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A PHENOMENOLOGICAL EXPLORATION OF A NON-TRADITIONAL INTRODUCTORY STATISTICS COURSE AMONG COMMUNITY COLLEGE STUDENTS

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A PHENOMENOLOGICAL EXPLORATION OF A NON-TRADITIONAL INTRODUCTORY STATISTICS COURSE AMONG COMMUNITY COLLEGE STUDENTS

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Completing my PhD has been a life-long dream of mine for as long as I can remember. The journey has been long and difficult at times. There were times of uncertainty and self-doubt. Throughout it all, my family and siblings have supported and encouraged me to achieve my dream. This dissertation is dedicated to my family, who without their continued support this journey would not have been possible. I would like to express my deep appreciation to Tammie, who has been a constant source of support. When life got crazy and overwhelming, she was always there on the other side supporting me. I am grateful for the opportunity that you helped support and encourage over the last eleven years. I would also like to thank my son, Jayden, who has helped balance me during this journey. You have grown up watching me pursue this dream and one day, I hope my achievement can serve as an example. During this journey I have been moved by your innocence and your eagerness to see me finish. The countless years of family sacrifices have always reminded me that without your love, none of this would have been possible. I also dedicate this to my siblings; Tabatha, Warren and Veronica. Your support over the years has meant the world to me. I am grateful to have the love and support from you all.

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Table of Contents

List of Tables

Abstract

Calls for comprehensive innovative curriculum and pedagogical changes to mathematics courses and introductory statistics courses have been documented within multiple national reports during the last several decades. In recent years, research studies in statistical education aimed at the teaching of introductory statistics have emerged in the literature (see, e.g., Cobb, 1993, Garfield, 1995, Hoaglin & Moore, 1992, Moore, 1997). In addition, the National Science Foundation (NSF) has funded numerous projects specifically designed to implement various aspects of statistics education reform (http://www.nsf.gov). The essence of the introductory statistics reform movement promotes statistical literacy and quantitative reasoning rather than calculations, procedures and formulae. Although there is a plethora of research on reform based statistics, there has been little research that describes the characteristics of a problem-based introductory statistics course at the college level or on how students respond to a more conceptually-based introductory statistics course.

The purpose of this study was to describe through a phenomenological approach, the following: the characteristics of a non-traditional introductory statistics course designed for undergraduate students, approaches to learning statistical concepts as the student engaged in problem-based learning activities and to focus on the perceived student learning experiences and emerging statistics understanding as a result of engaging in various problem-based learning activities within the course. In an effort to deepen the community college students' statistical development, this study sought to examine alternative pedagogical practices that required students to negotiate their prior knowledge and past experiences to construct and formulate new statistical knowledge.

This study addressed the deficiency in literature regarding alternative pedagogical practices and problem-based learning within undergraduate level statistics courses. A study analyzing the relationship between students and their mathematical perspective benefits future and current educators as well as future higher education students. Understanding student's experiences and interactions with mathematics and statistics can offer insight into future curriculum development and pedagogical design. Considerable improvements in mathematics and statistics learning will not occur unless educators can succeed in transforming the way they are taught.

The results of this study offer important suggestions for PK-12 and post-secondary mathematics and statistics educators. The results of this study reveal first, that characteristics of this non-traditional introductory statistics course were consistent with the recommendations supported and outlined by the American Mathematical Association of Two-Year Colleges (AMATYC, 2006) and the Guidelines for Assessment and Instruction in Statistics Education (GAISE, 2012). Consequently, it is possible to design and implement undergraduate statistics courses that abide by the reform recommendations outlined by AMATYC (2006) and GAISE (2012). Additionally, the results of this study suggest that adopting such an approach has the potential to positively affect the teaching and learning of that course for the instructor and the students. As pointed out in the GAISE College Report (2012), “teachers of statistics should rely much less on lecturing and much more on alternatives such as projects, lab exercises, and group problem-solving and discussion activities" (p. 9). Despite the persuasive evidence in cognitive science and education research, too many college-level students experience lecture-based forms of instruction in mathematics and statistics courses. As noted by Laursen, Hassi, Kogan, and Weston (2014), this failure limits the advancement of undergraduate mathematics education. Therefore, if steps are not taken to provide instructors with professional development opportunities and resources to implement in their own classes, the teaching and learning of statistics will remain stagnate and efforts for reform will be ideals of dreamers. It is then incumbent upon members of our profession to disseminate education and cognitive research and model the pedagogical strategies that support cognitive construction and align with the reform movements set forth by AMATYC (2006), GAISE (2012), and NCTM (2000).

Secondly, the student perceptions regarding the characteristics of this course revealed that the restrictive nature of the traditional lecture-based model hinders our students' autonomous development. As mathematics educators, one of our goals is to develop our students' problem solving skills. Mathematicians and statisticians are efficient, independent problem solvers because they have years of experience and developed skill sets that allow them to reason multiple possibilities before selecting an approach. For students, mathematics and statistics is most frequently experienced through series of computational procedures and memorized formulae because teachers routinely prevent intellectual development by demonstrating examples. The student perspectives in this study revealed that despite their initial need for external validation and request for step-by-step examples, they eventually grew more confident in their own knowledge and confident to try multiple approaches in order to obtain a reasonable explanation.

Chapter I: INTRODUCTION

The role of education has always been important to civilizations and has been a point of contention for philosophers since ancient Greece. Plato's aim of a well-balanced, well-ordered society was created by an educational system that recognized and emphasized the strengths of the individual (Walker & Soltis, 2009). Democratic societies have traditionally valued education as a means of creating effective and responsible members of society. Throughout history, educational aims have been greatly influenced by the state and the goal of democracy. National discussions regarding higher education and the support for improved educational attainment continue to drive federal, state and local educational reform initiatives.

As it has for centuries, educational discourse serves various political, social and cultural aspects of our society. Within our democracy, the government has played an integral role in dictating what constitutes as "real knowledge" and "good knowledge". As described by the U.S. Department of Commerce, (2001) one purpose of education is to serve the economic interests of society by producing future workers for the global marketplace with "twenty-first century skills". According to Apple (2006) education is therefore a tool for sustaining the values of social reproduction. In an effort to protect one's social status, social reproduction becomes a trusted function of education (Gildersleeve, Kunts, Pasque & Carducci, 2010).

The components of the ideal education have also been debated for centuries. However, basic computation and measurement have long been considered to be key components of the ideal education (Walker & Soltis, 2009). The philosophical roots of knowledge, meaning and truth can be traced directly to mathematics. Despite this perceived importance, no formal epistemological position on mathematics education has been defined or accepted by mathematics educators and mathematicians. As with the discourse of science, conversation and research regarding how to define "mathematics education" continues to be debated.

Cognitive research continues to provide insight in an effort to understand how knowledge is acquired and utilized. One such perspective regarding how people learn and understand information is described and explained by cognitivism (Atherton, 2011). One of the most influential byproducts of cognitive research is constructivism, by which the process of learning requires the learner to actively construct knowledge. Multiple interpretations of constructivism exist within the domain of education. One common explanation for how people learn offered by von Glaserfeld is that "knowledge is not passively received but is actively built up by the cognizing subject" (1989, p. 162). Within this context, constructivism is an epistemological position rather than a formal position on how to teach.

Historically, the study of how mathematical and statistical knowledge is acquired and utilized has overwhelmingly dominated the research in mathematics and statistics education (Garfield, 1995; Lester, 1994, Lovett & Greenhouse, 2000; Prince, 2004, Savery, 2006). The learning theories of Piaget, Vygotsky, Dewey and Bruner for example, have propelled mathematics and statistics education research to greater depths of understanding. Such insight has spawned multiple epistemological perspectives that have influenced recent mathematics and statistics education reforms.

Recent efforts to define mathematics as a discipline of exploring patterns, formulating conjectures and seeking solutions can be found in the National Council of

Teachers of Mathematics (NCTM) documents such as; *An Agenda for Action* (NCTM, 1987), *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), *Professional Standards for Teaching Mathematics* (NCTM, 1991), *Assessment Standards for School Mathematics* (NCTM, 1995), and, *Principles and Standards for School Mathematics* (NCTM, 2000). NCTM's 1989 *Standards* represent what many believe was a paradigm shift within mathematics education. The NCTM standards placed an emphasis on mathematical processes, a move away from strictly computational proficiency toward a goal of understanding the mathematics that one does. In doing so, active learning and problem solving have been placed at the core of the PK-12 mathematics curriculum.

Over the last several decades, the influences of information and data have impacted our society in ways previously unimagined. One of the implications of this is the overall importance of critically thinking about the different aspects of our lives affected by data. Being statistically literate is now considered an essential skill both academically and socially. Statistical literacy as described by Gal's (2002) model is an example which includes: literacy skills, statistical knowledge, mathematical knowledge, context knowledge, critical questions and critical stance, beliefs and attitudes. As educated citizens, the ability to effectively communicate with data, understanding basic statistical concepts, and analyzing statistical data found in everyday life is paramount.

The learning process of the teacher-centered and behaviorism models require the teacher to control the learning process and the passive learner to memorize information. Influential theories of child development and educational psychology consider the learner as an active participant in the learning process. The work of Piaget and Bruner for example challenged educators to recognize the role of the learner and to develop instructional materials that invited and encouraged discovery (Walshaw, 2013). Years before the development of NCTM's *Standards*, mathematics education reform efforts included alternatives to the behaviorism model. Seymour Papert, for example, challenged mathematicians and mathematical educators to develop creative mathematical work for children of all grade levels. He argued that school mathematics curricula comprised of drill and practice and computational exercises were not the most fertile grounds for developing the growth of real mathematics (Papert, 1972). Based on the assumption that learning is actively constructed, building new knowledge from experiences and prior knowledge rather than a passive process, the NCTM standards and accompanying publications (1989, 1991, 1995, & 2000) do not focus on the accumulation of information but rather advocate non-routine problem solving, problem posing, and sound justification of solution findings.

With a curriculum emphasizing mathematics understanding, the behaviorism model that promotes rote practice, general memorization and inflexible procedures fails to address the cognitive demand of active learning and problem solving tasks proposed by NCTM. To obtain mathematics understanding, the teaching practice must promote a learning process and learning environment that actively engages students. NCTM's *Professional Standards for Teaching Mathematics* (1991) highlights the inadequacies of the traditional teacher-centered model and outlines the learning processes based on discovery learning and inquiry methods. According to NCTM (1989, 1991, 1995, & 2000), the use of active learning and problem solving in mathematics instruction provides opportunities for students to actively engage in authentic and meaningful mathematics.

Despite the various forms of research that have highlighted the cognitive understanding of how mathematical knowledge is acquired and utilized, students typically experience mathematics through years of fragmented encounters leading them to believe that mathematics is comprised of meaningless symbols, memorizing inflexible formulae and procedures, and exercises far removed from their own interests. This pervasive manner of teaching mathematics undermines meaningful learning. Teaching mathematics has unfortunately been reduced to a series of memorized steps and techniques for the teacher to demonstrate (Yackel, 2010).

Many mathematics and statistics courses at the college level continue to utilize what is commonly referred to as a traditional teacher-centered model. Procedures to obtain correct answers are demonstrated by the teacher with minimal student participation. Classrooms that follow this model produce students who according to Richards (1991) are “not prepared to inquire about mathematical issues, or assume responsibility for their own learning” (p. 16). In order to develop students’ conceptual and procedural knowledge and develop them as mathematical thinkers and problem solvers, teachers at all levels must mindfully engage students in active learning strategies and solving problems that interest them and raise their curiosities.

Establishing an active learning environment for learning statistics formulated in the context of constructivism theory is not a new idea. Collaborative and cooperative learning, problem-based learning and problem solving, case studies, course projects, simulations and the use of technology are examples of ways to involve and engage students in their learning. Statistics education reform research emphasizes a pedagogical change that is a shift from the predominantly theoretical and computational approach to a concept-based approach with specific attention to cognitive learning (delMas, 2002; Garfield, 2000; Moore, 1993). As within mathematics education, the mechanistic approach to teaching statistics (calculations and formulae) is deeply rooted and difficult to change. Such pedagogical differences are counter-productive to the mathematics and statistics education reform movement.

Foundation of the Problem

In order to understand where mathematics fits in the current general curriculum, it is necessary to understand the evolution of the pedagogical and curriculum goals of mathematics education within the United States. It is important to note that educational reform has always been impacted by larger social and educational conditions of the time. Mathematics and mathematics education reform at the primary, secondary and post-secondary levels have been influenced by the aforementioned differences in the philosophy of mathematics education.

The standard introduction to early mathematics had long been the study of geometry. This was changed as the need and desire to educate larger populations of society took precedence. The need for developed curricula placed an emphasis on the classics and in 1893 the Committee of Ten standardized the high school curriculum. The founding standard courses included science, English, mathematics, and social studies (Furinghetti, Matos, and Menghini, 2013; National Education Association, 1894; Walker & Soltis, 2009).

In 1903, E.H. Moore recommended the integration of mathematics to the secondary school curriculum (Kilpatrick, 1997; Moore, 1903). Integrating geometry within the curriculum was not well received among members of the mathematics education community. Experimental courses that integrated geometry with algebra, statistics and calculus were being developed although few high school curricula actually implemented them (Kilpatrick, 2007). Classic mathematics courses were seen unfavorably by a changing student population. Within a decade the call for continued reform was being echoed from teachers, parents, college presidents and school administrators.

The Mathematical Association of America (MAA) organized the National Committee on Mathematical Requirements (NCMR) to address the growing criticism of instruction (NCTM, 1970). In 1916, NCMR was formed to address mathematics education from the secondary level through the college level and make recommendations regarding mathematics course sequence and mathematics teaching. The committee released the 1923 report, *The Reorganization of Mathematics in Secondary Education* to refute claims that students needed less mathematics (NCMR, 1927). The report included a strong statement regarding mathematics education:

> The primary purpose of the teaching of mathematics should be to develop those powers of understanding and analyzing relations of quantity and of space which are necessary to a better appreciation of the progress of civilization and a better understanding of life and of the universe about us, and to develop those habits of thinking which will make these powers effective in the life of the individual. (University of Texas Bulletin, 1921, p. 14)

Once reserved as a professional field of study in higher education, previous reform efforts attempted to remove mathematics from the high school curriculum. During the Great Depression, students who would have left school to enter the workforce were remaining in school thereby altering the school population (Stanic & Kilpatrick, 1992). Within the mathematics education community the divide among defenders of the discipline and those who wanted more from school reform were firmly pitted against one another. The defenders of the traditional school curriculum faced insurmountable difficulties as the school population changed. Not only had the population increased significantly, but some argued that the school population had declined in overall quality (Stanic, 1986). The need to develop a curriculum that could be implemented with the masses and simultaneously address the needs of the changing population was desperately sought after. Educators and reformers who aligned with the social efficiency model were prepared to tackle the social issues and advance their position regarding mathematics education reform.

In 1920, the National Council of Teachers of Mathematics was established to prevent further attacks on the high school mathematics curriculum. Previous mathematics education reform efforts had been greatly influenced by non-mathematics educators and political rhetoric. The NCTM sought to rectify this and simultaneously advocated progressive teaching:

> Mathematics courses have been assailed on every hand. So-called educational reformers have tinkered with the courses, and they, not knowing the subject and its values, in many cases have thrown out mathematics altogether or made it

> entirely elective…To help remedy the existing situation the National Council of Teachers of Mathematics was organized. (Austin, 1921, p.2)

Contradictory perspectives regarding what specific mathematics should be taught, to whom mathematics should be taught, and the sequence of mathematics courses continued to be a matter of dialogue and research and is at the center of major reform initiatives. These early attempts to reform mathematics education did little actual reform by the turn of the 20^{th} century and failed to define a formal epistemological position of mathematics education excepted by mathematicians and mathematics educators (Ellis & Berry, 2005; Stanic, 1992).

The historical influences on curriculum are considered relevant to further understand and position the evolution of mathematics education reform movements from the 1950's to the present. As a field of study, mathematics education struggled to define a curriculum of mathematics. Education curriculums have been greatly influenced by the needs of our democratic state over the last century. At the turn of the 20^{th} century, schools across the country were faced with dramatically larger enrollments and a more diverse student population. Technological advances within industry demanded a uniquely skilled workforce that required formal and informal mathematics skills. The modern mathematics movement attempted to reorganize mathematics curriculums in order to reduce the gap between school mathematics and pure mathematics. Reform at the turn of the century on the other hand was emphasizing a unified and applied mathematics curriculum (Stanic & Kilpatrick, 2004).

When the Soviets launched the world's first Earth orbiting satellite, Sputnik I in 1957, critics of the educational system reemphasized the need of public education reform at all levels. The U.S. needed educational reform in order to reaffirm its position of national power. The political space race greatly influenced mathematics curriculum development for several years. Jerome Bruner's (1960) *The Process of Education* presented children as active problem-solvers capable of engaging in a challenging curriculum. Bruner's structuralist view of knowledge and his approach to the process of knowing was not the dominant view in education at the time. One of Bruner's concepts still found in current curriculums is the spiral curriculum. Bruner writes, "A curriculum as it develops should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them" (Bruner, 1960, p. 13).

During the first paradigmatic phase of curriculum theory (1918 – 1969), the function of curriculum development was to improve the institutional curriculum (Pinar, 2007). Many aspects of the measured curriculum are still prevalent in current curriculums: pre-determined objectives, sequential learning, and direct instruction, followed by standardized assessment. Growth and development of the individual is measured by the amount of external knowledge acquired. The individual's knowledge, experience and interests are excluded from the curriculum; all learners receive the same curriculum. Critics of the behaviorism model suggest that the focus on results only has separated the goals of learning from the processes needed to accomplish them (Varbelow, 2012).

The two decades that followed the Sputnik launch (1955 – 1975) were filled with multiple forms of mathematics education reform. The "new math" era was responding to a variety of opposing educational views (Stanic & Kilpatrick, 2004). In order for the U.S. to compete internationally, schools were under pressure to increase the number of engineers, the number of teachers and provide a workforce population for an evolving economy. Mathematics education reform has always been divided by defenders of the discipline and those who demand more from the school's preparing future generations of society.

Higher education has also been involved with and impacted by mathematics education reform. At the postsecondary level, the American Mathematical Association of Two-Year Colleges (AMATYC) has addressed mathematics education reform with *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus* (AMATYC, 1995). The *Crossroads* standards reflect many of the same principles found within PK-12 reform: emphasis on using technology as a tool and as an aid to instruction, developing general strategies for solving real-world problems, and actively involving students in the learning process. Effective pedagogical practices that have been implemented within the PK-12 curriculum could lead to improved student learning at the postsecondary level (Hodara, 2013). Despite the results of cognitive research and the various initiatives regarding active learning, many college level mathematics courses still favor procedural fluency and course instruction is comprised of lecture and independent seat-work.

Efforts to reform mathematics education over the past century have sought to question the core beliefs about mathematics and how mathematics is taught and learned. Epistemological positions regarding how mathematics it taught, how it is learned, and, what constitutes success in learning it are critical issues that require more than simple revisions of the current paradigm (Ellis & Berry, 2005). Earlier paradigm perspectives and reform efforts considered rigorous mathematical subjects appropriate only for societies' elite members; primarily white, middle class males. Advocating mathematics for all students certainly challenges the role of mathematics education and sparked controversy among educators, politicians and parents. Authentic mathematics education reform on the other hand must promote mathematical equity and excellence, and challenge the status quo in mathematics education (Martin, 2003).

Problem Statement

There is ongoing dialogue and research regarding the pedagogical methods for teaching mathematics and statistics. Within most of the curricula, emphasis is placed on developing students' computation proficiency with virtually no emphasis on developing conceptual understanding. Students only interact and engage with mathematics as a series of procedures that must be memorized in order to produce the solution. Within most PK-12 mathematics curriculum, students are not being asked to reflect upon mathematical procedures. By the time these students enter college, the numerous step-by-step procedures that form the foundation of their mathematical knowledge are forgotten (Stigler, Givvin & Thompson, 2010).

Although community college faculty are generally more knowledgeable about mathematics than PK-12 faculty (Lutzer, Rodi, Kirkman, & Maxwell, 2007), teaching methods at both levels typically employ pedagogical methods that align with a teacher-centered model despite ongoing and continual reform efforts. Lectures are the most common form of instruction within most community college level mathematics courses. Students who were previously unsuccessful in learning "drill-and-skill" algorithms are basically presented with the same instructional approach yet again. The methods that failed to develop students' mathematics understanding in PK-12 are found to be unsuccessful for most of the students in community college (Stigler, Givvin, & Thompson, 2010).

Calls for comprehensive innovative curriculum and pedagogical changes to mathematics courses and introductory statistics courses have been documented within multiple national reports during the last several decades. Specific recommendations for mathematics curriculum at two-year colleges are highlighted in *Curriculum in Flux* (Davis, 1989). In the same year, *Reshaping College Mathematics* (Steen, 1989) and *Everybody Counts* (National Research Council, 1989) provided mathematics curriculum recommendations. The American Mathematical Association of Two-Year Colleges (AMATYC) whose primary mission includes the development and implementation of curricular, pedagogical, assessment, and professional standards for mathematics in the first two years of college developed the first standards for curriculum and pedagogy in *Crossroads in Mathematics* (AMATYC, 1995). The standards are designed for the underprepared adult student entering college-level mathematics. Despite the attempts at reforming mathematics at the community college, there has been little research specifically addressing effective pedagogical approaches to the teaching of mathematics (Zachary & Schnieder, 2008).

