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Comparing the Impact of Traditional and Modeling College Algebra Courses on Student Performance in Survey of Calculus

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COMPARING THE IMPACT OF TRADITIONAL AND MODELING COLLEGE ALGEBRA COURSES ON STUDENT PERFORMANCE IN SURVEY OF CALCULUS

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Education in Workforce Development Education

By

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Abstract

Students in higher education deserve opportunities to succeed and learning environments which maximize success. Mathematics courses can create a barrier for success for some students. College algebra is a course that serves as a gateway to required courses in many bachelor's degree programs. The content in college algebra should serve to maximize students' potential in utilizing mathematics and gaining skills required in subsequent math-based courses when necessary. The Committee for Undergraduate Programs in Mathematics has gone through extensive work to help mathematics departments reform their college algebra courses in order to help students gain interest in the utilization of mathematics in solving real-world problems. In many instances, college algebra courses have evolved from a traditional curriculum into a modeling or applied curriculum. Successful completion rates and academic achievement in a survey of calculus course were compared between students who had traditional college algebra content versus modeling college algebra content. Results of statistical analyses between the two types of college algebra content determined that a higher percentage of students successfully completed survey of calculus on their first attempt when they had traditional college algebra content in a prerequisite course than students who had modeling college algebra content. No statistically significant difference was determined in academic achievement in survey of calculus, measured by average GPA of students, between the two types of college algebra content. The results of this study suggest that a higher percentage of students will complete survey of calculus with a grade of C or higher on their first attempt after successfully completing traditional college algebra content versus successfully completing modeling college algebra content; however, academic achievement based on GPA will not be significantly different between students who successfully complete either type of college algebra content.

This dissertation is approved for recommendation to the Graduate Council.

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Dedication

I would like to dedicate this work to all the people who have the desire to expand their horizons through hard work and a desire to continue learning. For those who do not seek the easy way through life, I hope this dissertation inspires you to challenge yourself to set goals and work hard to achieve them. I dedicate this body of work to my family. I hope I have made you all proud.

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Chapter One

Introduction

As part of a student's undergraduate degree plan, college algebra is a common general education course requirement for mathematics. Ideally, college algebra can serve as both a terminal course in a student's degree plan or as a prerequisite course to subsequent courses a student may need in order to complete their degree. College algebra is typically a prerequisite course that is used to prepare students for calculus (Ellington, 2005). The Mathematical Association of America (MAA) has written specific guidelines for college algebra, which are endorsed by the Committee on the Undergraduate Program in Mathematics (CUPM). These guidelines represent recommendations concerning the content of college algebra, and the role of college algebra as either a student's final mathematics course or a prerequisite course for subsequent mathematics courses (Mathematical Association of America, 2012). Subsequent courses listed by the MAA/CUPM for which college algebra is a prerequisite course are: trigonometry, precalculus, probability and statistics, business calculus, survey of calculus, finite mathematics, and mathematics for elementary education majors.

Many colleges and universities offer college algebra courses that are taught in one of two ways, either through a traditional approach, or through a modeling approach (Bressoud, 2007). Typically, in a traditional college algebra course, curriculum is primarily technique-driven, whereas a modeling college algebra course, or a problem-based quantitative curriculum, introduces real-world problems in a general context (Packer, 2002). As defined by Reyes (2009), a traditional college algebra course is "a study of relations and functions including polynomial, rational, exponential, logarithmic, and special functions. Other topics include complex numbers, systems of equations and inequalities, theory of equations, progressions, the binomial theorem, matrices and determinants, proofs, and applications" (p. 16). Modeling college algebra introduces many of the same topics, but the topics are more generalized into real-world applications. Arithmetic skills needed in a modeling college algebra course are specific to the problem at hand and are not carried as far or with such depth and detail as in a traditional college algebra course. In a modeling college algebra course, students spend a considerable amount of time analyzing real-world data, finding a representative mathematical model for the data, and using the model to make predictions pertaining to the context of the problem being analyzed (Ellington, 2005).

Status of the Issue

Poor performance in college algebra can hinder students from earning a college degree and prevent them from advancing in science, technology, and mathematics education (Knoop, 2003). The current national passing rate of students in college algebra is approximately 40% (Thompson & McCann, 2010). The failure rates in pre-calculus courses, such as college algebra and pre-algebra, are reported to be between 40% and 60% (Mayes, 2004; Ellington, 2005). Over the last twenty years, there has been a 32% increase in enrollment in college algebra course offerings across the nation (Ellington, 2005). Due to increased enrollment in American colleges and excessive failure rates in college algebra and pre-algebra courses, there is demand for more course sections in college algebra. Much of the need for more course sections is due to new, incoming students enrolling in the course for the first time, and other students enrolling for a second, or more, attempt at successfully completing the course. College algebra and pre-algebra account for 57% to 80% of enrollment in mathematics courses (Mayes, 2004). Ellington states that the enrollment figure would be "much larger if it included students enrolled in courses that include traditional college algebra topics in the curriculum but may cover other topics as well and are labeled with a different title other than 'College Algebra" (Ellington, 2005, p. 194). Many colleges and universities in the United States have other course options which are variations of college algebra and serve a more distinct cohort of students. For example, at Oklahoma State University, students may opt to take a course called math functions and applications.

In a traditional college algebra course, students are taught to correctly manipulate variables, solve for variables in equations and inequalities, and solve problems pertaining to analysis of a wide variety of graphs, including, but not limited to, linear, quadratic, cubic, rational, and radical. Students receive a rigorous treatment of finding zeros, x- and y-intercepts, and vertices of parabolas, and relative maxima and minima of the graph of a function. Additional topics include finding the domain and range of functions and graphs, and function values. Furthermore, exponential and logarithmic functions are covered which have a wealth of applications in and of themselves.

In a modeling college algebra course, students are encouraged to think about mathematics holistically and how to collect, analyze, and apply real-world data using spreadsheets, graphing calculators, and other technologies. Students are encouraged to collect data, analyze it, and report their findings in writing. This is very helpful in engaging students and making them feel in control of, and part of, their own learning experiences (Packer, 2002).

As educators try to reduce attrition in entry-level mathematics courses, the reform of college algebra has gained momentum. The move to a more applied approach to mathematics via modeling real-world data has been shown to help more students reach the end of the semester, actually take their final exams, and ultimately pass their course (Ellington, 2005; MAA, 2012; Packer, 2002; Reyes, 2009).

There is conflicting research regarding the effectiveness of the modeling and traditional college algebra course content in preparing students for subsequent math-based courses. An article by Ellington (2005) shows success in modeling content college algebra in preparing students for a subsequent business math application course; however, students in the traditional content college algebra course performed better in a subsequent precalculus course. A limitation to that study was the data were only collected and analyzed for one academic year.

Problem Statement

College algebra is a gateway course for many other mathematics courses and upper level college courses in various disciplines. Some of these disciplines include engineering, business, accounting, finance, and health occupations. These fields require students to have a strong background in mathematics; therefore, success in college algebra courses is essential.

Survey of calculus serves as a prerequisite course for many students in a variety of undergraduate degrees such as business, economics, accounting, health professions, sciences, and information technology. In a study by Hoag and Benedict (2010), results revealed that "taking college-level business calculus or higher level mathematics has an economically and statistically significant impact on performance in one's economics class" (p. 37). Therefore, more research needs to be done on how to help students be successful in survey of calculus, including gaining proper skill sets in mathematics, having appropriate prior learning experiences, and applying prior knowledge toward successful completion of future endeavors. This provides more evidence that a strong, appropriate mathematics background is imperative, especially in a prerequisite course, such as college algebra. In order to study the long term effects of the content in a college algebra course as a prerequisite to a survey of calculus course, it is necessary to study longitudinal data for each type of college algebra course content.

Purpose of the Study

The purpose of this study is to examine the differences in the academic performance of survey of calculus students who completed modeling college algebra versus traditional college algebra.

Research Questions

1. What are the demographic and background characteristics of survey of calculus students who took a traditional versus a modeling college algebra course? Characteristics include age, gender, and ACT math subject score.
2. What are the successful completion rates in survey of calculus, determined by a course grade of C or higher, for students who successfully completed traditional college algebra versus a modeling college algebra course? A prerequisite course, such as survey of calculus must be passed with a C - or higher - before any subsequent courses may be taken. These data will be measured on a nominal dichotomous scale where no = 1 and yes = 2.
3. What is the academic achievement in survey of calculus, as measured by course grade, for students who completed a traditional versus a modeling algebra course?
4. Is there a significant difference in successful completion rates in survey of calculus between students who completed traditional college algebra versus modeling college algebra?
5. Is there a significant difference in academic achievement in survey of calculus between students who have completed a traditional versus a modeling college algebra course?

Variables

1. Characteristics of incoming students are defined as age, gender, and ACT mathematics subject score.
2. Age will be measured on a continuous ratio scale.
3. Gender will be measured on a nominal scale with male = 1 and female = 2.
4. ACT mathematics subject scores are measured on an interval scale of 1 to 36. The minimum entrance ACT mathematics subject score necessary to enter college algebra is 19.
5. Successful completion of survey of calculus will be determined by whether a student has passed their survey of calculus course with a grade of C, or higher. Before a subsequent mathematics course may be taken, students must pass survey of calculus with a grade of C or better. These data will be measured on a nominal dichotomous scale where no = 1 and yes = 2.
6. Academic achievement in survey of calculus will be measured using a final course grade in survey of calculus. The final course grade is an ordinal/interval scale variable with A = 4, B = 3, C = 2, D = 1, and F = 0.

Limitations and Delimitations

This study will be conducted using existing data owned by one small regional mid-southern university gathered from 2004-2011. The researcher only analyzed data and examined results from survey of calculus for students who completed college algebra courses at this university. No other data from any other institution was used in this study. The results of this study may not accurately reflect the outcomes achieved at other colleges and universities.

Another key limitation in this study is the fact that college algebra courses taught using both types of content, traditional and modeling, were not offered simultaneously. Specifically, content in a traditional college algebra course was the only type offered before 2007; therefore, survey of calculus students' academic achievement and completion rates during the years 2004-2007 could be analyzed only based upon their prior completion of a traditionally based college algebra course. Content in a modeling college algebra course was the only type offered from 2008-2011; therefore, survey of calculus students' academic achievement and completion rates during the years 2008-2011 could be analyzed only based upon their prior completion of a modeling based college algebra course.

The survey of calculus curriculum content remained constant for all years of data used in the study; however, the college algebra curriculum content changed from traditional curriculum course content to modeling curriculum course content. The curriculum of these courses was specific to this university and may not be exactly the same as other institutions. Additionally, while each course of survey of calculus, traditional college algebra, and modeling college algebra has specific learning objectives, each instructor of these courses has complete academic freedom to cover the content in any depth, order, or intensity.

Moreover, course instructors did not remain constant for any of the courses in this study. Some faculty worked all the years in which this study was focused; some faculty only worked a subset of the years included in this study. Additionally, the courses were not always taught by the same faculty each year. Full-time and part-time, or adjunct, faculty instructors taught the survey of calculus courses and the college algebra courses in the years described above. Even though this study is not investigating differences in faculty status, faculty status may play an integral part in students' experiences in and out of the courses.

Other external factors of student experiences such as employment, sickness, death, or just dropping out of college altogether are not in the control of the researcher nor the university.

Faculty did not have the same grading policies and in-class methods of teaching, so that may play a role in how students' assignments are graded, final course averages are curved (or not curved), and ultimately create differences in successful completion rates and academic achievement results.

Significance of the Study

College algebra is a course that serves as a gateway to required courses in many bachelor's degree programs (Matthews & Farmer, 2008; Walston & McCarroll, 2010). This course, its content delivery, and its curriculum should serve to maximize students' potential in utilizing mathematics and gaining skills required in subsequent math-based courses. It is worth investigating whether the difference in the pass rates of students based on the particular approach to the course they took is related to success in subsequent courses.

Retention is a major focus at colleges and universities in the country. Colleges and universities must do a better job of retaining, educating, and graduating students. Hopefully this study will inform colleges and institutions about which type of college algebra course content will best help students remain in college and succeed in other courses for which college algebra is a prerequisite. This study will explore if the type of college algebra content, traditional or modeling, best helps a student successfully complete survey of calculus. This information may help colleges and universities make decisions about their curriculum content in college algebra. The results of this study may also aid other colleges and universities in choosing appropriate subsequent course offerings after college algebra, encourage flexibility in course content and learning objectives of college algebra in their institution, and help other institutions make better decisions in the ordering of degree plan course offerings in many mathematically related fields of study.

According to the MAA Task Force on the First College Level Mathematics Course -- Preliminary Report, approximately 60% of Americans attend college (Kime, Gordon, Madison, McGowen, Small, & Wood, 2000). University enrollment at the university level is increasing; however, student enrollment in calculus, a course in which college algebra is a pre-requisite, has not seen an increase in enrollment proportions -- an abysmal 9% of students (Kime et al., 2000). Is one approach the right approach when college algebra is not a terminal mathematics course in a student's degree plan?

It is necessary to understand the benefits each type of college algebra course content hold for students, educators, and advisors or counselors. It is also necessary to continually probe and study the benefits in these types of courses in order to revise course content, develop effective strategies and practices in mathematics departments, and effectively counsel and advise students about which college algebra course, if they have an option, will best serve their needs in earning their degree. Colleges and universities are experiencing increasing enrollment numbers, but students are struggling to pass college algebra. This struggle could influence a student's decision on which major to choose. Some students may even have to change majors or fields of study because of the inability to succeed in college algebra when a better designed course could make a difference in a student's ability to pass and move on towards graduation and a career they choose.

