THE EFFECTIVENESS OF INQUIRY-BASED VS. DIDACTIC TEACHING METHODS ON STUDENT PERFORMANCE IN UNDERGRADUATE STATISTICS

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APPROVAL SHEET

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The final copy of this dissertation has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Abstract

This study explored the impact of instructional style in the teaching of introductory statistics on students' attitudes towards statistics and on students' academic outcomes in statistics courses. Four university statistics instructors were surveyed to identify their instructional style. In addition, their students' ($n = 313$) mean course scores and mean scores on the *Learning Outcomes for Statistical Methods* instrument were analyzed. Based on an independent measure of learning outcomes for students, the data indicate instructional styles that are more inquiry-based may be more effective overall for student achievement on the *Learning Outcomes for Statistical Methods* instrument. There was a significant decrease found between pre- and post-survey SATS-36 means for the students' Value, Interest, and Effort component scores. This indicates students found less value, interest, and effort required for statistics after taking a statistical methods course. In addition, students who score higher on the pre-*SATS-36* Affect, Cognitive, and Effort sub-scores tended to have higher final course averages. In an analysis of gender, male students view statistics more favorably than female students, male students believe statistics is more difficult than female students, and male students believe statistics requires less effort than female students. Finally, students with a higher stress level tended to have a lower *Learning Outcomes for Statistical Methods* average.

Keywords: statistics education, undergraduate statistics instructional styles, learning outcomes, statistical attitudes.

Dedication

To my best friend, Joseph Altomere, whose countless hours of support have led me to pursue my dreams, to my father and sister who always believed I could do anything I wanted, and to Millie Lugo who provided encouragement for me to grow as a professional early in my teaching career.

Acknowledgments

There are many people I wish to acknowledge and thank for their help and guidance. First, I would like to thank all the members of my dissertation committee, Dr. Lynn Wilder, Dr. Elia Vázquez-Montilla, and Dr. Charles Lindsey, for their time, expertise, and ongoing support. Dr. Lynn Wilder has been my dissertation committee chair and advisor and provided guidance both professionally and personally. Dr. Elia Vázquez-Montilla provided me with opportunities to begin thinking about multicultural education in mathematics. Dr. Charles Lindsey sparked my interest in the topic for this study by allowing me to participate in a program evaluation. I would also like to thank Dr. Diane Schmidt for being my masters advisor and starting as my doctoral advisor prior to her retirement. It was her class that first opened my mind to inquiry teaching in mathematics. I would also like to thank Dr. Richard Schnackenberg and Dr. Menaka Navartna for supporting me as my department chairs while I was an instructor and working toward my doctoral degree. Lastly, I would like to thank Mr. Larry Southard for providing many excellent adventures during this journey.

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CHAPTER I

INTRODUCTION

The title for the dissertation is *The effectiveness of inquiry-based vs. didactic teaching methods on student performance in undergraduate statistics*. The topic of this dissertation is the effect of teaching method on student performance and attitude in undergraduate statistics. The Department of Mathematics at a state university in Southwest Florida agreed to allow the use of all sections of their Statistical Methods STA 2023 course to be used for analysis for this dissertation. This course is an introduction to statistics typical of many first level statistics courses offered at colleges and universities across the United States. Instructors of this course were given an instrument to measure how much their teaching methods align along a continuum with inquiry or didactic methods. Students were given a pre- and post-attitude survey and a final assessment. In this dissertation, the researcher analyzed how teaching methods change students' attitudes towards statistics and achievement of learning outcomes. Additional demographic and quantitative factors were analyzed to determine if there were any correlational factors contributing to students' attitudes towards statistics and their attainment of statistical learning outcomes.

Brief Literature Review

Learning Theory

Birney, Fogarty, and Plank (2005) noted a primary purpose of statistical instruction was to help students understanding the underlying structure of a problem, as opposed to understanding the surface details. To help with the understanding of the structure, Birney et al. (2005) described that the benefits of presenting problems in a familiar context reduces the demands on working memory. Students in mathematics develop schemas that allow them to group similar problems into categories which require similar solutions. Birney et al. (2005) suggested that not only does the depth of knowledge increase as knowledge becomes procedural, but expertise develops with the addition of schemas.

In a study about student reactions to the structure of an assignment, DePaolo, Lloyd, and Robinson (2009) concluded that students choose to complete assignments that fit into their cognitive style. The study also showed support for the claim that a student's self-efficacy is higher on assignments that match their preferred cognitive style. To accommodate different cognitive styles, DePaolo et al. (2009) suggested having two versions of an assignment: one version with more structure, and one with less structure. However, they conceded that having two versions of an assignment may be impractical for many instructors.

As noted by Birney et al. (2005) and DePaolo et al. (2009), the trend of statistical instruction is toward a more inquiry-based approach, and away from the more didactic methods. Inquiry-based instructional techniques for statistics focus on a conceptual understanding of the subject with less of a focus on the procedural calculations (Birney et al., 2005). This focus of inquiry-based instructional approaches allows for instructors to better meet the diverse preferred cognitive styles of their students (DePaolo et al., 2009). The literature suggests inquiry-based statistical instruction should demonstrate (1) more frequent meeting of learning outcomes and (2) an improved attitude towards statistics for university students. The literature merely suggests this link, but does not show a direct relationship.

Curriculum Theory

The most influential concept that Doll (1993) presented is that humans learn by interacting with other humans. Learning takes place through the feeling of disequilibrium, which in turn causes growth in the depth of understanding. Doll (1993) pointed out that this simplistic view of a linear cause-and-effect relationship did not adequately explain the complex human interaction between a person and their self, or between a person and their environment. Egan (1999) indicated that the new paradigm of curriculum focused on a students' mastery of abstract knowledge instead of just focusing on the accumulation of facts.

Doll (1993) pointed out that an essential ingredient of this new paradigm was a redefining of authority roles. This may be the most unnerving component of this new paradigm for teachers. The role of the teacher is no longer a dictator in the classroom, but a part of the learning community. In addition, decisions are not made prior to the learning but rather evolve through the learning. Egan (1999) stated that the new paradigm should be based in students' deeper understanding instead of trying to accumulate facts. Slabbert and Hattingh (2006) stated that this interconnection is a fundamental part of the post-modern paradigm. The concept of rigor by using questioning by teachers and students, as well as creating interest, should be the goal of all educators (Losin, 2001). This post-modern paradigm is one that emphasizes problem-based learning; there is recognition that the direct questions found in textbooks and standardized tests do not resemble how humans will face these problems in real life (Slabbert & Hattingh, 2006).

The trend in professional development for statistics instructors is to promote inquiry-based instruction that supports the new paradigm shift of redefining the roles of the instructor in the classroom from the presenter of information to leader of a learning community (Doll, 1993; Egan, 1999; Slabbert & Hattingh, 2006; Losin, 2001). The statistics classroom should be a classroom focused on problem-solving and statistical-understanding and not merely on the memorization of formulas or procedural calculations (Slabbert & Hattingh, 2006). The literature supports inquiry-based instruction as the preferred instructional technique to increase statistical understanding and students' attitudes towards the subject. The literature supports this claim, but there is not a direct relationship established between this new paradigm and the improved outcomes or attitudes in a statistics classroom.

Instructional Practices

Inquiry-based instructional practices improve students' accumulation of learning outcomes and improve their attitudes towards statistics (Derry, Levin, Osana, Jones, & Peterson, 2000; Rabin & Nutter-Upton, 2010; Perkins & Saris, 2001). Derry et al. (2000) designed a study to assess the effects of inquiry-based instruction on statistics education. Study results showed that an inquiry-based course in statistics was able to improve a student's ability to apply statistical knowledge, and to critique research reports and statistical items presented in the news. Overall, Derry et al. (2000) found students preferred the inquiry-based course over the traditional course.

Rabin and Nutter-Upton (2010) showed the use of a specific inquiry-based activity, journal excerpt, meant students significantly out-performed students in a traditional introduction to statistics course on subsequent assessments. This inquiry-based instruction promoted the statistical skill of reading tables and graphs, and the skills of reflecting on the meaning of those tables and graphs. This project utilized individual work or small group collaboration. This inquiry activity increased corrective feedback from peers and instructors and developed an environment of cooperation.

Perkins and Saris (2001) described the "jigsaw classroom" as an inquiry-based strategy. The "jigsaw classroom" utilizes worksheets containing different parts of a problem. Each small group worked on a different worksheet or part of the problem. The class then combined the parts to describe the overall problem before the end of the class. The use of the "jigsaw classroom" allowed for students to work on problems during class time and receive corrective feedback from the instructor. The use of the parts of problems allowed for a problem to be entirely finished before the end of class, allowing for discussion. Perkins and Saris (2001) noted that the use of the "jigsaw classroom" should not be used for introduction of concepts.

The literature supports inquiry-based instruction in statistics as one method that both improves student learning outcomes, as well as students' attitudes towards statistics (Derry et al., 2000; Rabin & Nutter-Upton, 2010; Perkins & Saris, 2001). Thus, this indicates the instructors should be encouraged to used inquiry-based instructional techniques in their statistics courses. Bond, Perkins, and Ramirez (2012) state instructors need to develop an awareness of students' preconceptions and conceptualizations about statistics in addition to their content knowledge. However, the literature does not indicate how much more effective the inquiry-based instructional practices were compared to more didactic ones. In a study conducted by Curran, Carlson, and Celotta (2013), they found a benefit to collaborative learning when comparing a traditional undergraduate statistics course to a course taught using a collaborative model, but they also indicated that their results suggest further empirical research on the benefits of collaborative learning. The literature also doesn't show a direct measure of the improvement of students' attitudes towards statistics only showing a qualitative improvement in the enjoyment of the course (Derry, Levin, Osan, Jones, & Peterson, 2000; Curran et al., 2013).

Technology

Maddux (2001) noted in previous years that statistics instructors have relied on rote mathematical calculations as the central part of an introduction to statistics course, neglecting the applications of statistics and the development of statistical concepts. Before electronic calculators and statistical software, statistical instructors had little choice but to focus on rote mathematical calculations. Maddux suggested that the use of electronic calculators or statistical software moves statistics education from an emphasis on rote mathematical calculations to a deeper understanding of statistical concepts.

In addition to the use of electronic calculators and statistical software, Gundy, Morton, Liu, and Kline (2006) suggested that the use of web-based instruction can reduce students' anxieties in an undergraduate statistics course. This study showed the use of online discussions forums enhanced a student's self-esteem and value by the students.

Summers, Waigandt, and Whittaker (2005) argued web-based courses transcribed from traditional courses do not show a significant improvement in student achievement. Their research indicated that online education should follow a constructivist approach. Web-based courses should contain bulletin boards, chat rooms, and threaded discussions. Bulmer and Rodd (2005) reported how web-based courses increase the awareness of students' performance to instructors. Consequently, this increase caused greater interaction of the instructor within the online content.

The literature indicates that the use of technology in the statistics classroom aids in students' understanding and enjoyment of the subject (Maddox, 2001; Gundy, Morton, Liu, & Kline, 2006; Summers, Waigandt, & Whittaker, 2005; and Bulmer & Rodd, 2005). Since there are a variety of approaches to the use of technology in the statistics classroom, the literature does not show the actual differences the various uses of technology have on student learning outcomes, or their improved attitude.

Statement of the Problem

Ben-Zvi and Garfield (2008) noted an increase in statistics instruction in recent years with the number of students taking statistics on the rise. This drastic growth of students has caused the attention of educators, researchers, and policy makers to focus on improving the quality of statistics education at all levels. Ben-Zvi and Garfield (2008) also indicated that the field of statistics is becoming a more necessary and widely applicable area of study. More and more majors are requiring some level of statistics understanding at both the undergraduate and graduate levels (Pearl et al., 2012). As a result, Pearl et al. (2012) described the increase in the number of sections taught by instructors with a variety of backgrounds and experience with statistics. In a paper outlining undergraduate statistical education, Wilks (2006) stated “one of the most serious long-range problems confronting the world of statistics is that of establishing a sound pattern of statistical education for college undergraduates” (p. 39). With the increase in students and instructors of varying backgrounds, there is a clear need to consider effective teaching methods for undergraduate statistics.

Statement of Purpose

With the increased requirement for undergraduate students to take a quantitative reasoning course dealing with statistical methods in many university curricula, there is a need to study what methods statistics instructors use, and which produce the best academic outcomes for students. In addition, since there is a wide range of teaching approaches, there is a need to analyze how these differences in methodology influence student attitudes toward the subject of statistics. The information gained in this study was used to recommend best practices in the teaching of introductory statistics, and how instructors can improve the learning experience for students.

Research Questions

By looking at how teaching method relates to both student achievement and attitude towards statistics, the purpose of this study was to provide a recommendation of teaching method to be used to teach introductory statistics in universities. The research questions are: (1) What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*? (2) Does teaching style contribute to differences in students' attitude toward statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36*? (3) What is the relationship between students' attitudes towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates? and (4) What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and DWF Rates?

Definition of Terms and Variables

Terms

For the purposes of this research study, the following definitions will be used:

- Closed-system: a systems view that neglected the influence of outside factors (Doll, 1993).
- Confirmatory Instruction: key components of confirmatory instruction are using strategies to guide students in discovering or confirming standard algorithms (in mathematics) (Schmidt, 2001).
- Constructivist Transitional Instruction: key components of the constructivist transitional instructional style reflect a mixture of the confirmatory and inquiry-based styles (Schmidt, 2001).
- Didactic Instruction (traditional instruction): key components of direct instruction are modeling, reinforcement, feedback, and successive approximations. Didactic instruction is considered traditional and teacher-centered (Schmidt, 2001)

- DWF Rates: this measurement is a traditional measurement reported by the university to assess course retention. This measurement contains the number of students who received a course grade of a "D" or "F" and students who withdrew from the course.
- Inquiry-Based Instruction: at the heart of inquiry instruction is Jean Piaget's Cognitive-Development Theory. His work focused on the reasoning processes at different stages of cognitive development. Piaget believed that knowledge was a dynamic construct that changed depending on a person's environment and could rearrange itself to adapt to the environment. Inquiry-based instruction is constructivist in nature and student centered (Schmidt, 2001)
- Linear: a curricula approach that presented topics in a sequential order without requiring the view of horizontal component (Doll, 1993).
- Modern: a curricula approach that was based in mechanistic view of education where the maximum amount of information was given in the minimum amount of time (Doll, 1993).
- Objectivist Transitional Instruction: key components of the objectivist transitional instructional style reflect a mix of didactic and confirmatory styles with a basis in the objectivist-based paradigm (Schmidt, 2001)
- Open-system: a systems view that accounts for the influence of outside factors (Doll, 1993).
- Post-modern: a curricula approach that moves out of the scientific curriculum and into a more open-systems curriculum that focuses on a student's experience throughout the learning process (Doll, 1993).

- Pre-modern: a curricula approach that primarily dealt with the accumulation of facts rather than a deeper understanding that prepared one to be a productive member of society (Doll, 1993).

Variables

- Independent variable – instructional method used
- Dependent variables – learning outcomes, students' attitude towards statistics

Significance of the Study

Since many general education programs at universities require at least one course in mathematics, and the trend is for this course to contain statistical understanding, success in mathematics is critical to college completion. The fact that many students struggle to fulfill the general education requirements in mathematics is well-documented (Bressoud, Friedlander, & Levermore, 2013; Vandal, 2014), and increasing student success in these courses is part of a national completion agenda and credentialing push (Lumina Foundation, 2013). Nationally, college completion currently stands at an all-time low (during the period from 1983 to 2013), with 24.4 percent completion rates from two-year colleges, and 36 percent from public four-year BA/BS degree-granting institutions (ACT (1), 2013, ACT (2), 2013). The significance of continued research into methods for improving mastery in postsecondary mathematics is clear.

Study Overview

The research design was causal-comparative research. The researcher attempted to determine the cause or consequences of differences that already existed between the teaching methods used by instructors of statistical methods. Data was collected from instructors and students in introductory statistics courses at a state university in Southwest Florida during the fall 2016 semester. The title of the course was Statistical Methods and was taught by graduate students, instructors, and professors. It was expected that the wide experience of instructors would present a variety of teaching methods. Typically, the class size was maxed at fifty-four students with most sections full. The fall 2016 course offerings included twenty-eight sections, approximately fifteen instructors, with a total of 1512 students. With the support of the chair of the Department of Mathematics and the course coordinator for statistical methods, it was anticipated that a large portion of the instructors, and thus students, would participate in this study.

Data Collection

Two instruments were used to answer the question, "What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*?" Course instructors were given the *Instructional Style Survey for Statistics* to determine where they lie along a spectrum on instruction styles from more didactic to more inquiry-based. The instrument, *Learning Outcomes for Statistical Methods*, was developed to access the statistical learning outcomes. All students participating in this study were given this instrument as their final exam in the course. The *Instructional Style Survey for Statistics* was developed as part of a dissertation in 2001 (Schmidt, 2001). Reliability and validity measures were found for this dissertation. Subsequent measures of reliability and validity of the instrument were also made in 2006.

Two instruments were used to answer the question, "Does teaching style contribute to differences in students' attitudes towards statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36?*" Course instructors were given the *Instructional Style Survey for Statistics* to determine where they lie along a spectrum on instructional styles from more didactic to more inquiry-based. An instrument designed to access students' attitudes towards statistics was administered at the beginning and end of the semester. There were at least three different instruments that have adequate amounts of evidence for their validity and reliability: *Survey of Attitudes Toward Statistics* (SATS) developed by Schau (1992, 2003); *Attitude Toward Statistics Scale* (ATS) developed by Wise (1985); and the *Statistics Attitude Survey* (SAS) developed by Roberts and Bilderback (1980). The *Survey of Attitudes Toward Statistics SATS-36* was used for this dissertation study. This instrument was found via systematic review to yield the most robust validity and reliability measurements (Nolan, Beran, & Hecker, 2012).

One instrument and final course averages were used to answer the question, "What is the relationship between students' attitudes towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates?" The *Survey of Attitudes Toward Statistics SATS-36* was administered to all students participating at the beginning and at the end of the semester. Final course averages were collected at the end of the semester from course instructors.

To answer the question, "What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and DWF Rates?" one instrument and final course averages were used. The *Instructional Style Survey for Statistics* was to all instructors participating at the beginning of the semester. Final course averages were collected at the end of the semester from course instructors.

Analysis

An SPSS version 24.0 (IBM Corp., 2016) was used to analyze the results of the student attitude survey and teacher teaching method preference. Descriptive statistics were calculated using the *Instructional Style Survey for Statistics*, *Student Attitudes Toward Statistics SATS-36*, *Learning Outcomes for Statistics*, and various grades recorded by instructors. A one-way ANOVA comparing the *Learning Outcomes for Statistical Methods* final exam scores and their final course average of participants who took a course from one of four different instructors was conducted. A one-way ANOVA comparing the student's final course average, their average score on the *Learning Outcomes for Statistical Methods*, and the *SATS-36* pre-sub scores by gender was also performed. A one-way repeated measures ANOVA comparing the student's affect component score at two different times was performed. A Pearson *r* correlation coefficient was calculated for the relationship between participants' SATS-36 six sub-scores and their final course average. A Pearson *r* correlation coefficient for the relationship between students' *SATS-36* post stress level rating and their *Learning Outcomes for Statistical Methods* average was also calculated.

Summary

This dissertation is organized into five chapters, a list of references, and appendices. Chapter II of the study presents a review of related literature as related to learning theory, curriculum theory, instructional practices, mathematical literacy, and culture in mathematics education. Chapter III describes the research design and methodology of the study. Included in the third chapter are descriptions of the population, sample design, research questions, measures, research design, data analysis procedures, preliminary studies, and delimitation. Chapter IV presents the results of the research study. This will include an analysis of the data used to determine the instructional method used by instructors, student attitudes toward statistics, and demonstration of statistical learning outcome achievement. Chapter V discusses the relationship of the results of this study to past research and theory on undergraduate statistics education, and concludes with implications for practice and recommendations for further research. With the increased requirement for undergraduate students to take a quantitative reasoning course dealing with statistical methods in many university curricula, there is a need to study what methods statistics instructors use, and which produce the best academic outcomes for students.