Mathematics education reform efforts have influenced the teaching and learning aspects of statistics education. Many similarities exist within the context of mathematics education reform and statistics education reform. Statistics education lacks a clear and concise definition that encapsulates the overarching goal of statistics education. Common terms such as statistical literacy, statistical reasoning and statistical thinking often overlap and are used interchangeably (Garfield & Ben-Zvi, 2002, 2007, Lutzer, Rodi, Kirkman, & Maxwell, 2007, Tishkovskaya & Lancaster, 2010). The emphasis of statistics education reform has focused on conceptual knowledge and understanding (Bude', 2007, Garfield, 1995, Slauson, 2008). Statistics education reform embraces the tenants of constructivism. Experiences that provide space for students to negotiate prior knowledge and past experiences to construct and formulate new knowledge is the basis of statistical education reform.

As noted previously, the typical college level mathematics course still favors procedural fluency, the dominant form of instruction is lecture based, independent seat-work, and problem sets are devoid of relevancy. Unfortunately, many introductory statistics courses at the college level prescribe to similar traditional teaching models (Moore, 1997). With a focus on computational proficiency and compartmentalized knowledge, many students find statistics to be difficult, unpleasant, frustrating, and are unable to relate statistics to their world (Cobb, 1992).

Considered as the basis for statistics education reform in the introductory college statistics courses, the Guidelines for Assessment and Instruction in Statistics Education (GAISE) outline the need for statistics educators to stress conceptual understanding rather than procedural knowledge (Hassad, 2008). Several research studies formulating principles of learning statistics in addition to the 2005 GAISE recommendations have offered a general framework for statistics education reform (see e.g., Garfield, 1995, Garfield & Ben-Zvi, 2007, Lovett & Greenhouse, 2000). The benefits of the cognitive demand of problem solving tasks proposed by NCTM to obtain conceptual mathematics understanding, is also advantageous for statistics education.

Marriott, Davies, & Gibson concluded that both teachers and learners would benefit from implementing the problem solving approach in the teaching of statistics (2009).

Although there is a plethora of research on reform based statistics, there is little research on the perspective of the problem-based learner in college level introductory statistics courses. In recent years, research studies in statistical education aimed at the teaching of introductory statistics have emerged in the literature (see, e.g., Cobb, 1993, Garfield, 1995, Hoaglin & Moore, 1992, Moore, 1997). In addition, the National Science Foundation (NSF) has funded numerous projects specifically designed to implement various aspects of statistics education reform (http://www.nsf.gov). However, there has been little research that describes the characteristics of a problem-based introductory statistics course at the college level or on student's responses to a more conceptually-based introductory statistics course.

Purpose of the Study

The purpose of this study was to describe, through a phenomenological approach, the characteristics of a non-traditional introductory statistics course designed for undergraduate students, approaches to learning statistical concepts as the student engaged in problem-based learning activities and to focus on the perceived student learning experiences and emerging statistics understanding as a result of engaging in various problem-based learning activities within the course. In an effort to deepen the community college students' statistical development, this study sought to examine alternative pedagogical practices that required students to negotiate their prior knowledge and past experiences to construct and formulate new statistical knowledge.

Research Questions

The following research questions were addressed:

1. What are the characteristics of a problem-based college-level introductory statistics course?
2. What are students' perceptions of the characteristics of a non-traditional introductory statistics course?
3. What are students' perceptions of their learning in this non-traditional introductory statistics course?

Significance of the Study

This study addressed the deficiency in literature regarding alternative pedagogical practices and problem-based learning within undergraduate level statistics courses. A study analyzing the relationship between students and their mathematical perspective benefits future and current educators as well as future higher education students. Understanding student's experiences and interactions with mathematics can offer insight into future curriculum development and pedagogical design. Considerable improvements in mathematics learning will not occur unless we can succeed in transforming the way mathematics is taught.

Organization of the Study

This study is presented through a five chapter organizational format. The first chapter provides a general overview, the foundation and statement of the problem, and the purpose of the study. I present a review of the relevant literature that will provide the framework for this study in Chapter Two. The methodology of this study will be presented in Chapter Three. Specifically, information relating to the setting, the participants, the research design, data collection procedures and instruments and the procedures for analysis of the data will be described. I present the analysis of the data in Chapter Four and the findings of the study in Chapter Five. Additionally, I present the implications of this study, the conclusions and need for additional research.

Chapter II: REVIEW OF THE LITERATURE

This chapter serves as a review of selected research literature relevant to this study and is divided into several sections. The specific issues of concern in statistical education that prompted the reform of statistics instruction and curriculum were based upon content, pedagogy, and technology. The literature as it relates to these three areas in greater detail was discussed within this chapter. Because this study is an investigation of student's learning experiences of statistics in higher education, the information presented within this chapter was representative of research specific to non-calculus based introductory statistics at the college level.

Definition of Statistics

In order to initiate the conversation about statistics learning and teaching, I believe it is necessary to define statistics. A review of the literature, several introductory statistics textbooks, fellow mathematics educators and my own students provided as expected, very different definitions and descriptions. Collectively, the different perspectives offer insight and contribute to our understanding on how statistics is interpreted and experienced. For the purpose of this study and the intended audience, I offer several statements from the literature highlighting the complexities of statistics as a discipline and more importantly, a way of understanding a world of variability and uncertainty:

> Statistics informs and enhances important skills, such as thinking critically and scientifically, understanding data, and charts, making decisions in the presence of uncertainty, and assessing risk. As our society becomes increasingly data intense and information based, statistical literacy skills are all the more

> important for today's citizens and a competitive work force (Joint position statement from American Statistical Association & National Council of Teachers of Mathematics, 2013).

This joint statement sought to solidify the importance of statistical literacy and to justify the need to incorporate statistical reasoning into the PK-12 curriculum.

With hundreds of different introductory statistics textbooks in use, there is no shortage of definitions for statistics within the context of an academic discipline. The mathematical statistics text used in this study defined statistics as "the science of colleting, organizing, analyzing, and interpreting data in order to make decisions" (Larson & Farber, 2012, p. 2). Former President of the American Statistical Association characterized statistics as "the discipline that studies how to understand the world through setting hypotheses, collecting and analyzing data relevant to those hypotheses, and drawing conclusions about the hypothesis from analysis of the data" (as cited in Steen, 2004, p. 42).

Advocates, researchers and educators promoting statistical literacy and or quantitative literacy (e.g., Patricia C. Cohen, Alan H. Schoenfeld and Lynn A. Steen) contend that an inability to think numerically prevents participation in civic life. Definitions that promote this perspective are also well documented within the literature. For example, Gordon and Gordon state:

> We live in a society which is ever more dependent on statistical reasoning. Major political, social, economic and scientific decisions are made using statistical information.Statistical reports affecting virtually all aspects of our lives appear regularly in all the new media. Business and industry leaders

> constantly call for greater statistical understanding on the part of our workforce. Statistics has thus become the primary quantitative tool in most areas. In turn, statistics offers have become one of the fastest growing segments of the undergraduate curriculum. (1992, p. viii)

During this study, students were asked on several occasions to answer the question “What is statistics?” One student defined statistics as “the study of numbers and how we use them to obtain data.” Another student stated that statistics “brings forth our own knowledge in making decisions in the way of collecting, analyzing, organizing, and interpreting data.” Both of these student definitions are consistent with the literature and illustrate that statistics is not mathematics. Studies suggest that in order to improve students’ learning and experiences, it is imperative to understand their descriptions of what statistics means to them (Gordon, 2004; Petocz & Reid, 2003).

Comparing Mathematics and Statistics

The multiple narratives provided above illustrate the different yet similar ways in which the literature and research characterizes statistics as well as addresses the issue of its importance. It is then necessary to discuss where students learn statistical concepts, reasoning and statistical thinking. Throughout PK-12 education, students are exposed to various statistical concepts. The *Principles and Standards for School Mathematics* (NCTM, 2000) include data analysis and probability concepts throughout the PK-12 mathematics curriculum. As students encounter these concepts within the context of the mathematics curriculum, statistics is often taught as a series of techniques and computations with no consideration of them as deep concepts. As a result, students experience statistic calculations as extensions of algebraic procedures and most fail to recognize the concepts as being part of statistics (Franklin & Garfield, 2006; Paulos, 1989).

Although the current view distinguishes mathematics and statistics as separate disciplines, statistics has historically been linked to mathematics. Significant areas of distinction exist between them (Moore, 1992). The context of many mathematics problems is removed such that students only engage in arithmetic or algebraic computations devoid of authentic purpose and meaning. Context according to Cobb and Moore (1997) provides meaning in data analysis. As such, understanding and describing are essential amidst the inference and interpretation process of statistics. Additionally, the inductive reasoning of statistics is not focused on an indisputable truth often associated with the deductive nature of mathematics (Hogue, 2012). As Scheaffer (2006) contends, in a prevailing curricula largely dominated by mathematics, steps must be taken to ensure students develop statistical reasoning. Mathematics and statistics also have academic distinctions that are often overlooked. Cobb and Moore (2000) characterize mathematics as a core discipline whereas statistics is a methodological discipline. As such mathematics and statistics, according to Scheaffer "can support the other and both can become stronger as a result, but they should not be merged into one" (2006, p.320). Similarly Cobb and Moore (1997) stated the "although statistics cannot prosper without mathematics, the converse fails" (p. 803).

Brief Historical Perspective of Statistics Education

Throughout our history, mathematics has been used to grapple with many of society's practical problems. Statistical inference emerged largely within the last two centuries from the contributions of the mathematical theory of probability. Between

1930 and the late 1950s, contributions from multiple professional organizations including the Mathematics Association of America (MAA) and NCTM, advocated including statistics and probability into the mathematics curriculum. Domestically, after World War II and the launch of the Russian satellite Sputnik, the federal government was committed to mathematics education reform. During this heightened period of mathematical reform, numerous organizations advocated for the inclusion of statistics into the then K-12 curriculum. Despite their efforts, changes to mathematics curriculum did not occur until the 1960s.

In 1967, NCTM teamed up with the American Statistical Association (ASA) and created a joint committee to improve statistical education in the secondary schools. In an effort to promote the work of the NCTM-ASA joint committee, NCTM highlighted probability and statistics in their annual yearbook (Shulte & Smart, 1981). The importance of providing support to teachers and administrators prompted the first publication of the *Statistical Teacher* (NCTM, 1982). The collective efforts of various organizations prompted the ASA to launch the Quantitative Literary Project (QLP) in 1984. With a continued effort of promoting the importance of learning statistical concepts, in 1989 NCTM published its *Curriculum and Evaluation Standards.*

As noted within several NCTM publications (NCTM, 1989; 2000), statistics has become an important focus in the current PK-12 mathematics curriculum. With increasing momentum from numerous initiatives, NCTM placed probability and statistics as a foundational area of content in their *Curriculum and Evaluation Standards* (NCTM, 1989). The reform-based initiatives of NCTM and others (e.g., ASA and MAA) have helped to continue the conversations and research studies about statistics and the pedagogical implications for teaching students about data and probability. During this time of reform, synthesis and analysis of the literature in statistics education began to emerge, paving the road for future research in curriculum and pedagogy (Becker, 1996; Gordon, 2004; Shaughnessy, 2003; 2007) and reforming statistics education (Chance & Garfield, 2002; Garfield, 1995; Shaughnessy & Chance, 2005).

Goals and Outcomes for Statistics Education

Pedagogical and curricular concerns are common topics of research and study within statistics education. As educators, we turn to research to provide us with insight on how to improve our teaching and increase student learning. Research in cognitive theory has influenced the concept-based reform initiative. Influenced by cognitive theories, Lovett and Greenhouse proposed five principles of learning that promotes constructivism: practice assists learning, knowledge is specific to its context, real-time feedback promotes learning, existing knowledge integrates with new knowledge, and an increased mental load reduces learning (2000).

A review of the literature suggests there are broad learning goals for statistics (e.g., NCTM *Curriculum and Evaluation Standards*, 1989). Garfield (1995) for example suggests several essential goals for students of statistics:

- The idea of variability of data and summary statistics.
- Normal distributions are useful models though they are seldom perfect fits.
- The usefulness of sample characteristics depends critically on how sampling is conducted.

- A correlation between two variables does not imply cause and effect.
- Statistics can prove very little conclusively although they may suggest things, and therefore statistical conclusions should not be blindly accepted (p. 26).

Additionally, the Guidelines for Assessment and Instruction in Statistics Education (GAISE) define goals of an introductory statistics course in the context of being statistically educated. The desired result of all introductory statistics courses according to GAISE is for students to develop statistical literacy and to think statistically. For example, students should know:

- How to interpret statistical results in context.
- How to critique news stories and journal articles that includes statistical information, including identifying what's missing in the presentation and the flaws in the studies or methods used to generate the information.
- How to obtain or generate data.
- How to make appropriate use of statistical inference.
- How to communicate the results of a statistical analysis (2012, Excerpts taken from pp.11-13).

Based upon a review of the literature focusing on the goals for introductory statistics education, the traditional curricular materials and pedagogical strategies were ineffective in developing student's conceptual understanding of statistics topics and statistical thinking (Cobb, 1992; Earley, 2007; Garfield, 1995, 2006; Nolan, 2002). As a result, the MAA commissioned a task force to provide reform recommendations for introductory statistics courses (Cobb, 1992). In the next two sections, the current statistics reform paradigm recommendations found within the literature is discussed.

Recommended Curricula Changes

The essence of the introductory statistics reform movement promotes statistical literacy and quantitative reasoning rather than calculations, procedures and formulae. The use of active learning strategies encourages students to experience statistics through applications that reach beyond mathematical calculations. Critical learning experiences that extend to overarching ideas of sampling, variation, distributions and inference are consistent curricular changes within the statistics reform movement (McClain & Cobb, 2001).

With some of the goals of an introductory statistics course defined by the literature, I will address the various curricula changes that are needed to obtain those goals. Discipline aside, introductory courses are designed to expose students to the fundamentals of the field and as noted by Moore (1998) they can influence beliefs and attitudes toward the discipline. A traditional course will list specific statistical topics that will be covered in the class (e.g., course syllabus or objectives). According to Macnaughton (1996), and Hogg (1990, 1992), course goals on the other hand emphasize what is essential and what will help students appreciate the general uses of statistics. Instead of developing a linear, topic-by-topic focused curricula checklist; statisticians, statistics educators and supporting organizations (e.g., NCTM, ASA and GAISE) place conceptual statistical understanding at the center of the statistics reform movement.

Statistically literate students will possess the ability to reason and question data, and be able to understand and explain variability. The GAISE Report specifically discusses and outlines what statistically literate means for students at the PK-12 and college levels. Supportive of the goals highlighted by Cobb's 1992 report, *Heading the Call for Change*; the GAISE Report provides six recommendations to help students attain the learning goals as previously described. With respect to the GAISE College Report (2010), the six recommendations include:

1. Emphasize statistical literacy and develop statistical thinking
    - Model statistical thinking instead of providing step-by-step procedures
    - Collecting and analyzing data is the practical operation of statistics
2. Use real data
    - Seek out real data directly from journals, surveys, and polls
    - Use data from a variety of contexts
    - Use class generated data
    - Integrate the same data throughout different parts of the course
3. Stress conceptual understanding, rather than mere knowledge of procedures
    - Focus on concepts rather than on a list of topics
    - Focus on discovery of concepts
4. Foster active learning in the classroom
    - Mix lectures with group or individual activities, discussions, and problem-solving activities
    - Collect data class
    - Use activities that allow students to discuss and think about the data and the problem
5. Use technology for developing concepts and analyzing data
    - Use various forms of technology to help students visualize abstract concepts (e.g., applets, spreadsheets, and graphing calculators)
    - Access large, real data sets and use technology to automate calculations
    - Generate appropriate statistical graphs
    - Create reports
6. Use assessments to improve and evaluate student learning
    - Align formative assessments with learning tools
    - Use a variety of assessment methods

- Provide constructive and timely feedback
- Use peer review of projects to provide feedback
- Use discussions for student presentations (pp. 14 – 22).

In terms of curriculum integration, Garfield (1995) and Shaughnessy (1977) uphold the position of activity-based activities and the use of small groups to enhance student learning of statistics. Chance and Garfield (2002) have done extensive work on assessment practices within statistics education and providing assessment resources that mirror the changes occurring within the classroom. In reflecting upon these changes, Earley (2007) points out that the time spent in class emphasizing what and how to understand statistical data requires instructors to develop experiences that promote and develop this understanding.

The development of statistical thinking that involves interpreting data and drawing conclusions is difficult for students (delMas, Garfield, & Chance, 1998). It can be a challenge for students who experience mathematics mechanically to think statistically. The use of implementing case studies within the introductory statistics course provides students with an opportunity to experience different perspectives of statistical research. Nolan and Speed (1999) for example created a course that integrates statistical theory and practice through the use of in-depth case studies. The use of case studies promote basic inter-disciplinary skills such as: collecting data, organizing data, interpreting data, representing data and communicating the findings. Additionally, the use of in-depth cases studies provides students with an opportunity to transfer their knowledge to new situations.

Recommended Pedagogical Changes

Students generally encounter an introductory statistics course within a specific discipline (e.g., psychology, business or economics) or as a general education course to fulfill degree requirements. Introductory statistics courses are traditionally taught within mathematics departments by mathematics faculty who may or may not possess a statistical background. It is not uncommon for students to have different mathematical backgrounds and for various instructors of the same course to have different goals for their students. Despite these differences, the research contends that there are effective ways for students to develop statistical literacy.

As discussed in the previous chapter, one of the most influential byproducts of cognitive research has been the theory of constructivism. Viewed as an epistemological position rather than a formal position on how to teach, the constructivist perspective on learning is a guiding theory for reform in statistics education. Garfield, (1995) proposed several general principles for learning statistics framed within the context of constructivism:

- Students learn by constructing knowledge.
- Students learn by active involvement in learning activities.
- Students learn to do well only what they practice doing.
- Teachers should not underestimate the difficulty students have in understanding basic concepts of probability and statistics.
- Teachers often overestimate how well their students understand basic concepts.

- Learning is enhanced by having students become aware of and confront their misconceptions.
- Calculators and computers should be used to help students visualize and explore data, not just to follow algorithms to predetermined ends.
- Students learn better if they receive consistent and helpful feedback on their performance.
- Students learn to value what they know will be assessed.
- Use of the suggested methods of teaching will not ensure that all students will learn the material (p. 26).

Toward this end, the concept-based approach to teaching introductory statistics involves active learning strategies such as group discussions, collaborative learning, problem-based learning, case studies, course projects, authentic data collection, and hands on data analysis, report writing, oral reports and the use of technology (Hassad, 2007; Tishkovskaya & Lancaster, 2012). Chance & Rossman (2006) similarly concluded that "we strongly believe that you will better understand and retain the concepts if you build your own knowledge and are engaged in the context" (p. xi).

Despite the amount that has been written over the last three decades about the introductory statistics course and the concept-based reform movement in statistics education, research reveals how difficult it is to implement universal change within education. The most frequent teaching method used in the college classroom is lecture and the most frequent forms of assessment are individual homework, quizzes and exams (Blair, Kirkmand & Maxwell, 20013; Garfield, 2000). A review of the related literature concludes that there is not a consensus among statistics educators regarding how the concept-based introductory course should be taught but that the course should be concept-based. Further complicating the issue is the uncertainty of the components of a successful course and how to implement them (Garfield, Hogg, Schau, & Whittinghill, 2000).

Pedagogical reforms toward the development of conceptual understanding and teaching suggest that new approaches toward teaching and learning will challenge the roles and identities of instructors and students found within the traditional lecture-based teaching model. Collaborative learning involves students and teachers working and learning together. Research suggests that a range of positive results such as student achievement, attitudes towards statistics and personal development are improved as a result of collaborative learning in the context of statistics education (Autin, Bateiha, & Marchionda, 2013; Garfield, 1993, 1995; Hogg, 1992).

Recommended Technological Changes

The emphasis of incorporating statistical literacy within statistics education is a result of the role information and data play in our everyday life (see e.g., Ben-Zvi & Garfield, 2005; Gal, 2002). The need for educated citizens to understand basic statistical concepts, interpret data and make decisions based upon statistical data are essential skills required to navigate the information age. Advancements in technology have impacted how professional statisticians work, the way in which students learn and the way in which instructors teach statistics (Chance, Ben-Zvi, Garfield & Medina, 2007; Moore, Cobb, Garfield, and Meeker, 1995). Support for using technology within introductory statistics courses was found within the literature. GAISE for example directly recommends the use of various forms of technology to “help students visualize concepts and develop an understanding of abstract ideas by simulations” (2012, p. 19).

Prior to powerful statistical software packages, spreadsheets and graphing calculators, students were required to perform tedious calculations manually using various statistical formulae. Technological advances in statistical software and the range of graphical and visualization offer students the opportunity to interact with data in ways that were previously unimaginable. The uses of statistical software packages (e.g., SPSS, SAS, and MINITAB) help students visualize statistical concepts. For example, in discussing the relationship between variability, central tendency, and the shape of a histogram, Lee (2005) had his students use MINITAB to investigate distributions, means, medians, standard deviations, and ranges between their guessed counts and actual counts. Students are also tasked with determining what graphical display and data summary represent their conclusion. This hands-on activity implements various uses of a single technology while exposing the students to the Empirical Rule. Technological tools such as applets and simulations assist students in exploring abstract concepts. Chance, delMas, and Garfield (2005) for example used software simulation to help students explore how sample size is related to the shape, center, and variability of the sample mean distribution. Simulating three samples from the same population and having students observe the distributions computed from these samples allow the students to experience and discover the Central Limit Theorem rather than providing a mathematical proof. As such, technology according to Erickson (2001) should encourage students to explore and interact with data sets.