Chapter Two

Literature Review

The purpose of this study is to examine the differences in the academic performance of survey of calculus students who completed modeling college algebra versus traditional college algebra. Many colleges and universities offer a traditional college algebra course with traditional content, while other colleges and universities offer an alternative approach to their college algebra course content. In some universities, college algebra courses are taught with a modeling emphasis on course content, and some are taught with traditional course content (Bressoud, 2007). College algebra is typically a prerequisite course that is used to prepare students for calculus (Ellington, 2005). These courses may serve as prerequisites to subsequent courses, or they may be used as a terminal course to fulfill the mathematics requirement in a student's degree plan.

College Algebra and its Prerequisite Stature

Research on prerequisite course appropriateness has mixed conclusions (Ellington, 2005). There is literature that suggests that success in a prerequisite course does not guarantee success in a subsequent course in the same content area or discipline (Bashford, 2000). College algebra is a prerequisite course for many subsequent mathematically based courses. Typically, in a traditional college algebra course, curriculum is primarily technique-driven, whereas a modeling college algebra course, or a problem-based quantitative curriculum, introduces real-world problems in a general context (Packer, 2002). Robert Mayes (2004) stated that, "The intent of having modeling as a focus of [college algebra] was to improve students' attitudes and beliefs about the utility of mathematics, in the hope that they would be more committed and persistent in studying the subject" (p. 66). The modeling delivery of college algebra was designed to show utility of mathematics and encourage interest, which should promote growth in the subject. Crauder, Evans, and Noell (2009) stated that, "Traditional college algebra courses focus on preparing students for an engineering-oriented course that few of them will ever take" (p. ix).

The Mathematical Association of America (MAA) has written specific guidelines for college algebra, which are endorsed by the Committee on the Undergraduate Program in Mathematics (CUPM). These guidelines represent recommendations concerning the content of college algebra, and the potential for a college algebra course to serve as a terminal course, as well as a pre-requisite course (Mathematical Association of America, 2012). Some courses listed by the MAA/CUPM for which college algebra is a prerequisite course are: trigonometry, precalculus, probability and statistics, business calculus, survey of calculus, finite mathematics, and mathematics for elementary education majors.

A balance between adequately preparing students with rote skills to help them perform algebraic manipulations skillfully while gaining their interest in real world applications of mathematics should be sought (Mayes, 2004; Achieving Quantitative Literacy, 2001; Mathematical Association of America, 2012; CUPM, 2004). This literature review will cover some of the findings in the literature with respect to student achievement, prior knowledge, and learning experiences in mathematics courses. Reports on mathematics courses, calling for reform and ways to create deeper, more meaningful learning experiences for students will also be discussed in this chapter (Ubuz, 2011; Mullin, 2012; Edge & Friedberg, 1984; CUPM, 2004).

Achievement and Success in Calculus

In terms of success in mathematics courses, student outcomes vary from institution to institution (Mullin, 2012). Some student outcomes include personal achievement, personal growth, developmental growth, and success in learning content presented in courses. Student success can be measured in what they accomplish after enrolling in a course or after a program is complete. In the article by Mullin (2012), he states, “It is important for researchers and institutional leaders to acknowledge and clarify the perspective of student success so as to portray the most accurate picture to general audiences and maximize the impact of research results and findings” (p. 14).

Student achievement in most classrooms can be measured by using grades and completion rates (Fasse, Humbert, & Rappold, 2009). These can be used as student learning outcomes which can indicate student success and measure effective learning. In their article, the authors note that one must be cautious when using completion rates to measure student success since students who did not withdraw and finished the course earning a D or F may be included in the completion statistics. The authors’ rationale was that any student earning a grade except for a W “completed” the course. The authors only considered grades of C or higher as successful completion. This supports the current study in only considering grades of C or higher in consideration of a successful completion of college algebra and survey of calculus (Fasse, Humbert, & Rappold, 2009).

A study analyzing course grades and learning outcomes with respect to developmental/ college-level mathematics pathway was conducted by Bashford (2000) at a regional southeastern community college. This study made the case for further investigation in planning appropriate learning opportunities for students in prerequisite coursework. Grades are not always a definite indicator of knowledge gained or success in learning (Bashford, 2000). The study by Bashford suggested that students may not always be adequately prepared by a prerequisite course in the same content area. This study reported that a student receiving a passing grade in the first of a two-course sequence does not imply that they are well prepared for their subsequent courses

(Bashford, 2000). The study revealed that students in reading and writing courses were prepared for their next course; however, students in a mathematics sequence were not always prepared for their next course. This stresses the importance of planning and preparation that must go into a prerequisite course, so that it adequately provides meaningful learning experiences for students which are transferrable to the next course the student takes in that subject area.

Student success in calculus is an important topic in colleges and universities in the United States and in other countries. For example, Ubuz (2011) conducted a study at a technical university in Turkey where he explored factors associated with success in a calculus course. His study investigated personal variables of students and how those variables correlated with success in calculus. The personal variables were gender, age, prior achievement, and academic major. Gender and prior achievement in pre-calculus mathematics courses were strongly correlated to success in completing calculus. Findings from the study were that students benefit greatly from learning experiences and prior knowledge of mathematical skills that they brought into a calculus course. Prior knowledge from prerequisite courses is very important for success in subsequent coursework. One limitation of this study was the analysis of a small sample size (n = 59). A second limitation of the study was the university at which the study was conducted is very selective and admits only top level students based on the university's entrance examination.

Another study that investigated factors affecting achievement in calculus was conducted by Edge and Friedberg in 1984. This study from almost thirty years ago puts into perspective how long education has sought to improve curricula and student learning experiences in order to maximize learning potential in mathematics. The authors conducted their study at a regional, mid-western university and reported a significant drop in the enrollment in courses which have calculus as a prerequisite. Edge and Friedberg (1984) listed four reasons for the drop in enrollment. Those reasons were: students shifting from hard sciences to social sciences and business, fewer students entering secondary teaching, unacceptably high failure rates or drop rates in the first course in calculus, and the lack of mathematical preparation of incoming students. The authors noted that declining national test scores at the secondary level were evidence for the lack of mathematical preparation of incoming students. The problem of low enrollment was also aggravated by the difficulties in determining in which math course the student should be placed. The authors concluded that enrollment in calculus and courses above calculus could be improved with a better understanding of proper placement procedures by college advisors; however, they noted that diversity in students' backgrounds and uniformly high grades, or grade inflation, have made advising difficult.

The Role of Prior Knowledge in Academics

Prior Knowledge in Subject/Content Matter

Subject-matter knowledge affects recall of prior learning and may increase interest in student learning. Prior knowledge at the domain and topic level influences learning and success in subsequent courses. The domain level of knowledge is where information comes from within a content area. The topic level of knowledge is related to a specific topic within a domain (Alexander, Schulze, & Kulikowich, 1994).

Prior knowledge is important for students because it helps them identify basic information and use it to solidify their understanding of concepts. Introductory courses should give students a foundation to build upon content in an area of interest (Shapiro, 2004). Success in a course may be directly related to prior knowledge including knowledge gained in prerequisite courses. Prior knowledge from prerequisite courses is very important for success in subsequent coursework (Ubuz, 2011).

Prior learning experiences are important in many disciplines including mathematics. Hailikari and Nevgi (2010) conducted a study to try and diagnose reasons for student success in chemistry. Their research in a hard science discipline may have implications for diagnosing at-risk students in mathematics. Even though Hailikari's and Nevgi's research was in chemistry, their research supported the strength of prior knowledge in learning new concepts. Learning is a cumulative phenomenon, and prior knowledge can be a significant factor in a student's success. The authors reported that academic performance in subsequent courses in the same subject would reflect prior knowledge gained in earlier courses (Hailikari & Nevgi, 2010).

College algebra is the traditional course that prepares students for calculus. Although there are many studies on demographic and academic testing variables that predict some form of achievement in mathematics, there are very few studies that deal specifically with predicting success in calculus (Edge & Friedberg, 1984). Additionally, few studies in predicting mathematical achievement have ever been replicated. Some of the academic variables Edge and Friedberg used in their study were American College Test (ACT) scores, Scholastic Aptitude Test (SAT) scores, college grade point average (GPA), and placement scores. The study's hypothesis was that the most important factor in determining success in calculus was a student's knowledge of manipulative skills in algebra (Edge & Friedberg, 1984). The authors found a high correlation, $r = 0.61$, between the algebra placement exam and the calculus achievement score. The algebra placement exam contained 31 questions which tested algebraic skills similar to those found on the Algebra III test of the Educational Testing Service. The dependent variable in the groups of students was calculus achievement as measured by overall course grade scores of 90-99 for a grade of A, 80-89 for a grade of B, 70-79 for a grade of C, and so on. The authors' original hypothesis was that algebraic skills played a significant role in student performance in calculus. Their hypothesis was supported by all three multiple regression models used in their study.

There is much concern about students taking calculus and the rote, manipulative learning that takes place (Cipra, 1988; White, 1990). Using technology to perform most of the manipulative procedures has freed students and instructors to explore applications (Palmiter, 1991). The general tendency is for more emphasis to be placed on underlying concepts and less emphasis on skills; however, the students' best interests in learning must be carefully weighed.

Conceptual and Procedural Knowledge in Mathematics

Conceptual knowledge in mathematics has been characterized as the understanding of the relationships between mathematical objects while procedural knowledge can be described as knowledge which can be applied when a recognizable cue is presented (Hiebert & Lafevre, 1986). Procedural knowledge may or may not be supported by conceptual knowledge (White & Mitchelmore, 1996). Procedural knowledge which is unsupported is similar to Skemp's instrumental understanding which is described as knowing rules without necessarily knowing why they work (Skemp, 1976). Skemp made a case for skills-based courses by noting that they are very efficient if the only criterion is for the student to have the ability to perform routine manipulations. Application problems call on conceptual knowledge. One of the main difficulties in learning algebra centers on students not understanding the meaning of a variable (Kieran, 1989). Much research has been conducted on conceptual and procedural knowledge in mathematics, structural perspective in early learning of algebra, understanding of basic mathematical concepts, such as the meaning of a variable, and the appropriateness and effects of technology on concept and skill acquisition (Kieran, 1989; Palmiter, 1991; Skemp, 1976; White 1990). This relates to the current study since traditional college algebra content places emphasis on procedural knowledge while modeling college algebra content places emphasis on conceptual knowledge. These two types of course content are not mutually exclusive. The approaches to learning course content is different, but there are some algebraic manipulation skills required in modeling college algebra content and some problem-solving skills required in traditional college algebra content. Traditional college algebra content is taught primarily with skill acquisition, fundamentals of algebra, and rote manipulation skills as the focus. Modeling college algebra content is taught primarily using technology to create a visual learning experience with less emphasis on manipulation skills and more emphasis placed on the real-world concepts of mathematical applications. The general tendency is for less emphasis to be placed on skills and greater emphasis on underlying concepts.

A study which investigated the success of students in working application problems was conducted by Mitchelmore and White in 1996. The purpose of their study was to investigate the performance on calculus application problems on a group of students who had previously experienced a traditional introductory calculus course (White & Mitchelmore, 1996). The study consisted of a sample of 40 first-year, full-time university mathematics students. Calculus topics were taught to the students for four hours per week over a six week period, which counted as half of a one-semester course. Students were tested before, during, immediately after, and six weeks after the calculus course. The students were divided into four groups of ten on the basis of their performance in an algebra course completed the previous semester. Students were unaware of the groupings. Students were given interviews to confirm that they were unaware that they were answering different versions of the same types of test items for data collection.

Responses to the test items suggest that “a major source of students’ trouble in applying calculus is an underdeveloped concept of a variable” (White & Mitchelmore, 1996, p. 91).

Students who show a manipulative focus on a variable have learned to operate with symbols without really knowing the contextual meaning of them. Those concepts are called abstract-apart. Traditionally taught algebra courses with manipulation as the focus seldom relate symbols to actual contextual meanings of a variable. When a student understands the contextual meaning of a mathematical symbol, that concept is called abstract-general (White & Mitchelmore, 1996). Most students in their study were reported to have had an abstract-apart concept of a variable that blocked meaningful learning of calculus.

White and Mitchelmore (1996) concluded that a prerequisite to a successful calculus class is an abstract-general concept of a variable. This concept is stressed in modeling algebra courses. Concept-oriented calculus may be difficult for students without an abstract-general concept of a variable. However, there is just as much a need for experience in manipulating and modeling mathematical expressions (Kieran, 1992). The authors also note in a previous study that students must spend a considerable amount of time using algebra to manipulate relations before they can achieve a mature concept of a variable (White & Mitchelmore, 1993).

Reform in Undergraduate Mathematics Programs

It is important to remain positive when facilitating student learning experiences, and institutions and programs must evolve to meet the demand of society with relevant course topics and curriculum (Tucker, 1995). Effective practices at some successful mathematics departments include: excellence in attracting and training large numbers of mathematics majors; preparing students to pursue advanced studies in mathematics; preparing future mathematics school teachers; and attracting and training underrepresented groups in mathematics. Tucker (1995) reported site visits to ten math departments and provided information on others. The common theme of the data collected was that there was no single key to being a successful mathematics department. The faculty members working in effective programs were not satisfied with their current programs and were constantly trying innovative methods for improving their department (Tucker, 1995).

