever use this in real life?". The project answers that question directly.”

When asked if their students assigned to projects enjoyed the projects themselves, both teachers responded similarly, saying that their students loved having the opportunity to develop a project that met the curricular standards and requirements outlined in the project grading rubric (see Appendix C), but even more so because “they were able to work with their peers, talk about
similar interests, and then go explore…they were very engaged and enjoyed the change of pace from the traditional math structure.”

Both teachers maintained that project-based assessments are much better in that they seem to “reduce stress, lower anxiety, and lead to more engagement and peer interaction.” The projects also offer students a way to realize their mistakes at the end of the project because they presented their flawed designed studies in front of their other peers. A learning process then commences, as students can ask questions of each other, provide suggestions. These are the true goals of any classroom – to actively encourage and promote collaboration and peer discussion.

When asked if both teachers thought that their students may be interested in taking a full Statistics course in high school, both commented that very few students want to take the current required math courses, so the number of students opting to take an upper-level mathematics elective would likely be minimized. However, if most, if not all, mathematics courses operated using project-based learning, then there likely would be a much better chance for more students to desire to take a full statistics course in high school.

Upon being asked if the participating teachers might incorporate more projects into their future mathematics courses, both emphatically affirmed that they both would indeed do so. When asked if they would suggest project-based learning to colleagues who may not have attempted the use of projects as assessments, both participating teachers stated that the natural higher student engagement provided by projects naturally translates to higher learning.

According to both teachers, the downside to projects as formative assessments is that they are not structured in such a way as to prepare students for the structures of state and district standardized examinations. Otherwise, the projects are an extremely useful assessment tool to advance learning of statistics and from a practical standpoint.
The final question posed to both participating teachers asked each teacher to rate their experiences with traditional versus project-based learning as a formative assessment tool. The first teacher stated “I had a good experience with both of these models. I think the slides could be made more applicable to a high school environment rather than a college lecture.” The other teacher compared the benefits and pitfalls of both traditional and project-based learning.

It was very interesting to see the differences between the two groups while teaching them the same material. The project-based group learned significantly more than the traditional group. The attitudes of the project-based group were infinitely better than those of the traditional group. Benefits of traditional: less likely to get away with cheating, more prepared for the format of the LEAP test, easier and faster to grade since there is an answer key. Benefits of project-based: less test anxiety, greater content mastery, more interesting for the teacher to grade. Pitfalls of traditional: higher levels of anxiety in students, no opportunity for students to self-correct during assessments, poor attitudes. Pitfalls of project-based: less preparation for standardized testing format, higher risk of students cheating, more subjective to grade so use of a rubric would be required. I’m not sure there is a perfect model for teaching any content, but perhaps a blend of project-based and traditional assessments would be best.

The major themes resulting from the two teacher interviews seem to be as follows:

1.) Teachers recognize the value and application opportunity for engagement that projects have on students.

2.) Teachers believe that projects are less stressful on students, but due to student inexperience with projects, the projects will likely be viewed as just another “task.”

3.) If more teachers across disciplines would assign more student-centered assessments, like projects, student comfort and ability levels may improve.

4.) Whether good or bad, traditional assessment use is easier because it is the common practice.

5.) Standardized testing is not structured well with a project-based learning format, which is a possible reason why projects are not nearly used as much as possible.
In summary, even from the teacher perspective, it seems evident that project-based assessments are much more engaging, enlightening, and certainly less stressful on the typical student than traditional formative assessments. Furthermore, projects naturally provide student-centered learning and student-led instruction through presentations, which is critical for education forward into the 21st century.
SUMMARY AND CONCLUSIONS

This research study comprised of two main portions. The first part of the study focused on student achievement and sought to understand if projects used as formative assessments increased student mastery of relevant statistics content as it related to the curriculum of an Algebra I or Geometry course more so than traditional formative assessments did. The second part of this research study concentrated on understanding the growth or “change” in student attitudes towards statistics before the statistics unit of these math courses and, again, after the unit was taught.

For the achievement portion of the study, the study looked at achievement in two sections of an Algebra I course with one participating teacher, and four separate sections of a Geometry course using two participant teachers. The results of the Algebra I part of the achievement portion of this study revealed that treatment method (i.e. projects vs traditional assessments) was an insignificant factor in student achievement. It is likely that the reasons for these insignificant results were based on external factors beyond the control of the study, for example, reduced time due to “other” student requirements such as required state and district-mandated standardized testing exams which took students out of the classroom. More time and better controls might have improved these results.

For the Geometry sections used in the achievement portion of this study, it was revealed that treatment method indeed had a significant effect on student achievement in the statistics unit of the Geometry course. The Geometry sections were not subject to as many external factors as their fellow Algebra I sections. Using participating teachers as blocks, the results showed no teacher by method interaction. These results help to provide sufficient answers to the first research question that I proposed for this study, that project-based learning (PBL) indeed seems to improve
student knowledge of basic statistics curricular standards as opposed to more conventional (i.e. traditional) methods when the content is first introduced in an Algebra I or Geometry course. However, given that there are many potential external factors that can prove problematic to the flow and delivery of the content of the statistics unit, which typically is taught at the end of a standard Algebra I or Geometry course, it is best to reserve final judgment until more sections across many teachers and within many schools can participate in a similar, yet grander study. The use of more Algebra I and Geometry sections across several schools and using more participating teachers, then, likely would show even more significant factors.

With respect to the attitudinal portion of the study, Cronbach’s alpha reliability analysis on both the pre-unit and post-unit surveys gauging attitudes towards statistics showed moderate to good internal consistency. Coupling the mean item “changes” in response from pre-unit survey to post-unit survey within each of the four facets, Work Ethic, General Attitude, and General Opinion only, performing paired $t$ test analysis yielded significant results for the Work Ethic and General Opinion facets. The test statistics for these facets were negative and positive, respectively, implying that attitudes tended to become more to the negative side for the Work Ethic facet (i.e. after the statistics unit), while the student attitudes for the General Opinion facet tended to increase after the statistics unit. Said differently, students seemed to realize the power and impact that statistics have on the world. This conclusion falls directly in line with the second research question, by revealing that student attitudes are indeed affected for the better (i.e. improved) when students are exposed to basic, statistics in lower-level mathematics courses.