CHAPTER II

LITERATURE REVIEW

Chapter 2 presents current literature related to this study and includes areas related to Learning Theory, Curriculum Theory, Pre-Modern Curriculum, Modern Curriculum, Post-Modern Curriculum, Didactic Instruction, Inquiry Instruction, Instructional Practices, Technology, Mathematical Literacy, and Culture in Mathematics Education.

Learning Theory

Birney et al. (2005) noted a primary purpose of statistical instruction is to help students understand the underlying structure of a problem, as opposed to understanding the surface details. To help understand the structure, Birney et al. described that a benefit of presenting problems in a familiar context reduces the demands on working memory. Students in mathematics develop schemas that allow students to group similar problems into categories which require similar solutions. These researchers suggested that not only does the depth of knowledge increase as knowledge becomes procedural, but expertise develops with the addition of schemas.

In a study about student reactions to the structure of an assignment, DePaolo et al. (2009) concluded that students choose to complete assignments that fit into their cognitive style. The study also supported the claim that a student's self-efficacy is higher on assignments that match their preferred cognitive style. To accommodate different cognitive styles, they suggested having two versions of an assignment: one version with more structure and one with less structure. They noted that having two versions of an assignment may be impractical for many instructors.

Curriculum Theory

The most influential concept that Doll (1993) set forward is that humans learn by interacting with other humans. This may define the difference between humans and the rest of the animal world. Learning takes place through the feeling of disequilibrium which in turn causes growth in the depth of understanding. Doll (1993) pointed out that simplistic view of a linear cause-and-effect relationship did not adequately explain the complex human interaction between a person and their self, or between a person and their environment. Egan (1999) indicated that the new paradigm of curriculum focused on a students' mastery of abstract knowledge instead of just focused on the accumulation of facts.

Doll (1993) pointed out that an essential ingredient with this new curriculum was a redefining of the authority roles. Giving up authority in the classroom is often difficult for teachers. The role of the teacher is no longer a sole director in the classroom but a part of the learning community. In addition, decisions are not made prior to learning but rather evolve through learning. Egan (1999) stated that the new curriculum should be grounded in students' deeper understanding instead of trying to accumulate facts. Slabbert and Hattingh (2006) stated that this interconnection is a fundamental part of the post-modern paradigm. This concept of rigor by using questioning by teachers and students and creating interest should be the goal of all educators (Losin, 2001). This post-modern curriculum is one that emphasizes problem-based learning; there is recognition that the direct questions found in textbooks and standardized tests do not resemble how humans will face these problems in real life (Slabbert & Hattingh, 2006).

Pre-Modern Curriculum

The pre-modern paradigm was fraught with the idea that there was no choice: individuals had pre-assigned roles for the good of society (Doll, 1993). People began early on with their pre-assigned role and could not deviate from it. Katz (1998) pointed out how early civilizations were content with the ability to calculate numerical answers to problems. People were assigned the roles of bookkeepers or scribes that involved performing rudimentary calculations. There really was not a sense that they needed to go further and explain why they were able to perform these calculations. Doll (1993) continued with this thought by indicating that individuals were not allowed to exit these roles or to rise into a higher class.

Doll (1993) noted that the ancient Greeks made a distinction between wisdom and the accumulation of facts. To the ancient Greeks, the concept of cognition moved past learning particular skills to understanding experiences at a deeper level to lead to a meaningful life. They viewed factual knowledge as only a remembrance; understanding is the act of questioning that knowledge. Egan (1999) argued that the ancient Greeks were primarily concerned with education as socialization. With socialization, education was viewed as being concerned with a particular set of beliefs, conventions, norms, and values.

Plato and Aristotle still considered this idea of pre-assigned roles when identifying their own thoughts of society. Plato began to look for a higher purpose in society and oneself, calling it the Christian soul; whereas, Aristotle did not use the concept of soul to describe idealized forms containing a classification system. They both, in essence, influenced the idea that there is something more out there to be discovered. Katz (1998) described how Aristotle believed in using syllogistic logic to take old ideas and form new knowledge. The works of Descartes and Newton began to formulize thought into a more mathematical representation. Doll (1993) noted that Descartes favored using reasoning in order to find the truth of statements. The mark of the modern paradigm was the concept of control. Everything had an order to be followed and if that order wasn't followed the whole house would come falling down (Doll, 1993).

Modern Curriculum

Entering the twentieth-century brought about a major change in the United States. The U.S., once based in agriculture, became one based in manufacturing. The growth in the number of factory workers during the late 1800s more than doubled in a period of thirty years (Fine, 1997). This time period became known as the Industrial Revolution. Not only did the Industrial Revolution change the economy of America, but it led to major changes in other realms including education (Doll, 1993; Fine, 1997). In addition to the increase in factory workers, the student populations began to increase during the early 1900s, which lead school leaders to look to the scientific management model to improve efficiency (Fine, 1997).

Viewing society through the lens of the Industrial Revolution resulted in trying to maximize the outputs of individuals while minimizing the time required for certain tasks. One method in accomplishing this maximizing and minimizing effort was to have managers look at the most efficient way of accomplishing tasks and then giving this sequence to employees on a daily basis. Building upon this sequence of tasks developed by mangers led the way to the assembly line. The concept behind the assembly line was that each employee would be responsible for a certain segment of the production. This employee would only work on said segment, and through repetition and mastery this employee would become faster and more efficient.

This assembly line was adopted by the school system in which teachers would become masters of certain parts of a student's education (Doll, 1993). Once a student finished with one teacher, he or she would be moved down the assembly line to the next teacher until they had a finished product at graduation. In addition to this assembly line model, the school system then began developing a single curriculum because of the rapid growth of the population. This common curriculum is known, by Doll (1993), as the "scientific" curriculum, and had the elements of efficiency and standardization. This scientific curriculum was comprised of pre-set goals, experiences, and evaluation. This scientific curriculum demanded a development of standards to measure the level of accomplishment of the goals, and to show the efficiency of the school system (Fine, 1997).

An early developer of the scientific curriculum was John Franklin Bobbitt. Null (1999) characterized Bobbitt's early work as being based in the principles of scientific management and engineering emphasizing efficiency-based management of curriculum. Particularly interesting is how Null (1999) stated that Bobbitt, in his final book, *Curriculum of Modern Education*, modified his stance on scientific curriculum later in his life to include four ideas: the importance of general education, uncertainty of the future lives or roles of students, focus on individual intellect, and a respect of the classic authors. This would certainly contradict the prevailing emphasis of the scientific curriculum to train students for work in the fastest way possible.

In the attempts to make a scientific curriculum, modernists chose to look at curriculum like a physicist. This view point caused the curriculum to be a closed system; one in which the outside experiences did not have an effect on the system. This closed-system curriculum led teachers to adopt a didactic form of instruction where teachers directed the students in their learning instead of allowing for situations where students can learn for themselves (Doll, 1993).

The modernist movement took on a different view of cognition. With the Scientific and Industrial Revolutions, modernists viewed learning as the accumulation of knowledge. The mind became viewed as a muscle that needed to be consistently exercised (Doll, 1993). This led teachers to focus on memorization and recitation.

Burbules (2000) described the Socratic Method through a story about Socrates teaching a slave a lesson in geometry. Socrates continued to question the slave until he broke down and finally said he didn't know how to solve the problem. It was not until the slave exhausted his previous assumptions about the problem that Socrates could then begin to lead him into the geometrical proof. It is through this questioning that Losin (2001) noted is the mission of educators. Educators are responsible for awakening the desire for learning in students.

Post-Modern Curriculum

The post-modern paradigm moves from the rigid control of the modern paradigm to one that contains more flexibility (Doll, 1993). This view of flexibility is to allow for the fact that the world does not exist in a bubble following a set of finite rules; but the world exists with many influences that help direct its course. In the post-modern paradigm, we look to see if there is room to allow for personal feelings, intuitions, or experiences (Doll, 1993). Ornstein and Hunkins (2004) mentioned that much of the current movement in education has been on reforming it.

In a move to a post-modern paradigm, a different science becomes the viewpoint of the post-modernist: biology. A biological perspective on curriculum positions the curriculum as an open system. This open system now accounts for outside influences that may affect it. Slabbert and Hattingh (2006) stated that this post-modern paradigm takes on more of an ecological view as they see humans are interconnected with not only others, but with the environment as well. Students do not learn in a linear fashion as suggested in the scientific curriculum. This open-system curriculum leads teachers to adopt a more conceptual-based form of instruction where students are faced with problems or experiences that cause a disequilibrium, requiring students to form new brain structures to explain the concept (Doll, 1993).

It is important to note the difference between chaos theory in mathematics and chaos theory used as a metaphor in the social sciences. At the very heart of this discussion are the fundamental similarities between the two. In general, chaos is defined in terms of the unpredictability of certain outcomes (Goff, 1998; Iannone, 1995). This is not to say that there is no pattern that emerges, but we simply cannot predict with any certainty the outcome. Doll (1993) described this unpredictability of phenomena with the following examples: Poincairé stated that systems with three or more bodies could not be shown to be stable. This is not to say that they aren't stable, it is just that we cannot prove them to be with our current mathematical knowledge. Unpredictability is also shown in the realm of weather. We cannot predict the weather beyond a few days.

Doll (1993) described his motivation to use chaos theory as a metaphor in looking at how students are not isolated individuals, but rather operate in a larger environment. This larger environment causes the student to become a complex system that cannot be predicted, hence the connection with mathematical chaos. Students bring outside experiences and previous knowledge with them to the classroom. This complex system then negates the ability to predict what the student will actually learn in a lesson. The connection with mathematical chaos and curriculum continues with the iteration process. Doll (1993) described this connection as having the students look back at their previous experiences, thus substituting their current experiences with their previous ones. The practice of self-reflection is in agreement with this connection.

The purpose of chaos in curriculum is to move the teacher from a didactic role to one in which he or she becomes part of the learning process (Doll, 1993). The teacher no longer stands in front of the classroom giving direct instruction, rather he or she leads the students in experiences that cause disequilibrium and forces the students in a process of self-organization and pattern recognition. In an analysis of their higher education classroom practices, Haushildt and Wesson (1999) noted that through the initial stages of confusion and panic in their students, the students began to do serious reading, produced well-written responses, engaged in more intense class discussions, and integrated their experiences with the classroom knowledge. They cite this post-modern pedagogy as the reason for success in their college courses, as opposed to their previous experiences in a K-12 setting where they used a more didactic way of teaching.

Hunter and Benson (1997) cautioned the use of mathematical chaos theory as an attempt to explain the complex human behavior. Their main argument centers on the concept that one should not use theories from the natural sciences to attempt to explain the social sciences. They agree with the error in using physics during the modern paradigm and extend this to the problem of now seeking to use chaos theory in the post-modern paradigm. MacPherson (1997) agreed with the problem of using novel scientific theories to explain phenomena beyond their original scope. He, however, did not see a problem with using those scientific theories as metaphors for phenomena happening in the social sciences. Interestingly enough, Morris (2005) posed the idea of going beyond chaos theory into the newer mathematical fields of M theory and string theory. Chaos theory is a complex theory that involves high level mathematics to explain the order within the disorder. The metaphor of using this complex mathematical theory as a curriculum theory illustrates the complexity of human behavior.

Didactic Instruction

The changing of American society into a more industrialized nation led for the need of more information about learning. John Watson proposed that the study of behavior would help to understand how an individual learns. “His rationale was that all organisms adjust to the environment through responses and certain responses typically follow certain events” (Gredler, 2009, 37). Watson was able to use the research of the motor-reflex by V.M. Bekheterev to develop his idea that behavioral control in the real world was a possibility.

There are three basic assumptions about learning behind behaviorism: (1) observable behavior should be the focus of study, (2) behavior should be studied in terms of its simplest elements, and (3) the process of learning is behavioral change. “The best-known experiments on reflexes were conducted in the research laboratories of Ivan Pavlov” (Gredler, 2009, 37). The basics of Pavlov’s experiments were that a response could be learned. Pavlov and his researchers would pair a natural response to some event with a stimulus, and would be able to transfer that response to the stimulus. This is the process of classical conditioning.

“The process by which new events or stimuli acquire the power to trigger responses became known as reflex or classical conditioning” (Gredler, 2009, 38). There are three stages in classical conditioning: (1) pre-experimental, (2) experimental, and (3) post-experimental. In the first stage, the natural response is observed in the subject. In the second stage, the researcher pairs the natural response with a new stimulus that is independent of the reaction. In the third stage, the new stimulus will alone trigger the natural response. Pavlov later tried the process of higher order conditioning. He attempted to layer another stimulus after the original response was learned. This did not prove to be a long lasting learned behavior.

Didactic or direct instruction has its roots in behaviorism. The research of Watson, Skinner, and Thorndike have been used to form what we now consider traditional instruction. Their research upheld a system of positive and negative reinforcements where students were rewarded for correct behaviors or answers and punished for incorrect behaviors or answers (Schmidt & Stepans, n.d.) Schmidt and Stepans (n.d.) hold that direct instruction has, at its core, that learning is a process of remembering information. Educators use beliefs about how information is stored in both short- and long-term memory.

Magliaro et al. (2005) makes a distinction about direct instruction: it is not lecture approach. It focuses on the interaction between teachers and students. The key components of direct instruction are modeling, reinforcement, feedback, and successive approximations. At the underpinning of direct instruction is the belief that behavior evolves. The five basic elements to direct instruction are:

1. Materials and curriculum are broken down into small steps and arranged in what is assumed to be the prerequisite order.
2. Objectives must be stated clearly and in terms of learner outcomes or performance.
3. Learners are provided with opportunities to connect their new knowledge with what they already know.
4. Learners are given practice with each step or combination of steps.
5. Learners experience additional opportunities to practice that promote increasing responsibility and independence (guided and/or independent; in groups and/or alone).
6. Feedback is provided after each practice opportunity or set of practice opportunities (Magliaro et al., 2005, pg. 44)

Watson had a huge impact on psychology and theories dealing with the behaviorism. Watson had a greater influence on psychologists then Pavlov or any other one person to explain the behavior that lay within in the nervous system (Bolles, 1979). His theory had the assumption that learning should be analyzed in terms of S-R connections (1979).

Inquiry Instruction

Some of the primary cognitive psychologists behind inquiry instruction were Piaget, Bruner, and Vygotsky (Schmidt & Stephans, n.d.). At the heart of inquiry instruction is Jean Piaget's Cognitive-Development Theory. His work focused on the reasoning processes at different stages of cognitive development. Piaget believed that knowledge was a dynamic thing that changed depending on a person's environment and could rearrange itself to adapt to that environment. This led the field of psychology into a new direction where they focused on how the learner progresses from one stage to another. This progression consisted of four essential factors: the physical environment, maturation, social influences, and equilibration. Equilibration refers to the process of maintaining intelligence while it adapts (Gredler, 2009).

A key concept in Piaget's Cognitive-Development Theory is operational (logical) thinking. Operational thinking consists of three essential characteristics: transformation happens with a change in another characteristic, the nature of the data remains invariant, and the transformation can be reversed to the original by an inverse operation. Reversibility is the key so that the child does not become confused. Necessity is essential to operational thinking, as well. In the early years of cognitive development, the child cannot differentiate between reality, possibility, and necessity. There are three basic principles to operational thinking which show up in early childhood: knowledge always involves inference, the meaning of an object includes what the object can do, and logic develops when a child can see a correlation between an object's actions (Piaget, 1970a/1970b).

There are two basic components of cognitive development. The psychological structure of logical thinking, and the second being the fundamental processes involved in interactions with the environment. Logical thinking occurs when a person can simultaneously coordinate an operation and its inverse, can anticipate the types of changes that can occur, and support their beliefs with necessity. There are four periods of cognitive development, which are sensorimotor, preoperational, concrete operational, and formal operational stages (Piaget, 1967/1970).

"To summarize the difference between the two families very briefly, whereas S-R conditioning theorists interpret learning in terms of changes in strength of S-R connections, associations, habits, or behavioral tendencies, cognitive interactionists define learning in terms of reorganization of perceptual or cognitive fields so as to gain understandings. Consequently, whereas a behavioristic teacher desires to change the observable behaviors of students in a significant way, a cognitive-interactionist teacher aspires to help students develop their understandings of significant problems and situations" (Bigge & Shermis, 1999, pg. 11).

Instructional Practices

Derry, Levin, Osana, Jones, and Peterson (2000) designed a study to assess the effects of inquiry-based instruction on statistics education. They showed that students had some prior statistical ideas and vocabulary, and that students were able to activate this prior knowledge along with using knowledge gained throughout the course. Their results showed that an inquiry-based course in statistics was able to improve a student's ability to apply statistical knowledge, and to critique research reports and statistical items presented in the news. Overall, Derry et al. noted students enjoyed the inquiry-based course more than the traditional one.

Rabin and Nutter-Upton (2010) showed the use of a journal excerpt activity significantly outperformed students in a traditional introduction to statistics course. This inquiry-based instruction promoted the statistical skill of reading tables and graphs, and reflection on the meaning of those tables and graphs. This project utilized individual work or small group collaboration. This inquiry activity increases corrective feedback from peers and instructors and develops an environment of cooperation.

Perkins and Saris (2001) described the "jigsaw classroom" as an inquiry-based course. The "jigsaw classroom" utilizes worksheets containing different parts of a problem. Each small group works a different worksheet or part of the problem. The class then combines the parts to describe the overall problem before the end of the class. The use of the "jigsaw classroom" allows for students to work on problems during class time and receive corrective feedback from the instructor. The use of the parts of problems allows for a problem to be entirely finished before the end of class, allowing for discussion. Perkins and Saris noted that the use of the "jigsaw classroom" should not be used for introduction of concepts.

Technology

Maddux (2001) noted in previous years that statistical instructors have relied on rote mathematical calculations as the central part of an introduction to statistics course, neglecting the applications of statistics and the development of statistical concepts. Before electronic calculators and statistical software, statistical instructors had little choice but to focus on rote mathematical calculations. Maddux suggested that the use of electronic calculators or statistical software moves statistics education from an emphasis on rote mathematical calculations to a deeper understanding of statistical concepts.

In addition to the use of electronic calculators and statistical software, Gundy, Morton, Liu, and Kline (2006) suggested that the use of web-based instruction could reduce students' anxieties in an undergraduate statistics course. Their study showed the use of online discussions forums enhances a student's self-esteem and value by the students.

Summers, Waigandt, and Whittaker (2005) argued web-based courses transcribed from traditional courses do not have a significant improvement in student achievement. Their research indicates that online education should follow a constructivist approach. Web-based courses should contain bulletin boards, chat rooms, and threaded discussions. Bulmer and Rodd (2005) reported how web-based courses increase the awareness of students' performance to instructors. This increase causes greater interaction with the instructor within the online content.

Mathematical Literacy

Low Socioeconomic Status. Purcell-Gates (2000) described the existence of several causal studies relating low socioeconomic status (SES) with lower academic performance of students. She further noted how the results of these studies showed a weak or even negative prediction between SES and academic performance of students. Cheema and Galluzzo (2013) found a significant difference between racial and socioeconomic gaps in math achievement in high school students. Gadsden (2000) posited two very thought-provoking questions: "Are poor children, particularly poor children of color, confined to living out the imposed statuses of inequity and limited access? If the answer is no, then what do we need to know about the contributions of family members, and how do we reconcile the multiple streams of influence in children's reading and writing development?" (p. 875). Brandt (2009) attributed differences in academic performances of students to education and income of parents. She stated how students from higher SES typically have more powerful literary sponsors whereas as students from lower SES typically have less access to literary sponsors.

Minami and Ovando (2009) stated how students from low socioeconomic backgrounds often use different linguistic codes at home than their teachers do in the classroom. This causes a barrier for students of low socioeconomic backgrounds as they too must learn a new linguistic code while also trying to learn the curriculum. "In summary, language researchers have shown in a variety of ways how children's home environments and language community affect their academic development" (Minami & Ovando, 2009, p. 582).

Best Practices in Literacy. Purcell-Gates (2002) synthesized the best practices of literacy programs by stating these programs primarily focus on three areas: (1) reading to their children, (2) helping with their homework, and (3) strategic communication with schools and teachers. Brandt (2009) mentioned, “Like many people I interviewed who were children during this period, Martha Day proudly recalled a progressive family identity that seemed to be delivered into many rural households along with the local newspaper. Periodical reading was linked to forward-looking thinking, intelligent farming, and political participation” (p. 53). Brandt noted in several interviews here parents would read to their children, have reading material available, help with homework, and communicate with schools.

