A LONGITUDINAL STUDY OF MODELING-BASED COLLEGE ALGEBRA AND ITS EFFECT ON STUDENT ACHIEVEMENT

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ABSTRACT

Low success rates and high withdrawal rates in gateway courses like College Algebra have deterred some students from attaining their educational goals. The university of study developed a Modeling-Based College Algebra course with the purpose of creating a better course for terminal students and yet still preparing nonterminal students for the next mathematics course. In this quantitative study, the difference between the two College Algebra courses in terms of average final grade, the D/F percentage, the withdrawal percentage, and the average final grade in a subsequent mathematics course was examined. The difference in median final grade, D/F percentage, and withdrawal percentage was statistically significant. The difference in average final grade in the subsequent math course was not statistically significant. The difference in median final grade, D/F percentage, and withdrawal percentage was statistically significant for female, male, and traditional students.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Graduate Studies, have examined a dissertation titled "A Longitudinal Study of Modeling-Based College Algebra and its Effect on Student Achievement," presented by Timothy Paul Chappell, candidate for the Doctor of Philosophy degree, and certify that in their opinion it is worthy of acceptance.

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DEDICATION

I dedicate my dissertation work to my wife Margaret. She has always been an inspiration to me and pushes me to pursue excellence. I hope the next 32 years are as great as the first 32 years have been.

I also dedicate this dissertation to my parents, Lyle and Barbara Chappell; I wish they were here to join in the celebration of this accomplishment. They helped mold me into the person I am today.

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CHAPTER 1

INTRODUCTION

Historically, College Algebra has been the common general education mathematics course requirement for students in non-STEM and STEM majors. More than 680,000 students take College Algebra each year, and only about 50 percent of those students earn a grade of A, B, or C (Ganter & Haver, 2011). However, not all incoming college students who need to complete College Algebra are allowed to enroll in College Algebra immediately. Nationally, 60 percent of college freshmen are required to take at least one developmental algebra course below College Algebra. Depending on the institution, students may be required to take up to three of the following courses: Basic Mathematics/Prealgebra, Introductory Algebra, and Intermediate Algebra. Of those students, only 20 percent successfully complete this developmental coursework to then enroll in College Algebra (Chen, 2016). Math should be a gateway to future success in a student's field of study and not a gatekeeper that separates students from their goal of attaining a degree in higher education (Laughbaum, 2017).

The Purpose of College Algebra

The primary purpose of College Algebra is to be an intermediate step between high school mathematics courses and upper level university mathematics courses such as Calculus (Ellington, 2005; Lunn, 1905; Rietz, 1910). The course emphasizes algebraic and graphical techniques that are essential to the analysis of functions in calculus. However, less than 10 percent of College Algebra students enter Calculus I (Ganter & Haver, 2011). Fewer than 40 percent of students entering college intending to major in a science, technology, engineering, or math (STEM) field actually complete that STEM degree according to the report from the President's Council of Advisors on Science and Technology (PCAST) (Olsen & Riordan, 2012). For the 90 percent who are not advancing to study Calculus, those students would benefit from a mathematics general education course that promotes quantitative literacy and an appreciation for the usefulness of mathematics to society (Steen, 2004). Steen also stated that college-level "quantitative literacy is essential for all graduates' personal and civic responsibilities," and "is inextricably connected to virtually all areas of undergraduate study." For these reasons, an alternative course to College Algebra is needed for the general education requirements for mathematics.

The Curriculum of College Algebra

Students in traditional College Algebra study various types of equations and inequalities, functions and their inverses, theory of higher degree equations, systems of equations, determinants, logarithms, exponentials and applications. The types of functions studied include linear, polynomial, exponential, logarithmic, radical, and rational functions. Lecture is the preferred delivery method for instruction. Technology is typically not used. Symbolic manipulation is the main focus with heavy emphasis on factoring of polynomials, and graphing of each function type is without the aid of technology (Gordon, 2016). Real world applications are seldom used in the course (Herriott, 2003).

The National Call for College Algebra Reform

Change has been needed in mathematics education for some time. In 1989, the National Council of Teachers of Mathematics (NCTM) released mathematics recommendations for kindergarten through twelfth grade in the report, *The Curriculum and Evaluation Standards for School Mathematics*. This report is often referred to as *The Standards*. Undergraduate mathematics curriculum recommendations begin to emerge after that, such as *Curriculum in Flux* (Davis, 1989), *Reshaping College Mathematics* (Steen, 1989), and *Moving Beyond Myths* (National Research Council, 1991). These reports focused on courses taken by mathematics majors but did not specifically address courses for students who were not going into STEM fields or students who needed college mathematics courses before Calculus.

As stated on its website, The American Mathematical Association of Two-Year Colleges (AMATYC) is the national mathematics organization whose vision is to be the leading voice and resource for excellence in mathematics education in the first two years of college. In 1995, AMATYC published the report *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus*. The document stated that collegiate mathematics programs must serve students who are prepared to study calculus, students who wish to study calculus but are unprepared to do so, and students who do not intend to study calculus. The writers further stated that until this Crossroads document, no group had established standards for mathematics programs that specifically address the needs of those last two groups of college students.

Three sets of standards for introductory college mathematics were presented. The Standards for Intellectual Development address problem solving, modeling, reasoning, connecting with other disciplines, communicating, using technology, and developing mathematical power. The Standards for Content provide guidelines for content in number sense, symbolism and algebra, geometry, function, discrete mathematics, probability and statistics, and deductive proof. The Standards for Pedagogy focus on instructional strategies such as teaching with technology, interactive and collaborative learning, connecting with other experiences, multiple approaches, and experiencing mathematics. The Crossroads authors stated the following principles as the philosophical framework for development of new courses or the revision of existing courses:

- All students should grow in their knowledge of mathematics while attending college.
- The mathematics that students study should be meaningful and relevant.
- Mathematics must be taught as a laboratory discipline.
- The use of technology is an essential part of an up-to-date curriculum.
- Students will acquire mathematics through a carefully balanced educational program that emphasizes the content and instructional strategies recommended in the standards along with the viable components of traditional instruction.
- Introductory college mathematics should significantly increase students' options in educational and career choices.

- Increased participation by all students in mathematics and in careers using mathematics is a critical goal in our heterogeneous society. (Cohen, 1995)

The purpose of these standards was not to define a specific course but to provide a flexible framework for the rebuilding of introductory college mathematics courses. The document defined introductory college mathematics courses to include College Algebra, Trigonometry, Introductory Statistics, Finite Mathematics, and Precalculus, along with the developmental courses of Basic Mathematics, Prealgebra, Introductory Algebra, and Intermediate Algebra.

In 1999, the Missouri Mathematical Association of Two-Year Colleges (MOMATYC) and the Mathematical Association of America-Missouri Section (MAA-Missouri) drafted a joint position paper to the Missouri Coordinating Board of Higher Education (CBHE) asking for an alternative to College Algebra to be accepted as a general education requirement in Missouri. In 2001, CBHE stated that an alternative course to College Algebra could fulfill the general education mathematics requirement as long as it included exploration of the concepts of algebra, geometry, and statistics. The course was also required to have the same prerequisites and level of rigor as a traditional College Algebra course. The mathematics department at the university in this study determined that either College Algebra would have to be modified or another existing course would have to be brought up to the same level of rigor as College Algebra. The seemingly better option at the university was to modify College Algebra. See Appendix A for the course modification form that was submitted. This new course will be referred to as Modeling-Based College Algebra in the rest of this document.

More mathematical organizations began focusing attention on course redesign or new course development. MAA's Committee on the Undergraduate Program in Mathematics (CUPM) issued guidelines for mathematics departments in 2004 and updated those guidelines again in 2015. AMATYC produced a new report called *Beyond Crossroads* in 2006 as a "call for continuous improvement in content, pedagogy, and professionalism" (Blair, 2006). A subcommittee of CUPM, the Curriculum Renewal Across the First Two Years (CRAFTY), published the report *Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra* (Ganter & Haver, 2011) which provided guidelines for College Algebra.

> College Algebra provides students a college level academic experience that emphasizes the use of algebra and functions in problem solving and modeling, provides a foundation in quantitative literacy, supplies the algebra and other mathematics needed in partner disciplines, and helps meet quantitative needs in, and outside of, academia. Students address problems presented as real world situations by creating and interpreting mathematical models. Solutions to the problems are formulated, validated, and analyzed using mental, paper and pencil, algebraic, and technology-based techniques as appropriate. (Ganter & Haver, 2011, p. 2)

That is how the report described the fundamental experience of College Algebra.

In 2015, the report *A Common Vision for Undergraduate Mathematical Sciences Programs in 2025* was published. This report was historic in that five major mathematics organizations collaborated on this project, also called the *Common Vision* project. The organizations were AMATYC, the American Mathematical Society (AMS), the American Statistical Association (ASA), MAA, and the Society for Industrial and Applied Mathematics (SIAM). This report chronicled the most recent seven reports published by the five organizations and affirmed the joint commitment to promote quality mathematics education in America at the college level.

College Algebra Reform Teaching Practices

There have been a number of College Algebra redesign efforts by teachers and researchers, some of which focused on the use of technology as a tool in the College Algebra classroom. In 2010, Neil Hatem conducted dissertational research on the relationship between the use of graphing calculators and student achievement for students in College Algebra and Precalculus at the University of Massachusetts Lowell. Hatem used multiple instruments to test the effect of graphing calculators on student achievement, and the results were inconsistent. An important result of the study focused on not whether graphing calculators should be used, but rather when the graphing calculator would prove most effective in student learning (Hatem, 2010).

Another study examined students using graphing calculators or Microsoft® Excel®(Champion, Parker, Mendoza-Spencer, & Wheeler, 2011). Students used one of the technologies to analyze and model data and used Excel® for graphs. An attitude survey showed that 91% of the survey respondents believed that knowing how to use computers will be important to a successful career, but the use of the project with real world data did not create a significant difference in attitudes between the students who did or did not do the project. This is concerning as algebra reform stresses the importance of using real world data and modeling to foster an appreciation for the usefulness of mathematics to partner disciplines.