Additional paired $t$ test analysis on items within each facet revealed that specific statements showed significant “growth” in student attitudes toward statistics, before and after the statistics unit. The results of the paired $t$ test analyses answered the third research questions and showed
that student attitudes related to the work ethic necessary to be successful, as well as a general opinion about the value and practicality of statistics to the world is improved when statistics is first introduced in lower-level mathematics course, and even more so when the mathematics course utilizes projects as formative assessments. In some ways, students’ attitudes towards statistics improved after the statistics unit. While for some facets and items within them, the attitude towards statistics regressed, likely due to the rigors of the content, the pressure to finish within an allotted time frame, and students ready to end the school year was certainly an external factor that should be considered in future extensions and replications of this research study.

MANOVA analysis conducted in the attitudinal portion of this research study revealed that Race/Ethnicity was a significant predictor with regard to mean changes in attitudes within the General Attitudes facet, suggesting that there were differences in changes in attitudes across races and ethnicities, however the covariance matrices were unequal, thus violating a major assumption for the MANOVA. This analysis also revealed that the treatment method used (i.e. projects vs traditional formative assessments) significantly changed attitudes towards statistics within the Work Ethic facet, suggesting that more work and commitment was necessary for one treatment type than the other, with more commitment and work ethic lent to the projects than with traditional formative assessments.

Wilcoxon signed rank analysis confirmed that certain items within each facet showed significant changes in attitude from pre-unit survey to post-unit survey, some as expected, others more surprisingly against expectation. The external factors surrounding the study were likely the cause for such results.

Finally, the individual participating teacher interview results revealed that projects are much more preferred type of assessment, simply because of the inherent opportunities for students
to collaborate to design practical projects that meet curricular and grading rubric requirements. Traditional assessments, while clearly more commonplace, prove to make students more apathetic to content, statistics-related or otherwise. The rich feedback attained in the teacher interviews certainly answered the fourth and fifth research questions, respectively.

The results of this study show that a more focused, deeper inspection into the use of projects as formative, and even summative, assessments would be rich in value. Expanding the study to more than simply Algebra I and Geometry would also provide a plethora of information useful in rewriting statistics curriculum into lower-level, secondary mathematics courses.
STUDY LIMITATIONS AND FUTURE IMPLICATIONS

This research study was riddled with a multitude of problems from the onset. First, the time-frame allotted for the statistics unit proposed by the College Board® SpringBoard curriculum for both Algebra I and Geometry are approximately five to six weeks. While the Geometry classes in this research study were allotted nearly all of those weeks (five, to be exact), the Algebra I classes were only allotted just under three weeks. For this reason, much of the Algebra I analyses were minimized. While traditional formative assessments (e.g. homework, quizzes, etc.) could easily be assigned, project assignments were minimized, primarily because it became very difficult for Algebra I students assigned to a section using projects to be taught content lectures covering five weeks’ worth of material, plus have students design projects meeting the curricular and grading rubric requirements, then submit prospectuses and develop presentations based on their design and analysis of a real-world situation, all in three total weeks, proved too much.

This study would be perfect if the statistics unit were moved from being taught as the last unit of the year to being taught as the first unit at the beginning of the school year. The statistics unit in most high school mathematics courses does tie into other math topics taught in those math courses during the year, however rather than treating the statistics unit as a “follow-up,” perhaps it should be considered a “teaser.” If teachers of statistics and mathematics can encourage districts to allow for the unit to be moved to the beginning of the curriculum, any “loose ends” that need tying in later can certainly happen as other units are covered later in the year. Moving the statistics unit to the beginning of the year would allow for a full six-week unit that would not be nearly as interrupted by external factors (e.g., end-of-year state and district standardized testing, final exam “dead week,” etc.).
Since the College Board® SpringBoard© curriculum covers statistics in most of the mathematics courses, sans Calculus, more teachers across schools in a district or state, maybe even nationally, could be asked to participate in a longitudinal study that compares project-based learning (or problem-based learning, perhaps even inquiry-based learning) to traditional learning, not just with formative assessments, but summative assessments as well. The pre-unit and post-unit examination instruments could be developed by veteran math teachers with experience teaching statistics, along with the advice of statistics professors, instructors, and teachers, both on the secondary and postsecondary educational levels. Large scale parametric analysis (or nonparametric analysis, if warranted due to non-normal distributions in populations) would be rich with information that can help advance statistics education.

The time to act is now. The world is moving more and more with each passing day towards requiring students and a workforce that is well-versed in data entry, management, and general analytics skills. For this reason, my lifelong goal now is to aid in this endeavor and I will not rest until significant advances are made. Even in this small case study, riddled with low sample sizes and external factors that made results generally insignificant, for the moments where significance was found, more often than not the case was relatively made, as I expected, that projects are the best method for advancing statistics education, both from the student perspective and the teacher perspective. The prospects are bright; the opportunities, endless. Let the action begin.
APPENDIX A: IRB APPROVAL

ACTION ON PROTOCOL APPROVAL REQUEST

TO: Eugene Kennedy
ELRC

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: March 25, 2019

RE: IRB# 4209

TITLE: Experimental Statistics - A Case Study in Favor of Using Project-Based Learning to Advance Preliminary Statistics Content Knowledge in the Algebra I and Geometry Classroom


Review type: Full ___ Expedited X ___ Review date: 3/21/2019

Risk Factor: Minimal ____ X ____ Uncertain ____ Greater Than Minimal ______

Approved _____ X ____ Disapproved ___________

Approval Date: 3/25/2019 Approval Expiration Date: 3/24/2020

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 350

LSU Proposal Number (if applicable):

By: Dennis Landin, Chairman Denlin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING – Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU’s Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins), notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
8. SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc.

*All investigators and support staff have access to copies of the Belmont Report, LSU’s Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb
June 11, 2019

Trey Earle
147 East Riveroaks Drive
Baton Rouge, LA 70815-4056

Dear Mr. Earle:

Your request to conduct the following research in East Baton Rouge Parish School System is approved.

“Experimental Statistics - A Case Study in Favor of Using Project-Based Learning to Advance Preliminary Statistics Content Knowledge in the Algebra I and Geometry Classroom”

Lee Magnet High School

We require that all data you collect protect the anonymity of participants, unless they specifically provide you with permission to identify them. It is my understanding that you will provide the East Baton Rouge Parish School System a summary of your research findings, once your project is completed.

We appreciate the opportunity of working with you. If we can be of further assistance, please contact Andrea O’Konski at (225) 922-5607 or andrea@ebrschools.org.