O’Brien and Bauer (2005) described how students are living in two worlds simultaneously: Institution of Old Learning and New Literacy. Students are being educated in a school system that promotes reading and writing using the techniques of old learning. A large reason for this is that current teachers were taught in this system and current educator preparation programs encourage this type of learning. Whereas students are actively switching the way they learn from print to the screen. As teachers are “in control of the curriculum, physical and social space, classroom interaction, participation structures, and the social positioning of themselves and students,” teachers and teacher educators must adapt their instruction to better meet the needs of our current students (O’Brien & Bauer, 2005, p. 127).

Reciprocal Learning. Gadsden (2000) mentioned an interesting result from researchers by stating how there might be a reciprocal relationship of learning between children and parents. Vygotsky (1934/1962) also takes on the view that learning is through social interaction between others. It is through a socio-cultural lens that there is a view that students learn from the teacher, students learn from one another, and teachers learn from students.

Multiple Identities. In describing one view of identity, Moje and Luke (2009) discussed the idea of multiple identities where a person has more than one identity that he or she may use in different contexts. This was further described as a person having multiple outward or visible identities a person displays to the society as a whole. Heath (1995) noted how today's youth do not identify themselves in terms of a "single ethnic group, place, or family; instead they pick and choose, change and reshape their affiliations of primary socialization" (p. 126).

In terms of using new literacies in understanding the role of social practices and cultural models in bilinguals and ESL students, O'Brien and Bauer (2005) noted how students of multicultural backgrounds are working (reading and writing) in their native cultural group in addition to working in a new cultural group requiring the students to be proficient in their native and new cultural group. Heath (1995) noted how today's youth do not identify themselves in terms of a "single ethnic group, place, or family; instead they pick and choose, change and reshape their affiliations of primary socialization" (p. 126). As one can see, a person cannot be defined in terms of solely one ethnic group or classification.

Steinberg and Kincheloe (2001) noted "along lines of race, class, and gender, individuals can simultaneously fall within the boundaries of one power bloc and outside another" (p. 36). Horn (2001) states similarly, "the recognition that the interaction of all the parts synergistically creates something larger and more unique than the mere addition of the individual parts to create a sum total" (p. 77). Heath (1995) stated the difficulty of defining community lies in the fact "few people live close by groups with which they feel the strongest communal association" (p. 114). The old sense of one's community consisting of one's national origin, ethnicity, and religion are no longer valid as a person's sense of community is more likely to be defined by their "self-conscious sense of purpose and self-interest, as well as socioeconomic class" (Heath, 1995, p. 116). This lack of a defined community for today's youth is due to several factors: intermarriage and geographic mobility cause many to view themselves as "mixed" cultures.

Perspectives in Literacy Change Over Time. Alexander and Fox (2008) described changing perspective in literacy over five eras: The Era of Conditioned Learning (1950-1965), The Era of Natural Learning (1966-1975), The Era of Information Processing (1976-1985), The Era of Sociocultural Learning (1986-1995), and The Era of Engaged Learning (1996-Present). The Era of Conditioned Learning was pushed forward after the conclusion of World War II and the resulting population boom, in addition to the space race between the United States and the Soviet Union. Much of this era was marked by the behavioral approach using a "medical metaphor of reading, with its diagnosis, prescription, and remediation, that prevailed during this era" (p. 14).

The Era of Natural Learning made a distinction between the rote learning in the previous era and a movement towards learning from experience. The Era of Information Processing made use of new cognitive research and a movement towards using research-based reading instruction. The Era of Sociocultural Learning was marked by research from people such as Vygotsky and focused on learning in a social context. The Era of Engaged Learning was marked by a focus on standards and assessment.

Shannon, Edmondson, Ortega, Pitcher, and Robbins (2009) described how the past 50 years have been marked by an increase in federal intervention into educational policy. Prior to this this push, much of the funding and curricula/pedagogical decisions were left to local and state boards of education. Originally, the federal government began with legislation to increase the equitable access to education for all students specifically targeting minorities and students with disabilities. The Federal Government has increased their level of involvement in funding and curricula decisions. This really has cumulated with The Elementary and Secondary Education Act: No Child Left Behind (2001) required highly qualified teachers to bring ALL students to a proficient level in reading and mathematics assessed by standardized tests. The Obama Administration has made a slight adjustment to this Act by allowing states to opt-out of some of the requirements by showing innovative education policy. Congress is currently debating the newest reauthorization of the ESEA.

Culture in Mathematics Education

Pedagogy and Practice. Darder (2012) postulated how critical pedagogy required “the willingness of teachers to culturally expand their critical lens when working to make sense of questions of gender and sexuality that arise in their practice with students, their parents, and their community” (p. 98). Glickman, Gordon, and Ross-Gordon. (2010) also described gender inequity in education. They stated gender inequity can have a negative effect on a girl’s self-confidence. A study conducted on first-year students in economics by Arnold and Rowann (2014) found a difference between female and male students in how females were more motivated to study but less confident in their performance. Fry (2003) described how sexual harassment was another barrier to a girl’s academic experience. When sexual harassment occurs at schools and educators do nothing in response, the harassment becomes part of the culture of the school. Fry (2003) noted 89 percent of girls surveyed had experience some form of sexual harassment. Bauer (2000) described gender inequity in the curriculum. Girls are often portrayed as being needy or in a supportive role in the books children read. In addition, history books often do not discuss the historical importance of females. Cheryan (2012), Gunderson, Ramirez, Levine, and Beilock (2012), Scafidi and Bui (2010), and Thorman, White, Yamawaki, and Koishi (2008) noted no difference between males and females in performance but stated that stereotypes of math related fields are reducing the number of women electing to continue in the science, technology, engineering, and mathematics (STEM) fields. Due to a lack of feedback from teachers and attention during class, Kommer (2006) stated girls stop being successful in math and science during middle school. In a study of participants aged four and a half to 90, Scheiber, Reynolds, Kajovsky, and Kaufmann (2015) found no gender-age difference between males and females. Bench, Lench, Liew, Miner, and Flores (2015) found in a study of STEM students at universities no real difference between males and females on performance but found males overestimated their academic abilities in mathematics. Liu and Wilson (2009) found a difference between male and female high school students but also attributed a gender gap due to females underestimating their mathematical ability. Darder (2012) noted “findings generally have indicated that where children are perceived as bright, articulate, and motivated, the children fulfill the prophecy of success. Where children are perceived as slow, dull, and unmotivated, they reproduce the behavior and attitudes that support negative teacher expectations” (p. 17). Supporting Darder’s statement, Cheema and Galluzzo (2013) found a difference between male and female high school students in math but this gender gap was signification reduced when controlled for math self-efficacy and anxiety.

Darder (2012) stated “as teachers gain a greater understanding of students’ lives outside of school, they are more able to create opportunities for classroom dialogue, which assists bicultural students to affirm, challenge, and transform the many conflicts and contradictions, that they face as members of disenfranchised groups” (p. 118). In the attempts to make a scientific curriculum, modernists chose to look at curriculum like a physicist. This view point caused the curriculum to be a closed system; one in which the outside experiences do not have an effect on the system. This closed-system curriculum led teachers to adopt a didactic form of instruction where teachers directed the students in their learning instead of allowing for situations where students can learn for themselves (Doll, 1993).

In a move to a post-modern paradigm, a different science becomes the viewpoint of the post-modernist: Biology. A biological perspective on curriculum positions the curriculum as an open system. This open system now accounts for outside influences that may affect the system. Slabbert and Hattingh (2006) stated that this post-modern paradigm takes on more of an ecological view as they see humans are interconnected with not only others but with the environment as well. Students do not learn in a linear fashion as suggested in the scientific curriculum. This open-system curriculum leads teachers to adopt a more conceptual based form of instruction where students are faced with problems or experiences that cause a disequilibrium, requiring students to form new brain structures to explain the concept (Doll, 1993).

Doll (1993) explained the notion of disequilibrium as presented in Piaget's work with the following:

> The learner's structures, as they interact with the environment, first do simple assimilations and accommodations but eventually – at a nonpredictable threshold or bifurcation point – combine to make a sweeping change (*tout ensemble*), transforming themselves into new and more sophisticated structures. (p. 71)

This explanation of disequilibrium is present in conceptual instructional models. These conceptual models have a similar structure. The lesson begins with posing a question or problem and allowing students to individually come up with an answer. The lesson then goes into sharing their thoughts with others, allowing for multiple perspectives and revision of initial ideas. Then, the learner is given an opportunity to explore the problem physically and mentally. This exploration causes disequilibrium for the students, and they are motivated to find another explanation. These models follow an open-system perspective as opposed to a model where the learner is not able to be influenced by his or her environment instead of just following the instruction of the teacher. The post-modern curriculum is one that emphasizes problem-based learning; there is a recognition that the direct questions found in textbooks and standardized tests do not resemble how humans will experience these problems in real life (Slabbert & Hattingh, 2006).

Null (1999) connected the closed- and open-system curriculum by following the evolution of Bobbitt's idea of learning. Bobbitt begins his career with a curriculum rooted in scientific management. This forced the curriculum to be a closed-system. Bobbitt then modifies his thoughts on curriculum to show the need for a more holistic curriculum. Bobbitt came to the realization that students control their learning (Null, 1999). [add transition here]

Culture and Power. Perez and Wiggan (2009) described how "in the age of globalization, global migration brings many new learners to U.S. public schools, and many of these students are English-language learners (ELLs)" (p. 196). The problem for ELLs is the fact that they must learn a new language while they must also learn the curriculum that will be tested on high stakes assessments. Darder (2012) further stated "it is significant to note that subordinate cultures are maintained in oppressive conditions not only through the dominant culture's function to legitimatize the interests and values of the dominant groups, but also through an ideology that functions to marginalize and invalidate cultural values, heritage, language, knowledge, and lived experiences which fall outside the purview of capitalist domination and exploitation – significant dimensions which constitute essential elements for the survival of subordinate cultures" (p. 29).

In addition to ELLs, Minami and Ovando (2009) stated how students from low socioeconomic backgrounds often use different linguistic codes at home than their teachers do in the classroom. This causes a barrier for students of low socioeconomic backgrounds as they too must learn a new linguistic code while also trying to learn the curriculum. “In summary, language researchers have shown in a variety of ways how children’s home environments and language community affect their academic development” (Minami & Ovando, 2009, p. 582).

Perez and Wiggan (2009) elaborated on several recommendations they have for educators. They suggested educators “[make] the connections clear, make classrooms safe environments, [and] give ELLs opportunities to demonstrate their competence.” This can be accomplished by changing “teacher beliefs, [using] cooperative groups and new norms of behavior, [improving] reading, [finding] other ways to develop reading skills, [and pursuing] parental and community support” (p. 193-195). Schools need to change to become welcoming to minority students. In order to accomplish this, Minami and Ovando (2009) suggested “(a) teachers treat their students as if they were their own biological children in social, emotional, physical, and academic matters; (b) teachers and school administrators believe in contacting family members or caregivers whenever it is necessary to do so; and (c) schools, parents, and community leaders jointly embrace the philosophy that all students can learn” (p. 583).

Johnson (2012) described how language and literacy can be used by the majority to further marginalize minorities. “In short, regulating the use of language is not just about controlling the way people speak a particular language – it is about controlling the people who speak that language” (Johnson, 2012, p. 55). Darder (2012) cautioned us by stating “as a consequence, power is commonly perceived either as an absolute force for good, or else as an evil or negative force that dehumanizes and divests the individual's capacity for justice and solidarity with others" (p. 110).

Cultural Democracy in the Classroom. Doll (1993) described the post-modern curriculum as a curriculum that is nonlinear and should be constructive. An important distinction is that there is a curriculum, but this curriculum should provide boundaries instead of stating the step-by-step progression of a student. In addition to this nonlinear approach, the curriculum should also look for connections with other subjects. "But for schools to meet this challenge, Dewey proposes that educators create environments where mutual interests are clearly recognized as the basic factor in social control, and where a commitment exists to continuously readjust as necessary when new situations produced by a variety of social discourses arise" (Darder, 2012, p. 59).

Doll (1993) also stated that this nonlinear curriculum still needs to have rigor. Students need to have a solid foundation in the material in order to reflect upon it. This firm understanding will also give students the confidence needed to be able to present their solutions and debate their ideas with others. Darder (2012) confirmed the use of the instructional technique of have students present solutions and debate their ideas by stating "students can only develop their voice through opportunities to enter into dialogue and engage in a critical process of reflection from which they can share their thoughts, ideas, and lived experiences with others in an open and free manner" (p. 62). Haushildt and Wesson (1999) described through a study that students were able to learn through risk-taking.

Doll (1993) pointed out that an essential ingredient with this new curriculum is a redefining of the authority roles. This may be the most unnerving of this new curriculum for teachers. The role of the teacher is no longer a dictator in the classroom but a part of the learning community. In addition, the decisions are not made prior to the learning but rather evolve through the learning. Darder (2012) agreed with Doll (1993) by postulating that "as a consequence of traditional pedagogical theories and practices, working-class bicultural students often face isolation, alienation, and despair in public schools because few opportunities exist for these students to reflect together on their collective histories and lived experiences, and to explore critically how these experiences relate to their participation in the larger society and to their process of emancipation" (p. 55).

This discussion is then summarized into Doll's (1993) four R's: richness, recursion, relations, and rigor. The depth of the curriculum is described as richness. Egan (1999) stated that the new curriculum should be based in students' deeper understanding instead of trying to accumulate facts. The reflecting back on material is described as recursion. The interactions of other subjects and interactions with the environment are described as relations. Slabbert and Hattingh (2006) stated that this interconnection is a fundamental part of the post-modern paradigm. The sense of rigor is the ability to look at alternative solutions, relations and connections. This concept of rigor by using questioning by teachers and students and creating interest should be the mission of all educators (Losin, 2001).

Conclusion: Making a Case for Research

With the increase in data collection over the years, there is a direct need for students trained in data analysis techniques. The first course in data analysis is introduction to statistics taken in the early years of an undergraduate program. This casual-comparative study seeks to understand how the inquiry-based teaching methods used by an instructor impacts students' affect constructs and statistical learning outcomes.

There are many quantitative studies examining students' attitudes in a statistics course (Pearl et al, 2012). The results of these studies suggest a student's affective construct can have an impact on learning statistics (Reid & Petocz, 2012; Gordon, 1995). There are few qualitative studies that examine the students' perception of teaching practices and how that relates to their statistical understanding. For the purposes of this study, affect constructs will be generally defined to "include the broad areas of attitudes, beliefs, emotions, dispositions, and motivations" (Pearl et al, 2012, p. 8).

Joyce, Weil, and Calhoun (2015) described five general areas of models for teaching: The Basic Information-Processing Models of Teaching, Special Purpose Information-Processing Models, The Social Family of Models of Teaching, The Personal Family of Models, and The Behavioral Family of Models. As outlined in the research above, the following models are appropriate models to use in an introductory statistics course for undergraduate students: Scientific Inquiry, Concept Attainment, Memorization, Group Investigation, Explicit Instruction, Mastery Learning, and Direct Instruction.

For this dissertation, the focus of the research is on learning theory related to models of instruction for statistics. Specifically, how students learn in introductory statistics – a college level course. It is the researcher's assumption that the course is extremely beneficial to students of varying ability levels and major preparations. Expected by the researcher is the validation of Joyce et al.'s tenants (2015):

- Students acquire knowledge by acting and thinking.
- Students learn by discovering their own solutions to open-ended problems.
- Students learn though interaction with peers and adults.
- Students learn when they can make sense of what they are learning.

- Students' misconceptions interfere with new learning.

Furthermore, "Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (NCTM, 2000, p.11). The ultimate goal for statistics education is for students to understand the concepts of statistics and to be able to use the knowledge gained in my course for future courses and research they interact with. In addition, and of great importance is the ability of students to use the information and skills learned in statistics to become better consumers of information in the real world including news and reports given to them in the occupation.

The current literature supports the need to embrace change in the design of an introduction to statistics course. A new course should be designed with the knowledge of varying student cognitive styles with a push to developing procedural knowledge and schemas. Technology should be embraced to reduce the demands of rote mathematical calculations and increase the conceptual statistical reasoning. Inquiry-based instructional strategies should be used in the regular lecture time along with additional web-based discussions.

CHAPTER III

RESEARCH METHOD

Introduction

With the increased requirement for undergraduate students to take a quantitative reasoning course dealing with statistical methods in many university curricula, there is a need to study what methods statistics instructors use and which produce the best academic outcomes for students in statistics courses. In addition, since there is a wide range of teaching approaches, there is a need to analyze how these differences in methodology influence student attitudes toward the subject of statistics. This study addresses the best practices in the teaching of introductory statistics and how instructors can improve the learning experience for students. During the first week of classes of the fall 2016 semester, instructors from a higher education institution were asked to complete the *Instructional Style Survey for Statistics* and students were asked to complete the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36* pre-survey. During the last week of classes of the fall 2016 semester, students were asked to complete the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36* post-survey in addition to taking a final exam which consisted of the *Learning Outcomes for Statistical Methods* instrument developed for this dissertation.

Additional exam grades and final course grades were collected from students. Data was analyzed during the spring 2017 semester. Surveys were administered on the course management software Canvas. The data was kept on a secure server administered by the university for a period of three years. The data was analyzed using the SPSS version 24.0 (IBM Corp., 2016) statistical analysis software.

Population

There were two populations of interest in this study: university statistics instructors and undergraduate students. For this study, the researcher collected instructional practice preferences of statistical methods instructors, the attitudes towards statistics of students, and the performance of students in their courses. Results underscored which types of instructional practices are correlated with an increase in student learning outcome achievement, and an increase in positive perception towards statistics.

Sample Design and Composition

Data was collected from instructors and students of an introductory statistics course at state university in Southwest Florida, during the fall 2016 semester. The title of the course was Statistical Methods and was taught by graduate students, instructors, and professors. The wide experience of instructors presented a variety of teaching methods. The class size capped at 54 students with most sections full. The fall 2016 course offerings included 28 sections, approximately 15 instructors, with a total of 1512 students. The support of the chair of the Department of Mathematics and the course coordinator for statistical methods, was instrumental that a large portion of the instructors and their students will participate in this study.

Research Questions and Hypotheses

By investigating how teaching method relates to both student achievement and attitude towards statistics, the purpose of this study was to recommend a teaching method to be used to teach introductory statistics. The research questions were:

(1) What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*?

(2) Does teaching style contribute to differences in student's attitude towards statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36*?

(3) What is the relationship between students' attitude towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates? and

(4) What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and DWF Rates?

Measures

Variables and definitions.

- Independent variable – instructional method used
- Dependent variables – learning outcomes, students' attitude towards statistics

Data collection instruments.

To answer the question, "What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*?" two instruments were used. Course instructors were given the *Instructional Style Survey for Statistics* to determine where they lie along a spectrum on instruction styles from more didactic to more inquiry-based. An instrument was developed to access the statistical learning outcomes. This instrument was called *Learning Outcomes for Statistical Methods*. All students participating in this study were given this instrument as their final exam in the course. The *Instructional Style Survey for Statistics* was developed for a dissertation in 2001 (Schmidt, 2001). Reliability and validity measures were found for this dissertation. Subsequent measures of reliability and validity of the instrument were also made in 2006. Measures of reliability and validity are reported later in this chapter.

To answer the question, “Does teaching style contribute to differences in student’s attitude towards statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36*” two instruments were used. Course instructors were given the *Instructional Style Survey for Statistics* to determine where they lie along a spectrum on instruction styles from more didactic to more inquiry-based. An instrument designed to access students’ attitudes towards statistics was administered at the beginning and end of the semester. There are at least three different instruments that have adequate amounts of evidence for their validity and reliability: *Survey of Attitudes Toward Statistics* (SATS) developed by Schau (1992, 2003); *Attitude Toward Statistics Scale* (ATS) developed by Wise (1985); and the *Statistics Attitude Survey* (SAS) developed by Roberts and Bilderback (1980). The *Survey of Attitudes Toward Statistics SATS-36* was used for this research. This instrument was found via systematic review to yield the most robust validity and reliability measurements (Nolan et al., 2012). Measures of reliability and validity for the *SATS-36* are reported later in this chapter.