Perhaps the most important use of technology is its capacity to empower students as users of statistics (Ben-Zvi, 2005). Real-world data often consists of large and complicated data sets. Technology provides students opportunities to engage in open-ended explorations, reflect and experience authentic real-world problems rather than focusing on numerical calculations. The literature also suggests that there are numerous ways for statistics educators to integrate technological tools to support the student-centered learning environment and promote collaborative exploration and inquiry. Equally as important is that the use of technology must be done carefully and instructors must remember that although there are good technological tools available for use, no one tool can do it all (Chance, Ben-Zvi, Garfield & Medina, 2007).

Problem-based Learning

As described within this chapter, statistics education research has emphasized the need for reform-oriented pedagogy in the area of teaching introductory statistics courses (Cobb, 1992; Garfield, 1995; Moore, 1997). Research-based strategies attempt to improve the learning and practice of teaching statistics in order to improve how students are educated and how they experience the discipline of statistics (Garfield, 1995; Garfield & Ben-Zvi, 2008). Traditional statistics education emphasizes methodological skills, procedures and computations but research has shown that this pedagogical approach does not promote statistical reasoning and thinking (Snee, 1993). Many researchers agree that adopting the problem solving approach in teaching statistics benefits both the teacher and the student (see e.g., Garfield, 1993, 1995; Marriott & Davies, 2009; Marriott, Davies & Gibson, 2009).

As a learner-centered approach to instruction and curriculum, problem-based learning integrates theory and practice as a means in which the learner applies knowledge and skills to construct a viable solution. A review of the literature indicates that different disciplines have unique definitions of problem-based learning. Grounded within constructivist epistemology, problem-based learning/problem-centered learning is an instructional strategy implemented to foster mathematics learning in which students learn by making sense of their experiences and constructs mathematics for themselves (Reynolds, 2010, Wheatley, 2010). Problem-centered learning emphasizes the importance of creating and developing tasks (problems) that are challenging but remain possible within the ability level of the learner. As with problem-based learning, collaboration and reflection are critical components of building mathematical understanding (Yackel, 2010). Learning to work together and verbally justifying mathematical thinking contribute to the effectiveness of problem-based learning and problem-centered learning (Feikes & Brice, 2010).

The influence of problem-based learning has expanded to multiple disciplines and has been found to be an effective teaching pedagogical strategy in mathematics education including statistics (see e.g., Boyle, 1999; Jaki & Austin, 2009; Marriott, Davies, & Gibson, 2009). Since the 1980s, problem-based learning has been emphasized in mathematics curriculums. One of the most prominent supporters of problem-based learning is the National Council of Teachers of Mathematics (NCTM). It has advocated for the focus of school mathematics to include problem solving within the *Agenda for Action* (NCTM, 1980), *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), and the *Professional Standards for Teaching Mathematics*

(NCTM, 1991). The foundation of mathematics curriculum within each report is built upon problem solving.

After 20 years as an instructional goal of mathematics teaching, problem solving has been de-emphasized. The *Principles and Standards for School Mathematics* (NCTM, 2000) promote the development of social norms and classroom communication rather than individual mathematical development (Cifarelli, 2010). The restructured *Standards* still promote problem-based learning and the benefits it provides outside of the classroom but perceptions regarding its role have affected research efforts. The literature suggests that problem solving was one of the most popular areas of research in mathematics education during the 1980s but the popularity has actually been declining (Cifarelli, 2010, Lester, 1994). The implications of this decline threaten the future of problem solving and the field of mathematics education. There is still a great deal that is unknown about problem solving and the implications related to mathematics learning and teaching.

Problem-based learning holds many positive implications for educational practices as opposed to the isolated direct instruction approach. Students are empowered to experience authentic, meaningful, and applicable real world situations that are compelling and engaging. Problem-based learning develops lifelong learning skills in which students learn to plan, execute, evaluate and defend their own work (Cifarelli, 2010, Wheatley, 2010). Research supporting the effectiveness of problem-based learning in higher education mathematics is deficient. Although AMATYC (1995) has defined the importance of problem-based learning, it remains almost unknown with the undergraduate curriculum (Savery, 2006). Although the results of problem-based learning in various disciplines and grade levels may be different, the literature has shown that further research can contribute to and provide opportunities to advance our pedagogical perspectives. Problem-based learning is not the single solution to all educational and learner needs but it does align with the guiding principles of the concept-based reform movement that stresses conceptual understanding and the development of statistical literacy. Additionally, it supports constructivist ideas about learning and teaching.

Summary

This chapter has provided a review of the literature relevant to this phenomenological study. In the next chapter, I offer the methodology utilized in this study. Chapter Four of this dissertation enumerates the specific instructional strategies that were implemented in the non-traditional introductory statistics classroom. An analysis of these instructional strategies and ideas are presented in Chapter Five of this dissertation. This final analysis is done through the lens of constructivism.

Chapter III: METHODOLOGY

The ongoing curriculum and pedagogical debates of mathematics education have carried the calls for comprehensive reform. Mathematics education reform efforts have influenced the teaching and learning aspects of collegiate statistics education. Although there is a plethora of research on reform based statistics, there is little research on the perspective of the learners in a problem-based college level introductory statistics course. While many studies existing in the literature evaluate the effectiveness of problem-based learning as an alternative pedagogical approach to teaching mathematics in the K-12 setting (Boaler, 2002, 2004; Cobb, Wood, & Yackel, 1991; Faaizah and Halimah 2008; Yackel, 1990), it is almost unknown within the undergraduate curriculum (Savery, 2006). This study addresses these deficiencies.

The purpose of this study was to describe the experiences and perceptions that undergraduate students of a nontraditional introductory statistics course hold and to describe the characteristics of a nontraditional introductory statistics course. This study utilized the descriptive and interpretive qualitative research design to investigate the students' experiences and perceptions related to a nontraditional undergraduate introductory statistics course. Individual student grades were not of interest in this study because the goal was to allow students the opportunity to share their unique perspectives about the learning process and the characteristics of the course they thought assisted them in developing their statistical knowledge.

The focus of this study was to explore the following questions:

1. What are the characteristics of a problem-based college-level introductory statistics course?

2. What are students' perceptions of the characteristics of a non-traditional introductory statistics course?
3. What are students' perceptions of their learning in this non-traditional introductory statistics course?

Qualitative data were gathered and evaluated to obtain understanding about the thinking of the students taking a nontraditional introductory statistics course and the aspects they felt helped or hindered their statistical development. The appropriateness of using qualitative methodology for this study was addressed in this chapter along with the method for collecting data and the procedures for analyzing this data. This chapter commences with a statement grounding the framework of the study, followed by a concise data collection section that details the participants in this study along with the setting in which the study took place. Additionally, the data collection section details the sources of the data as well as data management and data organization for analysis. The method of instruction that was used in this study is presented and complemented by my role as a participant researcher and instructor along with my previous experience teaching undergraduate mathematics courses.

Theoretical Framework

The theoretical framework for this qualitative investigation draws from the literature on constructivism. The constructivist perspective views learning as an active process in which the interactions within the environment are paramount. Learning is therefore understood as the process by which human beings construct knowledge from perceptions and experiences from previous knowledge (Simon, 1995). The behaviorist's interpretations of learning where an emphasis is placed on making skills automatic hardly align with the principles of constructivism. From the behavioral model, the acquisition of mathematical knowledge requires drill-and-practice thereby promoting the method of direct instruction (Walshaw, 2013). Although this model has been linked to better performance on standardized assessments, it has not been effective in developing skills essential for conceptual understanding (Hodara, 2011).

Grounded within constructivist epistemology, problem-based learning is an instructional strategy to foster mathematics learning in which students learn by making sense of their experiences and constructs mathematics for themselves (Reynolds, 2010; Wheatley, 2010). von Glaserfeld extended upon Piaget's ideas and concluded that in mathematics education, one is studying the construction of mathematical reality through the experiences of the individual (Steffe & Keiren, 1994). Classrooms that engage in genuine mathematical discourse are what Richards (1991) defines as *inquiry mathematics*: together students and the teacher engage in discussions, explore problems from various perspectives, attempt alternative methods, and defend their solutions. All of these activities provide opportunities and space for the student to deal with new ideas and hence the construction of new knowledge.

Any new idea that cannot assimilate into existing knowledge ignites a perturbation for the learner. Wheatley (2010) claims that "perturbations are the seeds of learning" (p. 11) and concludes that learning is enhanced through the process of the learner working to resolve these perturbations. Problem-based learning emphasizes the importance of creating and developing problems that are challenging but remain possible within the ability level of the learner. Collaboration and reflection are critical components of building mathematical understanding and are therefore essential components of problem-based learning. Learning to work together and verbally justifying mathematical thinking contribute to the effectiveness of problem-based learning (Feikes & Brice, 2010).

Implications of Phenomenological Research

Hermeneutic phenomenological research design was used to explore the students' perspectives of emerging mathematical understanding and approaches to learning mathematics in a problem-based learning undergraduate statistics course. van Manen (1997) explained that researching people's lived experience can transform what people do and why they do it into a narrative that reveals the pedagogical meaning of human experience. From a pedagogical perspective, phenomenological research has the potential to uncover universal meaning from human experience and offer insight (Moustakas, 1994). In line with the pedagogical nature of phenomenological studies, it was the aim of the researcher to accurately portray the richness and depth of the data through the realities of those who have experienced the phenomenon of learning in a nontraditional introductory statistics course that employed problem-based learning by honoring the human experience of meaning-making within their unique roles as learners.

Qualitative methodologists (Creswell, 1998; Jacob, 1987, 1988; & Patton, 2002) seek to discover participants' perspectives on their worlds and view inquiry as an interactive process between the researcher and the participants. The descriptive and interpretive components pertaining to a qualitative research study align well for framing how students discuss their experiences related to and perceptions of problem-based learning within their introductory statistics course. Patton (2002) suggests that qualitative methods better embody lived experiences and outlines several points specific to qualitative research:

1. The intent of the research seeks to address a process, implementation, or development of a program or its participants.
2. Individualized outcomes are central to the explanation.
3. Rich detail, rooted in the accounts of participants, is required to provide insight and analysis.
4. The distinctiveness and multiplicity of individual accounts is central to the research question.
5. The research question seeks to understand and participant accounts are central to this understanding (Excerpts taken from Patton, 2002).

Additionally, qualitative methodologists (Creswell, 1998; Jacob, 1987, 1988; & Patton, 2002) provide multiple theoretical orientations in qualitative inquiry. Patton (2002) explains that philosopher Edmund Husserl viewed phenomenology as the study of how people describe things and experience them; we can only know what we experience. To this end, qualitative research methods were helpful for revealing students' experiences and perceptions of their statistical understanding.

Setting

Although community college faculty are generally more knowledgeable about mathematics than PK-12 faculty (Lutzer, Rodi, Kirkman, & Maxwell, 2007), their teaching methods typically resemble pedagogical practices that are aligned with a behaviorism theory of learning that despite reform efforts, continues to dominate PK-12 teachings. Lectures are the most common form of instruction within most community college level mathematics courses. Students who were previously unsuccessful in learning “drill-and-skill” algorithms are basically presented with the same instructional approach yet again. The methods that failed to develop students’ mathematics understanding in PK-12 are found to be unsuccessful for most of the students in community college (Boylan, 2002; Hodara, 2011)

Mathematics pedagogical research aimed at the community college level may lead to improved student learning and improved teaching practices that actively engage students in the learning process. This specific study involved a community college instructor and her students as they engaged in a non-traditional undergraduate introductory statistics course.

This study was conducted at a small, rural, multi-site community college. The main campus is situated on a 55-acre site located within a western city in the Midwestern region of the United States. The community college was established in 1938 as a junior college and in 1991, the college’s name was changed to community college. According to the 2010 Higher Learning Commission report, the community college serves the needs of more than 5,000 urban and rural credit students each year. The college has a 160-bed apartment-style student housing complex for students.

The college offers 18 Associate in Science degree programs, 22 Associate in Applied Science degree programs, and 11 Associate in Arts degree programs. In addition to the student population enrolled in these degree programs, there are also students who are enrolled in transfer courses to four year college or universities and students enrolled in occupational tracts and three Certificate of Mastery programs in various fields. The college’s student enrollment reflects the ethnic diversity of the community and the service area. The student body largely consists of Caucasian students, with 26.7% representing the ethnic minority and 17% representing multiple ethnicities.

The introductory statistics course is only offered by the mathematics department and is offered each semester. No more than one section is offered each semester and the course is not offered online. The prerequisite for this course is a college level mathematics course and offered at a sophomore level. Students in the introductory statistics course have diverse mathematics backgrounds and fields of study. Course enrollment is limited to 25 students.

The intent of this course is to introduce students to basic statistical concepts and to develop conceptual statistical understanding. The statistics course topics listed within the syllabus include: exploratory data analysis techniques (steam-and-leaf plots, histograms, box plots, and scatterplots), measures of central tendency and variability, probability, sampling and sampling distributions, and inferential statistics (one-sample, two-sample, and paired *t*-tests, confidence intervals, contingency table analysis with chi-square). Although statistical computation is not the focus of this course (college algebra is the course prerequisite), a TI-83/84 graphing calculator is required. The course textbook is Elementary Statistics Picturing the World by Ron Larson and Betsy Farber. Course homework and quizzes are completed using the online interactive educational system MyMathLab that accompanies the course textbook.

Participants

During the Spring 2014 semester, there was only one introductory statistics course offered. The course was held Monday, Wednesday, and Friday from 8:00 am to

8:50 am for sixteen weeks. The students enrolling in the course had no knowledge that the class would be used as part of a research study and that the course would be conducted in a way that was different from a traditional Introductory Statistics course. All students who were enrolled in the non-traditional introductory statistics course were invited to participate in this study, of which 100% provided consent to participate in the study. One student withdrew from the course approximately in week five. Only those who agreed to participate and completed the course were included in this study. By agreeing to participate in this study each participant acknowledged being 18 years of age or older (See Table 1 for a summary of student ages). The participants in this study were 10 female and 6 male undergraduate students who self-enrolled in the introductory statistics course. Student participation, activities and assessment items used in this study were a part of the normal course expectations that were discussed on the first day of class and clearly outlined in the course syllabus.

Table 1. Student Participant Age Range

	Number of Students
Age Group	
18 – 21	11
22 – 25	4
26 – 29	1

Students in this introductory statistics course were pursuing five specific major fields of study. The fields of study are summarized below in Table 2. All of the students but one was classified as sophomore students. All students self-reported having taken a college mathematics course within the last two years (see Table 3). Only one student reported having enrolled in a previous statistics course, the remaining students had no formal background in statistics. All of the students indicated that the course was required for their respective majors.

Table 2. Participant's Major Field of Study

	Number of Students
Major	
Agriculture	5
Business Administration	4
General Studies	3
Pre-Professional	3
Nursing	1

Table 3. Number of Years since Last Mathematics Course

	Number of Students
< 1 year	6
1 – 2 years	9
3 – 5 years	1

Participant-Observer

According to Lester (1999), the purpose of phenomenological research is to illuminate the specific, to identify phenomena through how they are perceived by the actors in a situation. To effectively describe the individual experiences and perceptions from the participant's own perspectives, the researcher assumes the role of a participant observer. Fetterman (1989) describes participant observation as the process of learning the language and seeing patterns of behavior over time. It is an attempt to see the world from the other person's point of view. Within this study, I assumed the role as the researcher, teacher, learner, and I was also a participant observer. In this manner, I was an equal participant within this study. Assuming this dual role allowed me the opportunity to learn and record the perspectives held by the participants of this study, including my own. The essential role of the researcher within phenomenological research suggests it is important to make the researcher visible within the research as an interested and subjective actor rather than a detached and impartial observer (Stanley & Wise, 1993). Therefore, at this point, I would like to address aspects of my emergent roles during this study.

At the beginning of this study, I had been teaching college level mathematics for nine years. All of my teaching experience was at the community college level. Prior to teaching at this community college, I had taught mathematics courses at other community colleges and at a university in the state of Kansas. I completed my Bachelor of Science degree in Mathematics in 2000. I began teaching undergraduate level mathematics courses at several community colleges as an adjunct instructor in 2004. In an effort to pursue faculty teaching positions, I completed my Master of Curriculum and Instruction degree program in 2008. Personally and professionally, I wanted to improve my own teaching so in 2011, I began my Ph.D. degree in Mathematics Education at the University of Oklahoma.

Reflection on my own experiences with statistics. An essential element in conducting phenomenological research is to understand my own experience with the phenomenon in question before interpreting the participants' experiences (commonly referred to as bracketing or `epoche) (Marshall & Rossman, 2011; Merriam, 2009). My own student experiences with mathematics and statistics certainly influenced my teaching. Reflecting back, all of my mathematics and statistics courses would be characterized as traditional, teacher centered. My undergraduate experiences with statistics ultimately influenced my decision to not pursue a master's degree. The introductory statistics course was calculation-based and emphasized rote memorization of definitions and formulae. I recall a great deal of general frustration learning the unfamiliar Greek symbols and endless statistical formulae. This was the first mathematics course that allowed the use of a scientific calculator and I found it difficult to use. The second statistics course was feared by everyone. We all quickly learned to not ask questions in class for fear of public humiliation. The men in the class quietly took notes and the few brave women who asked questions often left the class in tears. I took pages upon pages of notes that only added to my growing frustration and confusion. At the end of the two courses I was grateful to check them off the list, but I left with little statistical understanding.

After completing these two required courses, I never wanted to step foot back into a statistics course. Returning to the classroom a decade later, my anxiety regarding statistics returned. Although I was confident with algebra, I had limited experience with statistics and to be honest, I had avoided statistics inside and outside of the classroom. As I was approaching the completion of my course work, I decided to immerse myself in statistics by teaching an introductory statistics course and completing the required quantitative research courses at the same time. In doing this, I began looking at my own teaching and the issues I was experiencing again as a student learning statistics. All of my personal experiences as a learner coupled with my experience as a mathematics educator lead me to ask, “What are my own students experiencing in my undergraduate statistics course?” Also, and of equal importance, “Are there more effective ways to teach statistics?”

Establishing a Mathematical Community

As an experienced community college professor, I have always connected with students in my courses. Despite the current educational differences between the students attending community college and myself, social and economic similarities allowed me to relate with the students. Mathematics is often a gate-keeper for many students. Community college students generally require remediation, and tend to believe they will experience failure in their mathematics courses. As a student, I had similar experiences and feelings towards mathematics. Palmer (2007) concludes that without knowing ourselves, we cannot know our students. Adopting and applying this perspective to my own experiences with mathematics provided me with an opportunity to relate to my students and developing a stronger relationship with my students.

Creating a community of learners and getting a clear picture of who they are, both as a group and as individuals is the foundation of effective teaching (Davis & Sumara, 2007). The concepts of relationships and power between researcher and participants are embedded in qualitative research. The desire to participate in a research study depends upon a participant's willingness to share his or her experience. Acknowledging the importance of these relationships, I purposely sought to create an environment that encouraged my students to reveal their mathematical processes and perspectives of the non-traditional introductory statistics class.

Establishing a Problem-Rich Mathematics Environment

Within this non-traditional introductory statistics class, emphasis was not on calculation or speed, but on understanding, relating, extending and connecting general statistical ideas. Establishing a sense of community provided a strong foundation for a problem-rich environment that was at the center of this non-traditional class. Although modified lectures were utilized throughout the class, time and space for students to work on problems in groups and individually were provided. In order for students to obtain understanding, emphasis was placed on analysis and process rather than computational and calculations. Tasks were designed to help students problematize the mathematics they already knew and apply it to statistical concepts. As students engaged in authentic problem solving, they did not have to rely upon memorized rules or formula. Selecting genuine tasks made the subject problematic for students and an opportunity to explore various mathematical processes.

Data Collection

In a phenomenological study, effective data collection begins with recognizing the final goal. Revealing the nature of the participants' experience with the phenomenon is the goal of phenomenological research. In order to accomplish this goal, the researcher must implement sound qualitative research collection methods: obtaining access and rapport with research participants, determining a sample strategy and collection method, effectively knowing how to conduct in-depth interviews, managing data, maintaining focus, obtaining data sufficiency, resolving field issues, and ensuring standards of quality and verification (Creswell, 1998; Moustakas, 1994; van Manen, 1990). Multiple qualitative data sources were collected, documented and analyzed continuously during the Spring 2014 semester. I collected data in three primary, interdependent ways: interviews (mid-semester conferences and focus group discussions), observations (self-reflective journal, digital audio and video recordings of various learning activities), and documents (student in-class journals, closed-book journals, course projects, and assessments). A short survey was administered in week 15 to collect demographic information from the participants in this study. The data sources helped me obtain a more comprehensive and precise representation thus helping to confirm my analyses. See Table 4 for an overview of the data collection. Below each of the data sources are described.