Approved:

Warren Drake
Superintendent

6/17/19
Date
LOCAL SCHOOL PRINCIPAL APPROVAL

Principal’s Consent Form for Research

I. Research Background (to be completed by researcher)

Study Title: Experiential Statistics - A Case Study in Favor of Using Project-Based Learning to Advance Preliminary Statistics Content Knowledge in the Algebra I and Geometry Classroom

Name of Researcher: Trey M. Earle Organization: Lee Magnet High School Teacher
Street Address: 147 East Riveroaks Drive City: Baton Rouge State: LA Zip: 70815
E-mail: tearle@lsu.edu Phone: (225) 571-1090

II. Description of Research Proposal

Performance Site: Lee Magnet High School in Baton Rouge, Louisiana.

Purpose of the Study: The purpose of the research project is to gauge the benefits of using group project assessments instead of traditional assessments (e.g. quizzes, homework, exit tickets, warm-up activities, etc.) to advance preliminary (basic) statistics knowledge in lower-level secondary mathematics courses (i.e., Algebra I and Geometry). Valuable information is expected to be retrieved from this proposed study so that curricular changes can be made to state educational standards and benchmarks. An additional purpose of this study is to provide vital information to stakeholders and administrators on the statewide, district and local levels, people who can make curricular and educational assessment decisions in the future.

Inclusion Criteria: Students will be used from randomly selected Algebra I and Geometry classes taught by a team of full-time Algebra I and Geometry teaching employees at Lee Magnet High School in Baton Rouge, Louisiana. This team includes the PhD candidate and co-principal investigator, Trey M. Earle. Students may voluntarily participate in some instruments (surveys and face-to-face focus group interviews) of the proposed study, yet be required to participate in other instruments (pre-unit and post-unit exam, and group projects) of the study, the latter of which is required by statewide educational and curricular course content. For no reason whatsoever will any willing and able participant in any Algebra I or Geometry class, randomly chosen to use project-based learning or otherwise, be punished or reprimanded for choosing not to participate in any survey or focus group interview instrument. Students who fit this inclusion criteria and who choose and are also given parental/legal guardian permission to participate in any and all surveys and focus group interviews can participate. To participate in the study, students must be enrolled in one of two select courses for one of two (2) Algebra I teachers and one of three (3) Geometry teachers on the Lee Magnet High School campus. Students must meet all requirements of both the inclusion and exclusion criteria, the latter of which is detailed below.

Exclusion Criteria: Students who do not meet the inclusion requirements or who are not enrolled in one of the sections per Algebra I or Geometry course sections being used in the study may not participate in the study.

Number of subjects expected for the study: 300 – 400

Study Procedures: Students from randomly selected Algebra I and Geometry classes taught by a team of full-time Algebra I and Geometry teaching employees at Lee Magnet High School in Baton Rouge, Louisiana, including the PhD candidate and co-principal investigator, Trey M. Earle, will voluntarily participate in instruments of the proposed study and be required to participate in other instruments of the study, the latter of which being required by statewide educational and curricular course content. This study will be a sequential

(Cont’d)
exploratory mixed methods design and will be comprised of four (4) primary study instruments: a pre-unit and post-unit survey, a before/during/after unit face-to-face focus group interview, a pre-unit and post-unit content exam, and for students whose Algebra I and Geometry classes have been randomly assigned to a project-based learning structure, group projects. Participants are not obligated to participate in the first two study instruments (the surveys and the focus group interviews), however all students are required to participate in the pre-unit and post-unit examinations and, for students in chosen classes, group projects. The examinations and group projects are being used as curricular assessment grades in the Algebra I and Geometry classes in which students are enrolled at Lee Magnet High School, as required by state, district and local course curriculum. Students who fit the inclusion criteria and who choose and are also given parental/legal guardian permission to participate in any and all surveys and focus group interviews will be asked relevant questions pertaining to the study through anonymous online surveys using Qualtrics survey software and follow-up face-to-face focus group interviews.

The instruments used in the study will be an online survey through Qualtrics software as well as a face-to-face focus group. All survey responses will be retrieved from individually chosen responses. Answers to survey questions/statements will be compiled and statistical analyses performed on the responses. With regard to the face-to-face focus group interviews, audio recordings will be performed so as to capture all important feedback and responses from focus group participants. The responses to questions delivered in the focus group will be compiled, transcribed, and thematic elements will be developed. In the focus group, each participant will be given a placard and randomly assigned a letter. In the focus group interview, each respondent will be addressed by this random letter (e.g., Student A, Student B, etc.). This way, all audio recordings will have no evidence of student names. All transcribed participant responses will occur through these same random letters, in the event that the information compiled is presented at a conference or published in a paper. Once transcribed, audio response files of the focus group interview will be erased forever. Focus group questions are written using general behavioral and attitudinal questions regarding the proposed topic of this study, but additional questions may be posed which expound upon compiled survey responses and valuable information retrieved in the initial focus group interview questions.

Additional sources of quantitative data include individual student score averages for pre-unit and post-unit examinations. Growth on the content of the examination will be assessed. For those students enrolled in classes that are randomly chosen to be taught using project-based assessments instead of traditional assessments, group project presentation results will be the primary instruments. For the group projects, group projects will be student-centered. Final assessment grades will be given by the individual classroom teacher using rubrics developed by the co-investigator, Trey M. Earle, but presentations will be assessed by specific audience members, including but not limited to local school administration, the classroom teacher of record, and possibly, but not required, members of the community. These audience members will provide feedback during and after the group project presentations. The final letter grade on a project will be given by the classroom teacher of record. The same letter assigned to students for the face-to-face focus group will be the same letter assigned to the student whose information will be compiled in a spreadsheet containing student grades. This will protect the identity of the student and the school. The latter quantitative data will be used to evaluate if group project assessments result in higher achievement on post-unit assessments regarding preliminary statistics curricular content.

Benefits: The study may yield valuable information about methods to enhance instruction of preliminary statistics in lower-level and full Statistics classes in secondary schools, to improve statistics and mathematics curricula on the state, district and local levels, and to serve as a foundation developing a method on how to train teachers in the United States to effectively and efficiently increase student knowledge of statistics in the secondary school classroom.

Risks: There are no expected potential risks involved, as all identities will be hidden and pseudonyms used. School location will be unknown at all times. Only a few demographic questions will be asked in the survey (specifically, gender, race/ethnicity, classification in school, current grade point average, current mathematics course, and if the assessments in the statistics unit were traditional-based or project-based).