To answer the question, “What is the relationship between students’ attitude towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates?” one instrument and DWF Rates was used. The *Survey of Attitudes Toward Statistics SATS-36* was administered to all students participating at the beginning and at the end of the semester. DWF Rates was collected at the end of the semester from course instructors.

To answer the question, “What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and

DWF Rates?" one instrument and DWF Rates was used. The *Instructional Style Survey for Statistics* was administered to all instructors participating at the beginning of the semester. DWF Rates was collected at the end of the semester from course instructors.

Validity and Reliability of Measures

In preparing the instrument *Learning Outcomes for Statistical Methods*, the guidelines for test item creation described by Thorndike and Thorndike-Crist (2010) were followed. For all test items: (1) clear directions for each item set told students how and where to respond, (2) each item will clearly assessed the learning outcome, (3) all references to religion, family, and SES were avoided, and (4) each item was reviewed to ensure it was clearly written without any unnecessary complexity. For all multiple choice items: (1) question stems contained a question or a complete sentence with as much information as possible, (2) the blank was at or near the end of the stem, (3) there was at least three alternative responses – two wrong answers and one correct response, (4) the distracters were plausible, likely to be selected, but not tricky, (5) if negatives are used in the stem, they were highlighted, (6) no clues were provided in the stem, (7) the alternatives had no unintentional clues, (8) the alternatives were short and organized in alphabetical, numerical, or some other logical order, (9) appropriate use of "all of the above" or "none of the above," and (10) each set of responses for each item was grammatically consistent. For binary response questions: (1) binary items were statements with just two choices for an answer, (2) items were not tricky – partly right and partly wrong, (3) the answers logically fit the item, (4) the responses were unambiguous, and (5) all negatives were avoided. For open-ended questions: (1) questions required critical thinking, (2) the questions were part of a test and not a stand-alone set, (3) clear directions were given with time, length, and scope, (4) scoring was clear and included on the test, and (5) points were subdivided into small quantities so scoring can be reliable. (Wilkerson, 2015)

Schau, Stevens, Dauphinee, and Del Vecchio (1995) demonstrated the *Survey of Attitudes Toward Statistics SATS-36* had a good fit to the observed interrelationships in sample of 1,403 undergraduate students enrolled in 33 introductory statistics courses. Schau (2003) reported Cronbach's coefficient alpha valued by components of the *SATS-36*: *Affect* (17 values from 9 studies) - .80 to .89, *Cognitive Competence* (16 values from 9 studies) - .77 to .88, *Value* (17 values from 9 studies) - .74 to .90, and *Difficulty* (16 values from 8 studies) - .64 to .81. Schau (2003) described measures of score validity: score validity for the four-component structure and concurrent validity. She performed two sets of confirmatory factor analyses and reported that the *SATS-36* fit into their hypothesized components. The *SATS-36* also had concurrent validity supported through significant correlations with Wise's ATS scales (Schau, 2003).

The *Instructional Style Survey for Statistics* (ISSC) had a standardized reliability coefficient of .87 (Schmidt, 2001). In addition, a Pearson correlation test was performed on the three factors present in the survey and how they related to instructional style classifications. All three factors were statically significant.

Research Design

The research design is causal-comparative research. Schenker and Rumrill (2004) described casual-comparative research designs as those using "pre-existing or derived groups to explore differences between or among those groups on outcome or dependent variables" (p. 117). Since undergraduate students choose their classes and/or professors, the researcher cannot assign students randomly to different instructors or sections. Schenker and Rumrill (2004) also describe how causal-comparative research designs are similar to experimental designs as they make use of independent variables that can be nominal in nature and dependent variables that are continuous.

Data Analysis Procedures

A SPSS version 24.0 (IBM Corp., 2016) was used to analyze the results of the student attitude survey and teacher teaching method preference. Descriptive statistics were calculated using the *Instructional Style Survey for Statistics*, *Student Attitudes Toward Statistics SATS-36, Learning Outcomes for Statistics*, and various grades recorded by instructors. A one-way ANOVA comparing the *Learning Outcomes for Statistical Methods* final exam scores and their final course average of participants who took a course from one of four different instructors was conducted. A one-way ANOVA comparing the student's final course average, their average score on the *Learning Outcomes for Statistical Methods*, and the *SATS-36* pre-sub scores by gender was also performed. A one-way repeated measures ANOVA comparing the student's affect component score at two different times was performed. A Pearson correlation coefficient was calculated for the relationship between participants' SATS-36 six sub-scores and their final course average. A Pearson correlation coefficient for the relationship between students' *SATS-36* post stress level rating and their *Learning Outcomes for Statistical Methods* average was also calculated.

Preliminary Studies or Pilot Tests

A pilot test of the *Learning Outcomes for Statistical Methods* was administered to one section of Statistical Methods during the Summer A term of 2016 with 32 students. The instrument was developed by following the stated learning outcomes of the common course syllabus. The instrument was distributed to three content experts and was assessed to adequately measure the learning outcomes for statistical methods. A Kuder and Richarson Formula 20 measure of reliability was calculated to be 0.640. The Kuder and Richarson Formula 20 is a substitute measure of reliability for the Cronbach Alpha when questions are graded either right or wrong and not on an interval. Figure 1 shows the results of measuring each questions difficulty (percent correct) against the discrimination (ability to distinguish students at the top 20% from students at the bottom 20%).

***Learning Outcomes for Statistics Methods* Questions**

Difficulty

Discrimination		**Hard (0-50)**	**Medium (50-85)**	**Easy (85-100)**
	Poor (<0.1)		9	11, 21, 29, 48, 50
	Fair (0.1-0.3)	31, 36	23, 26, 27, 34, 43	1, 2, 6, 7, 8, 14, 15, 16, 18, 25, 37, 38, 43, 44, 47, 49
	Good (>0.3)	5, 12, 39	3, 10, 17, 20, 22, 24, 28, 30, 32, 33, 35, 40, 42, 45	4, 13, 19, 41, 46

Figure 1. Difficulty against Discrimination of the *Learning Outcomes for Statistical Methods* Instrument. This figure displays how each question on the *Learning Outcomes for Statistical Methods* is rated based on difficulty and discrimination.

Delimitations

As statistical methods types of courses are increasingly becoming requirements for degree programs at universities and colleges around the United States, there are many universities and colleges teaching a statistical methods type of course. The research has chosen to only study the statistical methods course at one university. This will limit the generalizability of the results, but with a variety of instructional strategies utilized by the current instructors and the variety of types of students at this institution, focusing on one university is sufficient for this research project.

CHAPTER IV

DATA ANAYSIS

Introduction

This study explored the impact of instructional style in the teaching of introductory statistics on students' attitudes towards statistics and on students' academic outcomes in statistics courses. During the first week of classes of the fall 2016 semester, participating statistics instructors completed the *Instructional Style Survey for Statistics* and their students completed the *Survey of Attitudes Toward Statistics SATS-36* pre-survey. During the last week of classes of the fall 2016 semester, students completed the *Survey of Attitudes Toward Statistics SATS-36* post-survey in addition to taking a final exam which consisted of the *Learning Outcomes for Statistical Methods* instrument developed for this dissertation. Additional exam grades and final course grades were collected from students. Demographic information was collected on instructor gender, ethnicity, and teaching experience. Demographic information was also collected on student gender, citizenship, age, mathematical course background, and college major. Data was analyzed during the spring 2017 semester.

Surveys were administered on the course management software Canvas. Data was analyzed using the SPSS version 24.0 (IBM Corp., 2016) statistical analysis software. The one-way ANOVA required a single dependent variable and a single independent variable. Groups were independent of each other. In addition, ANOVA assumed that the dependent variable was normally distributed. A Shaprio-Wilk test for normality was calculated on the Final Course Average along with calculating the skewness and kurtosis, and it was determined that Final Course Average was not normally distributed. A Shaprio-Wilk test for normality was also calculated for all the sub-scores on the *SATS-36*. Only the Pre-Cognitive Sub-Score and the Post Affect Score were normally distributed.

Descriptive Statistics for the Entire Sample

There were two samples of interest in this study: university statistics instructors and undergraduate students. An email recruitment letter was sent to fourteen university statistics instructors scheduled to teach twenty-seven sections of Statistical Methods for the fall 2016 semester. This provided a potential sample size of 1501 undergraduate students. Four university statistics instructors agreed to participate in this study. These instructors taught a total of nine sections of Statistical Methods with a total of 504 students. All four participating university statistics instructors identified themselves as Caucasian. For the purposes of clarity, the four participating university statistics instructors will be referred to as Instructor A, Instructor B, Instructor C, and Instructor D.

Table 1

Teaching Experience

Instructor	Percent of Sample	Semesters of Experience
C and D	50	1-4
NA	0	5-10
A	25	11-20
B	25	21-34

As can be seen in Table 1, instructors had a range of experience from 1 to 34 semesters, with 50% in the 1-4 semester range; the other 50% had over 11 semesters of experience. The mean level of experience was 12.25 semesters with a median of 7 semesters. The total sample was compromised of 3 male and 1 female instructors.

Table 2

Instructional Styles

Style	Description	Number	Percent
1	Didactic	0	0
2	Objectivist Transitional	2	50
3	Confirmatory	1	25
4	Constructivist Transitional	1	25
5	Inquiry	0	0
Total		4	100

Table 2 displays the results of the *Instructional Style Survey for Statistics*. There were no instructors who used primarily a didactic approach to instruction that would focus on a paper and pencil approach to instruction. Instructors B and D used primarily an objectivist transitional approach to instruction which is a mix of didactic and confirmatory approaches. Instructor C used primarily a confirmatory approach to instruction preferring to only use manipulatives in such a way that the textbook describes when introducing algorithms. Instructor A used primarily a constructivist transitional approach to instruction which is a mix of confirmatory and inquiry approaches. There were no instructors who used primarily an inquiry approach to instruction where one would favor allowing students to develop concepts themselves. Though this study did not have instructors who were identified as "didactic" or "inquiry," this study had teachers who were categorized within the middle of the instructional style spectrum. The objectivist transitional style is a form of didactic instruction and constructivist transitional is a form of inquiry instruction. As such, there were instructors present in the study who were classified as being didactic or inquiry.

Table 3

Number of Students Taught by Instructional Style

Instructor	Instructional Style	Number	Percent
A	Constructivist Transitional	47	15.0
B	Objectivist Transitional	91	29.1
C	Confirmatory	37	11.8
D	Objectivist Transitional	138	44.1
Total		313	100.0

Table 3 shows the distribution of students in instructors' courses by instructional style. Most students, 73.2%, were in an instructor's course who was classified as objectivist transitional because there were two instructors, 50%, who were classified as objectivist transitional. The fewest percentage of students, 11.8%, were in an instructor's course who was classified as confirmatory.

Table 4

Number of Students by Day and Time

Days	Time	Number	Percent
MWF	8:30-9:20 am	47	15.0
MWF	9:30-10:20 am	44	14.1
MWF	10:30-11:20 am	47	15.0
MWF	2:30-3:20 pm	24	7.7
MWF	3:30-4:20 pm	23	7.3
TR	3:00-4:15 pm	27	8.6
TR	4:30-5:45 pm	29	9.3
TR	6:00-7:15 pm	72	23.0
Total		313	100

Table 4 illustrates the distribution of students by day of week and time of day. Courses that were used in this study meet on either a Monday, Wednesday, and Friday or a Tuesday and Thursday schedule. The times the course met varied from early morning (8:30 am) until late evening (7:15 pm). There was roughly an equal representation of students for the various combinations of possible meeting times for courses. The largest percentage of students, 23%, was in the Tuesday and Thursday meeting from 6:00 pm until 7:15 pm because there were two sections meeting at that time used in this study.

Table 5

Number of Students by Major

Major	Number	Percent
Arts/Humanities	21	4.2
Biology	34	6.7
Business	73	23.3
Chemistry	2	0.6
Economics	3	1.0
Education	14	4.5
Engineering	12	3.8
Mathematics	5	1.6
Medicine/Pre-Medicine	24	7.7
Other	90	28.8
Psychology	19	6.1
Sociology/Social Work	3	1.0
Not Answered	13	4.2
Total	313	100.0

Table 5 shows the distribution of students by their self-reported major. There were several relatively high reported majors: Other, 28.8%; Business, 23.3%; Medicine/Pre-Medicine, 7.7%; Biology, 6.7%; Psychology, 6.1%; Education, 4.5%, and Arts/Humanities, 4.2%. There were also several relatively low reported majors: Mathematics, 5%; Sociology/Social Work, 1%, Economics, 1%, and Chemistry 0.6%.

Table 6

Number of Students by Degree

Degree	Number	Percent
Associate	37	4.2
Bachelors	234	74.8
Masters	18	5.8
Doctorate	8	2.6
Post-bachelor's	1	0.3
Other	2	0.6
Total	313	100.0

Students were also asked to identify the degree they were working towards as illustrated in Table 6. The largest percentage, 74.8%, of students reported they were working towards a Bachelor's degree. Since the university where this study takes place is primarily a four-year university, this high percentage of students working towards a Bachelor's degree is in line with expectations. The percentages that were interesting were students reporting they were working towards a Post-Baccalaureate degree or higher. Since this course is an introductory statistics course, the population of students it is intended for would be for university students working towards an Associate's or Bachelor's degree.

Table 7

Number of Students by Gender

Gender	Number	Percent
Female	166	53.0
Male	134	42.8
Not Answered	13	4.2
Total	313	100.0

Table 7 describes the gender breakdown of students in this study. Females made up 53% of the sample, while males made up 42.8% of the sample. Though not a specific question for this study, the question of gender differences in math education has been debated through many articles. In addition, the relative percent of females to males confirms with national data about gender in higher education.

Table 8

Number of Students by Citizenship

Citizenship	Number	Percent
US Citizen	289	92.3
Foreign Student	8	2.6
Other	2	0.6
Total	313	100

A supermajority of students in this sample reported they were U.S. Citizens, 92.3%, as shown in Table 8. Only 2.6% of the sample reported they were foreign students. With such a small cross-section of foreign students, further data analysis into how foreign students compare with U.S. Citizens is not justified in this study.

Table 9

Number of Students by Age

Age	Number	Percent
17	4	1.3
18	109	34.8
19	103	32.9
19.5	1	0.3
20	33	10.5
21	22	7.0
22	7	2.2
23	6	1.9
24	5	1.6
25	2	0.6
26	3	1.0
27	1	0.3
32	1	0.3
Invalid	1	0.3
Not Answered	13	4.2
Total	313	100

Table 9 depicts the age distribution of students in this study. With the traditional age of undergraduate students being between 18 and 21, this study is made up of 85.5% of traditional aged students. Approximately 2.2% of the students in this study are older than 24 years of age.

Descriptive Statistics of the *SATS-36*

The Student Attitude Towards Statistics SATS-36 is a survey designed to measure students attitudes towards statistics. Table 10 displays the average component scores of students in this study. Students in Instructor A's section(s) had pre-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.25, 4.99, 5.03, 3.51, 4.52, and 6.49 respectively. Students in Instructor B's section(s) had pre-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.15, 4.95, 4.96, 3.54, 4.33, and 6.59 respectively. Students in Instructor C's section(s) had pre-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.08, 4.86, 5.11, 3.55, 4.59, and 6.42 respectively. Students in Instructor D's section(s) had pre-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.52, 5.13, 4.76, 3.85, 4.43, and 6.55 respectively.

Table 10

Average Component scores on the SATS-36 pre-survey by Instructor

Instructor	Instructional Style		Affect	Cognitive	Value	Difficulty	Interest	Effort
A	Constructivist Transitional	Mean	4.25	4.99	5.03	3.51	4.52	6.49
		N	43	43	43	43	43	43
		Std. Dev.	1.18	1.06	1.00	0.82	1.29	0.64
B	Objectivist Transitional	Mean	4.15	4.95	4.96	3.54	4.33	6.59
		N	82	82	82	82	82	82
		Std. Dev.	1.34	1.12	1.20	0.74	1.62	0.65
C	Confirmatory	Mean	4.08	4.86	5.11	3.55	4.59	6.42
		N	37	37	37	37	37	37
		Std. Dev.	1.29	1.07	0.89	0.73	0.94	0.74
D	Objectivist Transitional	Mean	4.52	5.13	4.76	3.85	4.43	6.55
		N	138	138	138	138	138	138
		Std. Dev.	1.10	1.06	1.14	0.85	1.35	0.63
Total		Mean	4.33	5.02	4.90	3.68	4.44	6.54
		N	300	300	300	300	300	300
		Std. Dev.	1.22	1.08	1.11	0.82	1.38	0.65

Table 11 displays the average component scores of students in this study. Students in Instructor A's section(s) had post-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.05, 5.21, 4.82, 3.77, 3.92, and 5.94 respectively. Students in Instructor B's section(s) had post-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 3.92, 5.24, 4.50, 3.79, 3.49, and 6.04 respectively. Students in Instructor C's section(s) had post-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 3.46, 4.40, 3.99, 3.07, 3.34, and 6.36 respectively. Students in Instructor D's section(s) had post-mean Affect, Cognitive, Value, Difficulty, Interest, and Effort scores of 4.29, 5.09, 4.49, 3.97, 3.95, and 5.87 respectively.

Table 11

Average Component scores on the SATS-36 post-survey by Instructor

Instructor	Instructional Style		Affect	Cognitive	Value	Difficulty	Interest	Effort
A	Constructivist Transitional	Mean	4.05	5.21	4.82	3.77	3.92	5.94
		N	13	13	13	13	13	13
		Std. Dev.	0.84	0.94	0.54	0.98	1.34	0.85
B	Objectivist Transitional	Mean	3.92	5.24	4.50	3.79	3.49	6.04
		N	38	38	38	38	38	38
		Std. Dev.	1.06	1.35	1.30	1.02	1.76	0.88
C	Confirmatory	Mean	3.46	4.40	3.99	3.07	3.34	6.36
		N	19	19	19	19	19	19
		Std. Dev.	0.72	1.17	1.28	0.92	1.20	0.74
D	Objectivist Transitional	Mean	4.29	5.09	4.49	3.97	3.95	5.87
		N	49	49	49	49	49	49
		Std. Dev.	1.08	1.43	1.30	1.09	1.45	1.19
Total		Mean	4.01	5.04	4.45	3.75	3.70	6.01
		N	119	119	119	119	119	119

Std. Dev.	1.03	1.33	1.24	1.06	1.52	1.00

Descriptive Statistics of Course Grades

Table 12 shows the final course average of students in this study by instructor. Instructor A had a final course average of 78.5%. Instructor B had a final course average of 81.5%. Instructor C had a final course average of 75.1%. Instructor D had a final course average of 84.9%. The overall final course average of all students in the study was an 81.7%.

Table 12

Overall Averages by Instructor

Instructor	Instructional Style		Final Average
A	Constructivist Transitional	Mean	78.5
		N	47
		Std. Deviation	18.0
B	Objectivist Transitional	Mean	81.5
		N	83
		Std. Deviation	10.5
C	Confirmatory	Mean	75.1
		N	36
		Std. Deviation	20.9
D	Objectivist Transitional	Mean	84.9
		N	129
		Std. Deviation	11.7
Total		Mean	81.7
		N	295
		Std. Deviation	14.3

Descriptive Statistics of the Learning Outcomes for Statistical Methods

Table 13 shows the average score of the *Learning Outcomes for Statistical Methods* of students in this study by instructor. Students in Instructor A's section(s) had an average score on the *Learning Outcomes for Statistical Methods* of 76.24%. Students in Instructor B's section(s) had an average score on the *Learning Outcomes for Statistical Methods* of 73.38%. Students in Instructor C's section(s) had an average score on the *Learning Outcomes for Statistical Methods* of 76.79%. Students in Instructor D's section(s) had an average score on the *Learning Outcomes for Statistical Methods* of 73.90%. The overall average score on the *Learning Outcomes for Statistical Methods* for all students in the study was an 74.40%.