Qualitative Measures

The primary means of data collection within phenomenological research is the in-depth interview (Creswell, 1998; Moustakas, 1994, van Manen, 1990, 1997). According to Marshall & Rossman (2011), phenomenological interview's primary advantage "is that is permits an explicit focus on the researcher's personal experience combined with those of the interview partners" (p. 148). To sufficiently present and describe the participants' experiences and perspectives, van Manen (1990) suggests collecting stories, experiences and anecdotes during the research. Additional data collection methods such as reflective journals, handwritten artifacts, and audio and or video recordings are also utilized within phenomenological research. In line with additional research decisions, the purpose of collecting interviews aligns with the goal of this study.

Mid-semester Conferences

As part of the regular course expectations, all students participated in the mid-semester conference. Further all students gave consent for their direct quotes from the mid-semester conferences to be used in this study. The mid-semester conferences were semi-structured interviews conducted during weeks 8 and 9 (See Appendix A). The questions used during the mid-semester conference allowed the researcher to gain a

Table 4. Summary of Data Collected

When collected	Data Collected	Format	Completed by	Analysis
Week 1	Early Course Perspectives	Open-ended	Students	Both Content Analysis Frequency Count
Week 5 – 6	Both Project #1 Reflection	Open-ended	Students and Instructor	Qualitative Content Analysis
Week 8 – 9	Both Project #2 Reflection	Open-ended	Students and Instructor	Qualitative Content Analysis
	Mid-Semester Interviews	Interview Protocol	Students	Qualitative Content Analysis
Week 12 – 14	Both Project #3 Reflection	Open-ended	Students and Instructor	Qualitative Content Analysis
Week 15	Demographic	Multiple choice	Students	Descriptive
	Focus Groups	Open-Ended	Students	Both Content Analysis Frequency Count
Week 16	Final Course Perspectives	Open-ended	Students	Both Content Analysis Frequency Count
Ongoing	Classroom Observations Teacher Journal	Non-participant	Students and Instructor	Both Content Analysis Frequency Count
Ongoing	Documents	Assessments, student reflections	Students	Both Content Analysis Frequency Count

better picture of the students' perceptions and characteristics of the non-traditional introductory statistics course. Additional follow up questions addressed how the characteristics affected the students' statistical understanding. Audio recordings of the mid-semester conferences were transcribed and analyzed for themes that describe the "textures of the experience" (Creswell, 1998, p. 150).

The expectations of the mid-semester conference were discussed on the first day of class and further details were outlined in the course syllabus. The option to speak individually had been presented to the class in the event anyone was more comfortable in that setting. Within the conference setting, students were asked to describe the course, and their experiences with the various activities, and their interactions with others in the course. During the conferences, my focus was on listening rather than talking to prevent influencing the students' responses (Moustakas, 1994).

Data collected offered insight about the student perspectives of the course activities and overall experience with non-traditional instructional activities. Although several class meetings were recorded, the information obtained through the student surveys was such that could not have been collected through direct observations. Another essential element of conducting the conferences involved developing a rapport with the students. In order for the students to reveal their experiences, it was essential that they felt comfortable and trusted me with their responses. Maintaining a professional manner and being organized while interacting with the students assisted in developing that trust (Creswell, 1998). As expected, I had to probe the students during the interview process in order to have them sufficiently describe their experiences.

Focus Group Interviews

A focus group is another method of qualitative research data collection. Interviews occur within a group of people who have knowledge of the research topic (Merriam, 2009). The essential element of focus groups is the social interactions. Members of the group consider their own perspectives in the context of the views of others (Patton, 2002). To obtain insight regarding student's perceptions of their statistical development and understanding, focus groups were constructed by self-selection. Groups of 3-4 were provided with a variety of pre-determined questions. Each group would have approximately 10 minutes to discuss the questions and record their responses. All of the questions were rotated between groups until all questions were discussed. At the conclusion of the activity, each group shared their responses to the entire class.

Observations

Noting and recording of specific events, behaviors, and artifacts are essential to qualitative research. In order to capture the essence of the setting, classroom dynamics and student interactions, field observations were a vital component of this phenomenological study. Throughout the course of this study I kept a reflective journal in order to record classroom interactions and occurrences related to the specific teaching strategies used. For the duration of this study, I assumed the role of participant observer (Merriam, 2009). Several class activities were videotaped in order to gather important interactions and dialogue that may have been missed while I was participating in the activities.

Teacher Journal

To ascertain the effectiveness of teaching, practitioners within all levels of education explore the reflective practice as a tool to enhance their teaching and monitor their effectiveness. The function of reflection is according to Dewey (1944), to make meaning among the elements of an experience and other experiences. Dewey states:

> In discovery of the detailed connections of our activities and what happens in consequence, the thought implied in cut and try [sic] experience is made explicit…Hence the quality of the experience changes; the change is so significant that we may call this type of experience reflective – that is, reflective par excellence (1944, p. 170).

The purpose of keeping my self-reflective journal was not simply to capture the events of the day or to simply mull over something. Rather as Dewey ascertains, reflective thought requires "definite units that are linked together so that there is a sustained movement to a common end" (p. 5). In an effort to uncover the student's perspectives, my reflective journal assisted me in being present to the classroom experiences and openness to their potential meanings.

By incorporating my field notes and classroom recordings, my reflective journal also provided an opportunity to deal with frustrations and confusions, and thoughts about what I should have or could have done within a specific situation. Recording my perspectives also required me to confront my own personal biases and or expectations. As difficult as it may be, researchers must attempt to limit their personal bias and approach phenomenon with an open mind (Creswell, 2007). As an experienced teacher, I entered this study with some contextual knowledge about the phenomenon being studied. Identifying my interpretations of the phenomenon throughout this study was essential to prevent misinterpretations of the data and erroneous conclusions.

Course Documents

Merriam (2009) uses the term documents to refer to sources of qualitative data other than interviews or observations. Qualitative research seeks to represent the participant's perspective. Documents offer insight into a person's attitudes, beliefs, and view of the world (Merriam, 2009). Various forms of student work were collected throughout this study to provide the researcher some insight into discovering the student's perspectives of the non-traditional introductory statistics course.

Student in-class journals. A series of short response papers (366 in total) were collected in this study. These student journals served to provide immediate feedback by class members after class activities were completed. Students completed the in-class journals prior to the end of class and turned them in for my review. I provided comments and returned them at the next class period. The in-class journals provided a baseline of student thinking at the beginning of new chapters and over time they offered quick glimpses into student thinking and understanding. The in-class journals also provided information about students' misunderstandings. For example, while discussing population and sample, all but one correctly defined a sample and a population. However when asked to explain the differences between a population and a sample, several students were unable to adequately do so. See Appendix B for a sample of the in-class journal prompts.

Closed book journals. As a designed component of the non-traditional introductory course, students were asked to reflect upon their thoughts, feelings and experiences at various times throughout this study. Students were asked to journal at the beginning of new topics. Students were asked to reflect upon what they knew, wanted to know with regards to specific statistical concepts and their feelings regarding the problem-based learning activities. For example, prior to completing the Wage Gap project, students were asked to write what they knew regarding the wage differences between men and women. These documents are not representative or necessarily reliable accounts of what actually occurred within the course, but they do offer the student's perspective.

Course projects. As outlined in the course syllabus, the emphasis in this course was not on calculation or speed, but on understanding, relating, extending and connecting general statistical ideas. Additionally, the course had changes in pedagogy, replacing passively received lectures with problem-based learning activities. Bradstreet (1996) and Cobb (1991) argued that the superiority of statistical methods should be replaced with statistical reasoning. One way to develop statistical reasoning is to infuse active learning strategies that allow students the opportunity to design studies, collect data, analyze, prepare written reports and give oral presentations. The use of incorporating projects, laboratory-based courses, or in-class activities into statistics courses is nothing new. Bradstreet (1996) writes that, "Learning is situated in activity. Students who use the tools of their education actively rather than just acquire them build an increasingly rich implicit understanding of the world in which they use the tools and of the tools themselves" (p. 71). In light of my research questions and emphasis of my research, data from course projects were collected.

Students were required to complete three projects in the non-traditional introductory statistics course (See Appendix C). Each project required the student to apply statistical concepts, statistical reasoning and statistical analysis as outlined in the course topics. Traditional homework and quizzes were regularly assigned prior to the projects. A majority of the students had no previous experience completing projects within a "mathematics" course. Most in fact, voiced concerns, fear and uncertainty about completing the assignment and what the expectations were. These concerns were displayed throughout the course projects. However, at the conclusion of the last project most of the students spoke very favorably about all of the projects and the contributions they made within the context of statistical understanding.

Assessments. Assessment serves multiple purposes and has several configurations. As explained by Steen (1999), assessment is used to diagnose student needs, monitor student progress, rate teaching effectiveness, and evaluate curricula. Within the context of education, Steen (1999) and assessment pioneers alike advocate that assessment must be broad, flexible, diverse, and suited to the task. In order to obtain the objectives of this non-traditional introductory statistics course, I was aware that non-traditional methods of assessment would be needed (Trowell & Wheatley, 1999). Traditional homework, quizzes and exams were normal expectations of this course. Additionally, three course projects, oral presentations, and various class activities were used to view and assess student's intellectual development, discovery, frustration, formulation, self-assessing and their level of statistical competence. The advantages of using a variety of assessment measures allowed me to collect information about individual student performance and it provided insight on how students were thinking, learning and processing the course.

Procedure

Unlike quantitative research that evolves linearly as a sequence of one-directional steps, qualitative research design "should be a reflexive process operating through every stage of a project" (Hammersley & Atkinson, 1995, p.24). The objective of phenomenological research according to Moustakas (1994) is to reveal the nature of the participant's perceptions of a specific phenomenon. And, as Creswell (2007) suggests, it is an attempt to depict the essence of the experience. The everyday lived experiences and social actions of an individual are at the center of phenomenological qualitative research (Merriam, 2009; Van Manen, 1990). Several principles guide the thinking and planning stages of qualitative research to understand a complex phenomenon experienced by the participants themselves (Merriam, 2009). Following these principles and stages, this study was conducted in several phases after initial IRB approval (See Appendix D).

The first phase of this study involved asking student to participate in the study. In accordance with the IRB, the details of the study were outlined to the students by a third party. Students were provided with a written copy of the informed consent and given the option to participate in the study. Those agreeing to participate signed an informed consent. As the researcher and instructor, I was not aware of who agreed to participate in this study until after the final course grades were calculated and posted. The second phase of this study was an ongoing phase of data analysis. As Merriam (2009) states, qualitative data collection and analysis proceed simultaneously.

The qualitative data for this study (as previously described) were collected by means of the transcripts of semi-structured, mid-semester conference interviews and focus groups, student journal entries, closed book journal responses, course projects and assessments. As a conscientious educator, I continuously reflected on the data to ensure the objective and goals of the course were being met. As the researcher, the reflection process required for qualitative analysis was challenging. Making notes as the data collection and analysis occurred was a useful strategy and a constant reminder to remain open-minded and unbiased in my interpretations and impressions.

The third phase, at the conclusion of the course was a more formal analysis of the data. All data sources were initially reviewed and the data were allowed to "speak for themselves" (Merriam, 2009). Subsequent readings allowed me to sort each data source into categories, define their properties, and make sense of them. Within this phase of analysis, I implemented the principle of triangulation to establish relationships among the categories. Resulting themes and categories from transcribed interviews, observational field notes and additional data sources were corroborated. During this phase of the study pseudonyms were assigned to each student to help ensure the privacy and confidentiality of students who consented to participate. The final phase occurred once I determined that analysis had reached saturation (Marshall & Rossman, 2011). I concluded that I had reached this point when I was able to answer all of the research questions. Further review was conducted to retrieve specific examples to be used to corroborate my findings.

Data Analysis

As noted by Merriam (2009), the process of data collection and analysis is recursive and dynamic and occur simultaneously. As this study evolved, data analysis became more intensive. To assist me during this phase of the study, I implemented several of Merriam's (2009) recommendations for analyzing data:

- Plan data collection sessions according to what you find in previous observations
- Write "observer's comments" as you go
- Try out ideas and themes on participants
- Play with metaphors, analogies, and concepts

Each of the data sources were initially coded, then subsequently reduced into general categories. During this phase of analysis, I was looking for evolving patterns to create final categories that captured synthesized relationships among the qualities found to exist within the data. Shank (2006) referred to the process of uncovering patterns among categories as thematic analysis.

With the collection and analysis of the first set of data, an ongoing mental analysis provided direction into my teaching processes, producing a feedback loop of sorts. Within my own journal memos, I was purposely reflecting back to where students were before, where they were presently, and where I needed or wanted them to be to establish what Strauss & Corbin (1998) and Dick (2005) describes as constant comparison. In order for interconnected relationships to evolve, each subsequent data is related (or coded) to the "parent" data. Through the constant comparison process, data relationships evolve. The initial patterns, themes, and categories were used to describe the characteristics of the non-traditional introductory statistics course and the perspectives of the students about the course and how those characteristics contributed to their statistical development.

Qualitative Data Analysis

Qualitative data used in this study included student interviews (both the mid-semester conferences and the focus group interview), classroom observations, and various course documents. All of these data sources were analyzed for recurring themes and patterns through the process of content analysis (Patton, 2002). Specific content analysis of each data type is offered as a means of clarification and justification.

Classroom Observations

All of the direct classroom observations were transcribed and subjected to content analysis against data provided by video recordings and my own teacher reflection journal entries. Once transcribed, the notes were categorized into general themes (i.e., positive and negative reactions to alternative teaching strategy). Additional passes through the data created a feedback recursive relationship between the original themes and the final emergent themes.

Interviews

Using the semi-structured interview protocol, student interviews focused on the various experiences of the student throughout the course, reaction to alternative teaching strategies, feelings about the non-traditional activities, and the development of statistical understanding. All student interviews (including focus group interviews) were transcribed word for word using Dragon © dictation software. As previously described, the transcripts were organized into general themes and reviewed multiple times until no additional relationships emerged.

Course Documents

All of the collected course documents as previously described also underwent content analysis and major themes were identified. As with the other data sources, these themes were then grouped into new categories for further analyses. The results included the student's voice describing in great detail their various perspectives and general experiences throughout the course.

Assumptions

1. It was assumed that participants of this study would be traditionally-aged undergraduate students based upon the student demographics of the college.
2. It was assumed that each participant responded honestly and thoughtfully to all self-reflection exercises, conversations and surveys.

Limitations

1. The participants of this study were students enrolled in the statistics course designed for undergraduates that was taught by the author and researcher. The overall findings may not be generalizable to the general population of all undergraduate students as it was a sample of convenience.
2. This study was carried out during a typical spring semester; however a number of the participants participated in school athletics and school organizations. Absences therefore may have impacted individual students.

3. As a non-traditional course, students were reluctant to accept the course design. It took several weeks for students to become comfortable with the non-traditional course design (approximately week 10).
4. The author/researcher of this study had prior experiences with the course; therefore, she brought with her some preconceived notions regarding characteristics of the course design and its impact on students enrolled in the course.
5. The author of this study maintained dual roles: the researcher and the instructor. This dual role required her to be mindful of the perceived threat that students may have had with small group discussions and self-reflection activities. The author had to be aware of this and treat all students without bias.

Summary

The purpose of this chapter was to outline the methodological components such as research design, data collection, and data analysis of student's perspectives of a non-traditional introductory statistics course and the characteristics that contributed to their statistical development. This chapter described the community college setting, the participants and my role as researcher and observer participant. A discussion regarding the reasons and justification of a phenomenological research design was also provided. The focus of this study was to explore the following questions:

1. What are the characteristics of a problem-based college-level statistics course?

2. What are students' perceptions of the characteristics of a non-traditional introductory statistics course?
3. What are students' perceptions of their learning in this non-traditional introductory statistics course?

An overview of the respective data sources, the types of data and data analysis method are provided in Table 5.

Table 5. Data Source and Analysis Method

Research Question	Data Source
Question 1	• Course documents • Course syllabus • Instructor Journal
Question 2	• Videotapes • Field notes • Course documents • Interview transcripts
Question 3	• Videotapes • Field notes • Course documents • Interview transcripts

In the next chapter, Chapter Four, the results of the data analysis are presented followed with a discussion of the findings presented in Chapter Five.

Chapter VI: RESULTS

In this chapter research data assembled from interviews, observations, and course documents will be presented. The qualitative data gathered during this study was used to characterize a non-traditional introductory statistics course, to investigate student approaches to learning and emerging statistics understanding as a result of engaging in various problem-based learning activities within the course. In this chapter, research data will be presented that was used to answer the following research questions:

1. What are the characteristics of a problem-based college-level introductory statistics course?
2. What are students' perceptions of characteristics of a non-traditional introductory statistics course?
3. What are students' perceptions of their learning in this non-traditional introductory statistics course?

In this chapter, three major sections will be presented to answer each of the three research questions. First, the characteristics of the non-traditional introductory statistics course will be described by analyzing the course syllabus and course components as defined by the instructor. Second, qualitative data will be examined to determine the students' perceptions of the characteristics of this non-traditional introductory statistics course. Data collected from student interviews (mid-semester conferences and focus group interviews), instructor journal, and classroom observations will be used to answer this. The third section includes an examination of qualitative data to determine how student learning was impacted by the non-traditional classroom environment. Student interviews (mid-semester conferences and focus group interviews), project reflections, and student journals will be analyzed to describe student perceptions of their learning over the course of this study.

The first section provides characteristics of the course used in this study. The descriptions are presented to provide an overall picture of the non-traditional course design. This section offers descriptions of the course from the perspective of the course instructor who is considered to be a participant observer throughout this study. The second section of this chapter highlights the student's perceptions of the course characteristics. Various forms of student interviews, small focus groups, and reflections were utilized for students to share their thoughts and experiences. Findings in the third section will discuss how students perceived their learning and their opinions regarding the effectiveness of the various components used throughout the course.

Characteristics of a Non-Traditional Introductory Statistics Course

The course examined in this study is a non-traditional introductory statistics course designed for undergraduates and referred to as Elementary Statistics. This introductory level statistics course begins with descriptive statistics in which data analysis and graphical methods, such as dot plots, stem and leaf plots, box plots and histograms, to display and analyze data are investigated. Measurements of central tendency, dispersion, variance, confidence intervals, hypothesis testing and distributions such as normal, chi-square, student and *z*-distributions are some of the inferential statistics topics included within this course. Elementary Statistics (MATH 2193) is the only statistics course offered at the community college involved in this study. It has always been listed as a mathematics course and has routinely been taught by members of the mathematics faculty.

Prior to this study, I have taught one introductory statistics course with similar course topics and a similar timeline. To prepare myself for this course, I carefully reviewed the topics outlined in traditional course syllabus, reviewed the course textbook and instructor resources provided by the publisher and discussed the course with several instructors to get a sense of what goes on in a statistics classroom. I felt fairly confident in my ability to teach an introductory statistics course although my own formal statistics education only included two undergraduate level statistics courses and two graduate level quantitative research courses.

Unlike traditional introductory statistics courses that tend to emphasize mathematical algorithms and statistical formulae, I sought to develop student's statistical literacy through active problem solving and to develop their statistical decision making skills by engaging in data collection and analysis. To achieve this I encouraged and expected students to work together in pairs or small groups while I served as a facilitator. Students were allowed and encouraged to self-select their groups. On occasion group membership changed due to non-attenders or the dynamics of specific class activities. All were encouraged to participate with equal value and authority.

In the beginning, students turned to me for validation instead of working with their peers or challenging their own understanding. This unconventional setting was different from their previous experiences in mathematics classes. Many of the students were uncomfortable and frustrated by the class design and my approaches. Recognizing that students must be willing to negotiate the learning process (Cobb, 2000) I had to carefully ease the students into a shared responsibility of learning and understanding. To accomplish this, I utilized probing questions as suggested by Wheatley (1995) rather than providing answers to the general tasks. Over time, students began exploring their ideas, examining their misconceptions and errors within their groups without me providing any unnecessary validation. The classroom environment transformed into a space rich with conversation, mutually respective discussion and sustained interactions among all the students in the class.

On the first day of class, the course syllabus, required course materials and general expectations of this non-traditional course were discussed. Since this was the only section of Elementary Statistics (MATH 2193) offered, I felt it was important for students to be aware of the non-traditional format of the course from the beginning. The course expectations as stated in the course syllabus included:

> This course is activity based and problem centered in nature. Since learning involves a degree of cognitive dissonance, you should be prepared to be taken out of your comfort zone at times and struggle with ideas. Hence, you should be prepared to work and to think. Throughout the course you will be expected to think deeply, creatively, critically, and support your conclusions with varied forms of evidence, and support our classroom community of learners (See Appendix E).

Students were exposed to problem solving activities on the first day of class. As the community became stronger, the level of difficulty of the activities increased. This was not necessarily intentional by design as much as it was the nature of the course topics. For example, the course begins with the introduction of descriptive statistics (mean, median, and mode). Most of the students knew the computational algorithm to calculate arithmetic mean by adding and dividing. Conceptually, students had difficulty understanding applying the mean in the context of problem solving. This simpleseeming mathematical concept was discussed in a way that many students commented regularly that their previous understandings were poorly constructed (See Appendix F). Further results of student's poor conceptual understanding are presented in this chapter.