(Cont’d)
Right to Refuse: Participation in the surveys and face-to-face focus group interviews are voluntary, and a student will become part of the study only if both the student and parent agree to the student's participation. At any time, either the student may withdraw from the survey/focus group interview or the student's parent may withdraw the student from the survey/focus group interview without penalty or loss of any benefit to which they might otherwise be entitled. To opt out of a survey/focus group interview, simply contact Mr. Earle by email or at the telephone provided above at any time.

Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless disclosure is required by law.

III. Agreement (to be completed by principal)

I, [Handwritten: Bob Hawle], principal of [Handwritten: Lee Magnet] school, understand

• the study and what it requires of the staff, students, and/or parents in my school,

• that the privacy and confidentiality of any staff or student will be protected,

• that I have the right to allow or reject this research study to take place in my school,

• that I have the right to terminate the research study at any time,

• that I have the right to review all consent forms and research documents at any time during the study and up to three years after the completion of the study.

I [Handwritten: Checkmark] grant permission to the researcher, Mr. Trey M. Earle, to conduct the above-named research in my school as described in the proposal.

I [Handwritten: Checkmark] DO NOT grant permission to the researcher to conduct the above-named research in my school as described in the proposal.

I [Handwritten: Checkmark] understand that data should be released only by the departments that maintain them. My staff and I will not release data to the researcher without prior approval from the East Baton Rouge Parish Schools Research Review Board.

[Handwritten: Signature of Principal]  [Handwritten: 3/18/2019]
APPENDIX B: PROSPECTUS FOR APPROVAL OF STUDENT PROJECTS

Prospectus of Individual Statistics Project (Required Before the Commencement of any Group Project)

1. What is your topic? If you wish to try and prove a relationship, think of a conjecture. (ex: Oreo Double Stuff cookies don't really have double the filling.). What is/are your proposed research question(s)? What is your hypothesis?

2. What/who is your population? Are they people or things? Describe the individuals carefully.

3. Will human, animal, or sensitive subjects be used in this proposed study? If so, please explain in clear, full detail and be as explicit as possible. Note: Any study involving human, animal, or sensitive subjects MUST secure Institutional Board Review (IRB) approval before the study can commence. If IRB approval is deemed warranted, your Elementary Statistics instructor must complete the IRB application with you.

4. How many will be in your sample? What kind of sampling method do you intend to use for this project? (The more complex your experiment/survey is, the fewer samples you will be able to take. A minimum of 30 is required but more will give you a better result. Remember - this is a subset of your population.)

5. How will you go about drawing your sample? Go into detail.

6. What set(s) of quantitative data will be required for this project? What statistical analyses will you be performing to test your hypotheses and answer your research questions - t-test, regression, or ANOVA analysis? Remember that quantitative data are measured. Try to get a set that can be measured to at least the nearest tenth of a unit.

7. What sets of categorical data will be required for this project? Will you be using Chi-square analysis? If so, what association will you be testing or will you be testing for independence? Explain.

8. Will a community partner (e.g., outside expert/advisor) be used in this project? If so, provide his/her/their names, occupation, contact information, and relationship to the project.

Name(s): ___________________________ Project Number:____________
APPENDIX C: SAMPLE COMPLETED GROUP PROJECT PROSPECTUS

Prospectus of Individual Statistics Project (Required Before the Commencement of any Group Project)

1. What is your topic? If you wish to try and prove a relationship, think of a conjecture. (ex: Oreo Double Stuff cookies don’t really have double the filling.). What is/are your proposed research question(s)? What is your hypothesis?

Question: How have profits and sales for the most popular fast-food chain industries in the United States been affected over the last five years?

Hypothesis: Our hypothesis is that the sales of the fast-food industries has decreased over time.

2. What/who is your population? Are they people or things? Describe the individuals carefully.

The population is fast food restaurants in the city in which we live. A restaurant is a thing.

3. Will human, animal, or sensitive subjects be used in this proposed study? If so, please explain in clear, full detail and be as explicit as possible. Note: Any study involving human, animal, or sensitive subjects MUST secure Institutional Board Review (IRB) approval before the study can commence. If IRB approval is deemed warranted, your Elementary Statistics instructor must complete the IRB application with you.

No

4. How many will be in your sample? What kind of sampling method do you intend to use for this project? (The more complex your experiment/survey is, the fewer samples you will be able to take. A minimum of 30 is required but more will give you a better result. Remember - this is a subset of your population.)

All of the most popular fast-food restaurants in our city.

5. How will you go about drawing your sample? Go into detail.

We will be drawing our sample by creating bar graphs of profits and sales for each year over the last five years. This is to compare the data.

6. What set(s) of quantitative data will be required for this project? What statistical analyses will you be performing to test your hypotheses and answer your research questions - t-test, regression, or ANOVA analysis? Remember that quantitative data are measured. Try to get a set that can be measured to at least the nearest tenth of a unit.

Sets of quantitative data will be sales and profit we will use to see how much money was lost during the pandemic.

7. What sets of categorical data will be required for this project? Will you be using Chi-square analysis? If so, what association will you be testing? Will you be testing for independence? Explain.

There will be no categorical data.

8. Will a community partner (e.g., outside expert/advisor) be used in this project? If so, provide his/her/their names, occupation, contact information, and relationship to the project.

No
APPENDIX D: GRADING RUBRIC FOR STUDENT PROJECTS

<table>
<thead>
<tr>
<th>Rubric for Statistics Projects</th>
<th>Points Possible</th>
<th>Points Earned/Suggested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction/Title:</strong></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Title is clear and in the form of a question</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Brief introduction clearly describes the research question(s) that is/are being investigated</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Data Collection:</strong></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>The method or source of data collection is relevant to study</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>The method or source of data collection describes sampling procedures</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>The quantity of data collected is appropriate</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Graphs and Summary Statistics:</strong></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Appropriate graphs are used (to help answer the overall question of interest)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Graphs are accurate and neat</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Graphs are easy to compare (same scale, colors, etc.)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Appropriate summary statistics are calculated (to help answer the overall question of interest)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Summary statistics are calculated correctly (raw data is included)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Discussion and Conclusions:</strong></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Conclusion clearly and correctly addresses the question of interest</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Conclusion is supported by the appropriate procedure</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Appropriate generalizations are made with supporting evidence</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Shortcomings and/or suggestions for improvement are discussed</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Oral Presentation:</strong></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Presentation is well organized</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Presentation is thorough</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Questions are handled appropriately</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Note: This rubric will be used by your math teacher, school administrators, and any community partner/expert/advisor, where applicable, to grade project presentations.
Are there enough chocolate chips in Chewy Chips Ahoy cookies?