Other studies used technology by using an online homework system. Online programs provide instructors with feedback on student performance that can be used to modify the presentation of material in class. Online homework also provides feedback to students quicker and allows students to spend more time on problems they are having difficulty with. A study by Brewer and Becker revealed that students using online homework performed better than students using paper homework, but the difference was not statistically significantly different (Brewer & Becker, 2010). Burch and Kuo (2010) found that online homework students earned significantly higher test scores and had higher retention than those using traditional paper homework. The ability to redo homework problems and review them interactively was considered a prominent factor in the success in both studies (Burch & Kuo, 2010).

One College Algebra redesign incorporated the replacement model approach (Thompson & McCann, 2010). "The key characteristic of the replacement model is a reduction in class-meeting time, replacing face-to-face time with online, interactive learning activities for students" (Twigg, 2003). Thompson and McCann (2010) defined their replacement model treatment group as classes with no more than 50 percent of the required class time spent on lecture and instruction to the entire class. The control group used traditional lecture. The results of the study show that the treatment group students did significantly better on tests, had significantly lower math anxiety, and felt significantly greater confidence in their mathematical ability than the control group students (Thompson & McCann, 2010).

Herron et al. (2012) used technology-based instruction as the primary mode of delivery. Students learned through videos and interactive computer lessons on the computer. The researcher compared the final grades of students in computer-assisted sections of College Algebra with those in traditional sections. The success rate, measured in grades of A, B, or C, was higher for the computer-assisted sections but not statistically significantly higher (Herron, Gandy, Ye, & Syed, 2012).

Several other researchers used the emporium model for their reform efforts. The emporium model was first developed at Virginia Tech in 1997. “The emporium model eliminates all class meetings and replaces them with a learning resource center featuring online materials and on-demand personalized assistance” (Twigg, 2003). In 2001, Black Hills State University redesigned College Algebra used the emporium model (Hagerty, Smith, & Goodwin, 2010). From 2001 to 2006, the university saw the College Algebra pass rate increase from 54% to 75%, a 300% increase in enrollment in the next subsequent math course, a 25% improvement in attendance, and a 10% increase in nationally normed test scores. Cousins-Cooper et al. (2017) studied the emporium model and found statistically significantly higher test scores for the emporium students (Cousins-Cooper, Staley, Kim, & Luke, 2017). A study by Boyce and O’Halloran (2019) also used an emporium model approach. The initial findings of the study showed an improvement in procedural math skills and a weakness in conceptual understanding (Boyce & O’Halloran, 2020).

Another reform of College Algebra is the supplemental model which can include any number of additional sources of learning, including but not limited to supplemental instruction, tutoring, and twitter feeds. Miller and Schraeder (2015) combined large lectures, a recitation laboratory class, and an extra day devoted to supplemental practice (SP). For supplemental practice, students worked in groups on a worksheet of examples and problems based on the previous week's material. The control group was given a question-and-answer session. The experimental group performed statistically significantly better on tests than the control group (Miller & Schraeder, 2015). Porter (2015) also success with students in a redesigned College Algebra course with a lab component, software package, and a writing component (Porter, 2010). Lazari and Simons (2003) did not find significant difference for their supplemental instruction group compared to the traditional lecture group (Lazari & Simons, 2003). Another study investigated outcomes of College Algebra students who used an online tutoring service with statistically significant results (Kersaint, Dogbey, Barber, & Kephart, 2011). Tanner et al. (2013) used Twitter as a tutoring method in which the researcher responded back and forth with the students on specific problems. Tanner found that the method improved retention in the course (Tanner, Hartsell, & Starrett, 2013).

Several studies investigated the impact of open educational resources (OER) upon College Algebra students. Chiorescu conducted a study at Georgia College where they use an emporium model for College Algebra. The student grades were higher with the OER materials, but not significantly higher (Chiorescu, 2017). Hilton et al. (2013) also studied a switch to OER resources and found no significant difference in student achievement. The department considered that favorable due to the low cost of the OER materials (Hilton III, Gaudet, Clark, Robinson, & Wiley, 2013).

The flipped classroom model has created a paradigm shift in mathematics education in recent years. The flipped classroom is appropriately named; the lecture is done at home via instructor-created videos and the homework is worked on in class. Typically, the students work on worksheets or other homework assignments in groups within the classroom. There are a number of studies that investigate the impact of the flipped classroom on student achievement and engagement in College Algebra.

Jaster implemented a flipped classroom in College Algebra and used an OER textbook. The study reported perceptions from a survey and field notes from the researcher; no statistical analysis was done (Jaster, 2017). Overmyer compared five sections of a flipped College Algebra with six traditional sections. Sections with instructors with prior experience in inquiry-based and cooperative learning methods saw statistically higher common final exam scores (Overmyer, 2015). Ichinose and Clinkenbeard also used a flipped classroom. The students in the flipped class scored statistically significantly higher on four of the five tests and averaged 7% higher course grade (Ichinose & Clinkenbeard, 2016).

Van Sickle taught several College Algebra classes for two semesters using the flipped classroom model and then taught a traditional lecture-based class the following semester. Test scores and student feedback both indicated that students learned more in the flipped classroom (Van Sickle, 2015). Ogden implemented a flipped classroom for College Algebra over three semesters. The study revealed that students felt more comfortable in asking questions in class, the course structure promoted student learning, students enjoyed being able to pause and play the video at their own pace, and students had more confidence in their mathematical ability (Ogden, 2015).

College Algebra Reform Curriculum/Teaching Practices

Some researchers created a Modeling-Based College Algebra course. A typical course will 1) incorporate activities that help students' learning and communication, 2) encourage multiple approaches to problem solving, 3) present key ideas and concepts from a variety of perspectives, and 4) employ a broad range of examples and applications to motivate students and to connect to other subjects (Barker et al., 2004).

Ellington (2005) piloted a Modeling-Based College Algebra course. Each section of the course had an instructor and two teaching assistants who helped with activities in the classroom. Each Modeling-Based (treatment) and traditional lecture (control) section met for two 75-minute class periods as well as a 50-minute computer lab session. Students in the Modeling-Based group had a statistically significantly higher success rate and performed better on final exam questions common to both groups. Modeling-Based students continuing on to Precalculus did worse in that class, but Modeling-Based students did slightly better than traditional students in a subsequent business mathematics course. A greater percentage of Modeling-Based students successfully completed College Algebra course and a subsequent major course by the end of the following semester. Attendance was better in the Modeling-Based sections than the traditional sections (Ellington, 2005).

A study by Pinzon et al. (2016) investigated an active learning College Algebra class that was Modeling-Based and used a flipped classroom model. Results of the study showed that students did slightly better than students in traditional lecture sections on final exam questions common to both classes (Pinzon, Pinzon, & Stackpole, 2016).

Oty et al. (2000) created an Algebra for the Sciences course to replace College Algebra for students who do not need to take another mathematics course. This course included problem solving and modeling, algebra and functions, quantitative literacy, support for partner disciplines, and use of technology. The course contained cooperative learning group activities and individual projects based on science topics. Results showed that student perceptions of the usefulness of mathematics and class engagement were significantly higher for the new course compared to the traditional College Algebra course. The students "found mathematics to be more interesting, practical, and important" (Oty, Elliott, McArthur, & Clark, 2000).

The Pathways Movement

In addition to redesigning College Algebra courses, efforts were made to consider and develop alternative entry-level mathematics courses. Building Math Pathways to Programs of Study is a joint initiative of the Dana Center and Complete College America. The Charles A. Dana Center at the University of Texas at Austin (Dana Center) was founded 30 years ago and works with educators, administrators, and policymakers to support all students, especially the underserved (UTDanaCenter.org). Complete College America was established in 2009 and advocates for better college completion rates and closing equity gaps to improve student success (CompleteCollege.org). Missouri was one of six states chosen to receive technical assistance to establish pathways. The Math Pathways Task Force was formed in October 2014 and was charged with finding entry-level mathematics courses most beneficial for each academic major. Four pathway courses were identified: Mathematics Reasoning and Modeling, Precalculus Algebra, Precalculus, and Statistical Reasoning. A fifth course Elementary Education is currently under consideration. A student at any Missouri college or university that successfully completes one of these courses can transfer that course to another Missouri college or university as the mathematics general education requirement.

The mathematics department at the university of study considered multiple pathways for STEM and non-STEM students but felt that there were not sufficient resources to offer multiple pathways within the small department. They decided that the modified College Algebra course would be a better terminal mathematics course than traditional College Algebra for the many non-STEM students who will never need to take another mathematics course. In addition, the STEM students who need College Algebra to prepare for other mathematics courses or for academic major courses that have College Algebra as a prerequisite would still have the necessary College Algebra concepts to enable them to continue their academic progress.

Modeling-Based College Algebra: Curriculum

The initial proposed course description for the Modeling-Based College Algebra course is listed below.

> A three-hour course that explores the use of algebra in the real world. This exploration takes place by examining the concept of function. Conceptual

understanding of linear, exponential, logarithmic, quadratic, and other polynomial functions is grounded in the collection and statistical analysis of real world data. Functions will be used to solve real world problems using modeling techniques. The concept of function is also explored in detail using analytic geometry.

This Modeling-Based course was a replacement for the traditional College Algebra course so students taking this Modeling-Based course are expected to perform at or above the level of traditional College Algebra students in a subsequent mathematics course that has College Algebra as a prerequisite. And since this course would presumably be better suited for non-STEM majors, the pass rate for this new course should be statistically higher than the pass rate for the traditional College Algebra course.

Students in the Modeling-Based College Algebra course study most of the same topics as the traditional course: various types of equations and inequalities, functions and their inverses, theory of higher degree equations, systems of equations, logarithms, exponentials and applications, but focus on different aspects of those topics at times. Concepts such as factoring techniques, rational expression computation, rationalizing denominators, and completing the square are de-emphasized, with more emphasis placed on constructing and reading tables, studying the growth of functions, reading graphs, and using technology. The revised content adds a section on statistical analysis of data on the first day of class. The study of functions is more focused algebraically and geometrically as functions with real world data are represented in tables, graphs, and spreadsheets throughout the course. Tutoring sessions conducted by upper level mathematics education majors were offered three to four nights per week as a supplemental instruction strategy. These sessions were encouraged but not required. Some instructors gave some sort of replacement credit for a missed assignment for attendance at tutoring.