CUPM's Call for Reform in Undergraduate Mathematics

The Mathematical Association of America's (MAA) Committee on the Undergraduate Program in Mathematics (CUPM, 2004) makes recommendations to mathematics departments to help them with designing curricula for undergraduate students. CUPM reports are updated about every 10 years. The report issued in 2004 is based upon four years of work supported by the National Science Foundation (NSF) and the Calculus Consortium for Higher Education and includes extensive consultation with mathematicians across the United States. The *CUPM Guide 2004* addressed college-level mathematics for all students, even students who will only take one mathematics course. Previous CUPM reports focused on the undergraduate program for mathematics majors. The 2004 report did as well, but went even further to involve everyone who would be affected by college-level mathematics (CUPM, 2004).

CUPM Guide 2004 included six recommendations for departments, programs, and all courses in the mathematical sciences. The MAA Board of Governors approved these recommendations at their Mathfest 2003 meeting. Recommendation one charged mathematical science departments to understand the strengths and weaknesses, career plans and aspirations, and areas of interest for students. Mathematics departments were challenged to look internally and determine the alignment of courses and programs offered with the needs of students and their goals in mind, and determine whether or not those goals are achieved. Mathematics departments are also expected to continually strengthen courses and programs so that they better align with students' needs, and assess the effectiveness of those efforts.

Recommendation two was for every mathematics course to incorporate activities to help all students grow and develop analytical, critical thinking and reasoning, problem-solving, and communication skills. The activities should be designed to promote and facilitate each student's progress in learning how to carefully state problems, modify problems when necessary, articulate and appreciate the value of precise definitions, reach conclusions, and interpret the results logically and intelligently. Mathematics departments are urged to create activities to help students approach problem solving with the willingness and ability to try multiple approaches to problem solving, to be persistent when difficulties arise, explore examples, pose questions, and assess the correctness of solutions. Finally, activities for students should be designed to help students learn to read mathematics with understanding and communicate mathematical ideas clearly and coherently via written works and speaking with groups in class and the class as a whole.

Recommendation three challenged mathematics departments to create courses which present key ideas and concepts from a variety of perspectives. College mathematics departments are also charged to use a wide range of problems and applications to motivate students and illustrate the concepts that should be mastered. Courses should be designed to promote awareness of connections of math to other subjects and strengthen each student's ability to transfer and apply skills they have learned to other subjects. Contemporary topics from mathematical sciences and their applications are to be used in the courses created. Courses should enhance student perceptions of the vitality and importance of mathematics in the modern world.

The fourth recommendation is faculty buy-in. Mathematical sciences departments should encourage and support faculty collaboration with colleagues from other disciplines. The collaboration should help modify existing math courses and develop new ones which are current. Collaboration with other professionals in a variety of areas would help create joint or cooperative majors, devise undergraduate research projects, and foster an environment for team-teaching courses or units within courses, although resources and time constraints could damper this.

Recommendation five called for a pro-technological approach to teaching content. It was recommended that at every level of the curriculum that math courses should incorporate activities that will help all students to progress in learning to use technology appropriately and effectively as a tool for solving problems and as an aid to understanding mathematical ideas. Additionally, recommendation six challenged mathematical sciences departments and administrators to encourage, support, and reward faculty efforts to improve the efficacy of teaching and strengthen curricula (CUPM, 2004).

Retention in mathematics courses is another critical issue addressed by Lutzer, Maxwell, and Rodi (2002) and the Conference Board of the Mathematical Sciences (CBMS). Some statistics pertaining to graduation numbers are noted. With respect to graduation rates, from 1985 to 2000, the number of bachelor's degrees awarded in the United States rose 25%, and the number of science and technology degrees rose 20%; however, the total number of degrees awarded by mathematics and statistics departments remained relatively flat (Lutzer, Maxwell, & Rodi, 2002). Data collected by the CBMS in 2000 showed that between 1995 and 2000, the annual total fell 4%, and the number of degrees awarded annually fell 19% in the 1990s (Lutzer, Maxwell, & Rodi, 2002). Trends in upper level math courses are worse. Enrollment in advanced mathematics courses dropped 25% overall between 1985 and 2000.

The CUPM (2004) calls for all mathematics departments to serve the needs of all students, not just the students in the mathematical sciences. The steps recommended to help math departments reach this goal include: designing undergraduate programs and courses that address a broad set of problems in disciplines which make use of mathematics concepts and skills; teaching students how mathematics is used in the real world, its history, and its place in society; using a broad spectrum of techniques in instruction that encourage students to communicate and explore important ideas of modern mathematics and its use in society; creating an environment and experiences for students to explore and analyze mathematics; understanding how technology with course content can also help with instructional techniques; and asking administration to encourage and support faculty in these endeavors (CUPM, 2004).

Reforming Student Preparation for Calculus

The MAA Task Force on the First College Level Mathematics Course reported that approximately 60% of Americans attend college (Ganter & Barker, 2004). Calculus enrollments are stable and stagnant at 9%, while growth in mathematics enrollment is contained in the before-calculus courses – where 57% to 80% of mathematics course enrollment is in before-calculus courses.

The MAA Task Force (2004) identified some major issues to be resolved for math courses that are taken by students before reaching calculus. Those issues, as reported by Mayes (2004, p. 63) are:

- What should be student outcomes?
- What should be the quantitative literacy goals with respect to a liberal arts education?
- What should be the course sequence?
- Should there be multiple algebra tracks?
- What should be the course content?
- Which teaching approaches are most successful?

- What should be the role of technology?
- What are the necessary prerequisite skills?
- How should prerequisite skills and articulation issues be addressed?

One university had been attempting to answer all the questions posed. A regional, eastern university established the Institute for Mathematics Learning (IML) in their mathematics department. The primary mission of the IML was to improve instruction in their math department, curriculum in classes offered, and assessment in their before-calculus courses (Mayes, 2004). Those courses include: applied college algebra, college algebra, college trigonometry, precalculus, and applied calculus. The IML has been addressing issues of reforming the courses since 2001.

One impetus for the change in the applied college algebra course came from the Achieving Quantitative Literacy report in 2001. Quantitative literacy is defined as reasoning capabilities required of citizens in the information age (Achieving Quantitative Literacy, 2001). The report called for an increase in reasoning with data in real world contexts. Additionally, the report called for a de-emphasis on skill development for future courses. The applied algebra course addressed quantitative literacy through a focus on modeling real world data.

A second impetus for the applied college algebra course reform came from the Curriculum Foundations Project: Voice of Partner Disciplines report from Ganter and Barker in 2004. The report provided insight from other disciplines on outcomes sought after completion of mathematics courses. The report stressed the need for courses to cover conceptual understanding and critical thinking strategies pertaining to mathematic modeling (Ganter & Barker, 2004). Additionally, the report called for a reduction in computational skill building, and increased emphasis in problem solving, communication, and real world applications.

Overall, with a modeling approach to college algebra, or in this case applied college algebra, students are presented with real world data that can come from many different disciplines. The focus on understanding mathematical concepts and skill development, paired with modeling real world data, encourages students to develop reasoning and critical thinking skills. Since the data pertains to real world situations, students can see firsthand the use of mathematics in their world. Cooperation among students is encouraged in order for them to brainstorm and develop appropriate models for the data; this helps students develop communications skills. Modeling data requires students to evaluate which mathematical model best fits the data. Moreover, students have to interpret their model within the context of the problem. This enriched approach to mathematics is intended to turn students on to mathematics and give them a deeper understanding of the applications of mathematics (Ganter & Barker, 2004).

As reported by Mayes (2004), the challenge of engaging students in before-calculus mathematics courses is tough. It is difficult to change direction from the basic rote manipulation strategies employed in a traditional college algebra course. Students who enroll in courses before calculus seldom have the necessary skills to succeed in the course, and the majority of students lack the initiative or internal motivation to engage in a traditional algebra course (Mayes, 2004). The belief of the Institute of Mathematics Learning (IML) is that working with real world data and encouraging group work and discussion is a better way to engage students.

A second attempt by a major organization to restructure mathematics courses involved work by the IML. The IML developed a common vision for the restructuring of its lower division mathematics courses. Those courses included: liberal arts mathematics, college algebra, applied college algebra, trigonometry, precalculus, and applied calculus. The common visions are: computer enhanced courses, curriculum materials, laboratory based courses, active student learning, formative and summative assessments, and student accountability. Specifically, for the applied college algebra course, the common visions were implemented completely over a three year period (Mayes, 2004).

Curriculum materials for the applied college algebra course included the ACT in Algebra Text, 10 interactive laboratories, 10 online quizzes, 4 online exams, exam reviews, pre-tests to assess student deficiencies, 22 classroom participation activities, and 22 PowerPoint presentations to guide large lecture classroom teaching and provide real world data problems for class discussion. Students in the lab setting worked in groups of 2 or 3 on understanding a math concept or in modeling a real world problem.

Mayes had mixed emotions about the goals of the reformation of the applied college algebra course. For all students who received a grade of A, B, or C in applied math during the spring 2002, fall 2002, and spring 2003 semesters, 170 out of 225 students passed their subsequent applied calculus course with a grade of A, B, or C. This is equivalent to a 75.6% pass rate in a subsequent course. The most recent data presented in the article shows only 22 out of 36, or 61%, of students passing applied calculus with a grade of A, B, or C. The author noted a big decrease in enrollment which is counter to what was expected from the redesigning of the course (Mayes, 2004). There was supposed to be an increase in enrollment in math courses beyond applied college algebra. One intention of the modeling, real world approach was to improve students' views and stimulate their interests in the mathematical sciences. The goal of IML was to reduce DFW (grades of D, F, or W – withdrawal) rates to 30% over a five-year period; however, the data showed an increase in DFW rates every semester since 2001 when the applied college algebra course was implemented. The IML team reported the increase in DFW rates as a possible lack of student engagement, which countered the goal of stimulating student interest. Class attendance and participation activities were required in applied college algebra, but the average attendance was only 75% in the fall 2003 semester and 62% in spring 2003.

Pilot Program in Reforming College Algebra

In the fall 2004 semester, another regional, eastern university mathematics department designed a research program to determine the impact of a pilot program. This project involved implementing a modeling-based college algebra course which focused on fewer mathematical concepts, studied more in-depth, that are important to other academic disciplines such as business and biology. The course encouraged and helped students develop the ability to communicate quantitative ideas orally and in writing (Ellington, 2005).

In the study, 284 students in eight sections were offered the modeling-based course. In the same semester, 989 students in twenty-eight sections were offered a traditional college algebra course. Grades of A, B, or C were earned by 71.83% of the students in the modeling-based course, while 49.70% of those in the traditional sections earned grades of A, B, or C. Imbedded statistics show that 89.6% of students in the modeling-based course took their final exam. Only 71.33% of students in the traditional course took their final exam. Class sizes for both types of college algebra were limited to 35 students. Attendance policies were stated in the syllabi for the modeling courses, but no attendance policy was required in the traditional, skill-based courses. Two teaching assistants were present in each section of the modeling classes. No teaching assistants were present in the traditional sections.

Based on a two sample test of proportions, the percentage of students earning an A, B, or C in the modeling-based course was significantly larger ($p < 0.01$) than the students in the traditional, skill-based course (Ellington, 2005). Ellington (2005) reported that, "these courses were taught under very different syllabi and, therefore, the higher passing rate is not necessarily a reflection of student achievement" (p. 206). There was only a 5.6% withdrawal rate of students in the modeling-based course while there was a 20.3% withdrawal rate of students in the traditional, skill-based course.

A group of problems from the final exams was used to compare the results from the two types of college algebra courses. Ellington was a modeling instructor, and she wrote the final exams. Ten skill questions were analyzed for both courses. These made up the whole skill section for the modeling algebra final exam and 41% of the skill section for the traditional course. Three modeling questions were evaluated as common problems for both courses. Analysis was conducted on all eight sections of modeling algebra while data from eleven randomly selected sections of traditional algebra were used. One person graded all the final exams from these 19 sections to provide consistency in grading.

A two sample t-test for the data on the entire set of test questions showed that the average score for modeling students was higher than the average score for students in the traditional courses. Now, with respect to subsequent courses, Ellington (2005) reported no significant difference between the percentages of students who passed a subsequent course of precalculus or business calculus when the percentages for both courses were combined. It should be noted that 63.47% ($n = 167$) of students from a modeling algebra course earned an A, B, or C in a subsequent course, and 70.18% ($n = 399$) of students from the traditional sections earned an A, B, or C in a subsequent course. Ellington (2005) did report significantly higher passing percentages in business mathematics among students coming from a modeling course who took a college algebra course at another institution. However, at a 5% significance level, the percentage of students passing precalculus or business mathematics was not significantly different than the percentage of students passing a subsequent course after completing a traditional college algebra course.

Summary of the Chapter

Student achievement is vital to the successful advancement of American educational institutions. Success in mathematics has been an enigma for many researchers and educational committees for years. This chapter provides the reader with a glimpse of research that has been done in areas of student achievement and prior knowledge which have been reported as two major components of student success in college mathematics.

The content of college algebra and the learning experiences provided by college algebra curricula have been a hot point of discussion among professionals in mathematics. Reform efforts in college algebra and calculus have been researched and discussed among professionals too. Traditional algebra has been a course with the main purpose of preparing students for calculus, but little attention has been given to how this course can provide a robust array of learning experiences for students, including those for whom college algebra is a terminal math course. Modeling algebra is taught as part of a reform effort that provides students a real-world approach to solving problems with mathematical concepts. Traditional algebra teaches students to carefully manipulate variables and has been described as promoting an abstract-apart, manipulative focus. Modeling algebra teaches students to use mathematics in a contextual setting with less focus on manipulations. An abstract-general concept has been shown to be a meaningful part of learning calculus.