On average, how many chocolate chips are in a Chewy Chips Ahoy cookie?

We believe that at least 15 chocolate chips would be provided in a chips ahoy cookie.

INTRO
To gather information, we bought 30 chewy chips ahoy chocolate chip cookies, and broke them up.
Then we counted how many chocolate chips was in each cookie to see the average chocolate chips in each cookie.

DATA
MEAN: 12
MEDIAN: 13
MODE: 10
RANGE: 15
VARIANCE: 7.922222
STANDARD DEVIATION: 2.794927
MEAN ABSOLUTE Deviation: 1.302

CHOCOLATE CHIPS IN EACH COOKIE
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1

BOX PLOT
To find the box plot of the steps:
1. We ordered our 30 number from least to greatest:
   (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1)
2. Then we found the median by ranking it as an even amount of numbers we need the middle 2 numbers
   and took the mean of the the 2 which was 10 because both the numbers were the same
3. Then we found the median of the lower half of the data set (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1)
   which was 1.
4. Next we found the lower and higher number which was 1 and 12
5. Then we joined them on a numberline and drew vertical lines between the lower median, higher median
   and the middle one.

CONCLUSION
In conclusion on average there are 15 chocolate chips in a Chewy Chips Ahoy cookie. We think that is a perfect amount of chocolate chips because I mean it wouldn’t be a chocolate chip cookie without those!
APPENDIX F: SAMPLE COMPLETED GEOMETRY GROUP PROJECT PRESENTATION

What is the probability of a dog being adopted or euthanized based on size?

Question

Are some sizes of dogs more likely to get adopted? Are others more likely to be euthanized?

Hypothesis

We hypothesized that small dogs will be adopted at a higher rate than medium and large dogs.

We used data from the last month from Companion Animal Alliance. This data included a total of 954 dogs, all of these dogs were either adopted, euthanized, or transferred to a different facility. The data was classified by breed so we used a chart to classify them based on weight into the categories of small, medium, and large.

Sample Space

Purpose

We wanted to do this project to raise awareness of the need to spay and neuter dogs as well as the need to adopt. There are too many dogs that are on the streets and we thought that showing the statistics of what types of dogs were adopted could inspire people to adopt rather than buy dogs.

Data

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euthanized</td>
<td>1</td>
<td>12</td>
<td>78</td>
<td>91</td>
</tr>
<tr>
<td>Adopted</td>
<td>18</td>
<td>29</td>
<td>82</td>
<td>129</td>
</tr>
<tr>
<td>Transfer</td>
<td>10</td>
<td>13</td>
<td>54</td>
<td>74</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>54</td>
<td>211</td>
<td>294</td>
</tr>
</tbody>
</table>

Chart Used

None of the dogs in the data were classified as “giant” so we did not use this category.

Bar graph

See the handy list below to find out what size classification your dog belongs to:

- Small or toy dog breeds – 2 to 22 pounds (1-10 kg)
- Medium dog breeds – 23 to 57 pounds (11-16 kg)
- Large dog breeds – 58 to 99 pounds (27-44 kg)
- Giant dog breeds – 99 pounds or more (45 kg+)

Pie chart for small dogs
Hypothesis

- The probability of a small dog being adopted is 62%
- The probability of a medium dog being adopted is 37%
- The probability of a large dog being adopted is 30%

Other statistics

- The probability that a dog is large and euthanized is 36.6%
- The probability that a dog is medium sized and euthanized is 5%
- The probability of a dog being transferred is 25.2%
- The probability of a dog being adopted given that it is medium is 53.7%
- The probability of a dog being euthanized given that it is large is 37%

Conclusion

We concluded that our hypothesis was correct. The data showed a clear trend towards small dogs being adopted at a higher rate than large and medium dogs. Using a conditional probability, we found these trends. We calculated these probabilities: a dog being adopted given that it is large, given that it is small, and given that it is medium. This trend would allow us to generalize that smaller dogs are more popular to adopt.

Shortcomings

Although our hypothesis was supported by the data, there were a few issues with the data itself. The establishment we got it from only gave us one month of data, so we were limited to this amount of information. For example, there was only one small dog that was euthanized in the data given. There were also substantially more large dogs than any other size. This created somewhat of an imbalance in the ratios. Also, the facility itself does not euthanize dogs based on how long they were there like some pounds do, they only put them down for behavior and health issues. So, this project may not reflect all real-world statistics on euthanasia rates.
APPENDIX G: PRE-UNIT SURVEY FOR STUDENT ATTITUDINAL PORTION

Pre-Unit Survey using Qualtrics® Software
SATS-36 Developed and Published © Schau (1992, 2003)

DIRECTIONS: The statements below are designed to identify your attitudes about Statistics. Each item has 5 possible responses. The responses range from 1 (strongly disagree) through 3 (neither disagree nor agree) to 5 (strongly agree). If you have no opinion, choose response 3. Please read each statement. Mark the one response that most clearly represents your degree of agreement or disagreement with that statement. Try not to think too deeply about each response. Record your answer and move quickly to the next item. Please respond to all of the statements.
DO NOT IDENTIFY YOURSELF ANYWHERE ON THIS SURVEY!!!

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Disagree nor Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I plan to complete all of my statistics unit assignments in my math course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I plan to work hard in the statistics unit of my math course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will like statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will feel insecure when I have to do statistics problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will have trouble understanding statistics because of how I think.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics formulas will be easy to understand.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</tr>
<tr>
<td>Statistics is worthless for me to learn.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
</tr>
<tr>
<td>Statistics will be a complicated subject.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics skills should only be taught in an actual statistics course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics should be a required part of my secondary school academic training.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will be more comfortable with statistics concepts if they are taught to me in lower-level math classes (e.g., Algebra I, Geometry, etc.)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will have no idea of what's going on in the statistics unit of my lower-level math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statement</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>I am interested in being able to communicate statistical information to others.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics is not useful to the typical student.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I plan to fully prepare for every statistics assessment.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will get frustrated going over statistics assessments in class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I would have no problem presenting statistics projects to my classmates.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I would have no problem presenting statistics projects to individuals in the community outside of school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I think I will like math assessments that are project-based instead of test-based.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will be under stress during the statistics unit in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will enjoy learning statistics in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am interested in using statistics in the future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics conclusions are rarely presented in everyday life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics is a subject quickly learned by most people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am interested in understanding statistical information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Learning statistics requires a great deal of discipline.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I think I will be interested in learning more about statistics in future courses.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will have no application for statistics in my future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will make a lot of math errors in the statistics unit.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I plan to pay close attention to every statistics lesson in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am scared by statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am interested in learning statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics involves massive computations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I can learn statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will understand statistics equations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics is irrelevant in my life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Statistics is highly technical.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I will find it difficult to understand statistical concepts.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Most people have to learn a new way of thinking to do statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Using real world data to apply statistics would be a great way to learn statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>How well have you performed in mathematics courses that you have taken in the past?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**DEMOGRAPHIC QUESTIONS**

For each of the following, choose the value that best describes you or your position or with which you most identify.