Modeling-Based College Algebra: Teaching Practices

The format for the Modeling-Based College Algebra course was also changed. College Algebra has traditionally been taught using lecture as the primary mode of instruction. The Modeling-Based College Algebra course is exploration based and requires students to be much more involved in the process of learning. Students in the Modeling-Based course work in groups during class in addition to instructor lecture. The structured examples with real world data engage the students in discussing problem-solving strategies and working collaboratively toward possible solutions. These group explorations create a more student centered learning environment rather than teacher centered, which lines up with recommendations for mathematics teaching at the time of implementation (Leitzel, 1991; National Council of Teachers of Mathematics, 2000; National Research Council, 1989). Research has shown that lecture is not as efficient as other learning methods. Failure rates involving traditional lecture are 55 percent higher than the failure rates for active learning approaches (Freeman et al., 2014).

Graphing calculators were required initially for the Modeling-Based College Algebra course. As scientific calculators increased their functionality and other graphing systems became readily available via the Internet, graphing calculators are now optional for the course. But all sections of the course utilize graphing using some kind of technology as a tool to understand and represent functions.

Definition of Terms

Active Learning: Any learning activity in which the student participates or interacts with the learning process, rather than just passively taking in the information (SmartSparrow.com).

Developmental course: A course below college-level to help remediate students. Students learn the academic skills and knowledge that should have been acquired in high school that are needed for college-level work.

General education: A set of required courses that provide a broad background for every major.

Rigor: Course expectations that are academically and intellectually challenging.

STEM: An acronym for the fields of Science, Technology, Engineering, and Mathematics.

Student success: Academic achievement. In a course, student success is defined as completing a course with an A, B, or C grade.

Terminal mathematics course: The last mathematics course needed to satisfy the general education requirement or a specific major requirement.

Purpose Statement

The purpose of this study is to compare student success in two different College Algebra courses at a small, Midwestern university over a period of thirty-two years. The first course was a traditional College Algebra course taught at the university between Fall 1996 and Spring 2002. The second course was a Modeling-Based College Algebra course taught between Fall 2002 and Spring 2018. Success for each course was measured in terms of final grade, the average percentage of D/F grades, the average withdrawal percentage, and success in the next math class.

Research Question

The research question is intended to measure the effectiveness of the change in approach and curriculum from the traditional College Algebra course to the Modeling-Based College Algebra course. The effectiveness was measured in terms of success in the algebra course as well as success in a subsequent mathematics course.

1. Is there a difference in the College Algebra course approach/curriculum (Modeling-Based vs. traditional) in terms of student success in the College Algebra course?
2. Is there a difference in the College Algebra course approach/curriculum (Modeling-Based vs. traditional) in terms of student success in the subsequent mathematics course?

Null Hypotheses

Three null and alternate (research) hypotheses were developed from the first research question regarding success in the algebra course.

1. There is no difference between the means of the approach/curriculum in terms of final grade in the College Algebra courses.
2. There is no difference between the means of the approach/curriculum in terms of D/F percentage in the College Algebra courses.
3. There is no difference between the means of the approach/curriculum in terms of withdrawal percentage in the College Algebra courses.

The remaining null and alternate (research) hypotheses were developed from the second research question regarding success in the subsequent mathematics course.

4. There is no difference between the means of the approach/curriculum in terms of final grade in the next math class in the College Algebra courses.

Research Hypotheses

1. The mean final grade in the Modeling-based College Algebra course is statistically significantly different from the mean final grade in the traditional College Algebra course.
2. The percentage of D/F grades in the Modeling-based College Algebra course was statistically significantly different than the percentage of D/F grades in the traditional College Algebra course.
3. The withdrawal percentage in the Modeling-based College Algebra course was statistically significantly different from the withdrawal percentage in the traditional College Algebra course.
4. The mean final grade in the next math class for students in the Modeling-Based College Algebra course was statistically significantly different from the mean final grade in the next math class for students in the traditional College Algebra course.

Significance of the Study

College Algebra is a general education course that is a prerequisite for major courses in many bachelor's degree programs. The high D/F/W rates of this course is problematic as students need a C or higher to be able to take the next requisite course. In addition, failure to achieve success in this course may result in students repeating the course which could delay completion of their degree, causing the changing of majors, or possibly even dropping out of college altogether. It is important to mathematics educators to see if student success rates in the Modeling-Based College Algebra course are significantly higher than the success rates in the traditional College Algebra course. This success was measured by D/F percentages, withdrawal percentage, and final grade in the class.

The Modeling-Based course should contain the algebra concepts needed for the next subsequent mathematics course but should be tailored to provide the best possible experience for students. A student typically takes either Business Statistics, Business Calculus, or Calculus as the next subsequent mathematics course that has College Algebra as a prerequisite. It is of interest to mathematics educators to know whether students in a Modeling-Based College Algebra course are sufficiently prepared for the next subsequent mathematics course. The student success was measured by final grade in the class.

This study aids the mathematics department at the small, Midwestern university in determining if the Modeling-Based approach has resulted in lower D/F percentages, lower withdrawal percentage, and higher final grades. The results of the study also provide evidence to show whether or not the Modeling-Based course is adequately preparing students for the next subsequent course. The study adds to the literature on the comparison between traditional and alternative College Algebra approaches. As seen in the brief review of College Algebra reforms earlier in this chapter, researchers have examined the impact of technology tools, online homework systems, video lectures, emporium models, supplemental models, and flipped classrooms on student success and/or student attitudes toward mathematics.

Only three studies focus on Modeling-Based College Algebra or a similar course Algebra for the Sciences. The two studies by Ellington and Pinzon et al. that focus on Modeling-Based College Algebra were one-semester studies with disproportionate sample sizes for the experimental and control groups. The study by Ellington (2005) also involved a lab component in a 4-hour class. This study adds to the body of literature on Modeling-Based College Algebra by providing a longitudinal study for a 3-hour course with proportional sample sizes for the experimental and control groups. It also helps the university of study determine if the revised course is achieving the purpose for which it was created. The purpose of the Modeling-Based College Algebra course at the university of study was to be a better terminal general education mathematics course for the majority of students who will not take another mathematics course but yet still provide the algebraic foundation necessary for students who will go further in mathematics.

CHAPTER 2

LITERATURE REVIEW

The purpose of this study is to compare student success in two different College Algebra courses at a small, Midwestern university over a period of thirty-two years. The first course is a traditional College Algebra course taught between Fall 1996 and Spring 2002. The second course is a Modeling-Based College Algebra course taught between Fall 2002 and Spring 2018. Colleges and universities have struggled with how to offer collegiate mathematics courses for everyone that prepare them for life in general and also for their major field of study. Colleges have offered various general education mathematics courses, such as traditional College Algebra and Modeling-Based College Algebra in the past to Statistics and Mathematical Reasoning in the last decade. This literature review will begin with the review of the problem. This chapter will continue with review of the origins of College Algebra, traditional College Algebra, and College Algebra reform. The chapter will conclude with the summary of the chapter and the significance of this research to the university of study and to the mathematics education research community.

The Problem

More students take College Algebra than any other general education mathematics course at four-year colleges and universities according to a report from a 2010 survey conducted by the American Mathematical Society (Blair, Kirkman, & Maxwell, 2013). As high as 98% of students in College Algebra are taking the course because it satisfies a college requirement (Herriott & Dunbar, 2009). Many of those students are not successfully completing College Algebra, with DFW rates reported at 40 percent (Thompson & McCann, 2010) and 50 percent from the report “Common Vision” of the Mathematical Association of America (Saxe et al., 2015). A number of studies have discussed the alarming DFW rates for College Algebra, and the percentage of DFW grades have been stated as low as 40% and as high as 60% in the literature (Edwards, Haver, & Small, 2011; Haver et al., 2007; Herriott, 2003; Herriott & Dunbar, 2009). Students who were required to take development mathematics courses had a failure rate of 68% (Cohen & Kelly, 2019b). As a result, these students are not able to take classes in their majors that have College Algebra as a prerequisite.

Degree completion is strongly correlated to success in the first year of college (Graves & Twigg, 2006). Failure in this course then creates a huge barrier to students’ educational path, and they will have to choose one of several options to work around this obstacle. The students may withdraw from the university and never return to collegiate studies to complete a degree of any kind (Thompson & McCann, 2010). According to the PCAST Report, 31.5% of STEM students had no degree and dropped out of college, and 34.8% of non-STEM students had dropped out (Olsen & Riordan, 2012). The students may withdraw from the university and transfer to a trade school or community college. The students may change their major to another area of study if they are able to find another major that does not have this prerequisite requirement (Cohen & Kelly, 2019a). The students may retake the course in a subsequent semester to obtain a passing grade.

Successfully repeating the course allows those students to stay in their major at the university of origin. Repeating courses, however, adds classes to their future schedules, and that will almost always delay their date of graduation (Lewis, 2019). Because some major coursework has a particular sequence of requisite courses, students may have to take one or more additional semesters to be able to take the courses they need after successfully completing the requisite courses (Karimi, Manteufel, & Peterson, 2015). If the students are paying for their education themselves, this places a financial burden that may become another barrier to successful completion of their degree. If the student is using financial aid, the student will have to pay for the repeated course at a minimum, and the student may have to pay for additional semesters out of pocket "Many of those who do obtain a degree take longer than the advertised length of the programs, thus raising the cost of their education" for STEM degrees (Cohen & Kelly, 2019b).

The situations outlined above place students at a severe disadvantage, and this shows some of the reasons why persistence and retention rates are so low. The persistence rate is the percentage of students who return to college the next year, and the retention rate is the percentage of students who return to the same institution the next year. The National Student Clearinghouse reported that 73.9 percent of U.S. college students who started in fall 2016 were enrolled at some U.S. institution in fall 2017. The report also stated 61.6 percent of those students from fall 2016 were enrolled at the same institution in fall 2017. For all of the reasons listed above, it is imperative that mathematics faculty develop new curriculum or revise existing courses that prepare the students for what they need to know for other courses. These courses should also provide a positive experience for students, engaging them via modeling real world data and practical scenarios (Bonham & Boylan, 2012; Ellington, 2005).