The Mathematical Association of America (MAA) and the Committee on the Undergraduate Program in Mathematics (CUPM) have made recommendations to mathematics departments across the nation. These recommendations generally suggest that curricula be developed to provide meaningful experiences in the classroom for students by providing real-world applications, which allow students to share their methods and solutions through writing and verbal communication. The goal of reform is to increase student interest in the subject of mathematics, which is to stimulate student interest and thus increase retention and success rates.

Research summarized in this chapter has interesting results pertaining to which type of college algebra content, traditional or modeling, best serves as a predictor of success for students in calculus. One study resulted in good pass rates in calculus after students had an applied algebra class, but there was a big decrease in enrollment in math courses beyond applied college algebra. Another study resulted in a convincing argument that a modeling-based college algebra course led to a higher percentage of students taking their final exam and finishing the course. Students in the modeling college algebra course had a significantly higher percentage of students finishing with a grade of A, B, or C than students in a traditional college algebra course.

Chapter Three

Methods

Research Problem

College algebra is a gateway course for many other mathematics courses such as precalculus or survey of calculus, which are prerequisite courses to many upper level college courses in various disciplines (Matthews & Farmer, 2008; Walston & McCarroll, 2010). Some of these disciplines include engineering, business, accounting, finance, and health occupations. This study examines whether or not the course content taught in traditional college algebra versus modeling college algebra makes a difference in successful completion and academic achievement in survey of calculus. Successful completion is defined as passing the course with a grade of A, B, or C, and academic achievement is measured by final course grade. This information can help inform colleges and universities about their curriculum design, course offerings in many fields of study, and it can promote flexibility in course offerings and order of the offerings.

Academic preparation for college, in terms of course taking and achievement in courses such as mathematics, has been the subject of much research over the last 20 years (NCES, 2012). Therefore, a better understanding of this issue is necessary to understand whether or not the type of college algebra course content a student successfully completes determines their success in survey of calculus.

Purpose Statement

The purpose of this study is to examine the differences in the academic performance of survey of calculus students who completed modeling college algebra versus traditional college algebra.

Research Questions

1. What are the demographic and background characteristics of survey of calculus students who took a traditional versus a modeling college algebra course? Characteristics include age, gender, and ACT math subject score.
2. What are the successful completion rates in survey of calculus, determined by a course grade of C or higher, for students who successfully completed traditional college algebra versus a modeling college algebra course? A prerequisite course, such as survey of calculus must be passed with a C - or higher - before any subsequent courses may be taken. These data will be measured on a nominal dichotomous scale where no = 1 and yes = 2.
3. What is the academic achievement in survey of calculus, as measured by course grade, for students who completed a traditional versus a modeling algebra course?
4. Is there a significant difference in successful completion rates in survey of calculus between students who completed traditional college algebra versus modeling college algebra?
5. Is there a significant difference in academic achievement in survey of calculus between students who have completed a traditional versus a modeling college algebra course?

Research Objectives

1. Describe the characteristics of survey of calculus students who took a traditional college algebra course. Characteristics include age, gender, and ACT math subject score.
2. Describe the characteristics of survey of calculus students who took a modeling college algebra course. Characteristics include age, gender, and ACT math subject score.

3. Determine the successful completion rates in survey of calculus after a student successfully completed a traditional college algebra course.
4. Determine the successful completion rates in survey of calculus after a student successfully completed a modeling college algebra course.
5. Determine the academic achievement rates in survey of calculus after a student successfully completed a traditional college algebra course.
6. Determine the academic achievement rates in survey of calculus after a student successfully completed a modeling college algebra course.
7. Compare the successful completion rates in survey of calculus for students who completed traditional college algebra versus students who completed modeling college algebra.
8. Compare the academic achievement rates in survey of calculus for students who completed traditional college algebra versus students who completed modeling college algebra.

Variables

1. Characteristics of incoming students are defined as age, gender, and ACT mathematics subject score.
2. Age will be measured on a continuous ratio scale.
3. Gender will be measured on a nominal scale with male = 1 and female = 2.
4. ACT mathematics subject scores are measured on an interval scale of 1 to 36. The minimum entrance ACT mathematics subject score necessary to enter college algebra is 19.

5. Successful completion of survey of calculus will be determined by whether a student has passed their survey of calculus course with a grade of C, or higher. Before a subsequent mathematics course may be taken, students must pass survey of calculus with a grade of C or better. These data will be measured on a nominal dichotomous scale where no = 1 and yes = 2.
6. Academic achievement in survey of calculus will be measured using a final course grade in survey of calculus. The grade is an ordinal/interval scale variable with A = 4, B = 3, C = 2, D = 1, and F = 0.

Research Design

The design of this study is non-experimental, ex post facto. Non-experimental research does not involve manipulating variables. Ex post facto research is used to investigate relationships when the researcher cannot randomly assign subjects to different conditions or directly manipulate the independent variable (Ary, Jacobs, & Sorenson, 2010; Weiss, 2012). Since this study is based on preexisting data, the ex post facto design will be appropriate. In this study, the independent variables of age, gender, ACT scores, and college algebra course content cannot be changed for the data that will be analyzed.

Instrumentation

An archival dataset will be used for this study. The Office of Institutional Effectiveness (OIE) at the University of Arkansas – Fort Smith (UAFS) keeps data on all students who have attended the institution since its beginning in 1928. Data include demographics such as age and gender. OIE also keeps data on grades earned by students in each course in which they have completed and ACT scores earned by students. UAFS owns the data needed to conduct this study. Approval will be sought from the Institutional Review Board (IRB) at UAFS and the

Institutional Review Board (IRB) from the University of Arkansas (UA). Data from the OIE will be used for the study. Data from spring 2004 to fall 2007 will be used to examine academic achievement of students in survey of calculus who took traditional college algebra, and data from spring 2008 to fall 2011 will be used in the analysis for modeling college algebra. The two separate blocks of years is due to the fact that both types of college algebra content were not offered simultaneously. This gives an equal twelve semester time span – counting spring, summer, and fall semesters.

Human Subjects Considerations

Approval will be sought through the Institutional Review Board at UAFS prior to data collection. Upon approval of UAFS, the researcher will submit the approval letter with an application to the University of Arkansas IRB. This study will not involve direct contact or communication with human subjects about which the study is conducted. Data will be coded so that specific, identifiable characteristics about individual people will not be known to the researcher or the audience for which the study is intended.

Research Population

The target population for this study will be all students enrolled in their first attempt at survey of calculus at the University of Arkansas – Fort Smith between the years of 2004 and 2011. At the University of Arkansas – Fort Smith (UAFS), survey of calculus is a prerequisite course for two accounting courses, three economics courses, and one finance course. The total population of students enrolled in their first attempt at survey of calculus during the 2004-2011 calendar years was 2,251.

The population of survey of calculus students included two subgroups: (1) Students who had completed a traditional algebra course prior to enrolling in survey of calculus during the years of 2004 – 2007; and (2) students who had completed a modeling algebra course prior to enrolling in survey of calculus in the years of 2008 – 2011. The number of students enrolled in the first subgroup was 1,131. The number of students enrolled in the second subgroup was 1,120. Students from these two subgroups did not have an option of which college algebra course they could take. Traditional college algebra was the only course content offered to students during the 2004-2007 school years, and modeling college algebra was the only course content offered to students during the 2008-2011 school years.

Data Collection Procedures

Data will be retrieved with the cooperation of the Office of Institutional Effectiveness at UAFS. No personal contact with students will be required, anonymity will be ensured, and no identifying information will be used in the study.

Data Analysis

1. Describe the characteristics of survey of calculus students who took a traditional college algebra course. Characteristics include age, gender, and ACT math subject score. Means and standard deviations will be calculated on the quantitative independent variables of age and ACT math subject scores. A frequency table will be used to describe the qualitative variable of gender.
2. Describe the characteristics of survey of calculus students who took a modeling college algebra course. Characteristics include age, gender, and ACT math subject score. Means and standard deviations will be calculated on the quantitative independent variables of age and ACT math subject scores. A frequency table will be used to describe the qualitative variable of gender.

3. Describe the successful completion rates of student grades in survey of calculus after a student had a successful completion of traditional college algebra course offering. The researcher will use a frequency table to describe academic achievement of students per their course grades in survey of calculus.
4. Describe the successful completion rates of student grades in survey of calculus after a student had a successful completion of traditional college algebra course offering. The researcher will use a frequency table to describe academic achievement of students per their course grades in survey of calculus.
5. Describe the academic achievement of student grades in survey of calculus after a student had a successful completion of traditional college algebra course offering. The researcher will use a frequency table to describe academic achievement of students per their course grades in survey of calculus.
6. Describe the academic achievement of student grades in survey of calculus after a student had a successful completion of a modeling college algebra course offering. The researcher will use a frequency table to describe academic achievement of students per their course grades in survey of calculus.
7. Compare the successful completion rates in survey of calculus for students successfully passing traditional college algebra versus students successfully passing modeling college algebra. The researcher will conduct a two-proportion z-test of population proportions pertaining to the proportion of students successfully completing survey of calculus 2004-2007 sample versus the proportion of students successfully completing survey of calculus in the 2008-2011 sample. Additionally, the researcher will conduct a two-variable chi-square test of independence with the two independent variables defined as the two types

of college algebra content delivered, traditional versus modeling. Each of these independent variables have two levels, pass with a grade of C or higher or not pass with a grade of D or F. The purpose is to determine whether or not the two independent variables, which are type of college algebra delivery, are independent of one another.

8. Compare the academic achievement rates in survey of calculus for students who completed traditional college algebra versus students who completed modeling college algebra. The researcher will conduct an independent t-test of population means pertaining to academic achievement in survey of calculus. The overall GPAs from the representative samples will be used to test for a significant difference in survey of calculus academic achievement between the two types of college algebra deliveries.

Chapter Four

Results

Colleges and universities in higher education are obligated to serve students in the best way possible. This includes providing students with excellent learning environments and opportunities to succeed in both their general education courses and courses in their major field of study. In order to provide meaningful learning environments and opportunities for success, each academic unit in the institution must continually find ways to keep the curricula current and relevant, and provide robust means of teaching course content and helping students grow as independent learners.

College algebra not only serves as a mathematics requirement in general education, it also serves as a prerequisite course for other mathematics-based courses required in many degree programs. In some colleges and universities, college algebra course content is presented to students with traditional topics, while in other institutions college algebra course content is presented to students with a modeling emphasis. Does it matter what college algebra course content is taught in order for students to be successful? The purpose of this study was to examine the differences in the academic performance of survey of calculus students who completed modeling college algebra versus traditional college algebra. Survey of calculus was chosen as the subsequent course to college algebra because it serves as a prerequisite course to other courses in finance, business, economics, and some health professions, and because as a post-college algebra course, it serves a broad spectrum of students.

Demographic and background characteristics of survey of calculus students were examined from their first attempt at the course from the spring 2004 through fall 2011 semesters. The characteristics analyzed were age, gender, and ACT mathematics subject score. Data from spring, summer, and fall semesters was analyzed. No semesters were left out of the data for analysis. The spring 2004 to fall 2007 semesters were analyzed for students who had traditional college algebra content as a prerequisite course to survey of calculus, and the spring 2008 to fall 2011 semesters were analyzed for students who had modeling college algebra content as a prerequisite course to survey of calculus. The reason for the split in years was because both types of college algebra courses, traditional and modeling, were not offered during the same years. Other data analyzed included successful completion rates, as defined by course grade of A, B, or C in college algebra, since those grades are the only ones that could serve as a satisfactory grade in college algebra if it was to serve as a prerequisite course to survey of calculus. The entire spectrum of grades was analyzed for survey of calculus, defined by grades of A, B, C, D, F, and W. Successful completion of survey of calculus is defined as a grade of A, B, or C. Academic achievement was analyzed in survey of calculus for each type of college algebra course content. Academic achievement was defined as course grade point value, where A = 4, B = 3, C = 2, D = 1, F = 0, and W had no numerical value.

The results of this study are presented in several sections. The first section describes the population of students who took survey of calculus for the years 2004 to 2011. Demographic data of age, gender, and ACT mathematics subject score are discussed and are summarized in tables. Both age and ACT mathematics subject score were compared for the population of students to determine if any significant differences exist. The next section presents the data for the years 2004 to 2007 for traditional college algebra course content and the data for the years 2008 to 2011 for modeling college algebra course content. A comparison of the two sets of data, with respect to demographic and background characteristics, is discussed. Successful completion of survey of calculus by college algebra content was tested via a two-proportion z-test for any significant differences in pass rates. A nonparametric, Chi-squared test for independence was also conducted because the data did not test normal by the Shapiro-Wilk Test for normality, but the data are arguably normally distributed as demonstrated with a histogram, boxplot, and normal Q – Q plot found in the Appendices. Academic achievement in survey of calculus was tested via an independent t-test and with a nonparametric Mann-Whitney U Test since the data did not test normally distributed by the Shapiro-Wilk Test for normality. In the section following data analysis, the research questions are answered, and finally a summary of the chapter is presented at the end of the chapter.

Population Characteristics

Population Demographics

Data were collected from 2,251 non-repeating survey of calculus students enrolled at a mid-southern regional university. Data were collected from the spring 2004 semester until the fall 2011 semester with all spring, summer, and fall student enrollment counted. The number of males enrolled in survey of calculus for the first time between the years of 2004 and 2011 was 1,104. The number of females was 1,147. From this population of students, the ages ranged from 17 to 58, with an average age of 23.27 and a standard deviation of 6.8067. The median age was 21, and the most frequent age, or mode, was 20. For the summary of the population characteristics by gender, see Table 1.