Table 13

Learning Outcomes for Statistical Methods Averages by Instructor

Instructor		Total
A	Mean	76.24
	N	41
	Std. Deviation	11.834
B	Mean	73.38
	N	78
	Std. Deviation	9.926
C	Mean	76.79
	N	28
	Std. Deviation	11.942
D	Mean	73.90
	N	125
	Std. Deviation	9.857
Total	Mean	74.40
	N	272

	Std. Deviation	10.433

Table 14 shows the average score of the *Learning Outcomes for Statistical Methods* of students in this study by section days and times. Students in the section meeting on Mondays, Wednesdays, and Fridays from 2:30 to 3:20 pm had an average score on the *Learning Outcomes for Statistical Methods* of 76.60%. Students in the section meeting on Mondays, Wednesdays, and Fridays from 3:30 to 4:20 pm had an average score on the *Learning Outcomes for Statistical Methods* of 75.90%. Students in the section meeting on Mondays, Wednesdays, and Fridays from 9:30 to 10:20 am had an average score on the *Learning Outcomes for Statistical Methods* of 74.38%. Students in the section meeting on Mondays, Wednesdays, and Fridays from 8:30 to 9:20 am had an average score on the *Learning Outcomes for Statistical Methods* of 72.49%. Students in the section meeting on Mondays, Wednesdays, and Fridays from 10:30 to 11:20 am had an average score on the *Learning Outcomes for Statistical Methods* of 74.98%. Students in the section meeting on Tuesdays and Thursdays from 3:00 to 4:15 pm had an average score on the *Learning Outcomes for Statistical Methods* of 72.00%. Students in the section meeting on Tuesdays and Thursdays from 4:30 to 5:45 pm had an average score on the *Learning Outcomes for Statistical Methods* of 73.00%. Students in the section meeting on Tuesdays and Thursdays from 6:00 to 6:15 pm had an average score on the *Learning Outcomes for Statistical Methods* of 74.69% and 76.69%.

Table 14

Learning Outcomes for Statistical Methods Averages by Section

Section		Total
MWF - 2:30-3:20 pm	Mean	.7660
	N	20
	Std. Deviation	.13379
MWF - 3:30-4:20 pm	Mean	.7590
	N	21
	Std. Deviation	.10478
MWF - 9:30-10:20 am	Mean	.7438
	N	37
	Std. Deviation	.11084
TR - 3:00-4:15 pm	Mean	.7200
	N	24
	Std. Deviation	.10681
TR - 4:30-5:45 pm	Mean	.7300
	N	22
	Std. Deviation	.10775
MWF - 8:30-9:20 am	Mean	.7249
	N	45
	Std. Deviation	.08678
MWF - 10:30-11:20 am	Mean	.7498
	N	43
	Std. Deviation	.09956
TR - 6:00-7:15 pm	Mean	.7469
	N	32
	Std. Deviation	.08837
TR - 6:00-7:15 pm	Mean	.7679

	N	28
	Std. Deviation	.11942
	Mean	.7440
Total	N	272
	Std. Deviation	.10433

Survey Reliability and Validity for the Sample

The survey results from the *SATS-36* pre-survey were analyzed by the researcher and compared to the measures reported by the survey author to determine the reliability and validity of the instrument within the sample. Shau (2003) reported a range of coefficient alpha values for each of the six attitude components from results reported in studies using the SATS-28. The Affect attitude component had a range of coefficient alpha values from .80 to .89. In this study, the Affect attitude component had a coefficient alpha of .814. The Cognitive Competence attitude component had a range of coefficient alpha values from .77 to .88. In this study, the Cognitive Competence attitude component had a coefficient alpha of .817. The Value attitude component had a range of coefficient alpha values from .74 to .90. In this study, the Value attitude component had a coefficient alpha of .774. The Difficulty attitude component had a range of coefficient alpha values from .64 to .81. In this study, the Difficulty attitude component had a coefficient alpha of .706. The Interest attitude component was a new component on the *SATS-36* and did not have a range of coefficient alpha values reported. In this study, the Interest attitude component had a coefficient alpha of .891. The Effort attitude component was a new component on the *SATS-36* and did not have a range of coefficient alpha values reported. In this study, the Effort attitude component had a coefficient alpha of .614.

A factor analysis was also conducted to validate the component divisions as shown in Table 15. Shau (2003) grouped questions 3, 4, 15, 18, 19, and 28 for the Affect component; 5, 11, 26, 31, 32, 35 for the Cognitive Competence component; 7, 9, 10, 13, 16, 17, 21, 25, 33 for the Value component; 6, 8, 22, 24, 30, 34, 36 for the Difficulty component; 12, 20, 23, 29 for the Interest component; and 1, 2, 14, 27 for the Effort component. The results of a factor analysis for this study developed seven components with questions 4, 5, 6, 8, 11, 15, 26, 28, 32, 35 for component 1; 7, 9, 10, 12, 13, 16, 17, 22, 25, 33 for component 2; 3, 19, 20, 22, 23, 29 for component 3; 14, 27, 31 for component 4; 1, 2 for component 5; 24, 30, 34 for component 6, and 36 for component 7. There were some overlaps of factors from this study and Shau (2003).

Table 15

Rotated Component Matrix for SATS-36 Pre-Survey

	1	2	3	4	5	6	7
Pre28N	**.778**	.155	.141	.004	-.021	.016	.065
Pre18N	**.756**	.105	.083	-.031	-.123	.060	.143
Pre5N	**.746**	.209	.063	-.028	.010	-.027	.163
Pre4N	**.729**	.100	.076	-.116	-.015	-.012	-.094
Pre35N	**.699**	.182	.096	.008	.025	.264	.222
Pre15N	**.694**	.127	.035	.057	.033	.164	-.223
Pre8N	**.656**	.066	.248	-.154	-.018	.175	.317
Pre26N	**.650**	.146	.141	.149	.052	.108	.136
Pre11N	**.539**	.208	.097	.340	.039	.051	.032
Pre6	**.522**	.060	.320	.046	-.023	.092	.390
Pre32	**.485**	.269	.045	.386	.019	-.005	.229
Pre25N	.176	**.767**	.012	-.026	.032	.027	-.129
Pre33N	.128	**.758**	-.020	.081	.076	.031	-.058

Pre16N	.225	**.715**	.032	.114	-.107	-.106	-.027
Pre13N	.149	**.698**	.095	.168	-.049	.014	.002
Pre10	.093	**.691**	.138	-.007	.102	-.213	.178
Pre17	.016	**.626**	.150	.021	.022	-.099	.259
Pre9	.072	**.624**	.323	-.180	.117	-.028	-.021
Pre22N	.093	**.598**	-.061	.161	-.080	.197	.048
Pre7N	.344	**.552**	.154	.214	.002	.186	-.168
Pre12	.160	**.534**	.387	.135	.028	-.323	.203
Pre19	.393	.289	**.674**	.097	.081	.053	-.110
Pre22	.055	-.110	**.642**	-.148	-.102	.398	.083
Pre20	.293	.539	**.599**	.128	-.002	-.154	.102
Pre23	.230	.547	**.567**	.180	.024	-.024	.016
Pre29	.313	.502	**.566**	.192	.034	-.169	.023
Pre3	.405	.150	**.426**	.167	.294	-.143	.192
Pre27	-.056	.054	.018	**.767**	.028	-.105	-.018
Pre14	-.035	.111	.089	**.749**	.125	-.178	.048
Pre31	.409	.300	.058	**.489**	.090	.102	-.139
Pre1	-.002	-.019	-.011	.021	**.921**	-.068	.061
Pre2	-.034	.039	.045	.154	**.913**	.015	-.040
Pre34N	.200	.064	.003	-.157	.024	**.683**	.203
Pre24N	.238	-.234	.185	-.279	-.105	**.610**	-.147
Pre30N	.240	-.050	-.205	.252	-.049	**.463**	.418
Pre36N	.328	.034	.071	-.033	.054	.122	**.654**

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 20 iterations.

The results from the Learning Outcomes for Statistical Methods were analyzed to determine reliability and validity of the instrument within the sample as compared to the results obtained during the instrument validation as described in Chapter 3. Reliability was calculated using the Kuder and Richardson Formula 20 as each item was not a scale item and Cronbach Alpha would not be appropriate. Reliability in the sample population was 0.721, up from 0.639 during validation.

Analysis of Data

First research question. What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*? For research question one, students' mean scores on the *Learning Outcomes for Statistical Methods* were examined across instructional style. A total of 271 students completed the *Learning Outcomes for Statistical Methods* for the four instructors in the sample.

Table 16

One-way ANOVA of Learning Outcomes for Statistical Methods by Instructor

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.041	3	.014	1.259	.289
Within Groups	2.909	268	.011		
Total	2.950	271			

The results of a one-way ANOVA comparing the *Learning Outcomes for Statistical Methods* final exam scores of participants who took a course from one of four different instructors are shown in Table 16. No significant difference was found ($F(3,268) = 1.259, p > 0.05$). The students from the four different instructors did not differ significantly on the *Learning Outcomes for Statistical Methods* final exam.

Table 17

Tukey's HSD of Learning Outcomes for Statistical Methods by Instructor

(I) Instructor	(J) Instructor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constructivist Transitional	Objectivist Transitional	.02859	.02010	.486	-.0234	.0805
	Confirmatory	-.00542	.02554	.997	-.0714	.0606
	Objectivist Transitional	.02340	.01875	.597	-.0251	.0719
Objectivist Transitional	Constructivist Transitional	-.02859	.02010	.486	-.0805	.0234
	Confirmatory	-.03401	.02295	.450	-.0933	.0253
	Objectivist Transitional	-.00519	.01503	.986	-.0441	.0337
Confirmatory	Constructivist Transitional	.00542	.02554	.997	-.0606	.0714
	Objectivist Transitional	.03401	.02295	.450	-.0253	.0933
	Objectivist Transitional	.02882	.02178	.549	-.0275	.0851
Objectivist Transitional	Constructivist Transitional	-.02340	.01875	.597	-.0719	.0251
	Objectivist Transitional	.00519	.01503	.986	-.0337	.0441
	Confirmatory	-.02882	.02178	.549	-.0851	.0275

Table 17 shows the results of a Tukey's HSD used to determine the nature of the differences between the instructors. The results show that students' learning outcomes when measured by instructional style in any one instructor's course did not significantly different from any of the other three instructors' courses.

Second research question. Does teaching style contribute to differences in students' attitude towards statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36*? For research question two, student's component score on the *Survey of Attitudes Toward Statistics SATS-36* were examined across instructional style. A total of 115 students completed the both the pre-survey and post-survey for the four instructors in the sample. Since scores were analyzed to see if there was an increase over time, only students completing both the pre- and post-surveys were used in the analysis.

Table 18

Repeated-Measures ANOVA of Affect Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.689	1	.689	.990	.322
	Greenhouse-Geisser	.689	1.000	.689	.990	.322
	Huynh-Feldt	.689	1.000	.689	.990	.322
	Lower-bound	.689	1.000	.689	.990	.322
time*Instructor	Sphericity Assumed	.255	3	.085	.122	.947
	Greenhouse-Geisser	.255	3.000	.085	.122	.947
	Huynh-Feldt	.255	3.000	.085	.122	.947
	Lower-bound	.255	3.000	.085	.122	.947
Error(time)	Sphericity Assumed	80.055	115	.696		
	Greenhouse-Geisser	80.055	115.0	.696		
	Huynh-Feldt	80.055	115.0	.696		
	Lower-bound	80.055	115.0	.696		

Table 18 displays the results of a one-way repeated-measures ANOVA comparing the student's affect component score at two different times: pre-survey and post-survey. No significant effect was found ($F(1, 115) = 0.990, p > 0.05$). No significant difference exists among pre-survey ($m = 4.05, sd = .134$) and post-survey ($m = 3.93, sd = .105$) means.

Table 19

Repeated-Measures ANOVA of Cognitive Competence Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	1.184	1	1.184	1.286	.259
	Greenhouse-Geisser	1.184	1.000	1.184	1.286	.259
	Huynh-Feldt	1.184	1.000	1.184	1.286	.259
	Lower-bound	1.184	1.000	1.184	1.286	.259
time*Instructor	Sphericity Assumed	4.543	3	1.514	1.645	.183
	Greenhouse-Geisser	4.543	3.00	1.514	1.645	.183
	Huynh-Feldt	4.543	3.000	1.514	1.645	.183
	Lower-bound	4.543	3.000	1.514	1.645	.183
Error(time)	Sphericity Assumed	105.862	115	.921		
	Greenhouse-Geisser	105.862	115.000	.921		
	Huynh-Feldt	105.862	115.000	.921		
	Lower-bound	105.862	115.000	.921		

Table 19 reveals the results of a one-way repeated-measures ANOVA comparing the student's cognitive competence component score at two different times: pre-survey and post-survey. No significant effect was found ($F(1, 115) = 1.286, p > 0.05$). No significant difference exists among pre-survey ($m = 4.82, sd = .116$) and post-survey ($m = 4.98, sd = .138$) means.

Table 20

Repeated-Measures ANOVA of Value Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	7.542	1	7.542	12.035	.001
	Greenhouse-Geisser	7.542	1.000	7.542	12.035	.001
	Huynh-Feldt	7.542	1.000	7.542	12.035	.001
	Lower-bound	7.542	1.000	7.542	12.035	.001
time*Instructor	Sphericity Assumed	4.433	3	1.478	2.358	.075
	Greenhouse-Geisser	4.433	3.000	1.478	2.358	.075
	Huynh-Feldt	4.433	3.000	1.478	2.358	.075
	Lower-bound	4.433	3.000	1.478	2.358	.075
Error(time)	Sphericity Assumed	72.069	115	.627		
	Greenhouse-Geisser	72.069	115.000	.627		
	Huynh-Feldt	72.069	115.000	.627		
	Lower-bound	72.069	115.000	.627		

Table 20 displays the results of a one-way repeated-measures ANOVA comparing the student's value component score at two different times: pre-survey and post-survey. A significant effect was found ($F(1, 115) = 12.035, p = 0.001$). A significant decrease exists among pre-survey ($m = 4.86, sd = .116$) and post-survey ($m = 4.45, sd = .130$) means. A Bonferroni Post-Hoc Test was performed but there were no significant pairwise differences between the four instructors.

Table 21

Repeated-Measures ANOVA of Difficulty Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.748	1	.748	1.511	.222
	Greenhouse-Geisser	.748	1.000	.748	1.511	.222
	Huynh-Feldt	.748	1.000	.748	1.511	.222
	Lower-bound	.748	1.000	.748	1.511	.222
time*Instructor	Sphericity Assumed	2.931	3	.977	1.973	.122
	Greenhouse-Geisser	2.931	3.000	.977	1.973	.122
	Huynh-Feldt	2.931	3.000	.977	1.973	.122
	Lower-bound	2.931	3.000	.977	1.973	.122
Error(time)	Sphericity Assumed	56.927	115	.495		
	Greenhouse-Geisser	56.927	115.000	.495		
	Huynh-Feldt	56.927	115.000	.495		
	Lower-bound	56.927	115.000	.495		

Table 21 displays the results of a one-way repeated-measures ANOVA comparing the student's difficulty component score at two different times: pre-survey and post-survey. No significant effect was found ($F(1, 115) = 1.511, p > 0.05$). No significant difference exists among pre-survey ($m = 3.520, sd = .088$) and post-survey ($m = 3.649, sd = .108$) means.

Table 22

Repeated-Measures ANOVA of Interest Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	18.784	1	18.784	20.267	.000
	Greenhouse-Geisser	18.784	1.000	18.784	20.267	.000
	Huynh-Feldt	18.784	1.000	18.784	20.267	.000
	Lower-bound	18.784	1.000	18.784	20.267	.000
time*Instructor	Sphericity Assumed	4.142	3	1.381	1.489	.221
	Greenhouse-Geisser	4.142	3.000	1.381	1.489	.221
	Huynh-Feldt	4.142	3.000	1.381	1.489	.221
	Lower-bound	4.142	3.000	1.381	1.489	.221
Error(time)	Sphericity Assumed	106.589	115	.927		
	Greenhouse-Geisser	106.589	115.000	.927		
	Huynh-Feldt	106.589	115.000	.927		
	Lower-bound	106.589	115.000	.927		

Table 22 displays the results of a one-way repeated-measures ANOVA comparing the student's interest component score at two different times: pre-survey and post-survey. A significant effect was found ($F(1, 115) = 20.267, p < 0.001$). A significant decrease exists among pre-survey ($m = 4.320, sd = .149$) and post-survey ($m = 3.677, sd = .159$) means. A Bonferroni Post-Hoc Test was performed but there were no significant pairwise differences between the four instructors.

Table 23

Repeated-Measures ANOVA of Effort Score

		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	10.886	1	10.886	21.920	.000
	Greenhouse-Geisser	10.886	1.000	10.886	21.920	.000
	Huynh-Feldt	10.886	1.000	10.886	21.920	.000
	Lower-bound	10.886	1.000	10.886	21.920	.000
time*Instructor	Sphericity Assumed	2.697	3	.899	1.811	.149
	Greenhouse-Geisser	2.697	3.000	.899	1.811	.149
	Huynh-Feldt	2.697	3.000	.899	1.811	.149
	Lower-bound	2.697	3.000	.899	1.811	.149
Error(time)	Sphericity Assumed	57.110	115	.497		
	Greenhouse-Geisser	57.110	115.000	.497		
	Huynh-Feldt	57.110	115.000	.497		
	Lower-bound	57.110	115.000	.497		

Table 23 displays the results of a one-way repeated-measures ANOVA comparing the student's effor component score at two different times: pre-survey and post-survey. A significant effect was found ($F(1, 115) = 21.920, p < 0.001$). A significant decrease exists among pre-survey ($m = 6.541, sd = .065$) and post-survey ($m = 6.051, sd = .105$) means. A Bonferroni Post-Hoc Test was performed but there were no significant pairwise differences between the four instructors.

Third research question. What is the relationship between students' attitude towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates? For research question three, student's final course averages and component score on the Pre-*Survey of Attitudes Toward Statistics SATS-36* were analyzed. A total of 300 students completed the *Survey of Attitudes Toward Statistics SATS-36* and completed the course for the four instructors in the sample.

Table 24

Correlations between SATS-36 Pre Sub Scores and Final Course Averages

		Affect	Cognitive	Value	Difficulty	Interest	Effort	Final Average
Affect	Pearson Correlation	1	.781**	.427**	.575**	.551**	.044	.170**
	Sig. (2-tailed)		.000	.000	.000	.000	.443	.004
	N	300	300	300	300	300	300	290
Cognitive	Pearson Correlation	.781**	1	.481**	.551**	.525**	.173**	.176**
	Sig. (2-tailed)	.000		.000	.000	.000	.003	.003
	N	300	300	300	300	300	300	290
Value	Pearson Correlation	.427**	.481**	1	.113	.707**	.158**	.057
	Sig. (2-tailed)	.000	.000		.050	.000	.006	.330
	N	300	300	300	300	300	300	290
Difficulty	Pearson Correlation	.575**	.551**	.113	1	.227**	-.172**	.106
	Sig. (2-tailed)	.000	.000	.050		.000	.003	.071
	N	300	300	300	300	300	300	290
Interest	Pearson Correlation	.551**	.525**	.707**	.227**	1	.227**	.064
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.276
	N	300	300	300	300	300	300	290

Effort	Pearson Correlation	.044	.173**	.158**	-.172**	.227**	1	.304**
	Sig. (2-tailed)	.443	.003	.006	.003	.000		.000
	N	300	300	300	300	300	300	290
Final Average	Pearson Correlation	.170**	.176**	.057	.106	.064	.304**	1
	Sig. (2-tailed)	.004	.003	.330	.071	.276	.000	
	N	290	290	290	290	290	290	295

**. Correlation is significant at the 0.01 level (2-tailed).

A Pearson correlation coefficient was calculated for the relationship between participants' *SATS-36* six sub-scores and their final course average as shown in Table 24. A weak positive correlation was found ($r(288) = .170, p = 0.004$), indicating a significant linear relationship between the *SATS-36* Affect sub-score and final course average. Students with a higher Affect sub-score tend to have a higher course average. A weak positive correlation was found ($r(288) = .176, p = 0.003$), indicating a significant linear relationship between the *SATS-36* Cognitive sub-score and final course average. Students with a higher Cognitive sub-score tend to have a higher course average. A weak positive correlation was found ($r(288) = .304, p < 0.001$), indicating a significant linear relationship between the *SATS-36* Effort sub-score and final course average. Students with a higher Effort sub-score tend to have a higher course average.

Fourth research question. What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and DWF Rates? For research question four, student's final course averages were analyzed across instructional style. A total of 294 students completed the course for the four instructors in the sample.