Origins of College Algebra

To fully understand the present, we must examine the past. Therefore, it is important to examine the origins of College Algebra and review its initial purpose. What we will find is that the structure of College Algebra has not changed significantly since its inception in the 1800s. The content of the course has remained virtually unchanged as well. We will see that Rietz cautioned College Algebra instructors to avoid making College Algebra a “sort of scrap heap of disconnected or rather remotely connected topics, rather than an organized body of knowledge” (Rietz, 1910, p. 50). It is the researcher’s opinion that many students would characterize the current College Algebra course in a similar way.

An early mention of teaching algebra in post-secondary education was in an Algebra and Trigonometry course at Yale in 1718 (Simons, 1924). In 1820, algebra was required of high school students as an entrance requirement to Harvard (Willoughby, 1967). Around the end of the nineteenth century, College Algebra became a standard course taught in American universities (Lunn, 1905; Rietz, 1910). Rietz defined “College Algebra” at that time as the algebra course to be taught to freshmen college students who have satisfied the entrance requirement of one- and one-half years of algebra in high school. College Algebra was taught along with trigonometry and analytic geometry in a comprehensive course of ten credit hours over an entire year of college. College Algebra was the intermediate step between high school mathematics courses and upper level university mathematics courses. These freshmen college students came from middle-class and wealthy families, and they had a strong mathematics background due to the high level of mathematics instruction in their high schools (Tucker, 2013). Tucker went on to state that "as students arrived knowing more mathematics, the level of mathematics taught in colleges rose slowly through the 19th century.

Rietz cautioned College Algebra instructors that "the chief danger in the selection of material and presentation of college algebra is that it is likely to be a sort of scrap heap of disconnected or rather remotely connected topics, rather than an organized body of knowledge" (Rietz, 1910, p. 50). He offered the following topics as a general curriculum guide for College Algebra: equations, graphs, functions, determinants, number types, theory of equations, logarithms, limits and infinite series.

Lunn stated that it is often difficult for instructors to "avoid leaving with the students the impression that they have labored over a set of isolated subjects, hard to master because of lack of interrelations" (Lunn, 1905, p. 123). Lunn created an outline of subjects that could show some semblance of natural unity among the subjects. His list included the fundamental problems of formula, graph, and table; geometrical operations regarding the graphic construction of curves; standard expressions and their graphs; algebraic theorems; interpolation; linear equations; determinants; and determination of roots.

Mathematics courses offered at most postsecondary institutions changed very little from 1920 to 1950 (Tucker, 2013). But as mathematics became valued more by industry by the end of World War II, enrollment in mathematics courses grew at the secondary level as well as for colleges. By 1950 students were better prepared as many were ready to study Calculus in their first year of college. due to the fact that high schools were offering two years of algebra, Euclidean geometry, and a course similar to the Precalculus course of today (Tucker, 2013). From 1950 to 1970, the percentage of students needing to take College Algebra and other courses below Calculus dropped substantially; during the same time period, the percentage of students enrolled in Calculus went up (Tucker, 2013). This phenomenon supports the idea that the level of mathematics instruction in the high schools had improved.

In the middle to late 1900s, there were a number of teachers who questioned the content and pedagogy taught in College Algebra. Studies were conducted to examine different methodologies in the course. In 1948, Danieley believed that “algebra by the lecture method is, for the most part, a waste of time for the teacher and for the student” and that teaching should be “an activity of stimulation and guidance, with students being assisted in their work” (Danieley, 1948, p. 323). In 1954, Willerding questioned whether the algebra taught in colleges was really College Algebra. She felt that “if students are taught at the level in which they enter the college algebra courses, then the algebra taught in colleges ceases to be college algebra” (Willerding, 1954, p. 203). Zahroon compared a tutorial model and a lecture-discussion model at Moorhead State. Statistical analysis was not done in the study, but the Mathematics Department saw enough positives that they expanded the tutorial method into additional sections (Zahroon, 1972).

Traditional College Algebra

Who takes College Algebra now? College students in the early twentieth century were an elite group with high mathematical aptitudes. Those students came from wealthy families and learned from the best teachers in premiere high schools. High performing students such as these still attend college, but most of these students are at the upper tier universities and come in ready to take higher level collegiate mathematics courses at or above the introductory calculus level. The number of students going to college has increased rapidly, especially in recent years, as enrollment has increased by 46% for four-year colleges and universities (Blair, Kirkman, & Maxwell, 2018). Subsequently, the number of incoming students who are deficient in foundational algebra skills has also increased greatly. College Algebra has become the only option available for students who were not prepared academically for calculus and who are required to take at least one semester of calculus.

The number of students enrolled in College Algebra is on the rise over the last fifteen years (Table 1). With the availability of more options to satisfy the general education requirement for mathematics, one would expect the numbers to diminish. That has not been the case. With small enrollment numbers overall in the mathematics department of the university of study, the significant enrollment numbers in this particular course has a dramatic impact on the department. In the past year, the number of sections of College Algebra amounted to 28 of the total mathematics sections offered by the department, and the enrollment for College Algebra accounted for 31% of the overall enrollment in the department.

Table 1. College Algebra enrollment at BA-granting institutions (Blair et al., 2018)

	2000	2005	2010	2015
Total fall semester enrollment in College Algebra (does not include College Algebra with Trigonometry)	211,000	201,000	251,000	261,000
Percentage of fall semester College Algebra enrollment out of total fall semester mathematics enrollment	13%	13%	13%	12%

College Algebra has been considered the intermediate course between high school algebra and upper level college mathematics. It begs the question whether the course is truly fulfilling that purpose. Dunbar studied the flow of students from lower level mathematics courses to higher level mathematics courses at the University of Nebraska at Lincoln (Herriott & Dunbar, 2009). He found that more than 20% of the 1458 students who took College Algebra had to repeat the course. Around 32% of the successful students were able to take Business Calculus. Very few, 11% of the successful students were still enrolled in Calculus I after the first three weeks of class, and only 4% were still in the Calculus II class after the first three weeks the following semester. Dunbar states that the College Algebra course is not an efficient primary feeder for calculus classes. Herriott adds that the students who take College Algebra rather than taking Precalculus or Calculus are most likely those who were not successful in high school algebra and also have a fear of mathematics in general (Herriott & Dunbar, 2009).

According to additional research conducted at UNL by Herriott and Dunbar, the College Algebra student is typically a freshman. This fits with the statement that College

Algebra is the first college mathematics course with students who have some high school algebra but are not yet ready for calculus. Since the typical student is a freshman, the stated major, if there is one, for each student is not a reliable measure of the major they will graduate with. At the university of study, freshmen are allowed to list a major on their record but do not obtain an advisor until during the spring semester of their freshman year. By the spring semester, many students have changed their intended major at least once. The research by Herriott and Dunbar found that 29% of the College Algebra students had not declared a major at the time they were enrolled in College Algebra (Herriott & Dunbar, 2009).

Their data revealed that only 9% of the surveyed students in College Algebra who had declared majors were planning to obtain a major that was mathematically intensive. Business majors comprised 43% of the declared majors of students in College Algebra, and 31% were intending to enter Life and Allied Health Sciences fields. Social Sciences (9%), Education (6%), and Humanities (2%) were the other non-intensive mathematics majors declared by the College Algebra students. The researchers found that 43% of the successful students took one semester of calculus. This coupled with the 43% of declared majors being Business majors supports the theory that students often take College Algebra as a prerequisite for Business Calculus (Herriott & Dunbar, 2009). Oty et al. surveyed College Algebra students at Southeastern Oklahoma State University. They found that many students were taking College Algebra as a terminal course. As a result, the students were failing to appreciate mathematics, often failing or withdrawing from the course, and were dissatisfied with their experience in the course (Oty et al., 2000).

The curriculum of traditional College Algebra has not changed a lot since the days of Rietz and Lunn in the early 1900's. Topics covered in traditional College Algebra focus on the study of various functions and their graphs (Herriott, 2003). Equations and inequalities, functions and their inverses, theory of higher degree equations, systems of equations, determinants, logarithms, exponentials, radicals, and rational functions are typically all covered in a three-hour, one-semester course. Symbolic manipulation and rote memorization are integral parts of the course. Applications are covered briefly with little to no context to real world scenarios and are usually contrived.

The mainstay approach to instruction in a traditional College Algebra course is lecture. According to the 2010 report of the Conference Board of the Mathematical Sciences (CBMS), 65% of four-year mathematics departments characterized their College Algebra courses as "primarily using a traditional approach" (Blair et al., 2013). Technology usage is minimal, and graphing calculators are the typical technology used in the course. Online homework systems are used to facilitate grading rather than as an interactive mode of learning. Modeling using real data, projects, in-class group work, out-of-class group work, presentations, spreadsheets, and graphing programs are not often utilized in a traditional College Algebra course (Blair et al., 2013).

The previous data demonstrate that traditional College Algebra is not advancing students who need to take further mathematics courses. The course is also not helping students who are taking the course as their only mathematics course. The course is not connecting to a student's everyday life. If the course did that, the student would develop a greater appreciation of the usefulness of mathematics (Oty et al., 2000). If the course were structured differently in terms of curriculum and instructional design, students might be able to apply mathematical concepts personally and have a rewarding experience in the class.

Factors Impacting College Student Success

This predicament is not exclusive to mathematics as College Algebra is just one of a number of gateway courses in which a significant number of students are not successful. To be successful, students must earn an A/B/C grade to continue on to upper level courses, and many of these students end up with a D/F grade or withdraw from the course altogether. There are a plethora of studies researching the lack of student success in gateway courses in other subject areas including, but not limited to, business, computer science, chemistry, biology, physics, psychology, sociology, and composition (Benford & Gess-Newsome, 2006; Frame & Cummins-Sebree, 2017; Lorah & Ndum, 2013; Roberts, Olcott, McLean, Baker, & Möller, 2018; Ueckert, Adams, & Lock, 2011; White & Gronfein, 2004).