A Typical Class

Most class sessions began with me asking for questions pertaining to the homework, previous class activities or questions in general. This was typically followed with a brief review of the course schedule and I made any necessary updates or changes and reminded students of upcoming exam dates as well as any pending due dates for projects. A brief overview of the day's topic related to previous discussions would introduce new concepts to the class. In some class meetings, we would collect data in the class or reference previously collected data to complete an activity or to discuss a simulation. Students would then work within the small group setting to complete the exercises for the day.

As a facilitator, I wanted students to spend most of the class time working within their small groups to explore and discover statistical principles. During this time, I would circulate the classroom, listening to group discussions, answering questions and questioning them about their own reasoning and responses to the activities. The purpose of this design was to engage students in their own learning without the need for external validation. When a common question or misunderstanding arose, I would stop the small groups in order to offer needed clarification, direction or pose alternative questions. This mini-lecture format allowed individuals to voice their questions as well as provide group reflection and discussion. Each class period would end with an overview of the activities and the findings.

Establishing a Supportive and Inspiring Classroom Environment

Research on classroom environment has identified a number of qualities associated with positive learning outcomes (Henningsen & Stein, 1997; McLeod, 1992):

- Supportive relationships among teachers and students
- Student participation in creating classroom norms, making decisions, and setting goals
- Clear expectations and responsibilities
- Opportunities for collaboration
- Adequate time for completing tasks and for discussions
- Opportunities to work on open-ended tasks
- Interesting and meaningful activities

In order to convey the nature of this course my syllabus (See Appendix E) incorporated several of these qualities:

> Consistently demonstrated patterns of commitment, preparation, and quality (of thought, work, and participation) are required to receive an exceptional grade in this class. Emphasis is also placed on your contributions to the development of a healthy and active classroom community. You should contribute your energy to class activities, demonstrate respect for all participants and help ensure that everyone is permitted and encouraged to share equally in class opportunities and responsibilities. Every member of our class is considered to be both a learner and a teacher. You will assume responsibility for both roles.

The first day of class is generally reserved for discussing the syllabus, where students passively gaze at the course documents and anxiously await early dismissal. To establish the importance of group activities, group discussions and to establish a sense of community, students participated in a group activity. According to my observation notes (Instructor notes, 01-13-14), students worked in groups of 3 – 4 to described various ways in which statistics are used to measure daily life (climate, car accidents, class grades, customers at mall, and state lottery), and to define ‘statistics’ in their own words (See Appendix G). Each group was provided with large poster paper and colored markers to record their group responses.

Once in groups, common exchanges such as “What are we supposed to write?” and “What did you write down?” were heard between students. I purposely let the students grapple with the activity for a few minutes. Contrary to the traditional teacher centered model wherein students typically are provided explanations and continual validation that most students have experienced, I wanted to provide students the opportunity to listen to one another, discuss their ideas, and discuss their questions. After a few additional minutes of listening to group discussions, I stopped the activity for a brief group discussion. This also allowed me to actively demonstrate the expectations of group activities and group discussions. I began by stating, “I hear a lot of great discussions and great questions. Use this as an opportunity to question your own ideas. There is no right or wrong answer to the questions in this activity. Discuss your thoughts and ideas with members of your group.” This activity concluded with each group sharing their thoughts and ideas with the entire class. This small group to whole group discussion allowed us to explore how we interacted with statistics on a daily basis and to identify the many purposes of statistics. Additionally, this helped establish a foundation for future discussions.

Establishing an environment that promoted and encouraged student collaboration was an essential element of this non-traditional introductory statistics course. During the first week of this class, I shared my beliefs about teaching and learning mathematics and the basic design of the course with my students: “this course will not be a typical lecture based class…you will actively engage in activities that will provide you the opportunity to share your ideas with one another…my goal is that our experiences together in this class will allow you to apply your problem-solving skills to real-world situations." (Observation notes, 01-15-14).

Analysis of course documents, video tapes, and fieldnotes illustrate my emerging pedagogical perspectives. Prior to and throughout this study, my own teaching has been evolving. Establishing a supporting and inspiring environment is a key component in guiding students toward an interactive and constructivist approach to learning (Stepanek, 2000). Widely accepted in education communities, 'constructivism' is a theory of learning that describes learning as actively constructing one's own knowledge (von Glaserfeld, 1987) and is a guiding theory for much research and reform in mathematics education (Garfield, 1995).

In order to facilitate an interactive approach that was in alignment with constructivist theories of learning, as the instructor I had to ask questions without providing direct answers, ask questions that would help move group discussions through periods of frustration and uncertainly and I also had to balance class time with overall course objectives and my own personal goals for the course. Common questions to solicit student input and participation included "How did you do this problem?", "Walk us through the approach you took", and "Did everyone approach this problem the same way; would anyone like to share what they did?" The purpose of my constant probing was to help students become independent learners and recognize the difference between knowing mathematics with understanding versus memorization (Roth & Roychoudhury, 1994).

Whole Class Discussions

Providing students with opportunities to share ideas, to question their understanding and to find common understandings are essential to learning. As an educator, I prescribe to the belief that knowledge is not constructed in isolation; knowledge is socially constructed. Creating new ideas and negotiating meaning are essential. Throughout this course, whole class discussion was used to communicate emerging ideas during our in-class activities, small group activities and course projects. Implicit in the above statement regarding learning as social construct is the need for communication wherein all members of the class listen and converse with one another about common topics (in this case, mathematics statistics).

Analysis of my instructor journal revealed that students were initially reluctant to speak. As an experienced instructor, this was anticipated. Recognizing that this group of students was more receptive to small group discussion, the use of whole class discussion evolved over a period of time. After some initial time was spent in small groups, whole class discussion was incorporated more and more to share ideas, to create meaning and to provide an emerging class narrative. The classroom community served as a foundation upon which whole class discussion aided students in developing meaningful statistical understanding.

Another emerging benefit of community and whole class discussion was developing student's skills to effectively work together. Aside from developing specific curricula goals, the purpose of education in general is to prepare citizens who can collaborate with others for the benefit of the whole society. Within this course, students were encouraged to work together inside and outside of the classroom. It was important to foster the perspective that working together was an opportunity to learn together rather than competing against one another. Analysis of student journals indicated that although some students never met with other students outside of class to discuss coursework or emerging theories, a majority of students did meet with one another. One student writes, “I meet with others just a couple times in order for both parties to get a better understanding of the subject matter.”

Class-Group Activities

Another key component in guiding students toward an interactive and constructivist approach to learning is as Garfield (1995) suggests; engaging students with the material, working in small groups, and constructing their own knowledge rather than passively listening to lectures. Shaughnessy (1977) and Jones (1991) similarly found that activity-based courses and use of small groups appeared to help students overcome misconceptions. Class-Group activities in this study introduced students to specific statistical concepts by means of hands-on discovery rather than a “drill-and-skill” practice worksheet. Statistical reasoning is an essential component to any statistical course and in order for students to reason, analyze information, make conjectures and make arguments; activities that develop statistical reasoning must be completed in multiple contexts.

At the beginning of class, I would ask the students if anyone had any specific questions related to the homework or previous activity. A short discussion would introduce new material and I would provide each student with the activity exercise. Students were encouraged to form small groups of 3 – 4 members. It was very rare for anyone to opt out of a small group. At times, an activity would begin as a small group only to evolve into a larger group and eventually the results would be discussed as a group. As the activities evolved, whole class discussions were utilized to highlight discoveries, clear up misunderstandings and to answer specific questions concerning the activities.

The following narrative illuminates a class-group activity process within this non-traditional introductory statistics course. This specific activity was used over a period of several days as we applied additional statistical concepts to the data sets (tabulating data, graphical representations, and measures of center, measures of variability, sampling and correctness of assumptions).

Example class activity. The M&M activity, as it became known, began with students independently collecting their own categorical data: the color distribution of regular M&M candies. Each student received a single fun pack of M&M candies, and a data collection sheet (See Appendix H) to record the color distribution. Students were told not to eat them until the activity was over. Analysis of class transcripts and my own observation notes (Observation notes 01-24-14) revealed that some students organized their candies by color prior to counting them while others kept them in a pile and systematically counted the individual candies. As the students completed the data collection, I asked "Did anyone have a full bag of just red M&M's?" Our eyes scanned the room looking for the lucky person with the single bag of red M&M's. No one had a bag containing only red M&M's. I followed up with the question, "Did anyone have a full bag of any single color?" Again the eyes of the room quickly scanned the desktops, heads popped up and some leaned over to see what each person had laid out on the desk tops. No one received a bag consisting of a single color.

To determine what colors were represented students were instructed to inventory their individual bag of M&M candies. Using the provided data recording sheets (See Appendix H), each student used a dot plot to record the number of M&M's by color. As students record their data, I walk around the room to get a sense of the color distribution and to observe students creating their dot plots (a previously discussed topic). Within a few minutes, each student completed their data recording. I ask the question, "Since no one had all reds or all blue, it looks like we all have a mixture of colors." Moving back towards the front of the class, I project my color distribution to the class. "Here is what your distribution should look like." As before, all eyes and heads quickly glance up. Some students are confused by what they see. A few heads look side to side, glancing at their neighbors. Others look up at the screen and back down at their own distributions. A few comments like, "I don't have that", "Wait, I didn't have any blue", and "We don't all have the same" and several others are echoed in the class. I reply, "You mean we all have something different?" One student raises her hand to comment, "I don't care for the red ones, and most of mine are red." Hearing this, another student is quick to reply and points to himself and remarks, "Me, I like the red. I didn't get as many red as you." Soon discussions between neighboring students are heard as students discuss what color M&M's they like the best and what ones they don't like. "It is all chocolate, so I like them all" is heard from the front and a few of the students laugh in agreement.

As student conversations about M&M's and candy in general continue, I bring the focus of the conversation back to their individual data sets. "Okay, so it appears we all have something a bit different. Did anyone think it was possible to receive a bag with just one color in it?" A few heads nod to indicate no, some shrug their shoulders as to suggest unsure, and a few comment; “Not impossible but I wouldn’t expect it”, and “Anything is possible.” In support of the comments and observed non-verbal indicators, I continue by stating, “Yes, of course. Anything is possible, but as suggested, it may not be probable. We will come back to this idea.”

I called upon several students to share their color distribution with the class. One students states, “I have 2 blue, 5 brown, 4 green, 6 orange, 1 red and 1 yellow. I ask, “Why do we all have different distributions of colored M&M’s?” Fairly quickly, the comment, “Because it is all random” is heard from the back and something similar is heard quietly up front. I echoed, “Yes, because it is all random.” Some students are seen shaking their heads to signal agreement and others are seen talking with their neighbor in support of the general consensus.

“Alright, let’s look at our distribution. My dot plots don’t seem to have any shape to them. I didn’t have any yellow candies, so this is simply blank.” From the back, “Oh, so that is what you do. I didn’t have blue” is heard. Students are instructed to look over their own dot plots and make comment about their data with their neighbor. Quickly the groups began discussing their data. Conversations regarding what colors were found to be the most prominent (mode) and the differences between their distributions emerged without formal prompting.

As described by Garfield (1995), students often grapple with the abstract concept of sampling distribution. Within a few minutes, this hands-on activity allowed students to experience and interact with sampling distributions. Some of the students were also using statistical terminology as they described their distribution with their neighbor.

Walking around the room, I stopped the conversations to have the students calculate their M&M color proportions. “So now you need to calculate the proportion for each color. Do we all remember how to calculate a proportion?” A few begin working, others whispered quietly in their groups and some were seen explaining it to their group. “Once you have calculated your individual proportions, we will discuss our findings.” As the calculations were taken place some students were seen utilizing their calculators, and others used their smart phones. I gave students a few minutes to finish their calculations and began discussing my own distribution proportions. “So here are my color distributions. Before I could calculate any specific proportion, what additional calculation did I need to do first?” Some students looked over their activity sheet to determine if any assistance was included. Others grabbed their notes and began to scan them over. I repeat the initial question, “Before we can calculate a proportion, what information do we need?” A few moments passed before one student commented, “Well, I don’t know if what I did is right, but what I did first was add up all the M&M’s and then divided by the number in each color.” Hearing this, others who did something similar also agreed, “Yes, that is what I did” is heard from another student. To clarify the student’s explanation, I asked one of them to give us an example of their calculation. The original student explained, “I have 18 M&M’s and 2 are blue. So I did 2 divided by 18. I got a long decimal.” Although the student calculated the division correctly, his initial explanation was incorrect. To correct this, I replied, “Thank you for that example. To calculate the proportion you divide the categorical frequency by the total number of M&M’s and represent the decimal as a percent. In this example, 0.111

can be expressed as 11.1%." As I was speaking to the class, I wrote out: 2/18 = 0.111 = 11.1%.

After students had completed their proportion calculations I ask a few students to share their findings and I record them for the class to see. The data in Table 6 is an example of a student's proportional data and Table 7 is the M&M color distribution data according to the manufacturer. While displaying the student's color distribution, I show the class my own color distribution. "We established that our samples are random. Take a moment to compare your color distribution with the two that we have recorded here. Do you have any similarities or differences? Take a few minutes to discuss with your neighbor" Once again, students refer to their own data and begin to compare it to the projected class examples. Neighboring students engage in conversation discussing their data and remark "I only had 3 colors all together. This whole bag was mostly blue" and "Yeah, I had a lot of reds but no yellow or orange". To direct the informal conversations toward proportions, I asked the question "So if you add up your individual proportions, what value do expect?" Walking around the room I can see and hear the student conversations center around the notion of having 100%. "Correct, adding each color proportion should equal one-hundred percent, or very close to it."

Table 6. Student M&M Color Proportions

	Proportion
Color	
Blue	11.1%
Brown	27.8%
Green	22.2%
Orange	27.8%
Red	5.6%
Yellow	5.6%

As this activity evolves, students are asked if the candy colors are evenly distributed based upon the data that has been collected. Collectively students compared their own data to the class examples and with their neighbor. To obtain a general consensus from the class, I posed the following questions: “Based on our data collection and analysis, can we determine if the colors are evenly distributed?” and “Can we determine what color is the most common? Do we have enough evidence for a prediction?” Since most of the students are familiar with the M&M candies, most are quick to respond that M&M bags are just random colors. At the front of the room I project the example proportions again (Table 6). “Based upon our data here, and your own collected data, there doesn’t appear to be any specific pattern. Would you all agree?” Students reply in agreement. “Did you know that although the colors are random, some colors are more common?” I project the color distribution of the M&M candies based on the data from manufacturer (Table 7). “Although this data is old, the manufacturer claims the color distribution of M&M’s is not evenly distributed. Let’s compare our data with the percentages that are provided.”

Table 7. M&M Color Distributions

	Proportion
Color	
Blue	24%
Brown	13%
Green	16%
Orange	20%
Red	13%
Yellow	14%

Although the class was rather small, for the sake of time, I only asked for students to report out the total number of blue and brown M&M’s. The data was projected for everyone to see and the calculation proportions were done in a large group setting. Once we determined the class color distribution of blue and brown, students were asked to compare this to their individual color distributions. “So as a class, our blue distribution is 20% compared to 24% and our brown distribution is 8% compared to 13%. For next time, I want you to think about the following questions. Take some time to think about what we did today, your data, our class data and the manufacturer data. Write down some of your thoughts to the following questions: What do you think is contributing to these differences? How do these compare to your individual distributions? Be prepared to discuss your thoughts.”

The data from this activity were used for several additional topics throughout the course. I found that this activity was extremely helpful as we discussed random sampling and the central limit theorem. Students quickly recalled that their individual sample color distributions (dot plots) lacked any formal shape. Our sample data mirrored our small class size. To compensate for this, I provided additional data collected from previous classes. Using the additional data sets, students created three separate plots of the distributions of sample means, one for each sample size. As noted by Garfield (1995), the abstract concept of sampling distribution is often difficult for students to understand but by weaving in this hands-on, self-discovery activity students were enabled to establish statistical formulation for themselves. Additional extensions of this simple activity provided opportunities for students to grapple with distribution, normality, and sample sizes; the influential concepts of the central limit theorem. The M&M activity is referenced as being one of the students’ favorite and most memorable in-class activities.

It is important to note that as this course evolved, outside influences did alter the course design. Student attendance became problematic in this course. As noted by Bers & Smith (1991), attendance patterns at community colleges differ from those typically found within the undergraduate population at traditional colleges and universities in that students attend class less frequently and are late to class more frequently than students at four-year institutions. For example, the class used in this study started at 8:00am and I typically arrived 15 minutes prior in order to set up. It was not uncommon to start class with only two students. Twenty minutes into the class, several others would start to trickle in. Although I planned for students to work activities in small groups, the number of students would often force me to utilize a whole-class design.

When the course transitioned from descriptive statistics to inferential statistics, the students' perceived unpreparedness coupled with continued high absenteeism made small group activities almost impossible. During several class meetings, it was very evident to me that the students were not coming to class prepared to discuss the focus topics although, when asked, they reported having read the textbook. Analysis of homework completion also revealed that most, if not all, of the students were not completing the assignments until the days prior to an exam. The formal assessments during this period of time were in my opinion a direct reflection of students not engaging with the course materials and activities. As a result, fewer small group activities were conducted and I utilized whole-class discussion in an effort to engage the students and attempt to continue through the required course content. Analysis of my own observation notes indicated multiple attempts were made to encourage the students "to read the course textbook" and "work through the assignments regularly" and reminding students that “statistics is more than computations” (Fieldnotes 01-27-14; 04-11-14).

To compensate for the slower pace of the whole-class discussions, I made modifications to the course schedule by adjusting assessment and project dates. The final course project provided an opportunity for students to collaborate in small groups once again. With the project due date and remaining exam occurring at the end of the course, some students attended class more regularly but for others, missing class became routine. Students were asked to comment on how missing class affected their understanding of the course concepts. Student comments are included in Table 8 below.

Table 8. Student Comments Regarding Their Absences

Student	Student’s Remarks
Matt	When you miss class you miss out on the material and with statistics being present in the classroom is a must. Only if you want to pass.
Dee	Missing class has affected it badly.
Robert	I missed class just once for a school activity but I could see where missing classes would greatly affect your understanding. The little that I missed I had to ask you about.
Ashley	Missing class made it hard to catch up and hard to understand.

Projects

Traditional statistics courses emphasize scripted textbook examples that are generally devoid of authentic meaning and require little student interaction with the data. This conventional model often creates students who are incapable of approaching data to form their own conjectures and conclusions. It is important for students to have the opportunity to interact with various forms of data, and to calculate and analyze data sets (Chance & Garfield, 2002). Projects, in this course, provided students with opportunities to see how statistics can be used to answer questions, and promote statistical thinking (Garfield, 1995; Holmes, 1997). Additionally, essential communications skills such as oral presentation, use of technology, and writing can be incorporated within well-developed, cross curricula projects.

Activities were not the only form of problem-based learning opportunities implemented in this course. Students were required to complete three projects in the non-traditional introductory statistics course to allow students additional opportunities to demonstrate their ability to apply various statistical concepts and to demonstrate understanding (See Appendix C). To incorporate the various statistical concepts that were discussed within the class, I staggered three different projects into this course. The projects included: calculating and analyzing case study data, creating, administering and analyzing a survey, and demonstrating an understanding of hypothesis testing.

Each project required the student to apply statistical concepts, statistical reasoning and statistical analysis as outlined in the course topics. However, the main reason I implemented the use of projects was to continue guiding students toward an interactive and engaging approach to learning more in line with constructivist theories about learning. The students that participated in this research study all had significant prior knowledge and all would be restructuring mathematics statistics into their own cognitive frameworks (Garfield, 1995). Permitting students to practice the all too familiar well-defined and flawless textbook type problems would be denying them the opportunity to think critically, analyze authentic data and to develop their own knowledge. To emphasize their importance, the course projects shared the same weight in the course as the exams.

A majority of the students had no previous experience completing projects within a “mathematics” course. Most in fact, voiced concerns, fear and uncertainty about completing the assignment and what the expectations were. These concerns were displayed throughout the course projects. However, at the conclusion of the last project most of the students spoke very favorably about all of the projects and the contributions they made within the context of statistical understanding.

Physician case study. The first several weeks of this course introduced descriptive statistics terms, statistical notations, concepts and different ways to visually represent data sets. Prior to completing the first project, students completed various in-class activities, on-line homework and quizzes, and two exams. The first project, the Physician Case Study (See Appendix F) was introduced within the context of descriptive statistics. This particular project was implemented to involve students in informal inferential reasoning (Adopted from Weiss, 2007). Presented with sample data, students were tasked with making an inference about two unequal populations. Analysis of my instructor journal and observations notes revealed that specific details describing the Physician Case Study were discussed during multiple class meetings. The project information was also posted electronically were all students had access to the case study documents, data set and project outline. On multiple occasions, I raised questions in class to continuously remind students about the project but to also get a sense of their processes as they navigated the assignment.

Since most of the students indicated that they never completed a project in a mathematics class before, I discussed this first project in great detail. Traditional textbook data sets are generally represented in a simple list or table. The case study provided the data set and the researcher's coding. I found this representation to be more authentic and it provided students with an opportunity to understand the additional steps that researchers go through before analyzing data. The 'coding' confused the students (See Appendix F) and more than one conversation took place regarding the purpose of coding. Comments like "What do we do with the zeroes and the ones?" (Fieldnotes 02-03-14), and "Do I use these numbers?" (Fieldnotes 02-12-14) provided an opportunity to discuss 'coding' and its purposes. A topic such as coding is an essential element of research and statistical analysis but it is often not included within an introductory statistics course.