The results of a one-way ANOVA comparing the Final Course Average of participants who took a course from one of four different instructors are shown in Table 25. A significant difference was found among instructors ($F(3,291) = 5.807, p = 0.001$). The students from the four different instructors do differ significantly in their Final Course Average.

Table 25

One-way ANOVA of Final Course Average by Instructor

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.340	3	.113	5.807	.001
Within Groups	5.677	291	.020		
Total	6.016	294			

Table 26 show the results of a Tukey's HSD used to determine the nature of the differences between the instructors. The analysis revealed that students who had Instructor A had a lower final course average ($m = 78.47, sd = 17.996$) than students who had Instructor D instructor ($m = 84.92, sd = 11.688$). The analysis also revealed that students who had Instructor C had a lower final course average ($m = 75.11, sd = 20.920$) than students who had Instructor D ($m = 84.92, sd = 11.688$). Students who had Instructor B ($m = 81.46, sd = 10.514$) were not significantly different from any of the other three instructors.

Table 26

Tukey's HSD of Learning Outcomes for Statistical Methods by Instructor

(I) Instructor	(J) Instructor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
A	B	-.02990	.02550	.645	-.0958	.0360
	C	.03357	.03093	.699	-.0464	.1135
	D	-.06454*	.02380	.035	-.1260	-.0031
B	A	.02990	.02550	.645	-.0360	.0958
	C	.06347	.02787	.106	-.0086	.1355
	D	-.03465	.01965	.293	-.0854	.0161
C	A	-.03357	.03093	.699	-.1135	.0464
	B	-.06347	.02787	.106	-.1355	.0086
	D	-.09811*	.02633	.001	-.1661	-.0301
D	A	.06454*	.02380	.035	.0031	.1260
	B	.03465	.01965	.293	-.0161	.0854
	C	.09811*	.02633	.001	.0301	.1661

*. The mean difference is significant at the 0.05 level.

Additional Findings

An additional item of inquiry was the effect gender had on a student's final course average, their average score on the *Learning Outcomes for Statistical Methods*, and the *SATS-36* pre-sub scores. The results of a one-way ANOVA comparing the student's final course average, their average score on the *Learning Outcomes for Statistical Methods*, and the *SATS-36* pre-sub scores and gender are shown in Table 27. A significant difference was found among gender ($F(1,298) = 9.953, p = 0.002$) and *SATS-36* Pre-Affect Sub-Score. Male students had a higher mean *SATS-36* Pre-Affect Sub-Score ($m = 4.5709, sd = 1.16629$) than female students ($m =$

$4.1315, sd = 1.122513$). A significant difference was found among gender ($F(1,298) = 4.877, p = 0.028$) and *SATS-36* Pre-Difficulty Sub-Score. Male students had a higher mean *SATS-36* Pre-Difficulty Sub-Score ($m = 3.7932, sd = 0.77370$) than female students ($m = 3.5852, sd = 0.83983$). A significant difference was found among gender ($F(1,298) = 13.790, p < 0.001$) and *SATS-36* Pre-Effort Sub-Score. Male students had a lower mean *SATS-36* Pre-Effort Sub-Score ($m = 6.3843, sd = 0.73363$) than female students ($m = 6.6581, sd = 0.54237$). No significant difference was found among gender and the remainder *SATS-36* Pre Sub-Scores, final course averages, or mean score on the *Learning Outcomes for Statistical Methods*.

Table 27

One-way ANOVA of Student Scores by Gender

		Sum of Squares	df	Mean Square	F	Sig.
Final Average	Between Groups	.031	1	.031	1.609	.206
	Within Groups	5.609	288	.019		
	Total	5.640	289			
Affect Sub-Score	Between Groups	14.314	1	14.314	9.953	.002
	Within Groups	428.566	298	1.438		
	Total	442.880	299			
Cognitive Sub Score	Between Groups	2.764	1	2.764	2.386	.123
	Within Groups	345.187	298	1.158		
	Total	347.951	299			

Value Sub Score	Between Groups	.927	1	.927	.748	.388
	Within Groups	369.240	298	1.239		
	Total	370.167	299			
Difficulty Sub Score	Between Groups	3.207	1	3.207	4.877	.028
	Within Groups	195.992	298	.658		
	Total	199.199	299			
Interest Sub Score	Between Groups	4.609	1	4.609	2.432	.120
	Within Groups	564.812	298	1.895		
	Total	569.422	299			
Effort Sub Score	Between Groups	5.559	1	5.559	13.790	.000
	Within Groups	120.119	298	.403		
	Total	125.677	299			
Learning Outcomes Total Percent	Between Groups	.014	1	.014	1.303	.255
	Within Groups	2.840	266	.011		
	Total	2.854	267			

One question on the *SATS-36* Post survey asked students to rate their stress level before going they entered the final exam week. The students rated their stress level from a scale of 1-7 with 1 meaning little to no stress and a 7 meaning high stress. A Pearson correlation coefficient was calculated for the relationship between students' *SATS-36* post stress level rating and their *Learning Outcomes for Statistical Methods* average as shown in Table 28. A weak negative correlation was found ($r(272) = -0.256, p = 0.006$), indicating a significant linear relationship between the *SATS-36* post stress level and *Learning Outcomes for Statistical Methods* average. Students with a higher stress level tend to have a lower *Learning Outcomes for Statistical Methods* average.

Table 28

Correlation between Learning Outcomes of Statistical Methods and Stress Level

		Learning Outcomes	Stress Level
Learning Outcomes	Pearson Correlation	1	-.256**
	Sig. (2-tailed)		.006
	N	272	112
Stress Level	Pearson Correlation	-.256**	1
	Sig. (2-tailed)	.006	
	N	112	117

**. Correlation is significant at the 0.01 level (2-tailed).

A third interesting finding was an effect of days of the week and time of day a section was offered. The results of a one-way ANOVA comparing the student's final course average their average score on the Learning Outcomes for Statistical Methods and section days and times are shown in Table 29. A significant difference was found among section days and time ($F(8,286) = 2.588, p = 0.010$) and final course average. A significant difference was not found among section days and time ($F(8,263) = 0.760, p = 0.638$) and *Learning Outcomes of Statistical Methods* average.

Table 29

ANOVA of Students' Final Course Average and Learning Outcomes for Statistical Methods and Course Days and Times

		Sum of Squares	df	Mean Square	F	Sig.
Final Course Average	Between Groups	.406	8	.051	2.588	.010
	Within Groups	5.610	286	.020		
	Total	6.016	294			
Learning Outcomes Total Percent	Between Groups	.067	8	.008	.760	.638
	Within Groups	2.883	263	.011		
	Total	2.950	271			

Table 30 shows the results of a Tukey's HSD used to determine the nature of the differences between the sections. The analysis revealed that students who took a statistical methods course on Mondays, Wednesdays, and Fridays in the morning had a higher final course average (9:30 – 10:20 am: $m = 87.00, sd = 9.515$; 10:30 – 11:20 am: $m = 85.40, sd = 11.488$) than students who took a statistical methods course on Tuesdays and Thursdays in the late evening (6:00 – 7:15 pm: $m = 75.11, sd = 20.920$). Students who had sections in the other days and times were not significantly different from any of the other days and times.

Table 30

Tukey's HSD of Final Course Average and Section

Dependent Variable	(I) Section	(J) Section	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Final Course Average	MWF - 9:30-10:20 am	TR - 6:00-7:15 pm	.11889*	.03237	.009	.0177	.2201
	MWF - 10:30-11:20 am	TR - 6:00-7:15 pm	.10289*	.03132	.031	.0050	.2008

*. The mean difference is significant at the 0.05 level.

Summary

Questions related to the effect of instructional style in the teaching of introductory statistics on students' attitudes towards statistics and on student's academic outcomes in statistics courses were analyzed considering the data available. Without sufficient data for various instructional styles, it is not possible to answer these questions. However, the data did reveal that there was a change in pre- and post-survey results for the Value, Interest, and Effort sub-scores on the *SATS-36*. In addition, there was a relationship between the pre-survey Affect, Cognitive, and Effort sub-scores and the students' final course grade. Further analysis revealed an effect gender has on a students' pre-survey Affect, Difficulty, and Effort sub-scores. There appears to be an effect on when a section is held (day and time) and the final course average. Lastly, there was a relationship found between a student's stress level at the end of the course and the Learning Outcomes of Statistical Methods average score.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

Introduction

This study explored the impact of instructional style in the teaching of introductory statistics on student's attitudes towards statistics and on student's academic outcomes in statistics courses. University statistics instructors were surveyed to identify their instructional style and their students' mean course scores and mean scores on the *Learning Outcomes for Statistical Methods* survey. Data were analyzed through a comparison of means. The results of this analysis were provided in Chapter 4. In this chapter, these findings will be discussed along with their implications.

Relevant Populations

There are two relevant populations in this study: university statistics instructors and undergraduate students. Data was collected about the following: (a) instructional practice preferences of statistical methods instructors, (b) the attitudes towards statistics of students, and (c) the academic performance of students in their statistics courses. Results indicate which types of instructional practices are correlated with an increase in student learning outcome achievement, and an increase in positive perception towards statistics.

Research Design

Data was collected fr*om instructors and students of i*n introductory statistics course*s* at *a state university in Southwest* Florida, during the fall 2016 semester. Prior to the beginning of the term, instructors were asked to complete the *Instructional Style Survey for Statistics which* categorized the instructional style of instructors. Instructors were then sent electronic versions of the *SATS-36* pre- and post-surveys to administer to their students. In mid-November, instructors were sent the *Learning Outcomes for Statistical Methods* instrument to administer as their final exam. After the semester, instructors sent the completed pre- and post-surveys of the *SATS-36*, course grades, and scanned *Learning Outcomes for Statistical Methods* to the researcher. After data collection and input, the researcher used SPSS to run statistical analysis of the data.

Measures

This study had one independent variable, the instructional method used by the instructor. This study had two dependent variables, student learning outcomes and student attitude towards statistics. The purpose of this study was to see how the instructional style of an instructor influenced students on two fronts: learning outcomes and attitudes. This study also looked at other co-factors such as gender, course time of day, and stress level at end of course.

Research as an Instrument of Inquiry – Discussion of Possible Bias

The researcher is a 34 year-old male living, until recently, in Southwest Florida since 1988. His bachelor degree is in mathematics, and masters degree is in curriculum and instruction. His mathematical proclivity shaped his view of research. The following is a personal from the researcher:

> I believe we all exist in the same reality; how we experience and perceive that reality is different for each person. Through subjective evidence, one can understand how a person's perception of that reality was formed. Uncovering those distinct perceptions and experiences allows one to understand fully the reality experienced by all.

The researcher's views were formed from his mathematical training. His view of mathematics is that the world exists already and we are meant to discover that world. For example, he believes the relationship between the sides of a triangle already existed before the Pythagorean Theorem was developed. It was through inquiry, testing, hypothesizing, and re-testing that this Theorem was believed to be true. It was the axiomatic basis of mathematics that led to the formal proof of this Theorem. There are some mathematicians that ascribe to the view that we can create the mathematical truths, but he is not one.

The researcher has taught various instructional methods in his math methods 6th grade through 12th grade course. In this course, he co-taught with Dr. Diane Schmidt utilizing several models showing pre-service teachers how to move away from the more traditional didactic models to models more concerned with conceptual understandings. As a math educator, he was very aware of a gender inequality in mathematics. During the classes he taught, he made sure to call on both boys and girls for answers, providing feedback for incorrect answers. He encouraged his female students to take advanced mathematics courses.

Research Questions

First research question. What are effective instructional approaches for developing or improving learning outcomes as measured by the *Instructional Style Survey for Statistics* and *Learning Outcomes for Statistical Methods*? Academic achievement for students in the classes represented in the sample were examined by instructional style. Three of the five instructional styles were represented by the instructors in the sample: (1) objectivist transitional, (2) Confirmatory, and (3) constructivist transitional. A comparison of means showed that there were no significantly different mean scores on the *Learning Outcomes for Statistical Methods* instrument among the four instructors in the sample. The confirmatory style with one instructor had the highest mean score of a 76.79% on the *Learning Outcomes for Statistical Methods* instrument followed by the constructivist transitional style with one instructor had a mean score of a 76.24%. On the scale of instructional styles, both styles are more closely aligned to an inquiry-based instructional style. Whereas, the objectivist transitional style with two instructors had lower mean scores on the *Learning Outcomes for Statistical Methods* instrument of 73.38% and 73.90%.

Though the findings were not statistically significant, the data indicates instructional styles that are more inquiry-based may be more effective overall for student achievement on the *Learning Outcomes for Statistical Methods* instrument. In addition, inquiry-based instructional styles may be more effective in the instruction of descriptive statistics and probability. Students have a difficult time with understanding variation in descriptive statistics and many of the topics of probability. With the nuances of these topics, students are not successful if they have a rote understanding. Inquiry-based instructional strategies promote a deeper conceptual understanding besides understanding the mechanics of the topics. This would indicate why students showed an improvement with descriptive statistics and probability. There were overlaps of effective styles between more inquiry-based and more didactic styles with the instruction of inferential and non-parametric statistics. The is a need for conceptual understanding in inferential statistics, but in the introductory course most of the instruction utilizes the mechanics of inferential statistics with small relative points awarded for a deeper conceptual understanding of inferential statistics. This finding confirms Birney et al.'s (2005) description of the primary purpose of statistical instruction was to help students understand statistics a deeper level as opposed to a surface understanding. This study shows a deeper conceptual understanding of statistics is helpful to students.

A more definitive answer to the first research question is probable in future research given a larger study with more than four statistics instructors. Results from this study indicate that for students with instructors who report using more inquiry-based instruction in class had higher mean scores on the *Learning Outcomes for Statistical Methods* instrument. This outcome supports the results of Derry et al. (2000), Rabin and Nutter-Upton (2010), and Perkins and Saris (2001) who all indicated positive student learning outcomes for students in inquiry-based statistics courses. In addition, Doll (1993) and Egan (1999) support curriculum design focusing on more inquiry-based instructional approaches.

Second research question. Does teaching style contribute to differences in students' attitude towards statistics as measured by the *Instructional Style Survey for Statistics* and the *Survey of Attitudes Toward Statistics SATS-36*? Attitudes of student study participants toward statistics were examined by instructional style. Three of the five instructional styles on the survey were represented by the instructors in the sample. The *Survey of Attitudes Toward Statistics SATS-36* had five component sub-scores: Affect, Cognitive, Value, Difficulty, Interest, and Effort. A comparison of means showed that there were no significantly different mean scores for the Affect sub-score on the *SATS-36* among the four instructors with differing instructional styles in the sample. A comparison of means showed that there were no significantly different mean scores for the Cognitive sub-score on the *SATS-36* among the four instructors in the sample. A comparison of means showed that there were significantly different mean scores for the Value sub-score on the *SATS-36* among the four instructors in the sample. A comparison of means showed that there were no significantly different mean scores for the Difficulty sub-score on the *SATS-36* among the four instructors in the sample. A comparison of means showed that there were significantly different mean scores for the Interest sub-score on the *SATS-36* among the four instructors in the sample. A comparison of means showed that there were significantly different mean scores for the Effort sub-score on the *SATS-36* among the four instructors in the sample.

A more detailed analysis of the significant pre- and post- mean differences of the *SATS-36* indicates some interesting discussion points. There was a significant decrease found between pre- and post-survey means for the students' Value component score. This would indicate students found less value for statistics after taking this specific statistical methods course. There was a significant decrease found between pre- and post-survey means for the students' Interest component score. This would indicate students found less interest in statistics after taking this specific statistical methods course. One rationale for this outcome would be a focus on presenting problems that may illustrate the concept but do not connect with the student. An effort should be made to look at the curriculum and choice of problems to increase interest in the course. There was a significant decrease found between pre- and post-survey means for the students' effort component score. This would indicate students found there required less effort for statistics after taking this specific statistical methods course. Traditionally, students perceive statistics as a difficult course. This is usually do to negative comments by other adults or students who have taken the course. This outcome indicates students find the course is not as challenging as they believed.

Since just four statistics instructors representing three of the five learning styles agreed to participate in this study, it is difficult to answer the second research question with certainty for two reasons. First, the future research should engage more than four statistics instructors as participants, Second, there was a considerable variance in the size of students in style groups. Both challenges can be solved with a larger instructor participant group. Dispositional study results show that for students taking this introductory course in statistics, their value for, their interest in, and their belief of effort required for statistics was lowered from the beginning to the end of the course. The results of this study are counter to Derry et al. (2000) who found students in inquiry-based courses had a more enjoyable experience than students in a traditional course. Though this study did not find similar results as Derry et al. (2000), this should not indicate that inquiry-based courses are not more enjoyable. One reason for this study's finding is the lack of interesting assignments as opposed to the use of inquiry-based instruction. This study's findings are also in conflict with DePaolo et al. (2009) who stated students chose to do assignments that fit into their cognitive style. Given these conflicting results, further research is needed to determine the effectiveness of inquiry-based instruction in university statistics courses. Likely, the types of assignments used in the courses could have played a part in how students' attitudes towards statistics were impacted. This study found inquiry-based instructional methods were not better than more traditional ones. However, there are confounding variables such as type of assignments, example problems chosen, and emphasis on completing the same online homework for all students. Slabbert and Hattingh (2006) and Losin (2001) described interconnection between students in instruction and the use of questioning by instructors. The literature would indicate further research is needed into the grouping techniques and types of questioning used by instructors in the classroom.

Third research question. What is the relationship between students' attitude towards statistics and the DWF Rates for Statistical Methods as measured by the *Survey of Attitudes Toward Statistics SATS-36* and DWF Rates? Attitudes toward statistics for students in the courses represented in the sample were examined by final course average. Three of the five instructional styles were represented by the instructors in the sample. The *Survey of Attitudes Toward Statistics SATS-36* had five component sub-scores: Affect, Cognitive, Value, Difficulty, Interest, and Effort. A correlation was found between a student's *SATS-36* pre-Affect sub-score and final course average. Results also demonstrated a relationship between a student's *SATS-36* pre-Cognitive sub-score and final course average. A correlation found a relationship between a student's *SATS-36* pre-Effort sub-score and final course average.

The results from this study indicated that students who score higher on the pre-*SATS-36* Affect, Cognitive, and Effort sub-scores tended to have higher final course averages. The reverse statement is also interesting to note: students who score lower on the pre-*SATS-36* Affect, Cognitive, and Effort sub-scores would tend to have lower final course averages. This particular study's finding for the Cognitive sub-score agrees with DePaolo et al. (2009) who noted how students prefer to do assignments that match their cognitive style. The implication of this result is that we could identify students likely to have lower final course averages at the end of the course with a pre-survey at the beginning of the course and assist those students throughout the course. In addition, Haushildt and Wesson (1999) described how initial stages of confusion and panic in students produced higher achievement scores indicating a use of the Effort sub-score. By early identification, instructors could focus early interventions to help increase overall course pass rates.

Fourth research question. What is the relationship between instructional approaches and the DWF Rates for Statistical Methods as measured by *Instructional Style Survey for Statistics* and DWF Rates? DWF rate is a measure used by the university to report how many students received a D or F in a course or withdrew. Since students who withdrew from the course could not provide all information required for this study, the researcher choose to use a similar measure of final course average. Instructional style for instructors represented in the sample were analyzed by student final course average. Three of the five instructional styles were represented by the instructors in the sample. A comparison of means found that there was a significant difference between the final course averages and the instructional style of the instructor. The analysis revealed that students who had an instructor with a constructivist transitional style had a lower final course average ($m = 78.47, sd = 17.996$) than students who had an instructor with an objectivist transitional ($m = 84.92, sd = 11.688$). The analysis also revealed that students who had an instructor with a confirmatory style had a lower final course average ($m = 75.11, sd = 20.920$) than students who had an instructor with an objectivist transitional style ($m = 84.92, sd = 11.688$). Students who had the other objectivist transitional style instructor ($m = 81.46, sd = 10.514$) were not significantly different from any of the other three instructors. Instructional style does impact the final course grades of students. Specifically, Instructor D (objectivist transitional) had the courses with the highest final course averages. This conclusion may not indicate that more didactic instructional methods are more effective in terms of final course average, because Instructor D hade several assessment scores that were curved and there was use of extra credit.