Table 1

Population of Survey of Calculus Students by Gender

	Frequency	Percent
Total	2,251	100.0
Gender		
Male	1,104	49.04
Female	1,147	50.96

Some data were missing from the ACT mathematics subject area. According to the institutional office that provided the data, some students entered college with an SAT score, while other students entered via Compass placement testing. Of the student population, there were 1,693 (75.21%) students who had ACT mathematics subject area scores stored in the data set retrieved by the researcher. Of those scores reported, the average ACT mathematics subject area score was 21.91 with a standard deviation of 3.7837. The ACT mathematics subject area scores ranged from 6 to 35. The median score was 22, and the mode was 23. For the summary of descriptive statistics for the population by age and ACT mathematics subject score, see Table 2.

Table 2

Population of Survey of Calculus Students by Age and ACT Mathematics Subject Area Score

Variable	*n*	*M*	*SD*	Med	Mode	Min	Max
Age	2,251	23.37	6.8067	21	20	17	58
ACT Mathematics Subject Area Score	1,693	21.91	3.7837	22	23	6	35

Population Comparison of Age and ACT Math Subject Score in Survey of Calculus

An independent t-test with equal variances was used to analyze the population of all students who were on their first attempt at survey of calculus. As seen below in Table 3, the standard deviations are practically identical for the ages and ACT math subject area scores in each comparison. No significant difference in age (t (2249) = 0.41, p = 0.68, two-tailed) was determined between students in survey of calculus from 2004 to 2007 (M = 23.43, SD = 6.80) and students in survey of calculus from 2008 to 2011 (M = 23.31, SD = 6.82). However, a significant difference was determined in ACT Math Subject Score (t (1691) = -4.12, p = 0.00004, two-tailed) between students in survey of calculus from 2004 to 2007 (M = 21.54, SD = 3.80) and students in survey of calculus from 2008 to 2011 (M = 22.30, SD = 3.73).

Table 3

Independent-Samples t-test Comparison of Survey of Calculus Students by Age and ACT Math Subject Area Score

	First-Time Enrollment of Survey of Calculus				
Variable	*n*	*M*	*SD*	*t*	**p*
Age				0.41	0.68
Years of enrollment					
2004-2007	1,131	23.43	6.80		
2008-2011	1,120	23.31	6.82		
ACT Math Score				-4.12	0.00004
Years of enrollment					
2004-2007	853	21.54	3.80		
2008-2011	840	22.30	3.73		

Note. *α = 0.05 two-tailed.

Population Grades in Survey of Calculus

For the population of students (n = 2,251) who took survey of calculus for the first time between the years of 2004 and 2011, the number of students who passed, with a grade of C or higher, was 1,318 (58.55%). The number of students who did not pass, or earned a grade of D, F, or W, was 933 (41.45%). Of the students who earned passing grades in survey of calculus, there were 333 A's, 461 B's, and 524 C's. For students who did not earn a passing grade, there were 174 D's, 356 F's, and 403 W's. See Table 4 for a summary of the population grades for students in their first attempt at survey of calculus between 2004 and 2011.

Table 4

Survey of Calculus Population Outcomes

Scale	Frequency	Percent
Total	2,251	100.0
Survey of Calculus Grade		
A	333	14.8
B	461	20.5
C	524	23.3
D	174	7.7
F	356	15.8
W	403	17.9
Survey of Cal Pass Rate		
Pass (C or higher)	1,318	58.6
Fail (D, F, or W)	933	41.4

Population Grades in College Algebra

There were 1,455 students who enrolled in college algebra as a prerequisite course at the university in this study. Some students took college algebra at another institution, and some students tested directly into survey of calculus. Of the population of students who took their college algebra course at this institution, there were 379 A's, 491 B's, and 585 C's. Since college algebra is the prerequisite course for survey of calculus, grades of D, F, or W were not considered. Only grades earned by students who enrolled in, and passed, college algebra at the university in this study were considered. Additionally, the most recent course grade in college algebra was used. Table 5 provides a summary of the college algebra grades.

Table 5

College Algebra Population Outcomes

Scale	Frequency	Percent
Total	1,455	100.0
College Algebra Grade		
A	379	26.1
B	491	33.7
C	585	40.2

Comparison of Characteristics of Survey of Calculus Subpopulations

Subpopulation Demographics

In this section, demographic data will be analyzed with respect to survey of calculus students who had traditional college algebra course content in the years 2004 – 2007 and with respect to survey of calculus students who had modeling college algebra course content in the years 2008 – 2011. The data will be presented with respect to gender, age, and ACT mathematics subject area score. These data from the survey of calculus population will not be analyzed unless the student successfully completed a college algebra course, with an A, B, or C, at this institution before enrolling in survey of calculus.

The population of students who enrolled in survey of calculus for the first attempt and successfully completed traditional college algebra content for the years 2004 to 2007 numbered 777. In this group, there were 354 (45.55%) males and 423 (54.45%) females. The average age was 24.17 years and ranged from 17 to 58. The median age in this group of students was 21 and the mode was 20. Some data were missing from the ACT mathematics subject area. Among this group of students, there were 595 (76.58%) students who had ACT mathematics subject area scores stored in the data set. Of those scores, the average ACT mathematics subject area score was 20.76 with a standard deviation of 3.5401. The ACT mathematics subject area scores ranged from 8 to 31. The median ACT math score was 20, and the mode was 19.

The population of students who enrolled in survey of calculus for the first attempt and successfully completed modeling college algebra content for the years 2008 to 2011 numbered 678. In this group, there were 338 (49.85%) males and 340 (50.15%) females. The average age was 24.47 years and ranged from 18 to 58. The median age in this group of students was 21 and the mode was 20. Some data were missing from the ACT mathematics subject area. Among this group of students, there were 502 (74.04%) students who had ACT mathematics subject area scores stored in the data set. Of those scores, the average ACT mathematics subject area score was 21.03 with a standard deviation of 3.5485. The ACT mathematics subject area scores ranged from 6 to 30. Both the median and mode ACT math score was 21. See Table 6 for gender data by type of course content. Additionally, Table 7 provides the data on age and ACT mathematics subject area scores by type of course content.

Table 6

Survey of Calculus Gender Comparison by College Algebra Course Content

Course Content	Traditional	Modeling	Total	Percent
Gender				
Total	777	678	1,455	100.0
Male	354	338	692	47.6
Female	423	340	763	52.4

Table 7

Survey of Calculus Age and ACT Comparison by College Algebra Course Content

Variable	*n*	*M*	*SD*	Med	Mode	Min	Max
Age							
Course Content							
Traditional	777	24.17	7.3638	21	20	17	58
Modeling	678	24.47	7.3552	21	20	18	58
ACT Math Score							
Course Content							
Traditional	595	20.76	3.5401	20	19	8	31
Modeling	502	21.03	3.5485	21	21	6	30

Subpopulation Grades in Survey of Calculus

For the subpopulation of students coming from a traditional college algebra course (*n* = 777) who took survey of calculus for the first time between the years of 2004 and 2007, the number of students who passed, with a grade of C or higher, was 461 (59.33%). The number of students who did not pass, or earned a grade of D, F, or W, was 316 (40.67%). Of the students who earned passing grades in survey of calculus, there were 126 A's, 174 B's, and 161 C's. For students who did not earn a passing grade, there were 58 D's, 136 F's, and 122 W's. See Table 8 for a summary of the population grades for students in their first attempt at survey of calculus between 2004 and 2007, after completing traditional college algebra course content.

For the subpopulation of students coming from a modeling college algebra course (*n* = 678) who took survey of calculus for the first time between the years of 2008 and 2011, the number of students who passed, with a grade of C or higher, was 372 (54.87%). The number of students who did not pass, or earned a grade of D, F, or W, was 306 (45.13%). Of the students who earned passing grades in survey of calculus, there were 71 A's, 128 B's, and 173 C's. For students who did not earn a passing grade, there were 56 D's, 101 F's, and 149 W's. See Table 8 for a summary of the population grades for students in their first attempt at survey of calculus between 2008 and 2011, after completing modeling college algebra course content.

Table 8

Survey of Calculus Outcomes by College Algebra Course Content

	Frequency			Percent		
Course Content	Traditional	Modeling	Total	Traditional	Modeling	Total
Total	777	678	1,455	53.4	46.6	100.0
Survey of Calculus Grade						
A	126	71	197	16.2	10.4	13.5
B	174	128	302	22.4	18.9	20.8
C	161	173	334	20.7	25.5	23.0
D	58	56	114	7.5	8.3	7.8
F	136	101	237	17.5	14.9	16.3
W	122	149	271	15.7	22.0	18.6
Survey of Cal Pass Rate						
Pass (C or higher)	461	372	833	59.3	54.9	57.3
Fail (D, F, or W)	316	306	622	40.7	45.1	42.7

Subpopulation Grades in College Algebra

There were 777 students who enrolled in college algebra with traditional content as a prerequisite course at the university in this study. Some students took college algebra at another institution, and some students tested directly into survey of calculus – these students were not analyzed. Of the subpopulation of students who took traditional college algebra course content at this institution, there were 260 A's, 243 B's, and 274 C's. Since college algebra is the prerequisite course for survey of calculus, grades of D, F, or W were not considered.

There were 678 students who enrolled in modeling college algebra content as a prerequisite course at the university in this study. Some students took college algebra at another institution, and some students tested directly into survey of calculus – these students were not analyzed. Of the subpopulation of students who took modeling college algebra course content at this institution, there were 119 A's, 248 B's, and 311 C's. Again, since college algebra is the prerequisite course for survey of calculus, grades of D, F, or W were not considered.

Only grades earned by students who enrolled in, and passed, college algebra at the university in this study were considered. Additionally, the most recent course grade in college algebra was used. Table 9 provides a summary of the college algebra grades for each type of course content.

Table 9

College Algebra Outcomes by Course Content

	Frequency			Percent		
Course Content	Traditional	Modeling	Total	Traditional	Modeling	Total
Total	777	678	1,455	53.4	46.6	100.0
College Algebra Grade						
A	260	119	379	33.5	17.5	26.1
B	243	248	491	31.3	36.6	33.7
C	274	311	585	35.2	45.9	40.2

Model Assumptions for Comparing Successful Completion and Academic Achievement

Model assumptions for parametric statistical comparison tests, such as independent t-tests and two-proportion z-tests, include a normal distribution of data and equality of variances. The model assumptions of normality and equality of variances were not met by a Shapiro-Wilk test or Levene's test, respectively. The Shapiro-Wilk statistic reported by SPSS 21 statistical software was $W = 0.887$ with an observed significance level of $p = 0.000$. Levene's test for equality of variances had a statistics of $F = 12.847$ with an observed significance level of $p =$

0.000. See Table 10. Levene's test for equality of variances can commonly return results of data not being normal when using large samples (Pallant, 2010). A histogram, boxplot, and Normal Q – Q plot indicates that the distribution of student achievement per their grades in survey of calculus were approximately normal. These are included in Appendices A through C.

Table 10

Model Assumptions for t-test and z-test Comparing Successful Completion and Academic Achievement of Survey of Calculus Students

	Shapiro-Wilk test for normality		*Equality of variances*	
Source	W	p*	F	p*
Survey of Calculus Grades	0.887	0.000	12.847	0.000

Note. $*\propto = 0.05$.

Comparison of Subpopulations in Survey of Calculus

Comparison of Successful Completion Rates

A two-proportion z-test was conducted under the assumption that the data were approximately normally distributed. Survey of calculus grades of A, B, and C were considered passing grades while grades of D, F, or W were not. Recall that 461 (59.33%) of 777 students passed survey of calculus after successfully completing a traditional college algebra course with a grade of C or higher. Also, recall that 372 (54.87%) of 678 students passed survey of calculus after successfully completing a modeling college algebra course with a grade of C or higher. The researcher conducted a right-tailed, two-proportion z-test to determine if there was a significantly higher proportion of students who passed survey of calculus on their first attempt after completing a traditional college algebra course compared to a modeling college algebra course. The test concluded that a significantly higher proportion of students passed survey of calculus on their first attempt after completing a traditional college algebra course than students completing a modeling college algebra course. The z-statistic from the one-tailed test was $z = 1.72$ with an observed significance level of $p = 0.043$. See Table 11 for a summary of the two-proportion z-test.

Table 11

Comparison of Student Successful Completion of Survey of Calculus by College Algebra Course

	Survey of Calculus Completion Rates				
Variable	*n*	*NC*	*PS*	*z*	*p**
College Algebra Course				1.717	0.043
Traditional	777	461	0.5933		
Modeling	678	372	0.5487		

Note. NC = number of successful completions. PS = proportion of successful completions. $^*\alpha = 0.05$ one-tailed.

Nonparametric comparison tests, such as a chi-square test for independence, do not make assumptions about the underlying population distribution; however, they are not as sensitive as parametric tests and may fail to detect differences between groups that actually exist (Pallant, 2010). This test is included because the data did not meet the normality and equality of variances tests mentioned above. So, a Chi-square test of independence (with Yates Continuity Correction) was conducted on the same data above. The results of the test returned no significant difference between the proportions of successful completion rates between students with a traditional or modeling college algebra prerequisite course. The results of the test were χ^2 (1, n = 1,455) = 0.001, p = 0.982, *phi* = 0.001.