According to the research, there are a number of possible causes for students receiving D/F/W grades. White and Gronfein (2004) considered being a first generation student, commuting, other significant time commitments, and inefficient teaching practices as possible causes for the lack of success in the gateway courses (White & Gronfein, 2004). Benford and Gess-Newsome (2006) identified possible causes as insufficient student recruitment efforts, academically underprepared students, lack of ethnic and cultural diversity for both students and faculty and outdated teaching strategies

(Benford & Gess-Newsome, 2006). The findings of other studies had some combination of the possible causes included in these two lists.

White and Gronfein (2004) paired an introductory sociology course with a composition course (White & Gronfein, 2004). The instructors incorporated interactive, online testing rather than in-class multiple choice exams. This freed up time for active learning within the classroom. Online discussion questions prompted student interaction outside of class. Students in this model received significantly less D/F/W grades than the traditional model.

Ueckert et al. (2011) added more group work within an introductory biology class and more online resources including tutorials, PowerPoints, and simulations (Ueckert et al., 2011). Their D/F/W grades reduced from 35.75% to 27.25%. There was an increase in the number of A/B grades as well.

Lorah and Ndum (2013) examined trends in academic achievement gaps over a twelve-year period (Lorah & Ndum, 2013). The researchers found that females outperformed males in all gateway classes, but especially in English Composition I and College Algebra. The racial and ethnic groups achievement gap widened in the social sciences over that time period, but the gap narrowed in biology. African American and Hispanic students had achievement gaps in English Composition I, social science courses, and biology. An interesting finding of this study was that there did not appear to be an academic achievement gap for African American and Hispanic students in College Algebra.

Reid (2016) redesigned a general chemistry course using the flipped classroom model (Reid, 2016). There was a reduction in withdrawals as the flipped section had 1.6% withdrawals compared to the traditional section with 6.3% withdrawals. There was no meaningful statistical difference in student evaluations, pre-tests, post-tests, and the standardized American Chemical Society (ACS) exam scores.

Roberts et al. (2018) used active learning and clickers to promote interaction in an introductory geology class (Roberts et al., 2018). Students had more just-in-time help as additional graduate teaching assistants and undergraduate teaching assistants were available for in class support. Females, first time freshmen, and underrepresented minorities achieved greater success with the active learning approach.

Achat-Mendes et al. (2020) used a modified Supplemental Instruction (SI) model as peer supplemental instruction (PSI) to support the gateway courses Principles of Biology I and II, Principles of Chemistry I and II, College Algebra, Precalculus, and Introduction to Programming (Achat-Mendes, Anfuso, Johnson, & Shepler, 2020). Supplemental instruction (SI) is a non-remedial approach to learning created at the University of Missouri-Kansas City. According to the university website, “SI consists of regularly scheduled, voluntary, out-of-class group study sessions driven by students’ needs.” Trained student leaders facilitate the sessions and use collaborative activities for peer-to-peer learning. The purpose of SI is three-fold: to increase retention in high-risk courses, to improve student grades in high-risk courses, and to increase student graduation rates. The researchers found that attendance of four or more PSI sessions led to an increase in student exam grades for biology and chemistry students. The study found that students with 3.5 GPAs or higher earned higher grades in the gateway course regardless of the PSI attendance. Students with lower GPAs were found to earn the same higher grade if they faithfully attended the PSI sessions. This data supports the fact that PSI or SI programs can help close the academic achievement gap in gateway courses.

National Call for College Algebra Reform

In 1989, the National Council of Teachers of Mathematics (NCTM) released mathematics recommendations for kindergarten through twelfth grade in the report, *The Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics. Commission on Standards for School Mathematics, 1989). This report contained extensive recommendations for new approaches to pedagogy and curriculum for the primary and secondary schools. Undergraduate mathematics curriculum recommendations begin to emerge as well. The *Curriculum in Flux* report was sponsored by the Mathematical Association of America (MAA) Committee on Undergraduate Programs in Mathematics (CUPM) and the American Mathematical Association of Two-Year Colleges (AMATYC). The report proposed guidelines for mathematical content in the two-year college curriculum (Davis, 1989). The *Curriculum in Flux* report proposed recommendations for curriculum content with suggested course outlines at two-year colleges. Also in 1989, Lynn Steen was the editor for a CUPM project, *Reshaping College Mathematics* (Steen, 1989). In 1991, the National Research Council (NRC) produced the report *Moving Beyond Myths* (National Research Council, 1991). These reports focused on courses taken by mathematics majors but did not specifically address courses for students who were not going into STEM fields or students who needed college mathematics courses before Calculus.

Soon after the aforementioned documents on K-12 and college reform, other professional mathematics organizations began work on the beginnings of College Algebra reform. In 1995, AMATYC published its first standards report, *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus* (Cohen, 1995). This report was the first document to "address the needs of college students who plan to pursue careers that do not depend on knowledge of calculus or upper-division mathematics, or those students who need calculus but enter college unprepared for mathematics at that level" (Cohen, 1995, pp. ix-x). The writers of the document outlined three sets of standards: intellectual development standards regarding student thinking, content standards as guidelines for content selection, and pedagogy standards to aid in using and developing instructional strategies. The authors write that "we believe this standards-based reform effort will provide all students with a more engaging and valuable learning experience. Our students deserve no less; our nation requires no less; and we must demand no less of ourselves" (Cohen, 1995, p. 69).

In 1999, the Missouri Mathematical Association of Two-Year Colleges (MOMATYC), the AMATYC affiliate group in Missouri, and the MAA-Missouri Section sought and gained approval of an alternative course to College Algebra as a general education requirement from the Missouri Coordinating Board for Higher Education (CBHE).

In 2004, the Committee on the Undergraduate Program in Mathematics (CUPM) of the MAA released the report, *Undergraduate Programs and Courses in the Mathematics Sciences: CUPM Curriculum Guide 2004* (Barker et al., 2004). The report focused on all areas of postsecondary mathematics, but there was a section regarding introductory mathematics courses like College Algebra. The authors recommended that mathematics departments review their general education course offerings. The courses should engage students meaningfully, develop quantitative and logical reasoning, improve students' ability to communicate mathematics, and encourage students to pursue additional mathematics courses (Barker et al., 2004).

In 2006, AMATYC produced a second standards document, *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College* (Blair, 2006). The purpose of this document was to "renew and to extend the goals, principles and standards set forth in *Crossroads* and to continue the call for their implementation" (Blair, 2006, p. 1). The authors of the document integrated previous recommendations from other organizations such as NCTM and MAA. One of the main goals of this new standards document was to provide clarity to instructors regarding standards-based mathematics education and to aid them in the implementation of those standards (Blair, 2006).

In 2007, MAA released the Curriculum Renewal Across the First Two Years (CRAFTY) report *Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra* which provided guidelines for College Algebra (Ganter & Haver, 2011). These guidelines outlined an academic experience rich in the following areas: problem solving and modeling, algebra and functions, quantitative literacy, support for partner disciplines, and use of technology (Ganter & Haver, 2011, p. 2). This report was the first to outline specifically what should be included in a College Algebra course. The goals for students in the course were organized in the competency areas of problem solving, functions and equations, and data analysis. The report also contained goals for the instructor in terms of pedagogy.

This global push for quality mathematics education in America was further illustrated in 2015 by a combined effort from five major mathematics organizations, AMATYC, American Mathematical Society (AMS), American Statistical Association (ASA), MAA, and Society for Industrial and Applied Mathematics (SIAM), who jointly produced the report, *A Common Vision for Undergraduate Mathematical Sciences Programs in 2025 (Common Vision)* (Saxe et al., 2015). The group examined seven documents produced by the five organizations and looked for commonalities. The overarching theme was that "the status quo is unacceptable" (Saxe et al., 2015, p. 12). There were four categories that needed significant further action: curricula, course structure, workforce preparation, and faculty development. Although not addressed in all of the individual documents, failure rates and other issues of College Algebra necessitate a close examination of the role of College Algebra (Saxe et al., 2015).

Teaching Practices: Technology

One of the recommended content standards in the Beyond Crossroads document involved students collecting, organizing, analyzing, interpreting, and using data to make informed decisions (Blair, 2006). Students need technology to assist in this data analysis of real-world problems (Blair et al., 2013; Gordon, 2016; National Council of Teachers of Mathematics, 2011; Olsen & Riordan, 2012; Saxe et al., 2015). Technology can serve as an instrument for involved computations, but it can also be used as a tool to develop conceptual understanding and to strengthen problem-solving skills (Saxe et al., 2015). NCTM published a position statement on the role of technology in the teaching and learning of mathematics. The statement, "Effective teachers maximize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics," is an excerpt from that position statement (National Council of Teachers of Mathematics, 2011). This technology can take many forms and is useful if the teachers use the technology strategically.

In 2010, Neil Hatem conducted dissertational research on the relationship between the use of graphing calculators and student achievement for students in College Algebra and Precalculus at the University of Massachusetts Lowell. Graphing calculators were integrated into the curriculum and the effect of this technological tool was evaluated in the teaching of function, one of the key concepts in College Algebra. Hatem used multiple instruments to test the effect on student achievement, and the results were inconsistent. However, the study did show that students perceived that they had improved in problem solving skills. An important result of the study focused on not whether graphing calculators should be used, but rather when the graphing calculator would prove most effective in student learning (Hatem, 2010).

A semester-long data analysis project was the focus of another study in which students used graphing calculators or Microsoft® Excel® (Champion et al., 2011).

Students used one of the technologies to analyze and model the data. The graphs for the reports were generated using Excel®. The researchers developed and administered a survey of students' attitudes toward the value of mathematics in their future careers. The survey used a Likert scale, and 91% of the survey respondents believed that knowing how to use computers would be important to a successful career. Surprisingly, the use of a project with real world data did not create a significant difference in attitudes between the students who did the project and the remaining students who did not do the project. This was concerning as algebra reform stresses the importance of using real world data and modeling to foster an appreciation for the usefulness of mathematics to partner disciplines.