Current GPA (using 4.0 scale and rounded to three decimal places)

|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------|

Your current mathematics course at your school where you will be taught statistics is

- Algebra I
- Geometry

Based on the grade you have now in your current mathematics course, which of the following is the grade you expect to earn at the end of your current mathematics course?

A    B    C    D    F

Your current classification at your school is

- Freshman
- Sophomore
- Junior
- Senior
The race/ethnicity with which you *most* identify is

African American/Black  Asian/Pacific Islander  Hispanic/Latino  Native American/American Indian  White  Other

The gender that you *most* identify with is

Male  Female  Transgender  Other

The formative assessment that *best* describes the statistics unit in your math course is

Project-based  Traditional

REFERENCES

APPENDIX H: POST-UNIT SURVEY FOR STUDENT ATTITUDBINAL PORTION

Post-Unit Survey using Qualtrics® Software
SATS-36 Developed and Published © Schau (1992, 2003)

DIRECTIONS: The statements below are designed to identify your attitudes about statistics. Each item has 5 possible responses. The responses range from 1 (strongly disagree) through 3 (neither disagree nor agree) to 5 (strongly agree). If you have no opinion, choose response 3. Please read each statement. Mark the one response that most clearly represents your degree of agreement or disagreement with that statement. Try not to think too deeply about each response. Record your answer and move quickly to the next item. Please respond to all of the statements. DO NOT IDENTIFY YOURSELF ANYWHERE ON THIS SURVEY!!!

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I tried to complete all of my statistics assignments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I worked hard in my statistics course.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I like statistics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I felt insecure when I had to do statistics problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I had trouble understanding statistics because of how I think.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistics formulas are easy to understand.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistics was worthless for me to learn.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistics is a complicated subject.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistics skills should only be taught in an actual statistics course.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistics should be a required part of my secondary school academic training.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am more comfortable with statistics concepts because they were taught to me in lower-level math classes (e.g., Algebra I, Geometry, etc.).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neither Disagree nor Agree</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>---------------------------</td>
<td>-------</td>
<td>---------------</td>
</tr>
<tr>
<td>I understand what was taught in the statistics unit of my lower-level math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am now able to communicate statistical information to others.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics is useful to the typical student.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I fully prepared for every statistics assessment.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I became frustrated while going over statistics assessments in class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I had no problem presenting statistics projects to my classmates.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I had no problem presenting statistics projects to individuals in the community outside of school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I prefer math assessments that are project-based instead of test-based.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistical thinking is not applicable in my life outside my school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I use statistics in my everyday life</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I was under stress during the statistics unit in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I enjoyed learning statistics in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am interested in using statistics in the future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics conclusions are rarely presented in everyday life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics is a subject quickly learned by most people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am interested in understanding statistical information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statement</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neither Disagree nor Agree</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>-----------------------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>Learning statistics required a great deal of discipline.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I will have no application for statistics in my future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I made a lot of math errors in statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I paid close attention to every statistics lesson in my math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I was scared by statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am interested in learning more about statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics involved massive computations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Learning statistics was easy.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I understand statistics equations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics is irrelevant in my life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Statistics is highly technical.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I found it difficult to understand statistical concepts.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Most people have to learn a new way of thinking to do statistics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Using real world data to apply statistics was a great way to learn statistics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>How good at mathematics are you?</td>
<td>Very poor, Very good</td>
</tr>
<tr>
<td>In the field in which you hope to be employed when you finish school, how much will you use statistics?</td>
<td>Not at all, Great deal</td>
</tr>
</tbody>
</table>
How confident are you that you have mastered basic, introductory statistics topics?

Not at all confident 1 2 3 4 Very confident 5

As you complete the remainder of your degree program, how much will you use statistics?

Not at all 1 2 3 4 Great deal 5

If you could, how likely is it that you would choose to take another course that covers major statistics concepts?

Not at all likely 1 2 3 4 Very likely 5

How difficult for you was the statistics unit material covered in your math course?

Very easy 1 2 3 4 Very difficult 5

**DEMOGRAPHIC QUESTIONS**

For each of the following, choose the value that best describes you or your position or with which you most identify.

Current GPA (using 4.0 scale and rounded to three decimal places)

<table>
<thead>
<tr>
<th>Grade Range</th>
<th>GPA Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.001 – 2.249</td>
<td>2.001 – 2.249</td>
</tr>
<tr>
<td>2.250 – 2.499</td>
<td>2.250 – 2.499</td>
</tr>
<tr>
<td>2.500 – 2.749</td>
<td>2.500 – 2.749</td>
</tr>
<tr>
<td>2.750 – 2.999</td>
<td>2.750 – 2.999</td>
</tr>
<tr>
<td>3.000 – 3.249</td>
<td>3.000 – 3.249</td>
</tr>
<tr>
<td>3.750 – 4.000</td>
<td>3.750 – 4.000</td>
</tr>
<tr>
<td>&gt; 4.000</td>
<td>&gt; 4.000</td>
</tr>
</tbody>
</table>

Your current mathematics course at your school where you will be taught statistics is

Algebra I Geometry

Based on the grade you have now in your current mathematics course, which of the following is the grade you expect to earn at the end of your current mathematics course?