Comparison of Academic Achievement

Academic achievement in survey of calculus was measured using the final student grade in the course. An ordinal/interval scale was used where A = 4, B = 3, C = 2, D = 1, and F = 0 points. An independent t-test was conducted with the assumption of unequal variances and approximately normal data. See Appendices A through C for the argument of approximately normal data. The results of the independent t-test conducted using SPSS 21 statistical software resulted in no significant difference (t (1160.95) = 1.589, p = 0.112, two-tailed) between academic achievement of students in survey of calculus after successful completion of traditional college algebra (M = 2.147, SD = 1.3913) or modeling college algebra (M = 2.023, SD = 1.2849). The magnitude of the differences in means (mean difference = 0.1239, 95% *CI*: -0.0291 to 0.2768) was small (eta squared = 0.002). See Table 12.

Table 12

Independent-Samples t-test Comparison of Survey of Calculus Academic Achievement by College Algebra Course

	Survey of Calculus Academic Achievement					
Variable	n	M	SD	t	$^{*}p$	$^{**}\eta^2$
College Algebra Course				1.589	0.112	0.002
Traditional	655	2.147	1.3913			
Modeling	529	2.023	1.2849			

Note. *α = 0.05 two-tailed. **Eta-squared.

The non-parametric alternative to the independent t-test is the Mann-Whitney U Test. This test came very close to reporting a significant difference in academic achievement between the two college algebra courses. The result of the Mann-Whitney U Test in SPSS was a test statistic of z = -1.940 with an observed significance level of p = 0.052, two-tailed. The effect size was small, r = 0.056. See Table 13.

Table 13

Mann-Whitney U Test Comparison of Survey of Calculus Academic Achievement by College Algebra Course

	Survey of Calculus Academic Achievement					
Variable	*n*	*MR*	*U*	*z*	**p*	***r*
College Algebra Course			162,204.5	-1.940	0.052	0.056
Traditional	655	609.36				
Modeling	529	571.62				

Note. MR = mean rank. U = Mann-Whitney U. *α = 0.05 two-tailed. **Effect size.

Results Related to Research Questions

This study attempted to determine if there was a difference in successful completion rates and academic achievement in survey of calculus based on a student's college algebra course of traditional content or modeling content. Data were retrieved for the 2004 – 2011 academic years for all students who were making their first attempt at survey of calculus. Statistical analysis of the data, using a two-proportion z-test, an independent t-test, a Chi square test of independence, and a Mann-Whitney U Test, were used to answer the following research questions:

1. What are the demographic and background characteristics of survey of calculus students who took a traditional versus a modeling college algebra course?

Of survey of calculus students who had traditional college algebra, there were 354 male students and 423 female students. See Table 6. The average age was 24.17 years with the youngest student at age 17 and the oldest student at age 58. The average ACT mathematics subject area score was 20.76 with a lowest score of 8 and the highest score of 31. See Table 7.

Of survey of calculus students who had modeling college algebra, there were 338 male students and 340 female students. See Table 6. The average age was 24.47 years with the youngest student at age 18 and the oldest student at age 58. The average ACT mathematics subject area score was 21.03 with a lowest score of 6 and the highest score of 30. See Table 7.

No significant difference in average age of survey of calculus students was determined between the two college algebra courses. A significant difference in average ACT mathematics subject area score of survey of calculus students was determined between the two college algebra courses. See Table 3.

2. What are the successful completion rates in survey of calculus, determined by a course grade of C or higher, for students who successfully completed a traditional college algebra course versus a modeling college algebra course?

Of survey of calculus students who had traditional college algebra, 461 (59.3%) students successfully completed with an A, B, or C in their first attempt while 316 (40.7%) students did not successfully complete, earning a D, F, or W. See Table 8.

Of survey of calculus students who had modeling college algebra, 372 (54.9%) students successfully completed with an A, B, or C in their first attempt while 306 (45.1%) students did not successfully complete, earning a D, F, or W. See Table 8.

3. What is the academic achievement in survey of calculus, as measured by course grade, for students who completed a traditional versus a modeling algebra course?

Of survey of calculus students who had traditional college algebra, the average academic achievement of students, based on an ordinal/interval scale where A = 4, B = 3, C = 2, D = 1, and F = 0 (no value assigned to W), was 2.147. See Table 12.

Of survey of calculus students who had modeling college algebra, the average academic achievement of students, based on an ordinal/interval scale where A = 4, B = 3, C = 2, D = 1, and F = 0 (no value assigned to W), was 2.023. See Table 12.

4. Is there a significant difference in successful completion rates in survey of calculus between students who completed traditional college algebra versus modeling college algebra?

A significant difference in successful completion rates in survey of calculus was determined by a one-tailed, two-proportion z-test. Students who had traditional college algebra passed their survey of calculus course in higher proportion than students who had modeling college algebra when all grades of A, B, C, D, F, and W were considered. See Table 11. However, when a nonparametric, chi-square test for independence test was conducted with only grades of A, B, C, D, or F, there was no significant difference in the proportion of students who passed survey of calculus on their first attempt.

5. Is there a significant difference in academic achievement in survey of calculus between students who have completed a traditional versus a modeling college algebra course?

No significant difference in academic achievement in survey of calculus was determined by a two-tailed, independent samples t-test. See Table 12. A nonparametric, Mann-Whitney U Test, used as a follow-up test, came very close to contradicting the t-test. However, the Mann-Whitney U Test also did not result in a significant difference in academic achievement in survey of calculus, barely missing the mark with an observed significance level, $p = 0.052$. See Table 13.

Summary of Results Chapter

Providing students with the best education and appropriate learning opportunities is important in higher education. It is important to continually evaluate course offerings and curricula in order to provide the best learning environments and opportunities for students to succeed. This study attempted to determine if students in survey of calculus were more successful if their prerequisite college algebra was a traditional or modeling course. Data were compared among students in their first attempt at survey of calculus coming from traditional and modeling college algebra prerequisite courses. Demographic data of average age of students between the two college algebra courses did not differ statistically, but the average ACT mathematics subject area scores did statistically differ. A statistically higher proportion of students passed survey of calculus on their first attempt when coming from a traditional college algebra course, when all grades of A through W were considered. No significant difference in academic achievement of students existed when only grades of A through F were considered.

Chapter Five

Conclusions and Recommendations

In higher education, college algebra serves as a general education course in mathematics and as a prerequisite course for other mathematically based courses in a student's degree plan. Some courses listed by the MAA/CUPM for which college algebra is a prerequisite course are: trigonometry, precalculus, probability and statistics, business calculus, survey of calculus, finite mathematics, and mathematics for elementary education majors (Mathematical Association of America, 2012). This study focused only on survey of calculus as the subsequent course for which college algebra was the prerequisite because survey of calculus, in turn, serves as a prerequisite to many courses in diverse subject areas, such as accounting, business, finance, information technology, and many areas in health occupations. This chapter includes the purpose and significance of the study, data collection methods, answers to the research questions, conclusions supported by the data in the study, recommendations for practice and research, and a chapter summary.

Summary of the Study

The purpose of this study was to examine the differences in the academic performance of survey of calculus students who completed modeling college algebra course content versus traditional college algebra course content. Poor performance in college algebra can hinder students from earning a college degree and prevent them from advancing in science, technology, and mathematics education (Knoop, 2003). Many colleges and universities offer college algebra courses that are taught either through a traditional approach to course content or through a modeling approach to course content (Bressoud, 2007). College algebra course content should serve to maximize students' potential in utilizing mathematics and gaining skills required in subsequent math-based courses. This study investigated whether the difference in the pass rates of students based on the course content they had in college algebra was related to success in subsequent courses.

An archival dataset was used for this study. No personal contact with students was required, anonymity was ensured, and no identifying information of students was used in the study. Data used in this study included demographics such as age, gender, and ACT mathematics subject area scores. Data from spring 2004 to fall 2007 was used to examine academic achievement of students in survey of calculus who took traditional college algebra content, and data from spring 2008 to fall 2011 was used to examine academic achievement of students who took modeling college algebra content. The two separate blocks of years had to be analyzed due to the fact that both types of college algebra content were not offered simultaneously at the university at which the study was conducted.

Demographic and background characteristics of survey of calculus students were examined from their first attempt at the course from the spring 2004 through fall 2011 semesters. The characteristics analyzed were age, gender, and ACT mathematics subject score. Data from spring, summer, and fall semesters were analyzed. The spring 2004 to fall 2007 semesters were analyzed for students who had traditional college algebra content as a prerequisite course for survey of calculus, and the spring 2008 to fall 2011 semesters were analyzed for students who had modeling college algebra content as a prerequisite course. Successful completion rates in survey of calculus, as defined by course grade of A, B, or C, were compared for students coming from traditional versus modeling college algebra content. The only data used in the analysis was from students who were taking survey of calculus for the first time and had completed college algebra with a grade of C or higher. Some students enrolled in survey of calculus had either tested into survey of calculus or transferred the course from another institution. The researcher did not have access to the type of college algebra content the student had completed. The entire spectrum of grades was analyzed for survey of calculus, defined by grades of A, B, C, D, F, and W. Successful completion of survey of calculus was defined as a grade of A, B, or C. Academic achievement was analyzed in survey of calculus for each type of college algebra course content. Academic achievement was defined as course grade point value, where A = 4, B = 3, C = 2, D = 1, F = 0, and W has no numerical value.

Data were collected from 2,251 non-repeating survey of calculus students enrolled at a mid-southern regional university. Data were collected from the spring 2004 semester until the fall 2011 semester with all spring, summer, and fall student enrollment counted. Some data were missing from the ACT mathematics subject area due to students having SAT scores or Compass entrance test scores. Of the student population, 1,693 (75.21%) students had ACT mathematics subject area scores stored in the data set retrieved by the Office of Institutional Effectiveness and the researcher. For this study, data were based upon 1,455 students who enrolled in college algebra as a prerequisite course at this university. Data from 238 students were not included because the researcher did not have access to which type of college algebra content they took at another institution or when they tested directly into survey of calculus.

Statistical analysis of the data, using a two-proportion z-test, independent samples t-tests, a Chi square test of independence, and a Mann-Whitney U Test, were used to answer the following research questions:

Question one asked what the demographic and background characteristics of survey of calculus students were who took a traditional versus a modeling college algebra course. The population of all survey of calculus students who had traditional college algebra included 354 male students and 423 female students. The average age was 24.17 years with the youngest student at age 17 and the oldest student at age 58. The average ACT mathematics subject area score was 20.76 with a lowest score of 8 and the highest score of 31. For the population of all survey of calculus students who had modeling college algebra, there were 338 male students and 340 female students. The average age was 24.47 years with the youngest student at age 18 and the oldest student at age 58. The average ACT mathematics subject area score was 21.03 with a lowest score of 6 and the highest score of 30. There was no significant difference in the average age of survey of calculus students between the two college algebra courses. A significant difference does exist in the average ACT mathematics subject area scores of survey of calculus students between the two college algebra courses. Students in the 2008 – 2011 (modeling content) years had a significantly higher average ACT mathematics subject area score than students in the 2004 – 2007 (traditional content) years.

Question two asked what the successful completion rates in survey of calculus were, determined by a course grade of C or higher, for students who successfully completed traditional college algebra versus a modeling college algebra course. For survey of calculus students who had traditional college algebra, 461 students successfully completed with an A, B, or C in their first attempt while 316 students did not successfully complete, earning a D, F, or W. For survey of calculus students who had modeling college algebra, 372 students successfully completed with an A, B, or C in their first attempt while 306 students did not successfully complete, earning a D, F, or W.

Question three asked what the academic achievement in survey of calculus was, as measured by course grade, for students who completed a traditional versus a modeling algebra course. For survey of calculus students who had traditional college algebra, the average academic achievement of students was 2.147. For survey of calculus students who had modeling college algebra, the average academic achievement of students was 2.023. These data were based on an ordinal/interval scale where A = 4, B = 3, C = 2, D = 1, F = 0, and no numerical value was assigned for a grade of W.

Question four asked if a significant difference existed in successful completion rates in survey of calculus between students who completed traditional college algebra versus modeling college algebra. A significant difference existed in successful completion rates in survey of calculus as a result of a one-tailed, two-proportion z-test. Students who had traditional college algebra content passed their survey of calculus course in higher proportion than students who had modeling college algebra when all grades of A, B, C, D, F, and W were analyzed. When a nonparametric, chi-square test for independence test was conducted with only grades of A, B, C, D, or F, no significant difference existed in the proportion of students who passed survey of calculus on their first attempt.

Question five asked if a significant difference existed in academic achievement in survey of calculus between students who completed a traditional versus a modeling college algebra course. No significant difference existed in academic achievement in survey of calculus as a result of a two-tailed, independent samples t-test. A nonparametric, Mann-Whitney U Test, which was used as a follow-up test, came very close to contradicting the t-test. However, the Mann-Whitney U Test also did not result in a significant difference in academic achievement in survey of calculus, barely missing the mark with an observed significance level, $p = 0.052$.

Conclusions

Based on the results of this study, the following conclusions can be made regarding successful completion and academic achievement of survey of calculus students based on the college algebra course content they had as a prerequisite course:

1. Successful completion rates of survey of calculus, with a grade of C or higher, are significantly higher when students had traditional college algebra course content (59.3%) versus when students had modeling college algebra course content (54.9%) as a prerequisite course. This could imply that traditional college algebra course content is better aligned with the content in survey of calculus, and that students coming from modeling college algebra course content may not have the necessary prerequisite skills required to be successful at their first attempt of survey of calculus. These results do not support the results of the study conducted by Ellington (2005) where a higher percentage of students earned a grade of C or higher in a subsequent course, specifically business mathematics, when they enrolled in modeling sections of college algebra as a prerequisite course. These findings support the results Ubuz (2011) reported when he conducted a study that explored factors associated with success in a calculus course. This supports the notion that students benefit greatly from learning experiences and prior knowledge of mathematical skills that were brought into a calculus course. Shapiro (2004) also reported that success in a course may be directly related to prior knowledge including knowledge gained in prerequisite courses.