The previous two studies researched the role of technology as a tool to conduct mathematical analysis and to generate precise graphs of functions, but technology can be used in so many more ways in mathematics education. Publishers have developed online mathematical homework systems to support their textbooks. Examples of online mathematical homework systems include ALEKS® by McGraw-Hill Higher Education, ConnectMath™ Hosted by ALEKS (CHBA) by McGraw-Hill Higher Education, MyMathLab® by Pearson Education, Inc., WebAssign® by Cengage, Inc., and WileyPLUS by John Wiley & Sons, Inc. The 2010 Conference Board of the Mathematical Sciences (CBMS) *Survey of Undergraduate Programs* reported that 68% of all College Algebra sections nationally used online homework generating and grading packages (Blair et al., 2013). Two studies examined the effect of online homework on student achievement in College Algebra. All class sections of each study followed a common syllabus, schedule, and homework list, and a common departmental final exam was administered. A study by Brewer and Becker (2010) revealed that students using online homework performed better than students using paper homework, but the difference was not statistically significantly different (Brewer & Becker, 2010). Burch and Kuo (2010) found that online homework students earned significantly higher test scores than those using traditional paper homework. The retention rate for the online homework sections was much higher at 86% compared to a 58% retention rate in the traditional homework sections (Burch & Kuo, 2010). The ability to redo homework problems and review them interactively was considered a prominent factor in the success in both studies (Brewer & Becker, 2010; Burch & Kuo, 2010).

One College Algebra redesign incorporated the replacement model approach (Thompson & McCann, 2010). "The key characteristic of the replacement model is a reduction in class-meeting time, replacing face-to-face time with online, interactive learning activities for students" (Twigg, 2003). Thompson (2010) defined their replacement model treatment group as classes with no more than 50 percent of the required class time spent on lecture and instruction to the entire class. This definition allowed for academic freedom for the faculty to utilize a wide range of activities and instructional methods. The control group used traditional lecture. The results of the study showed that the treatment group students did significantly better on tests, had significantly lower math anxiety, and felt significantly greater confidence in their mathematical ability than the students in the control group (Thompson & McCann, 2010).

Herron et al. (2012) used technology-based instruction as the primary mode of delivery. The researcher compared the final grades of students in computer-assisted sections of College Algebra with those in traditional sections. The same concepts and common final exam were applied to both types of sections. The success rate, measured in grades of A, B, or C, was higher for the computer-assisted sections but not statistically significantly higher (Herron et al., 2012).

Several other researchers used the emporium model for their reform efforts. The emporium model was first developed at Virginia Tech in 1997. “The emporium model eliminates all class meetings and replaces them with a learning resource center featuring online materials and on-demand personalized assistance” (Twigg, 2003). In 2001, Black Hills State University redesigned College Algebra using the emporium model (Hagerty et al., 2010). From 2001 to 2006, the university saw the College Algebra pass rate increase from 54% to 75%, a 300% increase in the next subsequent math course, a 25% improvement in attendance, and a 10% increase in nationally normed test scores. Hagerty noted that the use of computer-based mastery learning provided a differentiated approach to learning compared to the linear learning in a traditional textbook (Hagerty et al., 2010). Cousins-Cooper et al. (2017) studied the emporium model and found statistically significantly higher test scores for the emporium students (Cousins-Cooper et al., 2017).

A study by Brown compared the effectiveness of an emporium model redesign for College Algebra with a traditional lecture College Algebra in spring 2012 (Brown, 2012). Most of Brown’s research hypotheses showed no statistically significant differences between the two models. A surprising result was that the DFW rate for the emporium model redesign was 41%, compared to only 21% for the traditional lecture format (Brown, 2012). Demiroz (2016) utilized a mathematics emporium course redesign with supplemental instruction (Demiroz, 2016). Demiroz developed a new inventory to measure students' attitudes toward mathematics, their motivation to learn mathematics, and their level of satisfaction from the new technology-based instructional methods (Demiroz, 2016).

A study by Boyce and O'Halloran (2019) also used an emporium model approach (Boyce & O'Halloran, 2020). The initial findings of the study showed an improvement in procedural math skills and a weakness in conceptual understanding. The course was then modified to a blended format, combining computer-based instruction and activities. The department trimmed some of the procedural topics from the curriculum and added group activities to strengthen conceptual understanding. Another overhaul of the course resulted in utilizing student tracking data in the computer program to create peer-to-peer activities for students studying the same topics at the same time. The course designers are planning computer modules so that students must finish each one at the end of its week and may work on any other modules after they are finished with the current week. This should allow for more cooperative activities within the module for that (Boyce & O'Halloran, 2020).

Graphing calculators and Microsoft® Excel® are useful for analyzing and modeling model real-world data, but their effect is limited on student achievement and attitudes toward mathematics (Champion et al., 2011; Hatem, 2010). Students using online homework performed better in College Algebra than students using paper homework. The increase in student achievement was largely due to the ability to redo homework problems and review the results (Brewer & Becker, 2010; Burch & Kuo, 2010). Another study showed that students in a replacement model course did significantly better on tests, had significantly lower math anxiety, and felt significantly greater confidence in their mathematical ability than the students in the traditional course (Thompson & McCann, 2010). Herron et al. (2012) found that students learning through technology-based instruction performed better but not statistically significantly better than students in a traditional College Algebra course. Several studies showed positive effect of the emporium model on student achievement (Cousins-Cooper et al., 2017; Hagerty et al., 2010). Other studies on the emporium model showed no statistical difference in student achievement (Brown, 2012; Demiroz, 2016). Boyce and O'Halloran (2019) saw improvement in procedural math skills and a weakness in conceptual understanding, which led to substantial changes to the reform course. These changes included removal of topics, addition of group activities, and peer-to-peer activities based on computerized tracking of students (Boyce & O'Halloran, 2020).

Teaching Practices: Supplemental Model

Another reform of College Algebra is the supplemental model which can include any number of additional sources of learning, including but not limited to, Supplemental Instruction, tutoring, twitter feeds and Open Educational Resources (OER). Professors at the University of Missouri-Kansas City developed Supplemental instruction (SI) as a non-remedial approach to learning. SI study sessions are held regularly outside of class for students. The voluntary sessions promote peer-to-peer interaction and are led by trained student leaders. The purpose of SI is to bolster retention, improve student grades and increase student graduate rates.

Lazari and Simons (2003) did not find a significant difference for student achievement between the supplemental instruction group compared to and the traditional lecture group (Lazari & Simons, 2003). At first glance, not having a significant difference in student achievement seems unimpressive, but the mean SAT score of the SI group was significantly lower than the mean SAT score of the control group. A key takeaway from this study is that students who are weak in mathematics and who participate in SI courses can perform as well on average as students in traditional courses (Lazari & Simons, 2003).

Miller (2015) combined large lectures, a recitation laboratory class, and an extra day devoted to supplemental practice (SP) (Miller & Schraeder, 2015). For supplemental practice, students worked in groups on a worksheet of examples and problems based on the previous week's material. The control group was given a question-and-answer session. The experimental group performed statistically significantly better on tests than the control group (Miller & Schraeder, 2015). Porter (2010) also showed success with students in a redesigned College Algebra course with a lab component, software package, and a writing component (Porter, 2010).

A study by Kersaint et al. (2011) investigated outcomes of College Algebra students who used an online tutoring service with statistically significant results (Kersaint et al., 2011). Tanner et al. (2013) used Twitter as a tutoring method in which the researcher responded back and forth with the students on specific problems (Tanner et al., 2013). Tanner found that the method improved retention and test scores in the course.

Several studies investigated the impact of open educational resources (OER) upon College Algebra students. Chiorescu (2017) conducted a study at Georgia College where they use an emporium model for College Algebra (Chiorescu, 2017). After switching the course materials to a free e-textbook coupled with an inexpensive software package, retention was statistically significantly higher than before the change in materials. Retention went down again after the change back to a traditional textbook. The student grades were higher with the OER materials, but not significantly higher (Chiorescu, 2017). Hilton et al. (2013) also studied a switch to OER resources and found no significant difference in student achievement (Hilton III et al., 2013). The department considered that favorable due to the low cost of the OER materials.

Teaching Practices: The Flipped Classroom

The flipped classroom model has created a paradigm shift in mathematics education in recent years. The flipped classroom is appropriately named; the lecture is done at home via assigned videos and the homework is worked on in class. Instructors can make their own videos or use readily available videos from publishers or through online resources such as Khan Academy®. Typically, the students work on worksheets or other homework assignments in groups within the classroom. There are a number of studies that have investigated the impact of the flipped classroom on student achievement and engagement in College Algebra.

Jaster (2017) implemented a flipped classroom in College Algebra and used an OER textbook (Jaster, 2017). The study reported perceptions from a survey and field notes from the researcher. The flipped classroom allowed for better relationships between students and instructor as well as among students. Students embraced the new approach initially. Some students were unable or unwilling to complete the videos outside of class. Some students could not solve basic problems in class, even after writing down notes from the video. There were students who were not confident that became discouraged, and some students were not comfortable asking questions of the instructor during the class. Some students worked well in groups, and others preferred to work by themselves. There were students who were underprepared initially for the course that successfully completed the class with a grade of A, B, or C (Jaster, 2017).

Overmyer (2015) compared five flipped College Algebra sections with six traditional sections (Overmyer, 2015). All sections had the same homework sets and the same 30-question final exam. There was no statistical significance between groups on the common final exam. Two of the five instructors of the flipped sections had prior experience in inquiry-based and cooperative learning methods. Their flipped sections saw statistically higher common final exam scores. A limitation of the study was the lack of training for the instructors of the flipped sections. One instructor taught a flipped section but did not foster a dynamic, inquiry-based learning environment. The meeting times for that class was virtually a study hall. Another limitation of the study was the inconsistency of the instructional videos as there were three video creators with contrasting teaching styles. Overmyer found that flipped classrooms without the proper preparation of classroom activities and worksheets did not result in higher student achievement (Overmyer, 2015). Ichinose and Clinkenbeard also used a flipped classroom (Ichinose & Clinkenbeard, 2016). The students in the flipped class scored statistically significantly higher on four of the five tests and averaged a 7% higher course grade.