The results from this study indicated that students who had an instructor with a more didactic instructional style (objectivist transitional) had a higher final course average or were more successful academically as compared to those who had instructors with a more inquiry-based instructional style. Further analyzing the actual grades of the students from the instructor D with a significant different final average, this instructor curved several assignments thus artificially changing the grades for students. Upon deeper analysis of this finding, one can conclude that an instructor’s awareness of how students are doing in their course could help the instructor interact with the student. This confirms with Bumer and Rodd (2005) who stated how web-based courses increased the awareness of students’ performance for their instructors. Though this study did not include any solely web-based courses, all courses utilized an interactive online textbook and online homework system. The courses in this study could be considered blended learning courses using both online and in-person instruction.

Other Findings

Students' final course average, mean score on the *Learning Outcomes for Statistical Methods* ($n = 267$), and the *SATS-36* pre-sub-scores were analyzed by gender ($n = 299$). A comparison of means found a significant difference between traditional gender categories of male and female and *SATS-36* Pre-Affect Sub-Score. Male students had a higher mean *SATS-36* Pre-Affect Sub-Score than female students. A significant difference was found among gender and *SATS-36* Pre-Difficulty Sub-Score. Male students had a higher mean SATS-36 Pre-Difficulty Sub-Score than female students. A significant difference was found among gender and *SATS-36* Pre-Effort Sub-Score. Male students had a lower mean *SATS-36* Pre-Effort Sub-Score than female students. No significant difference was found between the traditional gender categories of male and female and the remainder *SATS-36* Pre-Sub-Scores, final course averages, or mean score on the *Learning Outcomes for Statistical Methods*.

Scheiber et al. (2015) conducted a large-scale study of participants aged 4.5 to 90 and found no gender-age difference between males and females in mathematics. Glickman et al. (2010) described a gender inequality where girls have a negative self-confidence in education. Arnold and Rowann (2014) found a difference between female and male students in a first-year economics course where female students were more motivated to study but less confident about their performance. Bench et al. (2015) found no real difference between males and females in a study of STEM university students but found males overestimated how well they performed on tests where females were more correct with their estimates. Liu and Wilson (2009) showed a difference on standardized tests between male and female high school students but indicate there was a more significant relationship between the perception of math ability and gender indicating that females general underestimate how they will perform in mathematics. Cheryan (2012), Gunderson et al. (2012), Scafidi and Bui (2010), and Thorman et al. (2008) found no difference between male and female students in mathematics but associated the reduced number of females in STEM fields to stereotypes about math related fields.

The results of this study indicate that male students view statistics more favorably than female students, male students believe statistics is more difficult than female students, and male student believe statistics requires less effort than female students. The results of this study would confirm the results from Bauer (2000) who described gender inequity in curriculum. An interesting result was that this study found no difference between males and females on final course grades or average grades on the *Learning Outcomes for Statistical Methods* instrument. This indicates there is not gender difference in performance in an introductory statistics course. This result is opposite of what Kommer (2006) discovered that girls stopping being successful in math in middle school. Cheema and Galluzzo (2013) found a gender difference between male and female students in mathematics with males performing slightly better on standardized assessments, but this difference was almost erased once controlled for math self-efficacy and math anxiety.

Students stress level at the end of the semester was also examined against their average score on the *Learning Outcomes for Statistical Methods*. A correlation was found between a student's stress level at the end of the semester and their average score on the *Learning Outcomes for Statistical Methods* instrument. Students with a higher stress level tend to have a lower *Learning Outcomes for Statistical Methods* average. This finding suggests that understanding students stress level at the end of a semester and trying to find ways to alleviate students' stress could help students perform better in statistics. In addition, since student stress level does have a negative impact on the *Learning Outcomes for Statistical Methods* average this could be confounding the results of instructional methods.

Students' final course average and average score on the *Learning Outcomes for Statistical Methods* instrument were also examine by what time of the day or evening a student took the course. A comparison of means found a significant difference among section days and time and final course average. A significant difference was not found among section days and time and *Learning Outcomes of Statistical Methods* average. Further analysis revealed that students who took a statistical methods course on Mondays, Wednesdays, and Fridays in the morning had a higher final course average than students who took a statistical methods course on Tuesdays and Thursdays in the late evening. Generally, students who take courses three days a week and in the morning hours are more traditional meaning they have fewer outside commitments. Students taking the course two days a week and in the evening or students who are have more commitments outside of their studies.

Recommendations for Further Research

The results of the *Instructional Style Survey for Statistics* completed with the four teachers in the sample indicate that there are varying instructional styles used in a university undergraduate introductory statistics course. There are mixed results with inquiry-based methods versus didactic methods. In additional to looking at instructional style, efforts in redesigning courses to better match cognitive style should be investigated. Analyzing how instructional methods are associated with assignment types and stress reducing techniques would be beneficial.

The small number of instructors participating in this study made it unlikely to draw adequate conclusions about instructional style. To adjust for this, a study needs to be conducted that involves a much larger number of undergraduate university statistics instructors. In addition to increasing the number of instructors participating in a study, it would be helpful if the instructors are representative of the five levels of instructional style as defined in this study. This could pose to be a challenge because university instructors are generally not exposed to varying teaching methods during their training. A instructional training program could be utilized to train instructors in the five different methods to help increase representation among the instructional styles. Initially, the study would begin by assessing the level of instructional style by administering the *Instructional Style Survey for Statistics* with an accompanying observation confirming the instructional style. An alternate form of design could be to use professional development to train instructors on using inquiry-based instructional strategies and compare them against instructors without the professional development. This also presents challenges as the instructors would need to undergo in-depth training and should use inquiry-based strategies with mentorship to develop these techniques over time. Then regular observation of instructors to ensure their use of inquiry-based techniques would need to occur.

The use of the *Learning Outcomes for Statistical Methods* instrument is one factor that was prevalent at varying degrees throughout this study. This instrument was used to compare student achievement, instructional style, and student attitudes towards statistics. This instrument was developed to administer by course instructors to all students participating in statistics courses to allow for a common point of comparison. Individual instructor-developed exams by instructors and course grades are too variable and may not be correlated to one another. Instructors had flexibility with course grading procedures allowing them to change individual category weights, curve grades, and offer extra credit. This study allowed for the use of a common instrument to assess learning outcomes because the course was delivered with a common curriculum and textbook. Further research should continue to use the *Learning Outcomes for Statistical Methods* instrument.

Strengths and Limitations

This study had representation from instructors who reported they primarily used a didactic or inquiry-based instructional style. There was a relatively large sample of students for each of the instructional styles presented. There was additional information collected from the instructors and students that allowed the researcher to look for additional correlations besides instructional style and learning outcomes. With this representation and the relatively large sample of students, the findings could be generalized to most undergraduate statistics courses across the country. In addition, the findings could be generalized to high school statistics courses due to the nature of the content and proximately of age of students. However, more research is warranted.

A recommendation for future research was for a replication of this study to more universities to help with the generalizability of the results. However, due to the relatively large number of students and the diversity of the sample, the sample is representative of most undergraduate statistics students. One limitation was the low number of students who completed the post-survey of the *SATS-36*. This did limit the degree of statistical significance that could be made for one of the research questions. And, of course, the low number of instructor participation is a limitation.

Implications

The implications of this study impact instructors of undergraduate and secondary courses of statistics. Introductory statistics courses and statistics courses in secondary schools have similar content coverage and instructional methods. With a large number of students aged close to eighteen in the university course, their age is similar to secondary school students. Though not completely comparable, there are similarities with course content and delivery that make the results of this study generalizable to both undergraduate and secondary statistics students. With an increase in programs that require an undergraduate course in statistics and an increase in statistical literacy at the secondary level, it is important to study how instructors can influence the learning outcomes and attitudes of students in their statistics courses. Additionally, there are other factors that this study have shown impacts attitudes and learning outcomes such as gender, *SATS-36* pre-survey sub-scores, and stress level. These additional factors will help to identify students early in the course to allow instructors to utilize additional instructional aides to these students. These additional instructional aides could be gender specific assignments and example problems, extra help offered to students scoring lower on the *SATS-36* pre-survey, and identification of students likely to have a lower final course average early in the semester allowing instructors to make a more personal connection with these students. There was a difference found between how females and males view the subject of statistics. Knowing this, instructors could help begin to design activities geared with a gender direction. Knowing stress at the end of the semester caused a lower mean score on the *Learning Outcomes for Statistical Methods* instrument could help instructors utilize stress reducing techniques towards the end of the semester.

Summary

The frequency distribution of instructional styles indicates that there are university statistics instructors who utilize instructional styles varying from didactic to inquiry-based. Analysis of student mean scores from their course and on the *Learning Outcomes for Statistical Methods* instrument across time of day, major, etc. indicate that instructional style was relevant for this group of students. Specifically, the mixed instructional style of objectivist transitional was effective. A key finding of this was the relationship between students' attitude towards statistics and the DWF Rates for Statistical Methods. Using the pre-SATS-36 survey, three sub-scores can be used to identify students at risk of not passing statistics early in the semester: Affect, Cognitive, and Effort. Students scoring low in these three sub-score areas are more likely not to pass statistical methods. Besides early identification, instructors could modify assignments types and instruction that might better match a student's cognitive style. The results presented here, indicate a need for future exploratory and experimental studies involving qualitative and quantitative data to ascertain the impact of inquiry and other instructional practices on students in a university introductory statistics course.

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Appendix A

Online Survey Consent Form - Instructors

Study Title: The effectiveness of inquiry-based vs. didactic teaching methods on student performance in undergraduate statistics

Principal Researcher: Robert L. Nichols
Faculty Sponsor: Dr. Lynn K. Wilder

You are being invited to participate in a research study conducted through Florida Gulf Coast University. Your participation in this study is voluntary. This research is being conducted as part of a dissertation for the completion of the Doctor of Education degree offered at Florida Gulf Coast University. In order to participate in this study, the University requires that I obtain your consent.

Your participation in the study is completely voluntary. If you decide to participate now you may change your mind and stop at any time, for any reason, without penalty or loss of any future services you may be eligible to receive from the University or Department of Mathematics.

The purpose of the research is to study what instructional methods statistics instructors use and which produce the best academic outcomes for students in statistics courses. The study will also analyze how these differences in methodology influence student attitudes toward the subject of statistics. The information gained in this study will be used to recommend best practices in the teaching of introductory statistics and how instructors can improve the learning experience for students.

I am asking you to take part in the study because you are an instructor of Statistical Methods STA 2023.

If you agree to be part of the research study, you will be asked to:

1. during the first week of classes of the fall 2016 semester, complete the *Instructional Style Survey for Statistics* online via Canvas. You can choose to not answer an individual

question or you may skip any section of the survey by clicking "Next" at the bottom of the survey page to move to the next question;

2. use the *Learning Outcomes for Statistics Methods* instrument developed for this dissertation (approximately 135 minutes) as your final exam for this course. Dr. Navaratna, Chair, Department of Mathematics, has approved the use of this exam as the course's final exam; and
   Please note that the use of this final exam is a mandatory component of the study, please contact the researcher if you usually give an alternate assessment to a final exam.
3. share the survey results and grades of students in your class(es) who participate in the study with me.

Students participating in the study will be asked to:

1. during the first week of classes of the fall 2016 semester, complete the *Survey of Attitudes Toward Statistics SATS-36 pre-survey* online via Canvas (approximately 15 minutes);
2. during the last week of classes of the fall 2016 semester, complete the *Survey of Attitudes Toward Statistics SATS-36 post-survey* online via Canvas (approximately 15 minutes); and
3. give permission for you to share their survey results and grades with me.

There are no known or anticipated risks to you if you join the study.

Although your participation in this research may not benefit you personally, it will help me develop best practices in the teaching of introductory statistics and how instructors can improve the learning experience for students.

If you join the study, I will make every effort to keep your information confidential and secure by taking the following steps. The Informed Consent Forms and research data will be stored in the office of Dr. Lynn K. Wilder. Dr. Lynn K. Wilder will shred all documents. Any electronic materials stored on Canvas will be destroyed with the assistance of the FGCU Department of e-Learning and Academic Web. However, despite these safeguards, there is the possibility of hacking or other security breaches that could compromise the confidentiality of the information you provide. Thus, it is important to remember that you are free to decline to answer any question that makes you uncomfortable for any reason.

I will not release information about you unless you authorize me to do so or unless I am required to do so by law. If results of this study are published or presented at a professional meeting, no information will be included that would make it possible to identify you as a study participant.

You will not be paid to take part in this study.

If you have any questions about this study, you may contact Dr. Lynn K. Wilder at 239-590-7787.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board through Sandra Terranova, Office of Research and Sponsored Programs, at 239-590-7522.

Statement: I have read the preceding information describing this study. All of my questions have been answered to my satisfaction. I freely consent to participate in the study. My decision to participate or to decline participating in this study is completely voluntary. I understand that I am free to withdraw from the study at any time. I am aware of my option to not answer to any questions I choose.

I understand that it is not possible to identify all potential risks I believe that reasonable steps have been taken to minimize both the known and potential but unknown risks. The submission of the completed survey is my informed consent to participate in the study.

If you would like a copy of the consent form, print a copy before continuing.

By clicking on the "Agree to Participate" link below you are consenting to participate in the research study.

If you do not wish to participate, click on the “Do Not Agree to Participate” link below.

Thank you for your time.

Robert L. Nichols, Principal Researcher

Dr. Lynn K. Wilder, Faculty Sponsor

Appendix B

Online Survey Consent Form - Students

Study Title: The effectiveness of inquiry-based vs. didactic teaching methods on student performance in undergraduate statistics

Principal Researcher: Robert L. Nichols
Faculty Sponsor: Dr. Lynn K. Wilder

You are being invited to participate in a research study conducted through Florida Gulf Coast University. Your participation in this study is voluntary. This research is being conducted as part of a dissertation for the completion of the Doctor of Education degree offered at Florida Gulf Coast University. In order to participate in this study, the University requires that I obtain your signed consent. You must be at least 18 years old to participate in the study.

Your participation in the study is completely voluntary. If you decide to participate now you may change your mind and stop at any time, for any reason, without penalty or loss of any future services you may be eligible to receive from the University or Department of Mathematics.

The purpose of the study is to study what instructional methods statistics instructors use and which produce the best academic outcomes for students in statistics courses. The study will also analyze how these differences in methodology influence student attitudes toward the subject of statistics. The information gained in this study will be used to recommend best practices in the teaching of introductory statistics and how instructors can improve the learning experience for students.

I am asking you to take part in the study because you are a student enrolled in Statistical Methods STA 2023.

If you join the study you, you will be asked to:

4. during the first week of classes of the fall 2016 semester, complete the *Survey of Attitudes Toward Statistics SATS-36 pre-survey* online via Canvas (approximately 15 minutes);

5. during the last week of classes of the fall 2016 semester, complete the *Survey of Attitudes Toward Statistics SATS-36 post-survey* online via Canvas (approximately 15 minutes); and
6. allow your instructor to share your anonymous survey results and grades for the course with me.

The surveys cannot be completed in more than one session.

There are no known or anticipated risks to you if you join the study. Please notify Dr. Wilder if you would like to break or terminate your participation. A referral will be made to CAPS, if necessary.

Although your participation in this research may not benefit you personally, it will be used to develop best practices in the teaching of introductory statistics and how instructors can improve the learning experience for students.

If you join the study, I will make every effort to keep your information confidential and secure by taking the following steps. The Informed Consent Forms and research data will be stored in the office of Dr. Lynn K. Wilder. Dr. Lynn K. Wilder will shred all documents; electronic materials stored on Canvas will be destroyed with the assistance of the FGCU Department of e-Learning and Academic Web. However, despite these safeguards, there is the possibility of hacking or other security breaches that could compromise the confidentiality of the information you provide. Thus, it is important to remember that you are free to decline to answer any question that makes you uncomfortable for any reason.

I will not release information about you unless you authorize me to do so or unless I am required to do so by law. If results of this study are published or presented at a professional meeting, no information will be included that would make it possible to identify you as a study participant.

You will not be paid to take part in this study.

If you have any questions about this study, you may contact Dr. Lynn K. Wilder at 239-590-7787.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board through Sandra Terranova, Office of Research and Sponsored Programs, at 239-590-7522.

Statement: I have read the preceding information describing this study. All of my questions have been answered to my satisfaction. I am 18 years of age or older and freely consent to participate in the study. My decision to participate or to decline participating in this study is completely voluntary. I understand that I am free to withdraw from the study at any time. I am aware of my option to not answer to any questions I choose.

I understand that it is not possible to identify all potential risks I believe that reasonable steps have been taken to minimize both the known and potential but unknown risks. The submission of the completed survey is my informed consent to participate in the study.

If you would like a copy of the consent form, print a copy before continuing.

By clicking on the "Agree to Participate" link below you are consenting to participate in the research study.

If you do not wish to participate, click on the "Do Not Agree to Participate" link below.

Thank you for your time.

Robert L. Nichols, Principal Researcher

Dr. Lynn K. Wilder, Faculty Sponsor

Appendix C

FLORIDA GULF COAST UNIVERSITY

Academic Affairs
Office of Research
and Graduate Studies

Protocol ID # S2016-69
Please refer to this Protocol ID number in all communications about this protocol with the IRB.

TO: Robert Nichols, PI
Dr. Lynn Wilder
College of Education

FROM: Institutional Review Board CMR / st

DATE: August 15, 2016

RE: The effectiveness of inquiry-based vs. didactic teaching methods on student performance in undergraduate statistics

This protocol has been approved. Your approval category and terms of approval are included below.

☒ **Expedited Approval** ☐ Full Board Review Approval ☐ Exempt from Further Review

☒ **This protocol has been approved as of August 15, 2016 for a period of one year.** Approximately two months prior to the approval end date, you will receive a Continuing Review Request Form. The form needs to be completed and returned to Research and Graduate Studies, even if the protocol has been completed or is discontinued.

☒ Attached to this memo are the approved, stamped versions of the Online Consent forms and recruitment emails. Do not use any other versions of the Consent Forms or recruitment scripts.

Please note:
As a student investigator, you must submit a copy of the signed consent forms and all other research data to Dr. Wilder to retain for a minimum of three years following the completion of the study.

Any changes to the protocol will require the submission of an amendment to the IRB *prior* to the implementation of the change. Any adverse reaction by a research subject is to be reported immediately to the Chair of the IRB through Sandra Terranova in the Office of Research and Graduate Studies, at 239-590-7522 or via e-mail at sterranova@fgcu.edu.

Questions concerning the IRB decision or any concerns may be directed to the IRB Chair through Ms. Terranova.
Attachment, if noted above
Cc: Dr. Robert Kenny, Chair Leadership Technology
Dr. Eunsook Hyun, Dean College of Education

(239) 590-7020 SUNCOM: 730-7020 FAX: (239)590-7024
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Appendix D

INSTRUCTIONAL STYLE SURVEY FOR STATISTICS

Circle the number in each row that most closely reflects your usual instructional practice when teaching **statistics**. Please circle only one number in each row.

1	2	3
1. Before instruction, I usually review and the previous day's homework.	Before instruction, I usually have students explain and self-correct homework	I usually begin instruction with a problem that will require prior knowledge.
1	2	3
2. I demonstrate the standard procedure or algorithm at the board or overhead.	I demonstrate the standard procedure or algorithm using manipulatives.	I have students explore problems without teaching procedures or algorithms.
1	2	3
3. I present the procedure as described in the textbook.	I lead students to understand the procedure as described in the textbook by using manipulatives.	I have students collaborate to create or invent their own procedures
1	2	3
4. I require that students work independently as they learn the new skill.	I allow students to work together and help each other practice the new skill.	I have students work together to develop skills and strategies through problem solving
1	2	3
5. I stress memorization of the standard procedure.	I stress understanding of the standard procedure.	I stress understanding of the concept, not the procedure.
1	2	3
6. I provide guided practice on the new statistical skill with paper and pencil problems.	I provide guided practice on the new statistical procedure with manipulatives as well as paper and pencil activities.	I provide guided practice through complex problem solving activities and group discussions
1	2	3
7. I check students' practice papers for accuracy.	I check students' practice papers for accuracy and use of correct procedure.	I have students compare their strategies with others' to evaluate their efficiency and effectiveness.
1	2	3
8. I provide students with many opportunities to practice new skills through drill and practice activities.	I provide hands-on activities and games for students to practice the standard procedure.	I provide students with challenging new problems and logic games to develop the concept and provide practice.
1	2	3
9. I assign statistical problems from the textbook for independent practice	I assign practice using a combination of statistical problems and word problems	I assign complex word problems involving multiple skills for practice
1	2	3
10. I use drill activities and to help students memorize facts.	I use a combination of drill activities and drill games to help students memorize facts.	I use patterning activities and logic games to help students develop strategies for recall
1	2	3

11. I rarely or never have students use math journals or learning logs.	I have students use math journals or learning logs to record procedures I teach in class.	I have students use math logs to describe and reflect upon their own invented procedures.
1	2	3
12. I generally evaluate mastery of skills with textbook tests.	I generally evaluate mastery of skills and using a combination of teacher-made tests and textbook tests.	I generally evaluate student mastery of skills using performance-based tasks that require students to explain their procedures.