In addition, students who came from modeling college algebra course content dropped their survey of calculus course at a higher rate (22.0%) than students who came from traditional college algebra course content (15.7%). This could imply that students attempted to successfully complete survey of calculus, but were not adequately prepared with a foundation of skills necessary to succeed. Non-academic, external factors such as health problems, financial struggles, or family issues may determine whether or not a student completes a course; however, these factors would most likely occur each year and not inflate the percentages of withdrawals for students in survey of calculus who had either type of college algebra course content. These results are consistent with other courses and these issues would not affect just college algebra.

2. Academic achievement is not statistically higher in survey of calculus for students coming from courses using either traditional college algebra content or modeling college algebra content. However, it should be noted that academic achievement in survey of calculus, as measured by average GPA, was slightly higher numerically for students coming from a traditional college algebra course (2.147) than students coming from a modeling college algebra course (2.023). The implication is that overall grades in survey of calculus may be higher overall if students have traditional college algebra content as a prerequisite to survey of calculus. This implication supports the findings of Hailikari and Nevgi (2010) who reported that academic performance in subsequent courses in the same subject area could reflect prior knowledge gained in earlier courses.

It is worth noting that more A's and B's were earned by students in survey of calculus coming from traditional college algebra content (16.2% and 22.4%, respectively) compared to students coming from modeling college algebra content (10.4% and 18.9%, respectively). More C's and W's were earned by students in survey of calculus coming from modeling college algebra (25.5% and 22.0%, respectively) compared to students taught using traditional college algebra content (20.7% and 15.7%, respectively). The migration of grades from A's and B's to C's and W's may explain the lower academic achievement average. Mayes (2004) reported a similar occurrence in his study of applied calculus courses when a prerequisite applied college algebra course served as the prerequisite course. Mayes reported an increase in DFW rates in applied calculus each year after an applied college algebra course was implemented. Survey of calculus grades of D were similar for students coming from traditional college algebra content (7.5%) and modeling college algebra content (8.3%). It should be noted that only 7.8% of all grades in survey of calculus were D for students coming from either type of college algebra course content.

3. This study revealed that academic achievement is not statistically different in survey of calculus based on prior knowledge as measured by ACT mathematics subject area scores even though a significant difference was determined in ACT mathematics subject area scores by an independent samples t-test. The average ACT mathematics subject area scores for survey of calculus students who had traditional college algebra content was lower (21.54) than the average ACT mathematics subject area scores for survey of calculus students who had modeling college algebra content (22.30). It is worth noting that academic achievement is numerically higher in survey of calculus when students come from traditional college algebra content (2.147) rather than for students who come from modeling college algebra content (2.023); however, the difference is not statistically significant. This may imply that the ACT mathematics subject area test is not a good indicator for success in survey of calculus at this institution. It should be noted that grades are not always a definite indicator of knowledge gained or success in learning (Bashford, 2000).

While analyzing data in this study, it appears that prior knowledge of mathematics, based on the students' ACT mathematics subject area scores, do not lead to higher pass rates, with a grade of C or higher, in survey of calculus. A significant difference was determined in ACT mathematics subject area score by an independent samples t-test. The average ACT mathematics subject area score for survey of calculus students who had traditional college algebra content was lower (21.54) than the average ACT mathematics subject area score for survey of calculus students who had modeling college algebra content (22.30). However, pass rates in survey of calculus were statistically higher for students coming from a traditional college algebra course. This may imply that much of the content in survey of calculus is not tested on the ACT mathematics portion. This implication does not support the finding in a study by Edge and Friedberg (1984) where the authors reported a strong correlation between the algebra placement exam scores of students and their calculus achievement scores. It should be noted, however, that the algebra placement exam contained questions from an Algebra III test from the Educational Testing Service. This test may vary in content when compared to the ACT mathematics subject area test. Another implication could be that content on the ACT mathematics portion tests concepts found in college algebra content primarily but tests few, if any, concepts in survey of calculus content. The ACT mathematics subject test may not be a good predictor of success in achievement in survey of calculus. However, this study did not focus on student success in survey of calculus when the student tested directly into survey of calculus.

Based upon observations of the data in this study, student age does not have an apparent effect on pass rates in survey of calculus. The average age of students coming from each type of college algebra course was statistically equal for both subpopulations. The implication being that a student of any age will be successful if he or she has the proper skills from a prerequisite course and can transfer their prior knowledge from that course into the subsequent course they take. This implication aligns with the study conducted by Ubuz (2011) where there was no significant correlation, $r = -0.06$, between age and test scores in a calculus course. While age may not play a role in a student's ability to succeed in a mathematics course, persistence, drive, and study habits may play key roles in a student's ability to learn and master course content.

Additionally, it appears that a student's background knowledge and skills gained from prior coursework play a significant role in their success in subsequent coursework.

This study explored the effects each type of college algebra course content has for student success and achievement. It is necessary to continually probe and study the outcomes of student success and achievement in these courses. Successful mathematics departments revise course content, develop effective strategies and practices in mathematics departments, and effectively counsel and advise students about which college algebra course, if they have an option, will best serve their needs in earning their degree (CUPM, 2004). Faculty should remain positive when facilitating student learning experiences and be open minded to necessary changes to curricula, content, and instructional methods. Institutions and programs must evolve to meet the demands of society with relevant course topics and curriculum (Tucker, 1995). Colleges and universities are experiencing increasing enrollment numbers in college level mathematics, and students are struggling to pass college algebra. This struggle could influence a student's decision about which major to choose. Some students may even have to change majors or fields of study because of the inability to succeed in college algebra when a better designed course could make a difference in a student's ability to pass their courses and graduate with the degree of their initial choice.

Recommendations for Practice

College algebra courses have been reformed to give students real-world applications involving the utility of mathematics and to give students meaningful learning experiences (Mayes, 2004). The goal of college algebra reform is to increase student interest in the subject of mathematics and increase retention and success rates. Students must be provided the best opportunities for success in subsequent courses and for success after graduation. Mathematics departments are expected to continually strengthen courses to better align with students' needs, incorporate activities that help students grow and develop analytically, and create courses which present key concepts from a variety of perspectives (CUPM, 2004).

The course content in survey of calculus remained the same throughout all the years, 2004 through 2011, in which this study was conducted. As per their respective course curricula syllabi on record with the university at which the study was conducted, the traditional college algebra content remained the same for the years 2004 to 2007, and the modeling college algebra content remained the same for the years 2008 to 2011.

The results of this study suggest that more students will successfully complete their first attempt at survey of calculus if the prerequisite college algebra course uses traditional content versus modeling content. However, if academic achievement of students, based on average GPA, is the concern in survey of calculus, then it seems that it does not matter which college algebra content a student completes as a prerequisite course. Either type of college algebra course content, traditional or modeling, should lead to statistically equal academic achievement in survey of calculus.

The Committee for Undergraduate Programs in Mathematics (2004) recommended that mathematical sciences departments encourage and support faculty collaboration to modify existing math courses, develop new courses which are current and relevant, and reward faculty efforts to improve the efficacy of teaching and strengthening curricula. Collaboration among faculty who teach survey of calculus and pre-calculus courses, such as college algebra, is essential. Individual learning objectives from the survey of calculus course should be carefully outlined and compared with the learning objectives in the college algebra course that serves as its prerequisite. This could create a more seamless transition in utilizing skills acquired in the prerequisite course and applications of those skills are advantageous for students in their subsequent coursework. Faculty should collectively look for improvements to be made each semester in order to align learning objectives in sequences of courses. Student learning is then maximized and meaningful learning experiences are created.

Recommendations for Research

According to the results of this study, students will successfully complete their first attempt at survey of calculus in higher percentages if students have traditional college algebra course content. An immediate follow-up study could be conducted at the same university. Beginning in the spring semester of 2012, traditional college algebra content was reintroduced. Modeling college algebra content was dropped from the curriculum content. Data for first attempt survey of calculus students beginning in summer 2012 who had the most recent traditional college algebra content could be collected, analyzed, and compared with the two cohorts of survey of calculus students from this present study. Data for first attempt at survey of calculus students from summer 2012 until present would provide a third group of data for comparative analysis, and successful completion rates and academic achievement could be compared among the three groups of students. Additional demographic data in both survey of calculus and college algebra could be collected and analyzed for more robust results in a more in-depth study comparing successful completion rates and academic achievement in survey of calculus on a student's first attempt. Demographic information in the new study could include: full-time versus part-time status of students, full-time versus part-time status of instructors, instructors with terminal degrees versus instructors without terminal degrees, number of times the instructor has taught the course using a particular type of content, academic achievement of students who tested directly into survey of calculus versus students who required a college algebra prerequisite course before enrolling in survey of calculus, and academic achievement of students who took survey of calculus during the daytime hours of 8:00 a.m. to 3:00 p.m. versus students who took survey of calculus during the evening hours of 4:00 p.m. to 9:00 p.m.

A limitation of this project was that course instructors did not remain constant for any of the courses in this study. Some faculty taught all the years in which this study was focused; some faculty only worked a subset of the years included in this study. The courses were not always taught by the same faculty each year. Full-time and part-time, or adjunct, faculty instructors taught the survey of calculus courses and the college algebra courses in the years described above. Even though this study did not investigate differences in faculty status, faculty status may play an integral part in students' experiences in and out of the courses. In a future study conducted at this university, the researcher would recommend the same group faculty teach survey of calculus, and a small cohort of faculty each teach a section of traditional college algebra and modeling college algebra. This may help control for differences in faculty styles of teaching and grading policies. This group of faculty would be able to openly communicate with each other to improve course curricula and streamline learning objectives, so that student learning opportunities and potential are maximized.

Additional research could focus on the effects of offering each course, traditional and modeling, simultaneously over the course of several semesters. Successful completion rates and academic achievement of all students enrolled in both types of courses could be analyzed. Differences in student achievement and completion rates could be examined for students who take a subsequent math course and for students who do not. The results could be used to help faculty determine whether only one type of content, or both, should be offered to students, as well as which type to recommend for students who need college algebra as a terminal course and to those who must take subsequent courses in mathematics to satisfy their degree requirements. For students who have college algebra as a prerequisite course, a common final exam score in survey of calculus could give the researcher a continuous variable to collect, analyze, and use for comparison between the two types of college algebra prerequisite content. Individual questions from a common final exam would promote further analysis of specific learning objectives that are mastered by students and learning objectives that are not. Item analysis of specific problems on the final exam would help the researcher recommend modifications to college algebra course content based upon learning objectives that are frequently not mastered by students.

Another approach would be to survey students in survey of calculus who have taken traditional college algebra or modeling college algebra. Students' experiences in survey of calculus could be examined with a focus on what elements they felt were missing from their college algebra course that would help them succeed in their current course. The results of the study could be used to explore potential modifications that could be made to each of the college algebra courses in order to better serve the students taking them. If only one college algebra course is deemed necessary, the best elements from traditional and modeling course content could be consolidated to establish a course that would stimulate student interest, promote maturation in problem solving, and give the best learning opportunities for students to be able to transfer skills to subsequent math courses.

Some of the limitations of this study were that only one university was studied, both types of college algebra content were not available simultaneously, and no common, standardized final exam was administered in survey of calculus. Also, this study should be conducted at more universities across the region offering both types of college algebra. More than just one subsequent mathematics course should be analyzed. Data analysis could be conducted on several subsequent mathematics courses, such as precalculus, trigonometry, and educational courses in mathematics for students enrolled in a teacher preparation program. Faculty at other institutions would provide meaningful insight into what they have found to be best practice measures for their universities.

Specific learning objectives in course curricula at one university may be different than the curricula at another university even if the courses share a common title. Therefore, close attention to learning objectives at other institutions would need to be considered and course sequencing in these institutions should be studied carefully. Institutions demonstrating consistent success in student achievement in college algebra and subsequent courses could provide a wealth of knowledge to other universities seeking improvements in their mathematics courses and programs. The implementation of learning objectives, course sequencing, and classroom experiences could help other institutions grow, retain, and graduate students who are better prepared.

Chapter Summary

Successful completion rates and academic achievement in a student's first attempt at survey of calculus were compared between students who had traditional college algebra course content and students who had modeling college algebra course content. A higher proportion of students passed survey of calculus, with a grade of C or higher, when they had traditional college algebra content as a prerequisite course. Academic achievement in survey of calculus, as measured by average GPA, of students was statistically equal; however, students did have a numerically higher average GPA of 2.147 when they came from traditional college algebra content compared to student who came from modeling content (2.023). No significant difference in average age was found between the two subpopulations of college algebra students. Students who had modeling college algebra content tested into college with statistically higher ACT mathematics subject area scores (22.30) compared to students coming from traditional algebra content (21.54). After a brief discussion of the implications of each of these conclusions was given, recommendations for practice and further research were also given. Much work still needs to be done in finding the right content to maximize student learning potential and give students the best opportunity for success in their collegiate and career endeavors.