Students were provided with an overview of the case study that included the research questions, and a detailed description of the study protocol. Students were tasked with calculating various descriptive statistics using the supplied data to determine if physician's spent less time with overweight patients compared to time spent with their average weight patients. Additionally, students were required to graphically represent the data and present a final analysis of the data. Assuming the role of a statistician provided an authentic opportunity to solve a real research question. The project allowed me to scaffold previous topics and activities, and connect those to additional topics. Class discussion involved reviewing our previous activities and the insights obtained from those activities. Project reflections also provided opportunities to investigate how they contributed with our overall conceptual development. This reintroduction emphasizes the importance of repetition as student understanding continues to evolve (Hewett, 1999).

Although this first project emphasized relatively simple arithmetic calculations, measures of center (mean and median), and measures of variability (range and standard deviation), my previous experience reminded me of the pervasiveness of the difficulties that students have learning statistical concepts (e.g., the mean). Analysis of student homework, quizzes, and exams revealed that although students were capable of computing a statistic and able to answer test items correctly, they misunderstood basic ideas and concepts. To answer the main question within the case study project, students were required to compare two groups (average weight patients and overweight patients), construct histograms from the frequency distributions they generated, assess the differences and apply statistical thinking to answer the question: “Based upon the results and your interpretations, do physicians discriminate against overweight patients?”

Analysis of previous student homework and assessments suggested that students were capable of calculating mean and standard deviation. Analysis of the student’s Physician Case study revealed that students only relied upon the measures of center and didn’t address the variability in the data. Students failed to address the unequal groups, failed to deal with the extreme data (e.g., data may have been an error) and some failed to adequately compare the two data sets. Although most students adequately sketched the required graphical displays of the data (histograms and boxplots), many had difficulties answering the questions comparing the distributions of data displayed in the histograms and boxplots.

After grading and analyzing the case study project, the whole class reviewed the project in great detail. This allowed me to identify what conceptual difficulties students experienced as they worked through the assignment. Some students reported having difficulties calculating the descriptive statistics with the larger data set (manual calculations and various forms of technology were used by students). Several students felt comfortable enough to share their computational difficulties and this allowed us to discuss different statistical tools that can handle larger data sets (e.g., Excel and SPSS). Although all of the students were competent mathematically and used various forms of current technology (e.g., smart phones, computers, and tablets). I was surprised to hear, "The calculations are still the hardest part for me" and "I just don't understand how to use the calculator." In an effort to reduce their anxiety, I used the classroom computer to demonstrate how I look up how to use the technology when needed. "Since I don't consider myself an expert at Excel, I search for online videos and tutorials to assist me." Although no direct comments were made as I demonstrated this, I believe it was helpful for students to see that is was acceptable to look for help when confronted with uncertainty.

Survey project. The second course project (See Appendix C) was also introduced within the context of descriptive statistics. Analysis of my instructor journal and observations notes revealed that specific details related to the Survey Project were discussed during multiple class meetings. In an effort to help students develop more autonomy as learners, the second project was developed to be more open-ended than the first project. Students selected a topic of interest in which they developed a survey around. As noted by Holmes (1997), allowing students to select a topic enhances student motivation and the opportunity to work with real data instead of flawless textbook examples. The project required students to create survey questions, distribute the survey, analyze the results, write a report about their survey and their findings, and to give an oral presentation.

Due to the various aspects of this project, this project required careful scheduling as it had multiple interconnected components. Over several weeks, multiple in-class activities assisted the students in selecting a topic of interest, narrowing their topic to come up with a general question, writing example survey questions and ways to visually represent the findings of their survey. Analysis of my instructor journal and observation notes revealed that students initially struggled with selecting a topic of interest. Some students voiced this frustration during our class discussions, within email correspondences and in personal conversations with me before or after class. As students progressed through the initial steps of the survey project, there were more requests for specific direction. A common question for example was “How many questions do we need to ask?” Instead of giving a direct answer, I replied “How many questions do you need to answer your question?”

Analysis also revealed that students often needed space for their emerging ideas to evolve. Helping and encouraging students to engage in continued reflection played a crucial role in helping students create effective survey questions to answer their big question. The depth and richness of the student surveys demonstrate the level of ownership that students undertook to complete this project. Oral presentations provided an opportunity for the students to share their project with the class. Each student completed a scoring rubric for each presentation (See Appendix I) in addition to my own feedback. I believe this additional level of peer involvement was beneficial to students.

Students were permitted to self-select their own presentation method. During class discussions, we discussed various applications that could be implemented to represent their data (e.g., Excel, Word, and PowerPoint). All students used some form of technology to present the results of their survey. Although questions regarding technology came up from time to time, I never demonstrated how to use the tools. I encouraged students to look for helpful online videos (e.g., YouTube and Microsoft) for instructions on how to use technology. Taking ownership in this manner promoted the development of becoming more autonomous with little need for external validation. Requiring students to determine their own methods also provided an opportunity for them to recognize that mathematics statistics is not simply done in ‘one way’.

Representing various degree disciplines, student survey topics included a variety of topics, including: adoption, same sex marriage, marijuana use, abortion, and vaccination of livestock. Student analysis of their own data revealed a deep connection developed between the student and the selected topic. Students were enthusiastic about discussing their survey questions, how they selected their sample and how they analyzed their data. Additionally, students were insightful with regard to the statistical concepts that we had discussed leading up to this project.

Wage gap project. This introductory statistics course concluded with the statistical concepts of confidence intervals and hypothesis testing. Based on my own experiences of teaching statistics, students struggle with the conceptual purpose of inferring about a population based upon sample data. A lack of thorough understanding prevents students from interpreting confidence interval estimates, interpreting *p*-values and confidence intervals and interpreting the results of hypothesis testing. In an effort to improve student's understanding of the aforementioned concepts, the third project (See Appendix C) sought to establish a connection between statistics and everyday life.

The Wage Gap Project first introduces students to the wage differences between females and males across multiple careers. Several resources were collected to provide the historical context of the wage gap and to offer multiple perspectives on the issue. Students were provided with the data on the median weekly earnings of full-time wage and salary workers, by gender, for 47 classes of occupations. As with the first project, students were required to compute the five number-summary, draw a box plot for both genders, and compute the mean and standard deviation for both genders. Additionally, students were required to construct their own confidence interval, interpret the interval and perform the *t*-test for paired samples to determine if they agreed or disagreed with the conjecture made about the earnings of women compared to the earnings of men.

The use of whole-class discussion was implemented during this project to assist students through the project. Over several class periods, I would devote time in class to discuss the project, check students' overall progress and discuss specific aspects as needed. For example, we reviewed the five number-summary, and how to utilize the graphing calculator to obtain a box plot. As time allowed, students discussed their progress and overall understanding within small groups on several occasions.

Analysis of my observation notes revealed that most of the students voiced difficulty with the calculations inherent in a paired *t*-test. With such a large data set, some students worked together and utilized their graphing calculators (one would call out the data and the other would enter it). As I continued to identify their challenges, it became clear that the notation itself was a challenge for some of the students. The formula for a paired *t*-test is calculated by means of the following formula:

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2) - (\sum d)^2}{n-1}}}$$

To prepare for the next class meeting, I copied the Wage Gap data into an Excel spreadsheet and created a small group activity (See Appendix J). During class, students paired up to manually work through the computations as I walked the classroom. After student pairs worked together for approximately 25 minutes, I projected the prepared Excel file (Fieldnotes 04-28-14).

The use of this particular project and the development of the activities surrounding the paired *t*-test provided me with more insight into what students knew and could articulate about inference, statistical estimation, significance tests, and *p*-values. This project also provided students with an opportunity to utilize formal statistical inference in way that connected the subject matter to the everyday world and their lives.

Course Characteristics

In order to determine the student perceptions about the characteristics of this non-traditional introductory statistics course, data were examined from student journal prompts, and interviews. From this data, students' perceptions of classroom environment, whole class discussions, class-group activities, and projects were examined. Additionally, the data were analyzed for themes and one theme emerged regarding the students' need for external validation.

Student Perceptions about the Course

At several points during the semester, I purposely reached out to collected informal feedback from the students regarding the established classroom norms and asking for their thoughts about how to improve the evolving classroom structure (Fraser & Fisher, 1986) and to verify if students' perceptions of the classroom were consistent with my own perceptions and intentions (Waxman & Huang, 1996). Analysis of interviews, observations and my instructor journal revealed that participants used words like overwhelming, difficult, hard to adjust to, fast paced and requires a lot of work to describe their experiences. Below are excerpts from journal entries about their early experiences during the course.

Table 9. Students' Early Remarks about Class

Student	Student's Remarks
Jane	I like what we are doing in class better than lecture.
Robert	I enjoy the activities…but I feel like they don't relate with what is on the homework all the time…I need more examples.
Susan	This course has been difficult for me…I have been calculating by hand but since learning how to calculate on my TI-83 I have found it easier…I enjoy the class activities a lot.

During this study, students experienced periods of discomfort as they navigated the course structure. Some of this frustration was by design (to engage with one another so they would develop as more autonomous learners) and at other times this frustration was the nature of the course (analysis emphasis rather than computation emphasis). The excerpts below in Table 10 reveal the frustration some of the students experienced when they did not receive direct answers or step-by-step examples to follow each time.

Table 10. Students' Early Frustration with Class

Student	Student's Remarks
Lynn	I like activities however I wish the problems would be more step by step.
Tyler	So far the activities done in class have been helpful…I am more of a hands-on learning person and I would like to see more examples done in the classroom as opposed to trying to figure them out in the homework.

During my own observations throughout this course, similar comments were overheard frequently. The need for external validation was a common theme throughout the course. Students seemed to have little faith in their own calculations, methods, and analysis. The first activity on day one illustrated their inherent need for external validation may possibly be the way students perceive mathematics in general (See Appendix G). Analysis of the mathematics-autobiography revealed that many used negative emotions to describe their perception of learning mathematics and is described in greater detail later in this chapter.

Classroom Environment

Although students were not asked to comment about the classroom environment specifically, references characterizing the environment as 'comfortable' were made. Two student reflections framed their classroom experiences as "This is the first class that I actually talk with other people in class about my ideas…I am not afraid of being wrong" and "I am not one to shout out an answer during a regular class because that's just not me…if I have questions I know I can talk about them during our group discussion where I am more comfortable." Some comments also suggested that although the environment was "different than any other math class" and "trying to figure this stuff out is overwhelming at times", in class they were "able to compare everything to 'real-life' making it easier to understand."

Whole Class Discussion

To obtain student's perspectives regarding the use of whole class discussions, they were asked to respond to a journal prompt about whole class discussions. The prompt read as follows:

> Most of the class time in this course is taken up by whole class discussion. This replaces the more traditional 'lecture.' Take a few minutes to reflect about this.

During my analysis, I read each response according to whether the response indicated a positive, negative, or neutral feeling about whole class discussion (See Table 11).

Table 11. Students' Positive Remarks about Class

Student	**Student's Remarks**
Michelle	I think class discussion is great and it ensures that everyone in class is on the same page. However, I do enjoy our traditional lecture time but the discussions do enforce material just learned and encourages me to not fear asking questions.
Adam	I enjoy it better because it keeps me focused and I don't lose interest as easy as I do with lectures.
Tina	I liked learning how others felt about what we were doing in class.

Although none of the students expressed negative feelings about whole class discussions, some responses expressed were interpreted as neutral (See Table 12).

Table 12. Students' Neutral Remarks about Class

Student	**Student's Remarks**
Sean	I think it was more helpful than normal lecture.
Robert	I think it is a lot better than traditional lecture.

Dee	I liked it because it made the class time go by faster.

Interviews revealed that for some students, whole class discussions were used as an external validation source and increased understanding. For some students, whole class discussions “helped because many other students had the same questions I did” and “it let us know and see if we were on the right page.” Students also felt that whole class discussions helped “me grasp the concepts more,” “helped in not only doing the work but it helped me learn what I may be doing wrong so I could correct it,” and “they made it easier to understand statistics” instead of “just taking notes in class and listening to the instructor.” Another positive response to whole class discussion involved listening “to get another perspective and hearing others helped me confirm what I may have thought, it helped us learn from each other and build off each other,” and “sometimes I didn’t know exactly how to approach a problem and listening to others around me really helped.”

Group Activities

My observations of group work revealed that students preferred the various group activities over the traditional lecture model that most experienced. Alex for example “enjoyed working in groups and the activities because we were able to put our strategies together and solve the problems”. For Dee, the group activities “were more in depth and they made it easier to grasp the concepts because just doing it on my own and coping notes doesn’t really help me.” Although most students described positive experiences with the group activities, a few struggled with them. Sean stated “They helped and they didn't help. It helped to know I was on the right page about things. But when it came to the homework I wasn't fully confident."

Projects

Most of the students in this study never completed a formal project in a mathematics course prior to enrolling in this problem-based course. Analysis of my observation notes, student journals and interviews revealed that despite the early feelings of anxiety and frustration, all of them revealed positive experiences with the course projects. Analysis of student journals, and interviews revealed more meaningful responses regarding the course projects. A theme that emerged from their journals and interviews was the students' perceptions about achieving a deeper understanding as a result of completing the various projects. Specific student perceptions about their learning and understanding will be provided in the next section of this chapter.

The first project provided students with data collected from a survey. For the second project, students created a survey and collected their own data. Both projects involved data analysis and statistical thinking. Early in the course, one specific journal prompt asked students to describe in their own words what a survey was to them. Several student responses are described below in Table 13.

Table 13. Students' Initial Understanding of Surveys

Student	**Student's Remarks**
Ashely	I understand surveys to be used mostly for polls, performance reviews of people, and statistics such as dropout rates of high school students.
Michelle	Surveys are questions that people ask.
Adam	A survey is a general idea of questions you ask a person to get their thoughts, beliefs, concerns and ideas on a specific topic.
Tyler	Surveys to me are different opinions about how people feel about a specific

	topic. To me, surveys divide different opinions.
Tina	People asking others to come up with their idea on a certain topic.
Dee	I imagine surveys coming from a very large group of people like a medical study.
Robert	Surveys let us understand what people are thinking and it can let us know if we can change something to help people.
Sean	Surveys get information from the public.

At the conclusion of the two projects, students responded to a project follow-up questionnaire (See Appendix K). Sarah commented that she "liked the how the projects introduced statistics and how data is obtained and used on a real-life bases as opposed to just learning the material out of a textbook." Susan indicated that "graphs make explaining what you surveyed so much easier than just having a piece of paper with words." Similarly, Jane's comments suggested that the two projects complimented one another very nicely. She stated "At first it was a great thinking factor for us as we had to figure out how to do everything and think about it all. It [the projects] made me understand the importance of making correct graphs so others can understand the information. I know the right way on how to establish different kinds of graphs with different information. I am glad these projects were brought forth because it showed me new knowledge."

As was done with the first project, students were introduced to the topic of the third project through a journal prompt asking students to describe how they felt about the wage gap (See Appendix L). Several student responses are provided below in Table 14.

Table 14. Students' Initial Understand of the Wage Gap

Student	Student's Remarks
Ashely	I believe that there should be no segregation within wages by what race, sex, or religion you are a part of. Being a woman I am very shocked to find out that there is a major wage gap between the wages of men and the wages of women. I believe that women are just as capable as men are at the majority of jobs. Although there are jobs that women have higher wages than men there just is not that many.
Dee	I feel there should no longer be a wage gap. Women have been in the workforce long enough now to deserve the same pay and respect that men receive in the workforce.
Adam	Considering today's economy and the push for the job rather they be a man or a women. While I have never been a part of a job interview or partaken in the interview process, I don't see myself offering a higher paying job to the man verses the woman but perhaps the higher paying job to the individual who has the higher potential to make the company more money. If the wage gap is based on race or gender then it is clearly absurd, but if the statistics just suggest that without obtaining other information that may have relevance such as work experience or the interview process then the wage gap has little significance.
Matthew	In my personal opinion, I think it wrong for there to be a wage gap between a woman and a man. The pay of a woman will always be lower than a man unless the government finally realizes that a woman can do just as much as a man can.
Rose	As a female, this type of discrimination is very unfair. If a male and female are equally qualified to do the same job, they should be paid the same salary.
Lynn	I feel that a woman is just as capable as a man but I believe that men are built a certain way for certain jobs (more physical jobs). Men are a lot stronger. I think why salaries differ is where you live and what the company can afford to pay you. Cost of living varies in different places.
Robert	I feel in some cases it is right and wrong. Of course we should all have equal rights just like women need to. We do know that women can't do near as much labor work that men can do so that is a disadvantage for women.
Sean	If a woman, or anyone for that matter, is doing a job that is of equal work value to another, there is no doubt that they should receive equal compensation. I believe that it is absolutely ludicrous that in the year 2014, women are still getting paid just a fraction of what men do for equivalent work.

The purpose of having students reflect upon the topic was to expose students to their feelings (biases) prior to their calculations. This also provided an opportunity for us to discuss research biases and the importance of putting aside personal emotions within a statistical context.

The third project was the most challenging for the class as previously described. Despite this, the comments on the project follow-up questionnaire were rather positive. For example, Robert stated “This project was great. Statistics is very confusing to me. I know understand that one can manipulate his or her results if one wanted to do so. More importantly, I see that statistics depends on many variables and changes suddenly.” Matthew noted that “Prior to this project, I was really trying to figure out standard deviation still and all about the hypothesis testing. The project was more realistic compared with online homework stuff. It was just bits of calculations and I was getting confused trying to remember all the different parts.”

How Students Perceive Their Learning

A more in-depth examination of how student’s perceived what and how they were learning was provided through qualitative data collection and analysis. Data analysis was conducted on four journal prompt responses (58 total responses), ten open-ended questionnaires (107 total responses), and one semi-structured interview (15 total interviews).

Self-Perception about Learning Mathematics

Students in this class revealed a variety of different perceptions about themselves as mathematics learners, as suggested by their descriptions of their past relationships with mathematics. Students shared their beliefs and experiences in their mathematics-autobiography and interviews. A student commented in their journal, “Numbers began to have different signs in front of them. Then I couldn’t remember if the sign would carry or not. I didn’t have a teacher that really could explain anything so I would work with myself to find out how it really worked.” Others shared their belief about themselves as mathematicians in their journals:

> Throughout my education in school, math was never my favorite class. Math always seemed to be the most difficult class…to achieve better grades; I would rework problems many times before a test.
>
> Math was never really a strong subject for me during my childhood years...I seemed to struggle with the concepts of math…my feelings toward the importance of math ranked the least on my priority list.
>
> I was always less interested in math…I got through it with lots and lots of repetitive practice.
>
> From the very start, I loved science and English…Math has always given me anxiety.
>
> I have never been a big fan of math…When algebra came around that is when my true hatred on math came around.

One student shared an all too common early mathematics experience, she wrote,

> In grade school we had to do timed multiplication tables. There would be 45 problems and we had 60 seconds to see how many we could do. That stressed me to the max and I became so flustered and nervous I could hardly get any done because I was so worried about how much time I had left.

Another journal entry by the same student written later in the semester provided insight on her conceptual understanding of statistics. She wrote:

> Algebra there is so many formulas and things to remember…I like that in Stats it isn’t all numbers and formulas…I like that there is more to all of it…I feel like the numbers explain things.

Self-perception about Learning Statistics

As previously described, students were not initially comfortable in the non-traditional introductory statistics course. Within the first few class meetings, several students approached me at various times with comments such as “I learn better with lots of in-class examples. Can’t you just come into class and work examples?” Others would claim “I understand it when I am in class, but when I do the homework it doesn’t make sense?” It was difficult at times for students to think independently and to have confidence in their own skills in order to solve problems that required them to analyze rather than just calculate.

Excerpts from student interviews discussing the projects offered some insight. I asked students a series of questions after completing the projects. I offer my interpretation of their perspectives along with representative quotes from two participants in Table 15.

Table 15. Survey Project Student Reflection

Question	**Describe to me what your survey was about.**
Sarah	I did this survey out of pure curiosity to see what people’s stances are on adoption. I surveyed 10 people and asked them 7 questions about adoption.
Dee	I wanted to look at drug trafficking in the United States. My dad’s job deals with this topic and I wanted to learn more about it.
Question	**So you had a curiosity. Were you comfortable asking people about this topic?**
Sarah	Yeah, sure. Everyone agreed that adopting a child is ethical. But at the same time, some of the same people said that putting a child up for adoption was not ethical. Some people said there were reasons for adoption but believed it was the mother’s responsibility to take care of the child.
Dee	With all the information that is constantly leaked to the internet and news media you would think that more people are being informed as to what is going on with drugs being brought from across the border. Having to ask people your questions can be very intimidating. There is a lot of data that has to be translated so people get a better understanding of what was surveyed and the outcome of it.

Question	**Describe to me what your survey was about.**
Question	**How did you select your sample? Would you change your approach?**
Sarah	Mainly I used people I know. The one thing I would have changed is the number of people I asked and I would ask people from different age groups and people who may have been adopted or who have adopted before.
Dee	I asked my neighbors. I think its best when a lot of people are surveyed rather than a few, because you get a better variety of answers.
Question	**How do you think those specific changes would have affected your results?**
Sarah	I would want to get a different variety of people and asking more people would have given way better results. It would be very interesting to see what my results would be if I did them on a larger scale.
Dee	I think it is important to have a lot of people and different people to get different opinions. Like if you only have women, then that will be biased because some women may have a completely different view of something
Question	**Describe your experiences as you completed the various aspects of this project.**
Sarah	I didn't expect to have biases but I noticed that I would catch myself manipulating the question to get the results that I wanted. When I did that I had to say the question again in a non-bias way. This project also taught me how to be more thorough in the collection process. I understand more now how to collect data and how to process the data that has been collected.
Dee	When I collected my data, I found that it was best to categorize the data right then instead of going back and having to sort through each and every response. So I had a check list of the categories and just checked marked it. Then I interpreted my data. I found it helpful to represent my data with graphs instead of just having a piece of paper with words on it. I would have liked to have some of the people recorded on video to that way I could have gotten a true feeling of how they felt answering the questions.