A B C D F

Your current classification at your school is

Freshman Sophomore Junior Senior
The race/ethnicity with which you *most* identify is

- African American/Black
- Asian/Pacific Islander
- Hispanic/Latino
- Native American/American Indian
- White
- Other

The gender that you *most* identify with is

- Male
- Female
- Transgender
- Other

The formative assessment that *best* describes the statistics unit in your math course is

- Project-based
- Traditional

REFERENCES

## APPENDIX J: FACETS OF ATTITUDINAL PORTION WITH STATEMENTS

### Work Ethic Items

| Q2 | Statistics Assignments Completion |
| Q3 | Work Hard in Statistics Unit of Math Course |
| Q16 | Plan to Prepare Fully for Statistics Assessments |
| Q23 | Stress During Statistics Unit of Math Course |
| Q33 | Pay Close Attention to Statistics Lessons |

### General Attitude Items

| Q4 | Like Statistics |
| Q5 | Feel Insecure Doing Statistics Problems |
| Q6 | Trouble Understanding Statistics Because of Learning Style |
| Q7 | Statistics Formulas Easy to Understand |
| Q8 | Statistics is Worthless to Learn |
| Q9 | Statistics is Complicated Subject |
| Q12 | More Comfortable with Statistics Content if Taught in Secondary Math Classes |
| Q14 | Interest in Communicating Statistical Information with Others |
| Q17 | Frustration Going over Statistics Assessments in Class |
| Q18 | Problem Presenting Statistics Projects to Peer Students |
| Q19 | Problem Presenting Statistics Projects to Non-Peer Students (Outsiders) |
| Q28 | Interest in Understanding Statistical Information |
| Q30 | Interest in Learning More about Statistics |
| Q31 | No Application for Statistics in Future |
| Q34 | Scared by Statistics |
| Q35 | Interest in Learning Statistics |
| Q37 | Ability to Learn Statistics |
| Q38 | Understanding of Statistics Equations |
| Q41 | Difficulty Understanding Statistical Concepts |

### General Opinion

| Q10 | Statistics Skills Should be Reserved for Statistics Courses Only |
| Q11 | Statistics Should be Required Part of Secondary School Curriculum |
| Q13 | Understanding Statistics in Lower Level Math Class will be Easy |
| Q20 | Prefer Project-Based Assessments than Traditional Assessments |
| Q21 | Statistical Thinking not Applicable Outside of School |
| Q22 | Expect to Use Statistics in Daily Life |
| Q24 | Enjoy Learning Statistics in Math Class |
Q25  | Interest in Using Statistics in Future  
Q29  | Learning Statistics Requires Discipline  
Q36  | Statistics Involves Massive Computations  
Q39  | Statistics not Relevant in Life  
Q40  | Statistics is Highly Technical  
Q43  | Using Real World Data is Great Way to Learn Statistics

Speculation

Q15  | Statistics not Useful to Typical Student  
Q26  | Statistics Conclusions Rarely Presented in Daily Life  
Q27  | Statistics is Subject Quickly Learned by Most People  
Q32  | Make Many Math Errors in Statistics Unit  
Q42  | People Must Learn New Way of Thinking to Perform Statistics

Behavioral Questions

Q44  | Past Performance in Math Classes  
Q45  | Personal Reflection on Math Ability  
Q46  | Statistics Use in Desired Field of Work in Future  
Q47  | Confidence on Mastery of Basic Statistics Concepts  
Q48  | Expected Use of Statistics in Future Secondary Math Courses  
Q49  | Likelihood of Taking Another Math Course with a Statistics Unit  
Q50  | Difficulty with Statistics Unit in Current Math Course

Demographic/Class Variable Questions

Q51  | Current Cumulative GPA (Intervals every 2.500, beginning with 2.001)  
Q52  | Current Math Course  
Q53  | Expected Final Spring Semester Grade in Current Math Course  
Q54  | Classification in School  
Q55  | Race/Ethnicity  
Q56  | Gender  
Q57  | Formative Assessment Method Used in statistics Unit of Current Math Course
APPENDIX K: SUMMARY OF VARIABLES USED IN ATTITUDINAL PORTION

Pre-Unit Survey Questions: Q2Pre through Q43Pre, Q44 through Q57

Post-Unit Survey Questions: Q2Post through Q43Post, Q44 through Q57

Difference in Post-Unit and Pre-Unit Survey Responses: Q2Diff through Q43Diff (Only)

Mean Response for Each Facet: MeanWorkEthic, MeanGeneralAttitude, MeanGeneralOpinion & MeanSpeculation
APPENDIX L: SAS® 9.4 CODE FOR ACHIEVEMENT PORTION

dm 'log;clear;output;clear';
options nodate nocenter pageno=1 ls=78 ps=55;
OPTIONS FORMCHAR="|---|+|----|--|--|--|--|--|--|--|\<>";
ODS listing; ods graphics on;
ods rtf;
title1 "Pre-Test and Post-Test Results for Geometry - Trey Earle
Dissertation Study";

proc import out=work.PrePostGeometryExamScoreEarle
   file='C:\Users\tearle\Desktop\Geometry and Algebra I Pre-Unit and
   Post-Unit Exam Scores - Dissertation Study.xlsx'
   dbms= EXCEL REPLACE;
sheet='Geometry';
getnames=yes;
run;

proc print data=PrePostGeometryExamScoreEarle;
run;

proc sort data=PrePostGeometryExamScoreEarle;
   by Method Teacher;
run;

proc univariate data=PrePostGeometryExamScoreEarle plot;
   var PercentDiff;
   by Method Teacher;
run;

proc means data=PrePostGeometryExamScoreEarle n mean median css std min max;
   by Method;
run;

proc means data=PrePostGeometryExamScoreEarle n mean median css std min max;
   class Teacher;
   by Method;
run;

proc capability data=PrePostGeometryExamScoreEarle normaltest;
   var PercentDiff;
   by Method Teacher;
run;

proc ttest data=PrePostGeometryExamScoreEarle h0=0;
   class Teacher;
   var PercentDiff;
run;

proc ttest data=PrePostGeometryExamScoreEarle h0=0;
   class Method;
   var PercentDiff;
run;

proc glm data=PrePostGeometryExamScoreEarle;
   class Teacher Method;
model Difference = Teacher Method Teacher*Method / effectsize;
random Teacher;
run;
title;
title2 "Pre-Test and Post-Test Results for Algebra I - Trey Earle
   Dissertation Study";
proc import out=work.PrePostAlgebraExamScoreEarle
   file='C:\Users\tearle\Desktop\Geometry and Algebra I Pre-
      Post-Unit Exam Scores - Dissertation Study.xlsx'
dbms= EXCEL REPLACE;
sheet='Algebra I';
getnames=yes;
run;
proc print data=PrePostAlgebraExamScoreEarle;
run;
proc univariate data=PrePostAlgebraExamScoreEarle plot;
   var PercentDiff;
   by Method;
run;
proc means data=PrePostAlgebraExamScoreEarle n mean median css std min max;
   by Method;
run;
proc capability data=PrePostAlgebraExamScoreEarle normaltest;
   var PercentDiff;
   by Method;
run;
proc ttest data=PrePostAlgebraExamScoreEarle h0=0;
   class Method;
   var PercentDiff;
run;
proc glm data=PrePostAlgebraExamScoreEarle;
   class Method;
   model Difference = Method / effectsize;
run;
ods rtf close;
APPENDIX M: TEACHER INTERVIEW QUESTIONS

1. From your perspective as the classroom teacher, did student participation in the Statistics unit of your math course seem to increase their interest in statistics? If so, please explain in detail.