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Appendix A

Figure 1: Histogram of Academic Achievement in Survey of Calculus by Student Grades

Figure 1: Histogram of Academic Achievement in Survey of Calculus by Student Grades

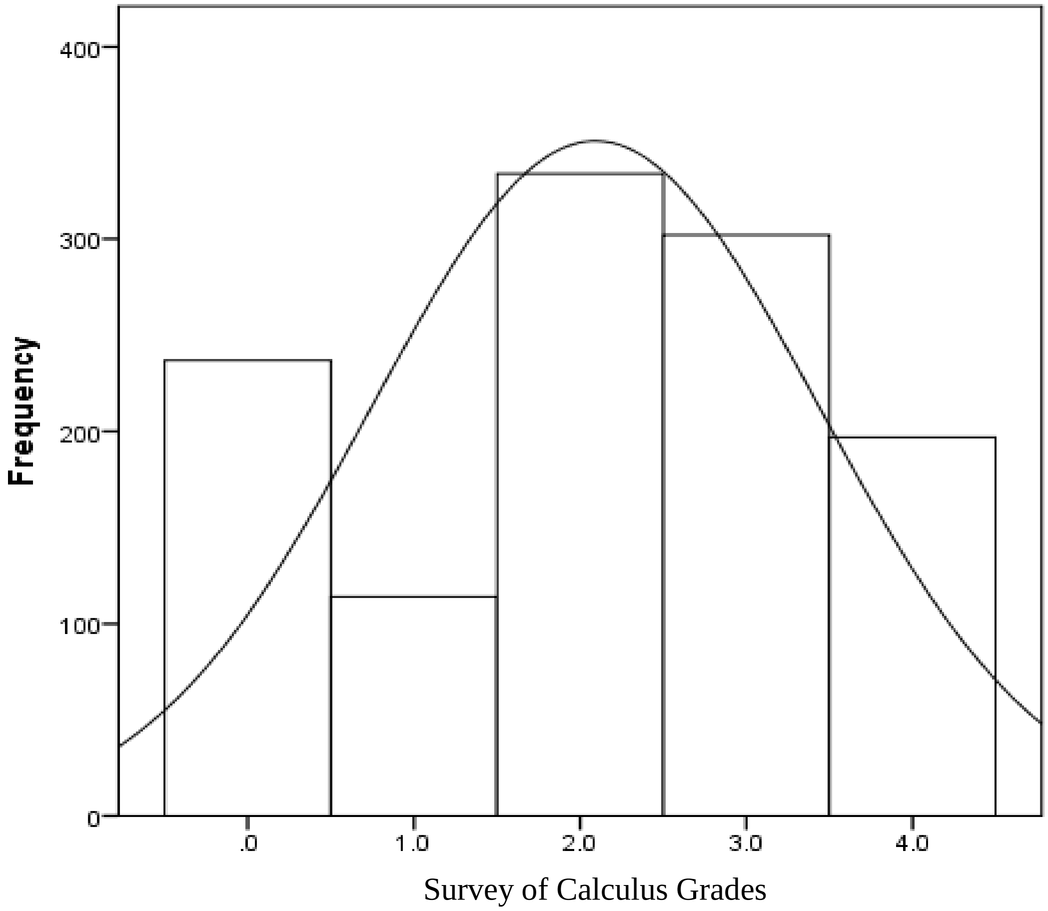
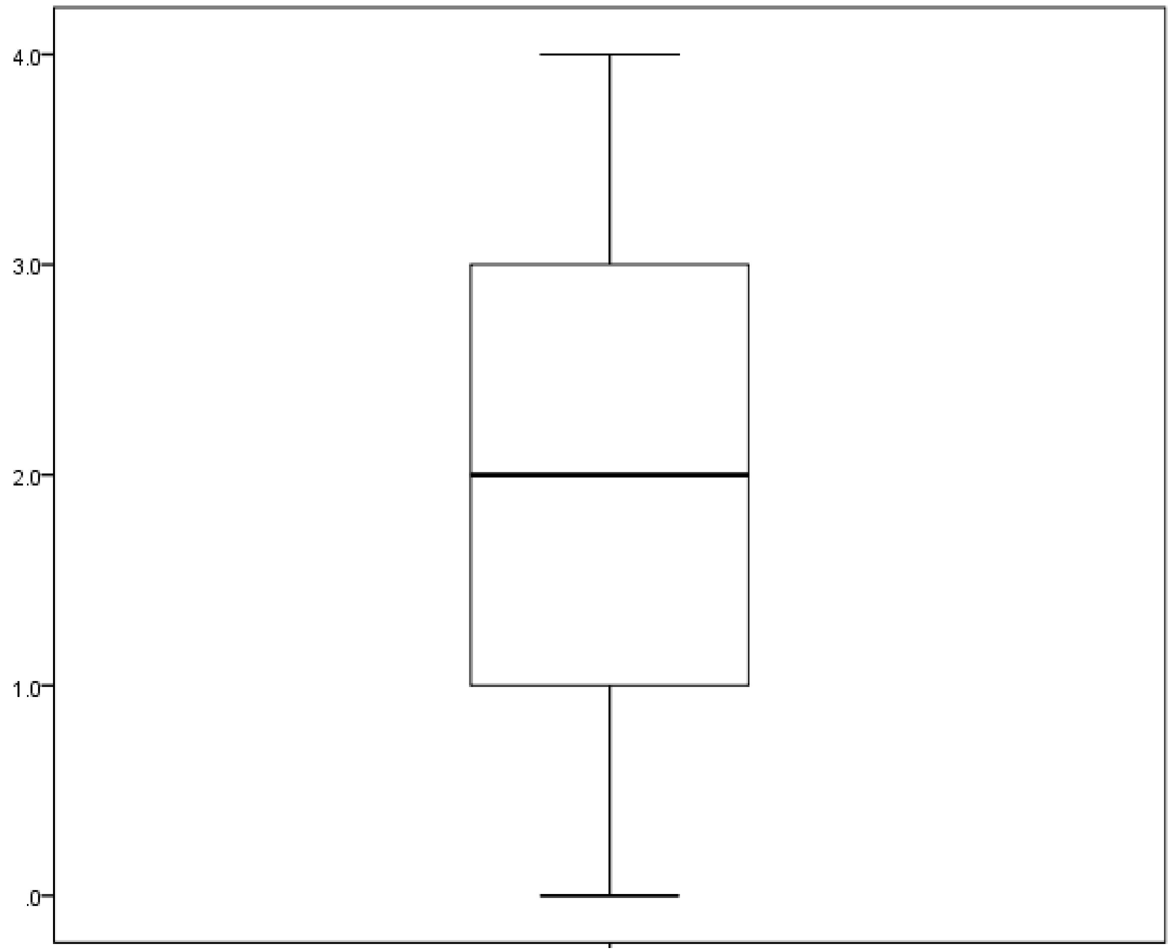


Figure 1. Histogram of Academic Achievement in Survey of Calculus Grades (n = 1,184, M = 2.09, SD = 1.346) to indicate an approximately normal distribution of the data as compared to the normal curve.

Appendix B

Figure 2: Boxplot of Academic Achievement in Survey of Calculus by Student Grades

Figure 2: Boxplot of Academic Achievement in Survey of Calculus by Student Grades



Survey of Calculus Grades

Figure 2. Boxplot of Academic Achievement in Survey of Calculus Grades (n = 1,184, M = 2.09, SD = 1.346) to indicate an approximately normal distribution of the data.

Appendix C

Figure 3: Normal Q – Q plot of Academic Achievement in Survey of Calculus by Student Grades

Figure 3: Normal Q – Q plot of Academic Achievement in Survey of Calculus by Student Grades

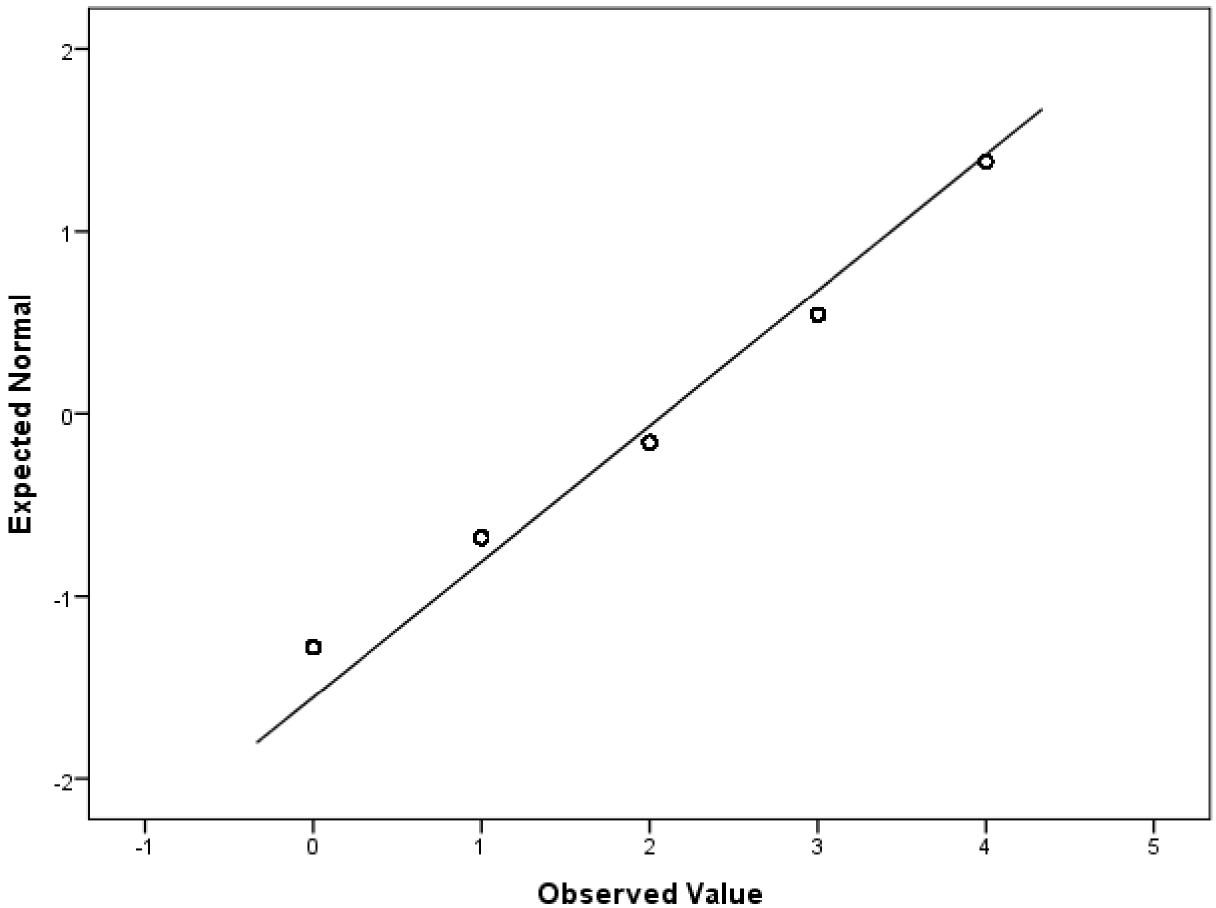


Figure 3. Normal Q – Q plot of Academic Achievement in Survey of Calculus Grades (n = 1,184, M = 2.09, SD = 1.346) to indicate an approximately normal distribution of the data.

Appendix D

IRB Approval Letters

December 13, 2012

MEMORANDUM

TO:	Jerry West Kenda Grover
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	12-11-307
Protocol Title:	*The Effects of College Algebra Course Content on Academic Achievement in Survey of Calculus*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 12/13/2012 Expiration Date: 12/12/2013

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 2,300 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

University of Arkansas - Fort Smith

Institutional Review Board
Response to Request for Review

UA Fort Smith IRB	Registration 12-025 Date 11-19-2012	
Principal Investigator	Name Jerry West Telephone : 479-788-7654	E-mail Jerry.west@uafs.edu
Project Title or Description	THE EFFECTS OF COLLEGE ALGEBRA COURSE CONTENT ON ACADEMIC ACHIEVEMENT IN SURVEY OF CALCULUS	
The items checked need to be completed for further review	☐ Add advisor/student contact information ☐ Add a statement that the participant is at least 18 years of age. (Under 18 require parental/guardian permission.) ☐ Add a statement that participation is voluntary and that participation can be withdrawn at any time without penalty. ☐ Provide a signature and date line for participants on the consent form. ☐ Add a space on the Parental Permission form for the child's name. ☐ Develop a simple assent form for review ☐ Add statement regarding video/audio tapes must include where they will be kept, for how long, when or if they will be destroyed, who will have access to them, etc. ☐ A statement from the school, institution, facility, etc., granting permission to conduct research is needed	☐ A cover letter for mail surveys is needed. ☐ A copy of the survey instrument is needed. ☐ A copy of the consent form is needed. ☐ A copy of the assent form is needed. ☐ A statement of how the data will be kept confidential is needed. ☐ What is the expected duration of the study? ☐ How will you protect the privacy of the subjects? ☐ How will you recruit subjects? ☐ Address debriefing or attach form ☐ References are needed. Comments: ________

Recommendations:

☑ **Exempt from Review**

Signed Dr. Sydney Fulbright Date 11-19-2012

☐ **Expedited Review**

- ☐ Approved as submitted
- ☐ Approved with conditions which must be met prior to initiation of research.
- ☐ Not approved

Signed ________ Date ________

☐ **Full Board Review**

- ☐ Approved as submitted
- ☐ Approved with conditions noted which must be met prior to initiation of research.
- ☐ Not approved

Signed ________ Date ________

Note: Approval expires one (1) year from the date above. If significant changes are made to this protocol, prior approval from the IRB must be obtained. If you disagree with the final IRB recommendation you may appeal the decision