Overall, students effectively demonstrated conceptual understanding regarding the importance of sample size, random samples, process of data collection, investigator biases, and how to graphically represent their data.

The focus group discussion was another part of the course design in which all students were expected to participate in the interviews. To facilitate the focus group format, I had to move around the room and visit each group. Each focus group was audio recorded to capture the authentic discussions. Due to the structure of the focus group, it was difficult to record each group discussion in its entirety. Hence, in its final form, the data obtained from the focus group discussions consisted of four digital audio recordings and one large group recording that occurred after each group completed the final discussion.

The focus group interview completed by students during week 15 focused on students' conceptual understanding of various statistical topics. Within the small group setting, each group was provided with three to four pre-determined discussion points. The focus groups had approximately 10 minutes to discuss the topic and then they would receive additional discussion points. The topics were rotated through the various groups until each group had the opportunity to discuss all of the topics. Although each group discussed the same points, I realized that each student and group may require further probing to uncover their conceptual understanding. The semi-structured format provided the space necessary to address the research questions.

Through the final journal prompt students indicated that the course activities contributed to their understanding of the concepts. Students were asked to comment upon the following statement:

> As a result of this course, the various activities, and numerous discussions, how has your knowledge, insight and reactions towards statistics changed?

Several student reflections about the class are included in Table 16.

Table 16. Final Comments about the Class

Student	Student's Remarks
Ashley	This course wasn't as bad as I thought it was going to be. I enjoyed talking with other students and hearing their ideas as we worked the projects and activities. It was more helpful than normal lectures. I have a better understanding of this course and it was worth taking.
Michelle	All of the activities and class discussions helped me to apply new material to something "real-life" which helped me to remember it (such as the M&M class). Without the discussions it would be easy for one to feel that statistics was impossible at times. I think it was all great and they enforced the material and encouraged me to not fear asking questions.
Adam	All of the group and in-class work we did really helped with learning the material better. In lectures I would lose interest very easily and in this class I was able to stay focused. Talking and working as a group helped me learn the material better.
Tyler	Coming into statistics I was not really even sure what "stats" was. Now I have a different look on the importance of data. I think statistics is a really cool course because you learn how to truly apply math rather than just a bunch of number gibberish.
Tina	I didn't know statistics was so deep. I only thought it was numbers on a page. But now I can see it goes into depth really far. I felt as I learned more from the group activities and projects rather than doing the homework.
Dee	Before I took this class, I didn't know how to do a lot of the equations and formulas. Nothing really made sense and I was just confused about statistics until I took this class. I know have a better understanding of how the calculations are done and what kind of answer to expect. The hands on things that were brought in gave me a better understanding as well.
Robert	Through the great period of time I have spent both in this class as well as working on assignments pertaining to it, I have come to the conclusion that statistics is one of the most if not the most crucial form of mathematics when it comes to business. Prior to this course, I had limited understanding of what statistics was and how much it truly applied to my desired career path but now my eyes have been opened to all of its importance. This course was a refreshing reminder that not all math classes are full of brutal number crunching but instead, some actually target the analytical side of your brain.
Sean	I now have an understanding how the calculations are preformed and the true meaning behind statistics. Before this course I did not even know there was difference between a population and sample. I clearly knew nothing about standard deviation or hypothesis testing, but after taking this course I now

Student	Student's Remarks
	can correlate numbers together and come up with certain statistics that can describe a population. This course has greatly enhanced my understanding of statistics.

Conclusion

This chapter described the characteristics of a non-traditional introductory statistics course and student perspectives about these characteristics. This chapter also addressed how students perceived what and how they were learning in a non-traditional introductory statistics course. The traditional teacher centered classroom was reconfigured to promote and encourage an interactive and constructivist approach to learning. Through the various course activities and projects, students experienced an introductory statistics course that emphasized conceptual understanding rather than mathematical formulae and computations. Qualitative analysis of the characteristics of this non-traditional introductory statistics course revealed that whole class discussion was the prominent characteristics of the course fueled by group activities, and course projects. I viewed my role as the course facilitator and assumed responsibility of directing classroom discussions and various class activities.

In order to explore student perceptions about the characteristics of this non-traditional introductory statistics course, qualitative data were examined. Analysis of data collected through journal prompts, and semi-structured interviews indicated that participants were initially frustrated by the course, but found the positive learning environment and learning experiences contributed to their overall understanding of statistical concepts. A majority of the participants found group activities to be helpful in the development of their statistical development. All of the participants believed that the course projects helped to strengthen their understanding of various statistical concepts and this non-traditional introductory statistics course had a positive influence on developing their statistical reasoning and understanding.

In the next chapter, I will summarize my findings, discuss the limitations of the study, and discuss the implications of the study's findings for alternative pedagogies for post-secondary mathematics education along with recommendations for future research.

Chapter V: CONCLUSION

> We must avoid giving students the illusion that by passing the tests we have now and obtaining good grades they are somehow prepared for the future. This illusion is fallacious and a denial of social justice. -Ubiratan D'Ambrosio (2012, p.16)

Overview of the Study

The aforementioned statement not only serves as a challenge for all educators, but has served as a constant source of reflection and has helped guide me during this research study, which was conducted to investigate the characteristics of a non-traditional introductory statistics course and student's perceptions regarding these characteristics. Additionally, this study examined how students responded to the non-traditional classroom and their experiences during the course. I set out to create an active-learning college classroom in which the environment was anchored by the sense of community, where communication was encouraged, and where time and space for students to engage with one another helped facilitate statistical understanding. This study employed qualitative data collection and analysis. A variety of course documents, semi-structured interviews and video recordings of class discussions and activities were analyzed to provide an intimate indication of student perceptions and experiences. Analyses of the qualitative data were used to answer the following research questions:

1. What are the characteristics of a problem-based college-level statistics course?
2. What are students' perceptions of the characteristics of a non-traditional introductory statistics course?
3. What are students' perceptions of their learning in this non-traditional introductory statistics course?

The participants in this study were sixteen undergraduate students who self-enrolled in the introductory statistics course offered during the Spring 2014 semester. As part of the normal course expectations, students completed curricular items that included in-class journals, course projects and assessments. Additionally, mid-semester conferences, focused group interviews and observations were collected and analyzed to determine the characteristics of the course, student perceptions of those characteristics, and how student understanding was impacted by the non-traditional classroom environment.

In this chapter, I offer a discussion of my findings and the implications of how this study contributes to the existing body of knowledge in the context of teaching and learning statistics. A summary of this study's limitations and concerns are presented as well.

Characteristics of a Non-Traditional Introductory Statistics Course

The first two research questions of this study explored the characteristics of a non-traditional introductory statistics course designed for undergraduate students and their perceptions of these characteristics. This course was considered non-traditional in the sense that it did not follow the teacher-centered, lecture model found in most college level mathematics and statistics courses. It would be difficult to reproduce or replicate this course by simply adopting the course text and implementing the activities described within this study. It requires creating an environment that questions and defies the very definitions of teaching and learning. The creation of an active-learning environment fueled by the continuous collaboration of all members of the class was an essential element of this course.

My role in this course was that of a facilitator rather than authoritarian. From this perspective, I supported the learning of all students by carefully selecting appropriate tasks, asking more questions rather than providing answers to them, and listening more than speaking. As this course evolved, students were urged and encouraged to become their own authority through a variety of problems, activities and projects. In light of these approaches, I valued and encouraged autonomous thinking, and supported the construction of new knowledge with meaningful connections to student's prior knowledge. My pedagogical approach in this course was consistent with the recommendations of American Mathematical Association of Two-Year Colleges (AMATYC) *Beyond Crossroad*s, and previously mentioned visions of teaching statistics (e.g., GAISE and NCTM). For example, the standards for instructional strategies outlined by AMATYC state that mathematics faculty will:

- Model the use of appropriate technology so that students can benefit from the opportunities technology presents as a medium of instruction;
- Foster interactive learning through student writing, reading, speaking, and collaborative activities so that students can learn to work effectively in groups and communicate both orally and in writing;
- Actively involve students in meaningful problems that build upon their experiences, focus on broad themes, and build connections within and between other disciplines;
- Use multiple strategies, such as interactive learning, presentations, guided discovery, teaching through questioning, and collaborative learning;

- Provide learning activities, including projects and apprenticeships, that promote independent thinking and require sustained effort (2006, p. 6).

The aim of this course was to create and develop an active learning environment that encouraged students to discuss, discover and experience various statistical concepts, and aid in developing statistical literacy. One essential feature of the learning environment of this course was whole class discussions. Student learning opportunities were maximized as a result of creating a learning environment that required active involvement from every member of the class. The whole class discussion framework provided a structure for students to participate in statistical discourse. This purposeful structuring involved establishing the classroom routine, creating the physical space, lesson planning and structuring time for effective discussions to emerge (Lamberg, 2013).

Whole class discussions anchored daily activities and student projects promoted a collaborative learning environment. This form of communication is characterized by Steffe & Gale (1995) as constructivist conversation. As students engage in the process of working together and constructing meaning, their learning deepens and their level of engagement improves. As this course evolved, students learned to communicate and negotiate meaning with one another as active participants rather than passive listeners. This evolution was not instant and it did create phases of disequilibrium for most of the students in this course. As a result, tasks were carefully chosen to encourage students to work together and for them to explore their own understanding. The uses of whole class discussion infused with the established sense of community permitted students to (re)construct and communicate their understanding in a variety of ways.

Student Perceptions

The student perceptions of participating and learning in this non-traditional introductory statistics course were explored. The results of the data analysis provided a description of how the students felt about these characteristics including whole class discussion, in-class activities, projects, and the classroom environment. Overall, students considered whole class discussions, in-class activities, and course projects to be beneficial. Students also reported that these components contributed to their understanding of statistical concepts and were a useful part of the class. While most of the students indicated some level of uncertainty and general frustration in the early weeks of the semester, they developed confidence to engage in statistical thinking and analysis as the course evolved. For example, reflecting about the survey project one student commented, “I was really frustrated at first. I wanted a list of just examples so I could get a feel for good ideas. Now that I have finished this project, I can say it has enhanced my understanding of the concepts and allowed me to make connections with what we did earlier in class and relate it to what we learned in class and the true purpose and meaning behind the survey and data collection.” Additionally, students felt that the active learning environment was more enjoyable than the traditional lecture model. The learning environment that was developed as part of this non-traditional introductory statistics course, as described by participants, aligns with the learning environment that emphasizes autonomous learning as illustrated in *Beyond Crossroads* (AMATYC, 2006).

This course design also caused students to confront their preconceived notions regarding their role as learners and my role as the teacher. Although each student came to this class with unique learning experiences and certain levels of prior knowledge, most students expected class time to consist of copying examples. As previously described, students were accustomed to the traditional lecture wherein my role would involve showing multiple example problems and the homework would include some variation of the problems completed in class. For example, early comments from students revealed that although they enjoyed engaging in the curricular routines of the class, there was a strong request for more step-by-step examples to be completed in class opposed to having them struggle through the homework. Overall their reliance on external validation for some things did diminish as the course evolved and was evident in their confidence and demonstrated within the course projects.

The student survey project, for example, required the students to address their own interests rather than being told what topic to address and what questions to include. The restrictive nature of previous learning experiences was difficult for students to overcome. Despite their initial anxiety, frustration, reluctance and fear, the students came away with a deeper understanding of statistical concepts, social issues relevant to them specifically and the inherent relationship between the two. Additionally, students felt that the active-learning environment of this course positively contributed to their learning and improved their confidence. Many described the impact of this course as if learning and understanding familiar concepts for the first time. The experiences they encountered allowed them to delve beyond meaningless formulae and memorization to a place of formulated conjectures and meaningful understanding. In doing so, students recognized the impact of opinion and emotion within the context of statistical biases and the inherent importance of understanding statistical concepts.

During this course, multiple interrelated systems interacted and competed with one another creating the perfect storm if you will. As the instructor, I had specific curricular obligations to adhere to. At the same time, I challenged myself to focus on my personal goals for each student: to leave the course with some level of statistical understanding that would prepare them for civic life and the responsibilities of being an informed citizen. From the student perspective, this course was seen as a degree requirement rather than an opportunity to develop skills necessary to understand complex systems represented by data. As with any course, students had perceptions about their own knowledge, abilities and feelings about the subject matter. The curricular routines of this course challenged and transformed those perspectives.

Implications for Practice

The results of this study offer important suggestions for PK-12 and post-secondary mathematics and statistics educators. The results of this study reveals first, that characteristics of this non-traditional introductory statistics course were consistent with the recommendations supported and outlined by the American Mathematical Association of Two-Year Colleges (AMATYC, 2006) and the Guidelines for Assessment and Instruction in Statistics Education (GAISE, 2012). Consequently, it is possible to design and implement undergraduate statistics courses that abide by the reform recommendations outlined by AMATYC (2006) and GAISE (2012). Additionally, the results of this study suggest that adopting such an approach has the potential to positively affect the teaching and learning of that course for the instructor and the students. As pointed out in the GAISE College Report (2012), “teachers of statistics should rely much less on lecturing and much more on alternatives such as projects, lab exercises, and group problem-solving and discussion activities" (p. 9). Despite the persuasive evidence in cognitive science and education research, too many college-level students still experience lecture-based forms of instruction in mathematics and statistics courses. As noted by Laursen, Hassi, Kogan, and Weston (2014), this failure limits the advancement of undergraduate mathematics education. Therefore, if steps are not taken to provide instructors with professional development opportunities and resources to implement in their own classes, the teaching and learning of statistics will remain stagnate and efforts for reform will be ideals of dreamers. It is then incumbent upon members of our profession to disseminate education and cognitive research and model the pedagogical strategies that support cognitive construction and align with the reform movements set forth by AMATYC (2006), GAISE (2012), and NCTM (2000).

Secondly, it would be difficult to reproduce or replicate this course by simply adopting the course text and implementing the activities described within this study. The creation of an active-learning environment fueled by the continuous collaboration of all members of the class was an essential element of this course. Standards for pedagogy as outlined by AMATYC (2012) emphasize understanding as opposed to memorizing procedures. Additionally significant is that "knowledge cannot be 'given' to students" (p. 6) and that "students should construct their own knowledge, and monitor and guide their own learning and thinking" (p. 6). To facilitate this, I had to carefully select tasks that would foster student's statistical development both orally and in writing, build upon prior experiences and knowledge and connect to other disciplines, and select projects that promoted independent thinking. These standards aligned with and complimented the GAISE (2012) recommendations previously mentioned.

Third, the student perceptions regarding the characteristics of this course revealed that the restrictive nature of the traditional lecture-based model hinders our student's autonomous development. As mathematics educators, one of our goals is to develop our student's problem solving skills. Mathematicians and statisticians are efficient, independent problem solvers because they have years of experience and developed skill sets that allow them to reason multiple possibilities before selecting an approach. For students, mathematics and or statistics is most frequently experienced through series of computational procedures and memorized formulae because teachers routinely prevent intellectual development by demonstrating examples. The student perspectives in this study revealed that despite their initial need for external validation and request for step-by-step examples, they eventually grew more confident in their own knowledge and confident to try multiple approaches in order to obtain a reasonable explanation. In order to facilitate my student's autonomy, I purposefully selected problems that required persistence. In addition, I provided opportunities for students to collaborate with one other to experience multiple problem-solving approaches to increase their self-confidence. The use of multiple approaches to solving problems was also demonstrated by members of the class to illustrate that the focus is not the solution, but rather the processes. The results of this study have implications for future research on student autonomy in relation to traditional and non-traditional mathematics or statistics courses.

An important feature of this course was the projects designed to engage students in meaningful statistical understanding and help them develop as more autonomous learners. Prior research reveals that in order to engage students in meaningful problem solving the problem's contexts should be meaningful to the learner (Reynolds, 2010, Trowell & Wheatley, 2010). As such, a recently developed area in mathematics education focused on social justice holds tremendous promise for engaging students in the kind of learning that was the aim of the course in this study.

Over the last two decades there has been an increase in research connecting mathematics education with society and concerns for equity, social justice and democracy (Skovsmose & Valero, 2005). Historically, research within mathematics education has focused more on cognition than the sociocultural contexts mentioned (Gutstein, 2003, Lester, 1994). However, researchers have been investigating the ways pedagogies relate to social situations; whether they are reflected, resisted, reinforced, reinscribed, or recapitulated (Popkewitz & Fendler, 1999).

Teaching mathematics for social justice (TMfSJ) extends the aforementioned problem solving standards within NCTM's policy documents (1989, 1989, 1991, 2000, and 2009) and the AMATYC standards (1995). By incorporating activities specifically around issues of social and political justice, students use mathematics to understand their world and propose social change (Stinson & Wagner, 2012). The research and literature suggests that TMfSJ extends students' knowledge of mathematics, and they begin to view mathematics as a part of their lives (Frankenstein, 2012, Gutstein & Peterson, 2006, Gutstein, 2006, Stocker, 2007). According to Gutstein (2006), the fundamental purpose for teaching mathematics for social justice should serve the purpose of “liberation from oppression” (p. 22). As such, this aligns with the goal that mathematics education should give people some understanding of the complex, often hidden, roles that mathematics plays in the society (Ernest, 1991). Educational classrooms that promote passive learning only serve to perpetuate the unequal social construction of society. Apple has expressed his opinion on this matter:

> It is unfortunate but true that there is not a long tradition within the mainstream of mathematics education of both critically and rigorously examining the connections between mathematics as an area of study and the larger relations of unequal economic, political, and cultural power. The relationships between three aspects; mathematics as a discipline, mathematics as a school subject, and mathematics as a part of people’s lives need serious analysis. To promote their vision of what mathematics education should be for; mathematics educators need to engage politically. (2000, p. 243)

When students raise their critical curiosities, political awareness, democratic participation and intellectual scrutiny, they are able to participate in activism (Ardizzone, 2007). Gutstein (2012) states:

> The mathematics makes sense to students. They understand why we study it because it helps shed light on real issues of meaning to young people. And they learn the mathematics because they want to change the situation and just make it through the gates. We cannot know whether my students would have learned more-or-less mathematics had they never taken my classes. But I can say that they learned mathematics and about their worlds. (2012, p.71)

This sentiment was evident in the Wage Gap project. Students were initially introduced to the concept of a "wage gap" through whole group discussion. Their initial reactions regarding the "wage gap" were recorded (See Table 14). As students navigated through the project they utilized various statistical concepts and statistical analysis. Additionally, students used the data and their statistical understanding to question their world and make sense of problems within society.

As previously noted, incorporating activities specifically around issues of social and political justice, students use mathematics to understand their world and propose social change. Student's extended upon their evolving statistical development as they viewed and engaged with statistics as a part of their lives. Social justice mathematics in a problem solving environment holds the promise and possibility for engaging students and instructors in important questions about what is mathematics and what it means to learn mathematics.

Implications for Future Research

Improving undergraduate education in mathematics and statistics education has been and continues to be an important area of research. Although this study provides additional contextual information related to the teaching and learning of introductory statistics, the body of statistics education literature is somewhat devoid of studies related to exploring student's experiences in a concept-based statistics course. As a mathematics educator, I believe that understanding how students react to and experience pedagogical changes contributes to understanding student learning about the subject area. Additionally, pedagogical changes alter the role of the instructor thereby presenting parallel challenges. Further research recommendations based on findings from this study leads to the following possible investigations:

- Additional studies should be conducted that involve perspectives of the instructor in a traditional lecture-based course versus a non-traditional course (e.g., Marchionda, Bateiha, and Autin (2014); National Center for Education Statistics (2011); Reeder, Cassel, Reynolds and Fleener (2006); Wagener, Speer, and Rossa (2007)).
- Results of this study suggest that future research should be conducted to explore the relationship of a non-traditional mathematics course and student achievement.
- Additional studies should be conducted that involve problem solving research in college level mathematics and statistics courses (e.g., Abdullah, Tarmizi, and Abu (2010); Ahlfeldt, Mehta and Sellnow (2005)).
- Additional studies should be conducted that incorporate social justice within undergraduate level mathematics and statistics courses (e.g., Gutstein (2003); McLeman and Piert (2013); Stinson, Bidwell, and Powell (2012)).

Limitations of the Study

A phenomenological research study is according to Lester "effective at highlighting the experiences and perceptions of individuals from their own perspectives" (1999, p. 1). From a research perspective, the intent of this study was to describe the phenomena through the perceptions of the participants, including the researcher participant. Since the experiences and perceptions of undergraduate students related to a non-traditional statistics class are devoid in the current literature, this study provides insight into a new realm of further research. However, this study is limited with respect to design, scope, implementation and individual student perceptions and experiences.