Which single statement best describes your instructional approach to teaching a new statistical skill?

Please mark only one choice.

I teach my students the standard algorithm (procedure) first.	
I provide opportunities for students to discover the standard algorithm.	
I allow students to invent and use their own algorithms.	

Demographic Information

Class

1. My instructional practices (do differ ___)(do not differ___) depending on the course.

2. My instructional practices (do differ ___)(do not differ___) depending on the type of class.

Teacher

1. Number of semesters of statistical methods teaching experience (including this semester) ________

2. Gender: _____ Male _____ Female

3. Ethnicity: _____Caucasian

   _____African-American

   _____Hispanic

   _____Multi-racial

   _____Other: Please Specify___________________________

Thank you for your time.

Appendix E

Learning Outcomes for Statistical Methods

STA 2023 - Statistical Methods

Name: ______________________________

Final Exam: Chapters 1-11

Date: _______________ CRN: __________

Directions:

This test contains 20 true/false, 30 multiple choice questions, and 5 free response questions. All true/false and multiple choice questions are worth 1 point. There are a total of 64 points available for this test. Make sure to clearly bubble your answer choice for the corresponding question number on the Scantron Test Sheet. Make sure to bubble the **Test Version Letter** located at the bottom of the exam in the K**ey ID** area on the Scantron Test Sheet.
Suggested test time allotment:

Total Time: 135 minutes; possible points: 64	**Points available for this section**	**Percent of total possible points**	**Minutes for this section**
Part 1: True/False Questions	20	31%	42
Part 2: Multiple Choice Questions	30	47%	63
Part 3: Free Response	14	22%	30
Total	64	100%	135

You may use the formula sheet provided with your text. You may not borrow another student's formula sheet during the test. You may use any calculator you wish. However, cell phones are not permitted for use in any way.

Any discussion or otherwise inappropriate communication between students, as well as the appearance of any unnecessary material or cell-phone usage, will be dealt with severely. Violations may result in an "F" for this test, "F" for the course, suspension, or expulsion.

TRUE/FALSE. Bubble A for 'T' if the statement is true and bubble B for 'F' if the statement is false.

1) In a research study, it is always preferable for the researcher to carefully choose his participants rather than randomly select them from a suitable group. **T or F**

2) Questioning every 14th customer leaving a theatre about the movie they had seen, would be an example of systematic sampling. **T or F**

3) Rating a restaurant by a number of stars is an example of an ordinal level of measurement. **T or F**

4) A person's hair color would be an example of a quantitative variable. **T or F**

5) A histogram is a graph that represents the cumulative frequencies for the classes in a frequency distribution. **T or F**

6) Two events are mutually exclusive if they cannot both occur. **T or F**

7) When the outcome of event A does not affect the probability of the outcome of a subsequent event B, then the events are said to be dependent. **T or F**

8) The sum of the probabilities of all the events in the sample space of a probability distribution must equal 1. **T or F**

9) In binomial experiments, each trial can be viewed as having only two outcomes. **T or F**

10) The area under a normal distribution curve is always positive even if the z value is negative. **T or F**

11) An interval estimate may or may not contain the true value of the parameter being estimated. **T or F**

12) The *t*-distribution must be used when the sample size is greater than 30 and the variable is normally or approximately normally distributed. **T or F**

13) The probability of commit ting a type II error is denoted as β. **T or F**

14) Stating the hypothesis should be the first step used in hypothesis testing. **T or F**

15) In performing a hypothesis test, one should decide whether to reject or not reject the null hypothesis before summarizing the results. **T or F**

16) The formula for the coefficient of nondetermination is $1.00 - r^2$. **T or F**

17) The range of the correlation coefficient is from 0 to 1. **T or F**

18) A regression line can be used to show trends in data. **T or F**

19) In a goodness of fit test between one observed frequency distribution and one expected frequency distribution, the degrees of freedom are equal to the number of categories minus two. **T or F**

20) The degrees of freedom for a 7×5 contingency table would be 24. **T or F**

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Bubble your choice on the scantron answer sheet. If you believe none of the answers listed is correct, bubble 'E' to represent none of the above answers is correct. If you bubble 'E', you must provide the correct answer on the back of the scantron with an explanation.

21) Which of the following correctly describes the relationship between a sample and a population? **21)** ___

A) A population is a group of samples that may or may not be included in a study.
B) A population and a sample are not related
C) A sample is a group of populations that are subject to observation.
D) A sample is a group of subjects selected from a population to be studied.

22) What is the upper class boundary of the class 23-35? **22)** ___

A) 7.5
B) 35.5
C) 35
D) 7

23) An automobile dealer wants to construct a pie graph to represent types of cars sold in July. He sold 72 cars, 16 of which were convertibles. How many degrees should be used for the convertibles section? **23)** ___

A) 60°
B) 50°
C) 80°
D) 100°

24) Approximate the sample standard deviation given the following frequency distribution. **24)** ___

Class	Frequency
0-14	17
15-29	10
30-44	15
45-59	12
60-74	11

A) 21.6
B) 458.5
C) 465.7
D) 21.4

25) Find the mean for the following data set: **25)** ___

12 12 23 24 18 28

A) 20.5
B) 16
C) 12
D) 19.5

26) The average resident of Metro City produces 590 pounds of solid waste each year, and the standard deviation is approximately 90 pounds. Use Chebyshev's theorem to find the weight range that contains at least 75% of all residents' annual garbage weights. **26)** ___

A) Between 320 and 860 pounds
B) Between 500 and 680 pounds
C) Between 410 and 770 pounds
D) Between 230 and 950 pounds

27) The average weekly earnings in dollars for various industries are listed below. Find the percentile rank of 729. **27)** ___

840 729 623 760 682 785 861 599 890 917

A) 45^{th}
B) 25^{th}
C) 35^{th}
D) 40^{th}

28) For the data set below, find the outlier(s). **28)** ___

186 153 154 161 160 157 145 176 133 154 157

A) 105
B) 133, 176, and 186
C) 133
D) None are outliers

29) At a certain college, there were 500 science majors, 300 engineering majors, and 700 business majors. If one student was selected at random, the probability that the student is an engineering major is **29)** ___

A) $\frac{1}{4}$
B) $\frac{4}{5}$
C) $\frac{1}{5}$

D) $\frac{1}{3}$

30) Below are listed the numbers of engineers in various fields by sex. Choose one engineer at random. Find $P(\text{electrical} \mid \text{male})$. **30)** ___

	Mechanical	Electrical	Biomedical
Male	8367	4724	6294
Female	2739	971	5298

A) 0.108
B) 0.829
C) 0.166
D) 0.244

31) How many different ways can a teacher select 5 students from a class of 16 students to each perform a different classroom task? **31)** ___
A) 80
B) 4368
C) 524,160
D) 55,440

32) Compute the standard deviation of the random variable with the given discrete probability distribution. **32)** ___

x	*P(x)*
0	0.15
5	0.35
15	0.4
25	0.1

A) 7.5
B) 56.2
C) 10.25
D) 11.25

33) If a student randomly guesses at 20 multiple-choice questions, find the probability that the student gets exactly four correct. Each question has four possible choices. **33)** ___
A) 0.218
B) 0.190
C) 0.085
D) 0.162

34) A university has 10,000 students of which 65% are male and 35% are female. If a class of 30 students is chosen at random from the university population, find the mean and variance of the number of male students. **34)** ___

A) Mean = 19.5, Variance = 6.8
B) Mean = 19.5, Variance = 2.6
C) Mean = 10.5, Variance = 2.6
D) Mean = 10.5, Variance = 6.8

35) Find the area under the standard normal curve that lies between z = 0.7 and z = 1.1. **35)** ___

A) 0.8937
B) 0.6357
C) 0.1063
D) 0.3643

36) In order to be accepted into a certain top university, applicants must score within the top 5% on the SAT exam. Given that the exam has a mean of 1000 and a standard deviation of 200, what is the lowest possible score a student needs to qualify for acceptance into the university? **36)** ___

A) 1250
B) 1330
C) 1100
D) 1400

37) In a survey of 253 registered voters, 120 of them wished to see Mayor Waffleskate lose her next election. Construct a 99% confidence interval for the proportion of registered voter who want to see Mayor Waffleskate defeated. **37)** ___

A) $0.443 < p < 0.506$
B) $0.393 < p < 0.555$
C) $0.401 < p < 0.547$
D) $0.266 < p < 0.683$

38) A sample of size $n = 12$ has a sample mean $\bar{x} = 9.4$ and sample standard deviation $s = 3.6$. Construct a 95% confidence interval for the population mean μ. **38)** ___

A) $7.1 < \mu < 11.7$
B) $8.7 < \mu < 10.1$
C) $8.2 < \mu < 10.6$
D) $7.5 < \mu < 11.3$

39) John Davis, a manager of a supermarket, wants to estimate the proportion of customers who use food stamps at his store. He has no initial estimate of what the sample proportion will be. How large a sample is required to estimate the true proportion to within 3 percentage points with 98% confidence? **39)** ___

A) 1,067

B) 756
C) 1,849
D) 1,509

40) A simple random sample of kitchen toasters is to be taken to determine the mean operational lifetime in hours. Assume that the lifetimes are normally distributed with population standard deviation $\sigma = 20$ hours. **40)** ___

Find the sample size needed so that a 95% confidence interval for the mean lifetime will have a margin of error of 9.

A) 19
B) 5
C) 88
D) 4

41) In a simple random sample of size 68, there were 31 individuals in the category of interest. It is desired to test H_0: $p = 0.32$ versus H_1: $p < 0.32$. Compute the test statistic z. **41)** ___

A) 0.06
B) 2.40
C) 6.52
D) 0.46

42) A recent survey indicated that the average amount spent for breakfast by business managers was $7.58 with a standard deviation of $0.42. It was felt that breakfasts on the West Coast were higher than $7.58. A sample of 81 business managers on the West Coast had an average breakfast cost of $7.65. Find the *P*-value for the test. **42)** ___

A) 0.0668
B) 0.4332
C) 0.1325
D) 0.2734

43) According to *Beautiful Bride* magazine, the average age of a groom is now 26.2 years. A sample of 16 prospective grooms in Chicago revealed that their average age was 26.6 years with a standard deviation of 5.3 years. What is the test value for a *t* test of the claim? **43)** ___

A) 0.30
B) 1.81
C) 2.13
D) 0.59

44) A test was made of $H_0: \mu_1 = \mu_2$ versus $H_1: \mu_1 < \mu_2$. The sample means were $\bar{x}_1 = 12$ and $\bar{x}_2 = 13$ the sample standard deviations were $s_1 = 3$ and $s_2 = 7$, and the sample sizes were $n_1 = 11$ and $n_2 = 16$. Compute the value of the test statistic. **44)** ___

A) -0.508
B) -1.187
C) -0.131
D) -0.682

45) In an experiment to determine whether there is a systematic difference between the weights obtained with two different mass balances, six specimens were weighed, in grams, on each balance. The following data were obtained: **45)** ___

Specimen	A	B
1	9.12	9.09
2	10.96	10.96
3	8.29	8.30
4	11.16	11.15
5	12.97	12.98
6	6.29	6.29

Compute the test statistics.

A) 0.495
B) 0.542
C) 0.067
D) 0.221

46) A recent survey reported that in a sample of 300 students who attend colleges, 105 work at least 20 hours per week. Additionally, in a sample of 225 students attending private four-year universities, only 20 students work at least 20 hours per week. What is the test value for a test of the difference between these two population proportions? **46)** ___

A) 4.18
B) 7.61
C) 6.95
D) 2.38

47) If the correlation coefficient r is equal to 0.663, find the coefficient of nondetermination. **47)** ___

A) 0.552
B) 0.814
C) 0.440
D) 0.560

48) If the equation for the regression line is $y' = 9x - 5$, then a value of $x = 4$ will result in a predicted value for y of **48)** ___

A) 41
B) 29
C) 14
D) 31

49) In a study of reaction times, the time to respond to a visual stimulus (x) and the time to respond to an auditory stimulus (y) were recorded for each of 8 subjects. Times were measured in thousandths of a second. The results are presented in the following table. **49)** ___

Visual	Auditory
196	185
198	191
232	219
246	233
231	222
185	179
187	181
248	232

Compute response time (y) from visual response time (x).

A) $y = 0.880349 + 15.644827x$
B) $y = 0.880349x$
C) $y = 15.644827 + 0.880349x$
D) $y = 15.644827x$

50) A four-year university has decided to implement a new approach to teaching Statistics. Full-time and adjunct professors were surveyed to determine whether they preferred the traditional lecture approach, a computer approach to teaching Statistics, or did not have a preference. **50)** ___

	Prefer Lecture	Prefer Computer	No Preference
Full-time	8	13	6
Adjunct	11	22	10

Computer the test value.

A) 0.97
B) 0.36
C) 1.24
D) 0.14

Free Response. Provide your detailed solution to these questions in the space provided. Partial credit will be given to correct steps in the solution.

The following data represent fare per week in dollars spent by riders of the Lee County Public Transportation System (LeeTran) using buses to arrive at FGCU.

26	28	27	35	36	33	31	40	42
41	40	51	51	50	47	51	61	80
60	60	55	65	68	75	74	55	54

51. (2 points) Create a Stem-and-Leaf Plot of this data. Comment on the shape of the distribution.

52. (2 points) Calculate the sample mean and sample standard deviation for this data.

53. (2 points) Calculate the 5-number summary of this data.

54. (2 points) Using the 5-number summary of this data, create a box plot.

55. The FGCU Board of Trustees claims students spend an average of $40 per week in bus fare to attend FGCU. The FGCU Student Government Association collected fare data from a sample of 27 students (listed above). Is there enough evidence to conclude that FGCU students, on average, spend different than $40 per week in bus fare to attend FGCU? Use $\alpha = .05$.

(a) (1 point) State the hypotheses and identify the claim.

(b) (1 point) Compute the test value.

(c) (1 point) Find the P-value.

(d) (1 point) Make the decision.

(e) (1 point) Summarize the results.

(f) (1 point) Find a 95% confidence interval for the mean bus fare spent by FGCU students. Does your confidence interval support the conclusion of your hypothesis test? Explain why or why not.

Key

Question	Answer	Section	Version A	Version B	Version C	Version D
1)	FALSE	1.3	14	16	12	13
2)	TRUE	1.3	3	17	15	11
3)	TRUE	1.2	20	19	4	18
4)	FALSE	1.2	11	1	9	9
5)	FALSE	2.2	12	10	2	8
6)	TRUE	4.1	2	7	7	17
7)	FALSE	4.3	1	12	10	3
8)	TRUE	5.1	13	13	13	16
9)	TRUE	5.3	17	8	14	4
10)	TRUE	6.1	16	14	5	6
11)	TRUE	7.1	8	4	1	7
12)	FALSE	7.2	19	20	8	14
13)	TRUE	8.6	10	11	19	5
14)	TRUE	8.1	5	2	3	10
15)	TRUE	8.1	4	5	20	20
16)	TRUE	10.3	15	15	6	12
17)	FALSE	10.1	7	6	16	2
18)	TRUE	10.2	9	18	18	1
19)	FALSE	11.1	6	9	11	19
20)	TRUE	11.2	18	3	17	15
21)	D	1.1	25	21	48	46
22)	B	2.1	43	46	49	28
23)	C	2.3	29	22	37	38
24)	A	3.2	26	47	44	40
25)	D	3.1	49	40	35	49
26)	C	3.2	50	24	30	45
27)	C	3.3	36	28	25	43
28)	B	3.3	39	34	40	35
29)	C	4.1	28	50	50	25
30)	D	4.3	41	29	47	33
31)	C	4.4	35	38	22	41
32)	A	5.2	37	41	33	26
33)	B	5.3	30	31	36	34
34)	A	5.3	44	45	32	32
35)	C	6.1	48	49	39	24
36)	B	6.2	22	44	21	50
37)	B	7.3	23	48	27	27
38)	A	7.2	45	32	34	47
39)	D	7.3	33	25	46	23
40)	A	7.1	42	23	38	44
41)	B	8.4	24	43	23	30
42)	A	8.2	46	35	43	21
43)	A	8.3	21	37	41	37
44)	A	9.2	47	26	29	48
45)	B	9.3	31	39	42	22

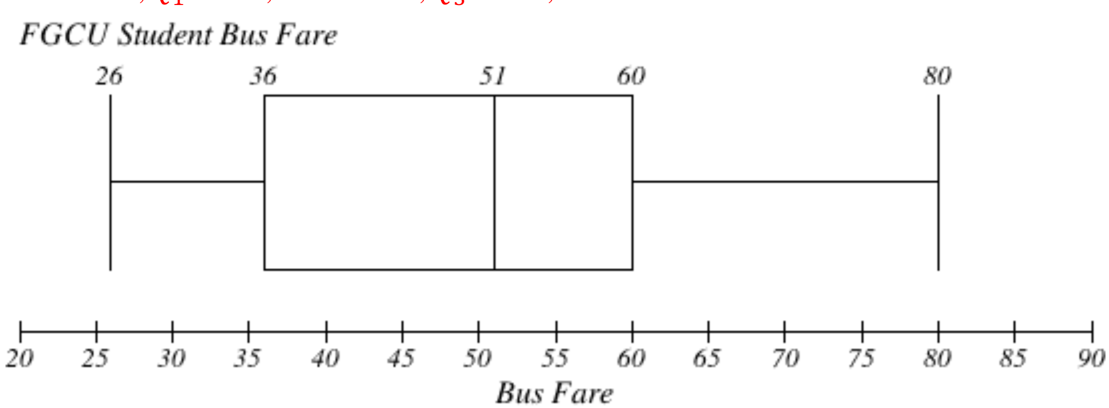
46)	C	9.4	38	36	26	42
47)	D	10.3	34	33	24	31
48)	D	10.2	27	27	31	39
49)	C	10.2	32	30	28	36
50)	D	11.2	40	42	45	29

51.

Stem	Leaf
2	6 7 8
3	1 3 5 6
4	0 0 1 2 7
5	0 1 1 1 4 5 5
6	0 0 1 6 8
7	4 5
8	0

52. $\bar{x} = 49.5, s = 15.3$

53. min $= 26, Q_1 = 36,$ med $= 51, Q_3 = 60,$ max $= 80$



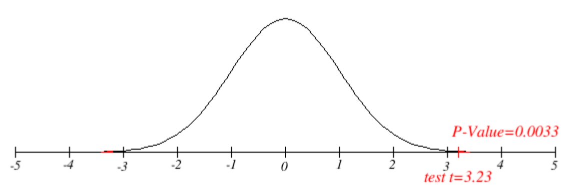
54.

55.

(a) $H_0: \mu = \$40, H_1: \mu \neq \$40, \alpha = 0.05$

(b) We will use the Student's t-sampling distribution since σ is unknown and our sample is unimodal and roughly symmetric. $t = \frac{\bar{x}-\mu}{\frac{s}{\sqrt{n}}} = \frac{49.5-40}{\frac{15.3}{\sqrt{27}}} \approx 3.23$

(c)



P-value = $2 \cdot P(t > 3.23) \approx 0.0033$

(d) Since $0.0003 < 0.05$, we will reject H_0. The data are statistically significant at the $\alpha = 0.05$ level of significance.

(e) We have sufficient evidence to conclude that FGCU students, on average, spend different than \$40 per week in bus fare to attend FGCU.

(f) $\$43.45 < \mu < \$55.51$. I am 95% confident that the true mean bus fare for FGCU students is between \$43.45 and \$55.51 per week. Since \$40 is not contained within the interval, I would also reject the H_0 confirming the results of the hypothesis test.