Van Sickle (2015) taught several College Algebra classes for two semesters using the flipped classroom model and then taught a traditional lecture-based class the following semester (Van Sickle, 2015). Test scores and student feedback both indicated that students learned more in the flipped classroom. Ogden (2015) implemented a flipped classroom for College Algebra over three semesters (Ogden, 2015). The purpose of the study was to examine student perceptions of the course redesign. The study revealed that students felt more comfortable in asking questions in class, the course structure promoted student learning, students enjoyed being able to pause and play the video at their own pace, and students had more confidence in their mathematical ability (Ogden, 2015).

Jaster explored student perceptions and instructor perceptions of the flipped classroom in College Algebra. Some students are uncomfortable asking questions, and yet some students benefit from the approach because they can ask questions when they have them. Overmyer identified proper instructor training in active learning strategies as a critical component of the flipped classroom model. His study reported that flipped classrooms with properly trained instructors using inquiry-based, cooperative learning methods had a positive effect on student achievement (Overmyer, 2015). Ichinose and Clinkenbeard (2016) and Van Sickle (2015) found that students in flipped classrooms performed statistically better on tests than students in traditional classrooms. Students in flipped classrooms also had more confidence in their mathematical ability (Ogden, 2015). The flipped classroom provides an innovative, interactive approach to the classroom but does not address the need for problem solving and modeling in College Algebra.

Curriculum: Modeling-Based

There are only three studies in the review of literature that focus on Modeling-Based College Algebra. Two of the studies are one-semester studies with disproportionate sample sizes for the Modeling-Based sections and the traditional sections of College Algebra (Ellington, 2005; Pinzon et al., 2016). A third study examines a new terminal general education mathematics course that provides an option for students who do not have to take a course that requires College Algebra as a prerequisite (Oty et al., 2000).

The MAA guidelines encourage instructors to incorporate problem solving and modeling in College Algebra. Interesting applications that students can relate to aid in retention and engagement. A typical course will 1) incorporate activities that help students' learning and communication, 2) encourage multiple approaches to problem solving, 3) present key ideas and concepts from a variety of perspectives, and 4) employ a broad range of examples and applications to motivate students and to connect to other subjects (Barker et al., 2004).

Ellington (2005) piloted a Modeling-Based College Algebra course (Ellington, 2005). Each section of the course had an instructor and two teaching assistants who helped with activities in the classroom. Each Modeling-Based (treatment) and traditional lecture (control) section met for two 75-minute class periods as well as a 50-minute computer lab session. Students in the Modeling-Based group had a statistically significantly higher success rate and performed better on final exam questions common to both groups. Modeling-Based students continuing on to Precalculus did worse in that class than traditional College Algebra students. There are some limitations to the study that could affect these percentages. This study was only a one-semester study. There were 167 students in the modeling sections and 399 students in the traditional sections. There is a need in the research community for a longitudinal study with comparative sample sizes for the two groups. Modeling-Based students did slightly better than traditional students in a subsequent business mathematics course. A greater percentage of Modeling-Based students successfully completed the College Algebra course and a subsequent major course by the end of the following semester (Ellington, 2005).

A study by Pinzon et al. (2016) investigated an active learning College Algebra class that is Modeling-Based and used a flipped classroom model (Pinzon et al., 2016). Some instructional videos that students viewed outside of class were instructor made, but most of the instructional videos came from outside sources such as Khan Academy® and PatrickJMT©. The course had several writing projects. Group work was strongly encouraged. Results of the study show that students did slightly better than students in traditional lecture sections on final exam questions common to both classes (Pinzon et al., 2016). There are some limitations to the study that could affect the results. This study was only a one-semester study. There were 47 students in the active learning, modeling sections and 534 students in the traditional sections. There is a need in the research community for a longitudinal study with comparative sample sizes for the two groups.

Oty et al. (2000) created an Algebra for the Sciences course to replace College Algebra for students who did not need to take another mathematics course (Oty et al., 2000). This course addressed many of the MAA guidelines outlined earlier: problem solving and modeling, algebra and functions, quantitative literacy, support for partner disciplines, and use of technology. The course contained cooperative learning group activities and individual projects based on science topics. Results showed that student perceptions of the usefulness of mathematics and class engagement were significantly higher for the new course compared to the traditional College Algebra course. The students "found mathematics to be more interesting, practical, and important" (Oty et al., 2000, p. 38). This course is a terminal mathematics course and is not intended to be a prerequisite course for another mathematics course. There is still a need of the university of study to have one course that can be a prerequisite course for Precalculus, Trigonometry, Calculus, Business Statistics, or Discrete Mathematics and yet be engaging for the students who do not need to take those other courses.

Equity in College Algebra

Even though this study focuses primarily on the effect of the Modeling-Based curriculum and approach on student success in College Algebra, it is necessary to include discussion of the historically inequitable subgroups of age, gender, and ethnicity. Ages for college students can be divided into various subgroups, but a common division of age separates traditional students from nontraditional students. Traditional students are classified as under 25 years of age, and nontraditional students are classified as 25 years of age or older. The effect of age on success and persistence in College Algebra has been widely researched, with varying results. A higher percentage of traditional age students successfully completed College Algebra compared to nontraditional College Algebra students in several studies (Burgess & Samuels, 1999; Calcagno, Crosta, Bailey, & Jenkins, 2007). A study found that older students were more successful in first level college mathematics courses (Wolfle & Williams, 2014), and some findings showed there was no significant difference between the two age subgroups (Reyes, 2010).

Although it was originally thought that males outperform females in college mathematics courses such as College Algebra, current literature refutes this claim and asserts that females do better in College Algebra than males (Lorah & Ndum, 2013; Struik & Flexer, 1984; Van Nelson & Leganza, 2006). Struik and Flexer (1984) suggests this phenomenon happens because female students in College Algebra arrived well prepared due to their high school courses and the females are more apt to do the work necessary to succeed in College Algebra.

Studies have shown certain ethnicities, specifically Hispanic and African-American, to be at-risk for success in college courses such as College Algebra (Culpepper & Davenport, 2009; Lorah & Ndum, 2013). The study by Lorah and Ndum (2013) found that, compared to White students, African American and Hispanic students earned lower college grades than what their high school grades and test scores would have predicted (Lorah & Ndum, 2013). Lorah went on to state that these findings support the fact that there is a college achievement gap where some ethnic subgroups perform lower than others even after controlling for grades and test scores in high school. The study conducted by Wolfle and Williams showed that ethnicity did not have a major solo effect on success or persistence in the first college-level mathematics course, but the variables of age, ethnicity, and gender together were significantly correlated.

Summary

Traditional College Algebra is not the best feeder class for Calculus. It is also not an ideal terminal class for students who do not need to take a class in their major that has a prerequisite of College Algebra. The course does not foster in students a greater appreciation of the usefulness of mathematics (Oty et al., 2000). If the course was structured differently in terms of curriculum and instructional design, students could apply mathematical concepts personally and have a rewarding experience in the class. All of the major mathematics organizations: AMATYC, AMS, ASA, MAA, NCTM, and SIAM, have published position statements or other reports calling for College Algebra reform.

There are a number of studies that investigate College Algebra reform. Some examples of College Algebra reform integrate technology such as Microsoft® Excel® and graphing calculators as a calculation tool, an aid to generating precise graphs, and a tool to develop conceptual understanding. Other reforms include the use of online homework systems. The ability to redo homework problems and review them interactively is a prominent factor in student success. The Modeling-Based College Algebra course at the university of study incorporates technology, usually Microsoft® Excel® or graphing calculators, along with an online homework system.

Instructional methodology and modes of delivery are key to a number of College Algebra reforms. Instructors have created courses that use computer-based instruction.

Others have restructured College Algebra using supplemental models such as supplemental instruction or tutoring. A number of reforms utilize a flipped classroom approach.

Only three studies focus on Modeling-Based College Algebra or a similar course Algebra for the Sciences. The two studies by Ellington and Pinzon et al. that focus on Modeling-Based College Algebra were one-semester studies with disproportionate sample sizes for the experimental and control groups. The study by Ellington (2005) also involved a lab component in a 4-hour class. This study will add to the body of literature on Modeling-Based College Algebra by providing a longitudinal study for a 3-hour course with proportional sample sizes for the experimental and control groups. It will also help the university of study determine if the revised course is achieving the purpose for which it was created. The purpose of the Modeling-Based College Algebra course at the university of study is to be a better terminal general education mathematics course for the majority of students who will not take another mathematics course but yet still provide the algebraic foundation necessary for students who will go further in mathematics.

CHAPTER 3

METHODOLOGY

Historically, College Algebra has been the common general education mathematics course requirement for students in non-STEM and STEM majors. Only about 50 percent of the over 680,000 students who take College Algebra each year earn a grade of A, B, or C (Ganter & Haver, 2011). The curriculum in a traditional College Algebra course is designed to prepare students for Calculus; however, less than 10% of students enrolled in College Algebra enroll in Calculus (Ganter & Haver, 2011). The building-block nature of algebra requires students to take prerequisite algebra courses to be able to enroll in College Algebra. Movements have been underway through the major mathematics education associations to improve the general education course options for mathematics. For small, private institutions such as the university of study, mathematics departments have had difficulty offering multiple pathways for students. The university of study developed a Modeling-Based College Algebra course to improve student experience in the class yet still providing the core algebra skills needed to take Calculus if the student is in a major that requires it. This research provides statistical analysis of a longitudinal study of a modeling-based College Algebra course and helps the university of study determine if the revised course is achieving the purpose for which it was created.

This research is quantitative. The study used archived data of students enrolled in a College Algebra class at a rural, private, Midwestern, multi-campus university between Fall 1986 and Spring 2018. The students were divided into two groups. Students in the first group were enrolled in a traditional College Algebra course using a standard textbook between Fall 1986 and Spring 2002. Students in the second group were enrolled in a modeling-based College Algebra course using an explorations textbook between Fall 2002 and Spring 2018. The transcripts of these students list a letter grade of A, B, C, D, F, or W for College Algebra on their transcript for a semester during the specified appropriate time period. Students with an incomplete, I, on their transcripts will not be included. Students who withdrew from the class without the course showing on their transcript will also be omitted from this study. The independent variable is the curriculum used in the traditional College Algebra course and the modeling-based College Algebra course. The dependent variables are final grade (4.0 scale), D/F percentage, withdrawal percentage, and final grade in the next math class (if it exists).