Although phenomenological research is not concerned with sample size, the sample selected for this study was not intended to offer generalizations that would apply to the undergraduate population enrolled in an introductory statistics course. It is worth noting that although students self-selected to enroll in this section of introductory statistics, no other section was offered during the semester in which the research was conducted. Although I was consciously aware of my dual role as teacher/researcher, the use of a phenomenological analysis introduces some level of general limitation and interpretation. It is plausible to expect different interpretations of the same data by another researcher leading to alternative results and conclusions.

Concluding Comments

The effectiveness of research-based, student-centered instructional approaches has failed to reach the front lines of the college classroom. As noted by Laursen, Hassi, Kogan, and Weston (2014), this failure limits the advancement of undergraduate mathematics education. As noted within this study, the awareness of reform documents in statistics education (i.e., GAISE) by mathematics and statistics educators is essential for reform to occur. Additionally, this study also provokes the questions of what qualitative understanding and thinking do our students need today to be effective citizens in our democracy. Most of our students will encounter just one course devoted to the discipline of statistics. In the current ever changing data rich environment, we must prepare our students for a life of learning rather than for simple completion of our course objectives. Depriving our students of the opportunities to develop essential problem-solving, critical thinking and reasoning skills undermines the future of democracy for us all. Gal & Garfield embraces this importance by stating:

> It is essential that we continue to jointly pursue improvements in current methods of assessment (statistical) in order to ascertain that all students can function effectively as citizens and workers in an information-laden, statically orientated society. (1997, p. 13)

With this study, I sought to add to the knowledge base of the teaching and learning of introductory statistics concepts by capturing and analyzing student perspectives and experiences. In doing so, I had to come to terms with the former student within me, the current teacher I am today and the teacher I hope to be in the future. Expanding upon this area of research may help mathematics and statistics educators bridge the gap between curricular goals and effective citizenship.

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APPENDIX A

Interview Protocol

Date of Interview

Participant #

Location of Interview

Time

I am going to ask you a few general questions. The point of this interview is to capture your experiences. Do not worry about being perceived as providing a right or wrong response. As we discuss the questions, I may have follow up questions based upon your responses.

1. In your own words, define *statistics*.
2. How would you describe this course to another student or friend?
3. During this course we have used a variety of hands-on activities and small-groups; describe your experiences.
4. Describe what you find to be the most enjoyable aspect of the course so far?
5. Describe what you find to be the least enjoyable aspect of the course so far?

APPENDIX B

Example Journal Prompt

In-Class Journal **Name: __________________**
Introductory Statistics
Spring 2014

Answer the following questions to the best of your ability. Please remember that in-class journals are **individual** assignments.

1. A researcher is interested in the percentage of New York traffic fatalities that involve alcohol. In a sample of 140 NY traffic fatalities, the researcher found that 55% involved alcohol. Identify each of the following:

a. Population	b. Sample
c. The variable in this study	d. Is the variable *categorical* or *quantitative*?

2. Identify each of the following variables as *categorical* (C) or *Quantitative* (Q).

a. the temperature in the classroom______________________

b. whether you own an iPhone or not____________________

c. the price of tea in China____________________________

d. the ACT Math score of the person sitting next to you______

e. the winner team of next year's Super Bowl______________

f. the number of friends on your Facebook page_____________

g. your zip code______________________________________

h. your credit card balance______________________________

i. the age of your car___________________________________

j. the model of your car_________________________________

3. For each of the following, indicate whether an *experiment* or an *observation study* is described.

a. To examine whether eating brown rice effects metabolism, we ask a random sample of people whether they eat brown rice and we also measure their metabolism rate.

b. To examine whether playing music in a store increases the amount customers spend, we randomly assign some stores to play music and some to stay silent and compare the average amount spend by customers.

c. To examine whether farm-grown salmon contain more omega-3 oils, and if the water is more acidic, we collect samples of salmon from multiple fish farms to see if the two variables are related.

APPENDIX C

Project Descriptions

Elementary Statistics

Course Projects

As noted in the syllabus and course outline, there are three projects to complete during this course. Additional information will be provided when the projects are formally introduced during the course. Course projects are 25% of your overall grade in this course.

Physician Case Study

This project provides data collected during a research study that was attempting to determine whether or not physicians spent more or less time with overweight patients compared to the time spent with average weight patients. You will be required to calculate various descriptive statistics using the data collected during the study. Additionally, you will analyze the data to make a conjecture based upon your results and interpretation.

Survey Project

This project will require you to create, administer and analyze a statistical survey. You will present the results of your survey to the class through a formal presentation and a written report. You will select a topic of interest and select your own participants. The various phases of this project will be implemented over several weeks and implement the very concepts discussed in the course.

Wage Gap Project

This project will require you to review data, analyze and make a conjecture based upon your interpretation and results. You will be required to calculate various descriptive statistics using the data collected during the study and use statistical tests to compare the two groups. Additionally, you will analyze the data to make a conjecture based upon your results and interpretation.

APPENDIX D

IRB Approval

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Approval of Initial Submission – Expedited Review – AP01

Date: February 17, 2014

IRB#: 3855

Principal Investigator: Rachel Mary Bates

Approval Date: 02/14/2014

Expiration Date: 01/31/2015

Study Title: A Phenomenological Exploration of Problem Based Learning among College Level Mathematics Students

Expedited Category: 6 & 7

Collection/Use of PHI: No

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. To view the documents approved for this submission, open this study from the *My Studies* option, go to *Submission History*, go to *Completed Submissions* tab and then click the *Details* icon.

As principal investigator of this research study, you are responsible to:

- Conduct the research study in a manner consistent with the requirements of the IRB and federal regulations 45 CFR 46.
- Obtain informed consent and research privacy authorization using the currently approved, stamped forms and retain all original, signed forms, if applicable.
- Request approval from the IRB prior to implementing any/all modifications.
- Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB policy.
- Maintain accurate and complete study records for evaluation by the HRPP Quality Improvement Program and, if applicable, inspection by regulatory agencies and/or the study sponsor.
- Promptly submit continuing review documents to the IRB upon notification approximately 60 days prior to the expiration date indicated above.
- Submit a final closure report at the completion of the project.

If you have questions about this notification or using iRIS, contact the IRB @ 405-325-8110 or irb@ou.edu.

Cordially,

Lara Mayeux

Lara Mayeux, Ph.D.
Chair, Institutional Review Board

APPENDIX E

Syllabus

Elementary Statistics

COURSE DESCRIPTION: This course covers the basic concepts of statistics and includes probability, Normal, Chi-Square, Student and Z distributions. Measurements of central tendency, dispersion and variance are covered along with confidence limits and testing of hypotheses.

RATIONALE: Many disciplines require mathematical credit or a proficiency in Elementary Statistics. The need for the knowledge of math in average jobs has dramatically increased in the last few years due to our high tech society. Elementary Statistics attempts to fulfill the increased need for this mathematical knowledge.

PREREQUISITES: Completion of Math 1513 (College Algebra).

NEXT COURSE: Trigonometry or Calculus I for science/technology majors.

TEXTBOOK AND MATERIALS:

A. Textbook: ***Elementary Statistics: Picturing the World***, 5th Edition by Larson and Faber, Prentice Hall 2012. Purchasing a physical textbook is recommended.
B. MyMathLab student access code is required. See Course Blackboard.
C. A graphing calculator is required for College Algebra. Acceptable models include Texas Instruments (TI)-83+, TI-84+ or TI-86.
D. Calculators with College Algebra systems are not allowed during tests. This includes but is not limited to the TI-89, TI-92, and Casio Algebra FX 2.

COURSE EXPECTATIONS

This course is activity based and problem centered in nature. Since learning involves a degree of cognitive dissonance, you should be prepared to be taken out of your comfort zone at times and struggle with ideas. Hence, you should be prepared to work and to think. Throughout the course you will be expected to think deeply, creatively, critically, and support your conclusions with varied forms of evidence, and support our classroom community of learners.

Consistently demonstrated patterns of commitment, preparation, and quality (of thought, work, and participation) are required to receive an exceptional grade in this class. Emphasis is also placed on your contributions to the development of a healthy and active classroom community. Thus, you should contribute your energy to class activities, demonstrate respect for all participants and help ensure that everyone is permitted and encouraged to share equally in class opportunities and responsibilities. Every member of our class is considered to be both a learner and a teacher. You will need to assume responsibility for both roles.

A major responsibility, both as a learner and a teacher, is to attend class regularly, arrive on time, stay for the duration of the class, and prepare by studying all materials and completing all assignments carefully and on time. It is ***extremely*** unlikely that you will earn an “A” for this course if you miss more than five classes for any reason, or a “B” if you miss more than ten classes. Please note that even perfect attendance does not guarantee an “A” or “B.”

ATTENDANCE: Attendance in this class is essential for success. Math is a participation subject. You must be present to participate. Failure to attend class regularly will result in poor performance. If you miss two consecutive class periods during the entire semester or have sporadic attendance, these absences will be reported to the office of the Vice-President for Student Services. A student is considered absent if the roll has been called and the student is not present; or if the student leaves before the completion of class. One (1) point will be deducted from a student’s total earned points for each unexcused absence. ***Nonattendance of class does not mean that the student has dropped the course. Students must drop the course by obtaining and processing the correct paperwork.***

PREPARATION & QUALITY PARTICIPATION IN CLASSROOM ACTIVITIES:
Class participation is a qualitative judgment of your preparation, intellectual curiosity and articulation of mathematical ideas and concepts as well as a quantitative assessment of class attendance. Throughout the course you will be expected to think deeply, creatively, support your conclusions with varied forms of evidence, and support our classroom community. Your contribution to the development of a healthy and active classroom community is essential. Every member of our class is considered both a learner and a teacher, and you will need to assume the responsibility for both roles. Thus, you should engage in class activities and conversations, contribute to collaborative learning activities in a meaningful, professional way, demonstrate respect for all participants, and help ensure that everyone is permitted and encouraged to share equally in class opportunities and responsibilities.

APPENDIX F

Physician Case Study Project

Background

Currently, almost one in every two Americans is overweight and one in every five is obese. These individuals face discrimination on a daily basis in employment, education, and relationship contexts. They are viewed as having a physical, moral and emotional impairment and there is a tendency for others to hold them responsible for their condition. Physicians -- people who are trained to treat all their patients warmly and have access to literature suggesting uncontrollable and hereditary aspects of obesity -- also believe obese individuals are undisciplined and suffer from controllability issues. The current research, conducted by Mikki Hebl and Jingping Xu, examines physicians' treatment of obesity in their patients more systematically by extending past research to look at physicians' behavioral intentions as well as their expressed attitudes toward male and female patients who are of average weight, overweight, or obese. Although past studies tend to compare only overweight and average-weight individuals, this study provides a novel look at multiple increments of overweight by including both overweight and obese patients. However, to simplify the presentation of this case study, only the average and overweight conditions will be presented.

Experimental Design

A total of 122 primary care physicians affiliated with one of three major hospitals in the Texas Medical Center of Houston participated in the study. These physicians were sent a packet containing a medical chart similar to the one they view upon seeing a patient. This chart portrayed a patient who was displaying symptoms of a migraine headache but was otherwise healthy. Two variables (the gender and the weight of the patient) were manipulated across six different versions of the medical charts. The weight of the patient, described in terms of Body Mass Index (BMI), was average (BMI = 23), overweight (BMI = 30), or obese (BMI = 36). Physicians were randomly assigned to receive one of the six charts, were asked to look over the chart carefully, and then complete two medical forms. The first form asked physicians which of 42 tests that they would recommend giving to the patient. The second form asked physicians to indicate how much time they believed they would spend with the patient, and to describe the reactions that they would have toward this patient.

In this presentation, only the question on how much time the physicians believed they would spend with the patient is analyzed. Although three patient weight conditions were used in the study (average, overweight, and obese) only the average and overweight conditions will be analyzed. Therefore, there are two levels of patient weight (average and overweight) and one dependent variable (time spent).

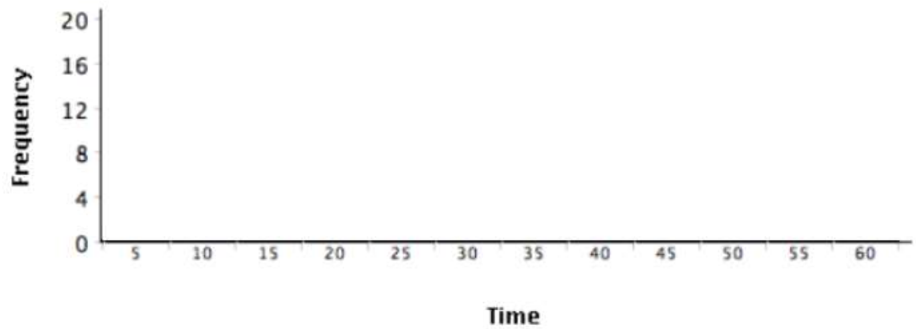
Descriptive Statistics

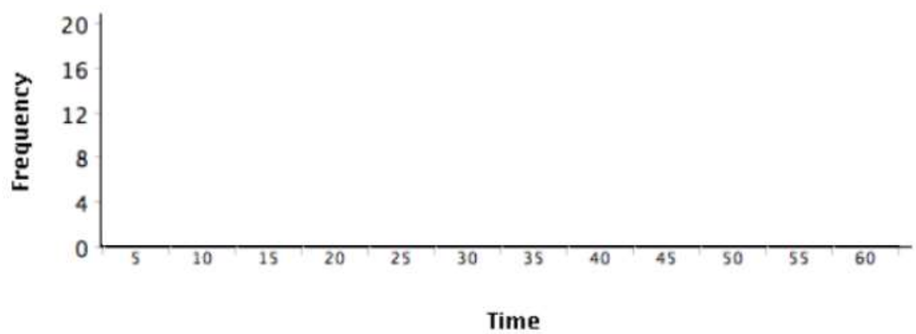
Using the provided data, calculate the basic descriptive statistics (you can use a TI-83/84).

Statistic	Average Weight Patient	Overweight Patient
Sample size:		
Mean:		
Median:		
25^{th} percentile:		
75^{th} percentile:		
Standard deviation:		

What is the approximate difference between the means (how many standard deviations)?

Using the provided data, construct two histograms, one that shows the time expected to be spent with the average-weight patient and one that shows the time expected to be spent with the overweight patient.





Using the provided data, construct (2) 5-number summaries that compare the time expected to be spent with the average-weight and the overweight patients (you can use a TI-83/84).

The expected time spent was generally higher for which group?

What was the highest expected time (identify the group as well)?

Approximately what proportion of the average weight patients had higher times than the median for the overweight patient?

Based upon the results (your interpretation): Do physicians discriminate against overweight patients?

Av. Weight Data		Overweight Data	
1	15	**2**	20
1	15	**2**	30
1	45	**2**	30
1	40	**2**	20
1	45	**2**	25
1	20	**2**	20
1	40	**2**	20
1	30	**2**	30
1	40	**2**	30
1	30	**2**	15
1	30	**2**	30
1	30	**2**	20
1	50	**2**	5
1	30	**2**	20
1	45	**2**	15
1	45	**2**	30
1	30	**2**	25
1	50	**2**	30
1	30	**2**	30
1	30	**2**	20

1	20	**2**	15
1	30	**2**	15
1	20	**2**	20
1	30	**2**	45
1	20	**2**	15
1	20	**2**	60
1	30	**2**	15
1	25	**2**	15
1	20	**2**	20
1	40	**2**	15
1	30	**2**	30
1	30	**2**	30
1	30	**2**	30
1	30	**2**	30
		2	30
		2	30
		2	30
		2	30

APPENDIX G

Example Class Activity

Statistics: How to Measure Anything

The table below lists five features of daily life that have statistical aspects. Explain what statistics are involved. Then write five more examples of your own.

Feature	**Statistics involved (including related factors)**
1. climate	
2. car accidents	
3. class grades	
4. customers at mall	
5. state lottery	
6.	
7.	
8.	
9.	
10.	

Explain what is mean by the term *statistics*. Give an example.

Adopted from *Real-Life Math: Data Analysis*, Walch Publishing, 2007.

APPENDIX H

M&M Data Collection Exercise

Data Collection

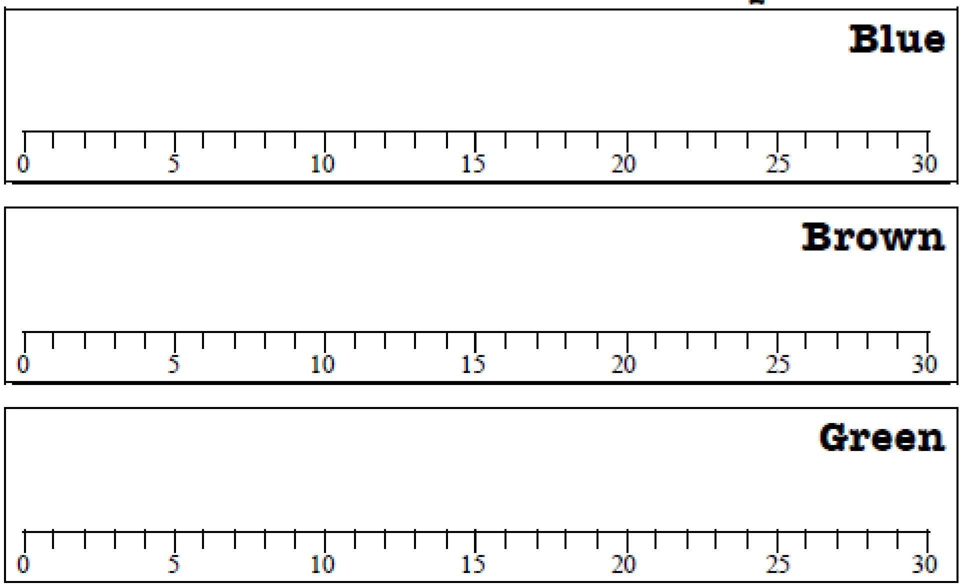
Your task is to collect data on the m&m color distribution through a carefully designed and controlled experiment. Upon receiving a "trial size" bag of regular m&m candies, you will:

- Count the total number of m&m's in your bag,
- Record the color distribution of your m&m's,
- Construct a dot plot based upon your color distribution,
- Construct a dot plot using the whole class color distribution.

Be sure to record you data accurately as we will utilize the data throughout additional activities.

Blue	Brown	Green	Orange	Red	Yellow

m&m's Color Distribution Dotplots



APPENDIX I

Project Presentation Rubric

Presenter: ________________________

Scoring Rubric for Oral Presentations

	Poor				Excellent
PRESENTATION SKILLS	**1**	**2**	**3**	**4**	**5**
Were the main ideas presented in an orderly and clear manner?					
Were the graphs/charts used appropriately? ………………………..……………………					
Was there a theme or take-home message to the presentation?					
STATISTICAL UNDERSTANDING					
Did the data and graphs/charts align with one another?					
Did the presenter make recommendations based upon the results of the survey?					
Did the main conclusions of the presentation follow from the material presented?					

OVERALL IMPRESSION _______ / 20

COMMENTS

TOTAL SCORE _______ / 50

APPENDIX J

Paired Sample t-test Calculation

Here is the formula for a paired t-test.

$$t = \frac{\Sigma d}{\sqrt{\frac{n\left(\Sigma d^2\right) - \left(\Sigma d\right)^2}{n-1}}}$$

The top of the formula is the sum of the differences (i.e. the sum of *d*). The bottom of the formula reads as:

The square root of the following: n times the sum of the differences squared minus the sum of the squared differences, all over n-1.

- The sum of the squared differences: $\sum d^2$ means take each difference in turn, square it, and add up all those squared numbers.
- The sum of the differences squared: $(\sum d)^2$ means add up all the differences and square the result.

Brackets around something in a formula mean (do this first), so $(\sum d)^2$ means add up all the differences first, then square the result.

$$\sum d =$$

$$\sum d^2 =$$

$$\left(\sum d\right)^2 =$$

$$n =$$

Using the calculations from Excel; make the necessary substitutions:

$$t = \frac{5827}{\sqrt{\frac{47(1{,}090525) - 33{,}953929}{46}}}$$

$$= \frac{5827}{\sqrt{\frac{17{,}300746}{46}}}$$

APPENDIX K

Survey Project Follow-up Questions

Statistics Name: ___________________________

As a result of completing the Survey Project, please answer these follow-up questions. Please answer as completely as you can. You may find it easier to type your responses. Use additional paper to record your responses.

1. **As a result of** completing the Survey Project, describe your "understanding" about surveys and provide specific details regarding any changes.

2. **As a result of** completing the Survey Project, how has your "understanding" about data collection been affected?

3. **As a result of** completing the Survey Project, how has your "understanding" about representing data with graphs been affected?

4. **As a result of** completing the Survey Project, how has your "understanding" about representing data with graphs been affected?

5. **As a result of** completing the Survey Project, how has your "understanding" about data biases been affected?

6. What suggestions do you have to improve this survey project?

APPENDIX L

Wage Gap Follow-Up Questions

Statistics Name: ___________________________

As a result of completing the Wage Gap Project, please answer these follow-up questions. Please answer as completely as you can. You may find it easier to type your responses. Provide a paragraph for each questions **after** you have completed the project. Use additional paper to record your responses.

1. As a result of completing the Wage Gap, describe your “understanding” about the Wage Gap.

2. As a result of completing the Survey Project, do you agree that a wage gap exists?

3. As a result of completing the Survey Project, how do you feel about this?

4. Select a specific statistic from any of the referenced articles, describe the statistic and discuss why you selected the statistic.