2. From your perspective as the classroom teacher, did student participation in the Statistics unit of your math course seem to increase their confidence in statistics? If so, please explain in detail.

3. What aspects of the Statistics unit of your math course had the greatest influence on your students' attitudes towards statistics? Please explain in full detail.

4. What aspects of the Statistics unit of your math course at your high school did your students seem to dislike the most? Please be as explicit and frank as possible.

5. To what extent did Powerpoint content slides as lecture content in the Statistics unit of your math course help your students learn statistics? Please be as explicit and frank as possible.

6. Were there any reasons why your students DISLIKED the delivery of lecture content in the Statistics unit of your math course? Please be as explicit and frank as possible.

7. For those students assigned to one of your math classes that used a traditional formative assessment structure (e.g., homework, quizzes, etc.), to what extent did quizzes used in the Statistics unit of that math course help your students learn statistics? Please be as explicit and frank as possible.

8. For those students assigned to one of your math classes that used a traditional formative assessment structure (e.g., homework, quizzes, etc.), to what extent did homework used in the Statistics unit of that math course help your students learn statistics? Please be as explicit and frank as possible.
9. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, what are your personal opinions about the course assessment structure that was used in the Statistics unit of your math course to help your students learn statistics? Please be as explicit and frank as possible.

10. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, to what extent did your students like or dislike the traditional assessment structure and why? Please be as explicit and frank as possible.

11. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, from your perspective as the teacher, do your students seem to prefer all formative assessments in a math course to be traditional (e.g. homework, quizzes, etc.) in nature? Why? Please be as explicit and frank as possible.

12. From your perspective as the teacher, do you seem to prefer all formative assessments in your math courses to be traditional (e.g. homework, quizzes, etc.) in nature? Why? Please be as explicit and frank as possible.

13. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, was the preliminary course instructional information (e.g. lecture notes, Powerpoint presentations, and supplemental worksheets/graphs/tables) provided to your students in line with the content on the final post-unit assessments? To what extent were they helpful, useless, or harmful? Please be as explicit and frank as possible.

14. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, to what extent were the preliminary course instructional information (e.g. lecture notes, Powerpoint presentations, and supplemental worksheets/graphs/tables) provided to your students helpful, useless, or harmful to them in regards to preparation? Please be as explicit and frank as possible.

15. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, to what extent did projects in general used in the Statistics unit of your math course help your students learn statistics? Please be as explicit and frank as possible.
16. For those of your students enrolled in your math class assigned to use a traditional formative assessment structure, to what extent did collaborations among students used in the Statistics unit of your math course help your students learn statistics? Please be as explicit and frank as possible.

17. As the teacher of a math class that used a project-based assessment structure to teach statistics content, what are your personal opinions about the course assessment structure that was used in the Statistics unit of your math course to help your students learn statistics? Please be as explicit and frank as possible.

18. For those of your students enrolled in your math class assigned that used a project-based assessment structure, to what extent did your students like or dislike the project-based assessment structure? Why? Please be as explicit and frank as possible.

19. As the teacher of a math class that used a project-based assessment structure to teach statistics content, do you prefer all formative assessments in a math course to be project-based or do you prefer the more common traditional assessment structure (like homework, quizzes, and tests)? Why? Please be as explicit and frank as possible.

20. As the teacher of a math class that used a project-based assessment structure to teach statistics content, do you feel that the preliminary course instructional information (lecture notes, Powerpoint presentations, and supplemental worksheets/graphs/tables) provided to your students was in line with the content on the final post-unit assessments? To what extent were they helpful, useless, or harmful? Please be as explicit and frank as possible.

21. Based solely on your students’ feedback on experiences, do you feel that your students would be interested in taking a full Statistics course in your high school? Why or why not? Please be as explicit and frank as possible.

22. Based solely on your teaching experiences now after having participated in this study, would you prefer to use more traditional formative assessments (e.g. homework, quizzes, etc.) or projects as formative assessments when you teach a math course. Why or why not? Please be as explicit and frank as possible.
23. Suppose a teaching colleague approaches you and asks you if he or she should use more traditional formative assessments (e.g. homework, quizzes, etc.) or projects as formative assessments when you teach a math course. What advice or suggestions would you give? Please be as explicit and frank as possible.

24. From a personal teaching standpoint, what are your thoughts on solely using projects as formative assessments instead of more traditional assessments (e.g. homework, quizzes, etc.)? What are the benefits and dangers of using projects instead? Please be as explicit and frank as possible.

25. Overall, how would you rate your experiences with teaching the statistics unit of your math class using the two different formative assessment models? What benefits and pitfalls are associated with each? Can a more "perfect" model be developed? Please be as explicit and frank as possible.
REFERENCES


Viali, L., & Sebastiani, R. G. Teaching statistics at high school: An alternative approach. In C. Reading (Ed.), *Data and context in statistics education: Towards an*


Trey Michael Earle, a native of Baton Rouge, Louisiana, worked as a high school mathematics teacher for eighteen years in his Baton Rouge, after receiving his bachelor’s degree in Liberal Sciences with a concentration in Scientific Inquiry and emphases in Mathematics and Chemistry from the Louisiana Scholars’ College at Northwestern (LA) State University. After nine years teaching all levels of high school mathematics, including Chemistry and Physics, he briefly left teaching to earn more degrees, all of them at Louisiana State University – Baton Rouge.

Since 2013, Trey has earned from LSU-BR an additional Bachelor of Science degree in Mathematics – emphasis in Actuarial Sciences, a Masters in Applied Statistics degree, and is currently a doctoral candidate in Educational Leadership, Research & Counseling, pursuing a Doctor of Philosophy degree in Educational Research Methodology, with an emphasis in Statistics Education. During the last five years, Trey has served as an adjunct instructor of statistics at Baton Rouge Community College and at his alma mater, Louisiana State University – Baton Rouge, in the Department of Experimental Statistics. As his interest in statistics has grown, he has decided to make rewriting secondary and postsecondary educational curriculum to improve and advance statistics education as his life’s work. Trey is currently seeking tenure-track professorship opportunities across the United States.