The university that was studied is a private, four-year comprehensive evangelical Christian school in the rural Midwest, with approximately 3,400 total students in graduate and undergraduate studies. The university has one main campus and three satellite campuses. College Factual is a college ranking website that ranks colleges by a number of different factors. According to College Factual, the university has a gender ratio of 36.3 males to 63.7 females. Incoming freshmen have an average ACT score of 22.7 and an average GPA of 3.56. College Factual ranks college diversity as the most plurality in diversity metrics. A school ranking high in those metrics has a great variety in ethnicity, gender, age, and geographic location of origin. The university's overall diversity score of 53 out of 100 is about average with a ranking of #1673 out of 2475 American universities (collegefactual.com). At the university, 39.1% of students are in the age 18-21 traditional age bracket, which is considerably lower than the national average of 60%. College

Factual ranks the university above the national average in terms of age. The student body composition of the university is below the national average in terms of ethnicity. See Table 2 for a summary of the demographic distribution of students. According to the university's website, more than 98% of the students received financial aid. College Factual also reported that about 79.9% of students at the university of study came from within the state, which is close to the national average.

Table 2. Demographic Distribution of the University of Study

		%
Gender	Female	63.7
	Male	36.3
Ethnicity	White	68.9
	Black or African American	4.7
	Hispanic/Latino	2.2
	Non-Resident Alien	1.4
	American Indian or Alaska Native	0.8
	Asian	0.6
	Native Hawaiian or Other Pacific Islander	0.2
	Ethnicity Unknown	21.3
Age	Under 18	14.0
	18-19	19.5
	20-21	19.6
	22-24	16.6
	25-29	10.4
	30-34	6.0
	35 and over	13.8

The course of the study was College Algebra. This course fulfilled the general education mathematics requirement. Most students at the university took this course; however, some students had prior credit in the course or qualified to take a higher-level mathematics course at the university. Prior to Fall 2002, the course at the university of study was a traditional College Algebra course.

A traditional College Algebra course involved factoring, radicals and rational exponents, linear equations, quadratic equations, exponential equations, and systems of equations with heavy emphasis on algebraic manipulations and complex calculations. Students learned in a typical traditional College Algebra course through notes written from lectures. No classroom activities were utilized. The course was taught three times per week in 50-minute class periods. Pencil and paper homework sets were assigned after each class period and collected periodically. Quizzes were given in class each week to gauge student understanding. It was expected that students attend all class meetings, and make up work is only available for students with a valid excuse for the absence. Four unit exams were given along with a final exam. Typical letter grade designations were given: 90-100% A, 80-89% B, 70-79% C, 60-69% D, and below 60% F.

The course was changed to a modeling-based approach in Fall 2002. A modeling-based college course involved most if not all of the same concepts as the traditional course. Some topics were covered minimally, such as factoring, and some other topics such as synthetic division and sequences were omitted completely. Power functions replaced the larger topics of polynomial functions of higher degree and rational functions. See Appendix B for a complete comparison of topics covered in both courses and

Appendix C and D for sample syllabi from each course. The emphasis was placed on creating models from data and interpreting the results. Small groups were used to invoke inquiry and discussion to facilitate learning in some sections. Other sections utilized iClickers™ to facilitate classroom participation. All students in all sections collaborated in small groups for class explorations. Participation points were awarded for active participation in all of the sections. The point distribution in the course stayed relatively the same. Pencil and paper homework assignments were replaced with online homework assignments and lab reports. Weekly quizzes were replaced with a participation grade for active participation in group work explorations and/or correct iClickers™ responses. The modeling-based sections continued to offer four unit tests, and a comprehensive final. The weight of the comprehensive final was reduced from 25% to 20%. The courses were still typically taught in three 50-minute class periods each week.

Table 3. Grading Criteria

Traditional Course	Points	%		Modeling-Based Course	Points	%
Homework	200	20		Assignments and Lab Reports	200	20
Quizzes	150	15		Participation	200	20
4 Tests	400	40		4 Tests	400	40
Final Exam	250	25		Final Exam	200	20

The student database, Colleague®, was the source of data after 2005. The previous student database was an earlier version of Colleague® whose data was converted to Microsoft® Access® and was the source of data prior to 2005. The administrative computer support specialist at the university provided the researcher with a Microsoft® Excel® spreadsheet with data for each student whose transcript listed College Algebra for semesters between Fall 1986 and Spring 2018. The spreadsheet included student grades in College Algebra, self-reported ethnicity and gender of the students, age of student during the semester College Algebra was taken, and the student grades in the first subsequent mathematics course with College Algebra as its prerequisite for those students who took such a class. The spreadsheet did not contain names, student ID numbers, or any other personal identifiers.

The independent variable approach was coded as 0 for traditional and 1 for modeling-based. The dependent variables were College Algebra final grade, D/F percentage, withdrawal percentage, and final grade in the next math class. The dependent variable for the final grade in College Algebra was based on the 4.0 grade scale. The 4.0 grade scale assigned a value of 4 for A, 3 for B, 2 for C, 1 for D, and 0 for F. The university of study did not use plus or minus grades. The dependent variable for D/F percentage was coded as 0 for students whose transcripts show a grade of A, B, or C for the course and 1 for students whose transcripts record a D or F for the course. Similarly, the dependent variable for withdrawal percentage was coded as 0 for students whose transcripts show an A, B, C, D, or F for the course and 1 for students whose transcripts display a W for the course. The dependent variable for grade in the next class was based on the 4.0 grade scale with the same point values as the dependent variable for the College Algebra final grade.

Research Question

The research question is intended to measure the effectiveness of the change in approach and curriculum from the traditional College Algebra course to the Modeling-based College Algebra course. The effectiveness was measured in terms of success in the algebra course as well as success in a subsequent mathematics course.

1. Is there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the College Algebra course?
2. Is there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the subsequent mathematics course?

Analysis of Research Hypotheses

Three null and alternate (research) hypotheses were developed from the first research question regarding success in the algebra course.

1. The mean final grade in the Modeling-based College Algebra course is statistically significantly different from the mean final grade in the traditional College Algebra course.
2. The percentage of D/F grades in the Modeling-based College Algebra course was statistically significantly different than the percentage of D/F grades in the traditional College Algebra course.

3. The withdrawal percentage in the Modeling-based College Algebra course was statistically significantly different from the withdrawal percentage in the traditional College Algebra course.

The remaining null and alternate (research) hypotheses were developed from the second research question regarding success in the subsequent mathematics course.

4. The mean final grade in the next math class for students in the Modeling-based College Algebra course was statistically significantly different from the mean final grade in the next math class for students in the traditional College Algebra course.

Methods of Data Analysis

All statistical analyses were conducted using either Microsoft® Excel® or IBM© SPSS® Version 26.0 (Statistical Package for the Social Sciences).

A Student *t*-test comparing two independent samples was run to determine if there was a statistically significant difference in the mean final grade for the two courses. The average final grade of the Modeling-Based College Algebra students was compared to the average final grade of the traditional College Algebra students. The Student *t*-test is a parametric statistic that determines the level of significance of the differences between two groups. Before employing this test, four assumptions were verified for the distribution of each group. (1) The two samples were independent. (2) The data values of each group represented a random sample from the population under study. (3) The distribution of the mean was normal. (4) The variances of the two groups were similar. The significance level, also known as alpha, is the probability of rejecting the null hypothesis when the null hypothesis is true. The significance level $\alpha = 0.05$ was used for all tests in this study.

A Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the percentage of D/F grades. The proportion of D/F grades of the Modeling-Based College Algebra course was compared to the proportion of D/F grades of the traditional College Algebra course. This test, also called the two-proportion *z*-test, determines the level of significance of the difference in proportions between two groups. Before employing this test, three assumptions were verified. (1) The data values of each group represented a random sample from the population under study. (2) The samples were independent. (3) Each sample included at least 10 successes and 10 failures.

A Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the withdrawal percentages. The three assumptions were verified before conducting the test.

A Student *t*-test comparing two independent samples was run to determine if there was a statistically significant difference in the mean final grade in the next math class for the two courses. The three assumptions were verified before the test was conducted.

Cross tabulation was used to show distributions by categories including gender, age, ethnicity, and instructor. Chi-square analysis was performed to analyze differences based on each of the four categories.

CHAPTER 4

RESULTS

The purpose of this study was to investigate student success in two College Algebra courses that differ in curriculum and teaching approach. The courses were taught at a small, Midwestern university over a period of thirty-two years. This chapter includes statistical analysis of the two research questions of the study: was there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the College Algebra course; and was there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the subsequent mathematics course?

The first course was a traditional College Algebra course taught between Fall 1986 and Spring 2002. Students in the traditional College Algebra course studied various types of equations and inequalities, functions and their inverses, theory of higher degree equations, systems of equations, determinants, logarithms, exponentials and applications. Lecture was the primary delivery method for instruction. Symbolic manipulation was the main emphasis. Technology use was minimal, and real-world applications were not an integral part of the course. The course was typically only taught in the fall and spring semesters, so this study is limited to the classes offered in the fall and spring from Fall 1996 through Spring 2002.

The second course was a Modeling-Based College Algebra course taught between Fall 2002 and Spring 2018. Students in the Modeling-Based College Algebra course studied many of the same topics as in the traditional course, but the focus was on conceptual understanding. Some topics such as factoring and other symbolic manipulation were omitted or reduced in scope so that students could work with real-world applications. Technology was integrated throughout the course to aid in graphing functions as well as computing messy calculations that are inherent in real world scenarios. This course was also typically only taught in the fall and spring semesters, so this study is limited to the classes offered in the fall and spring from Fall 2002 through Spring 2018. To prevent potential bias and possible influence from the researcher, the researcher omitted courses taught after the researcher began teaching at the university of study.

The study examined students at the university of study who were enrolled in College Algebra on the main campus from Fall 1986 through Spring 2018. The students were naturally divided into two groups, Fall 1986 through Spring 2002 and Fall 2002 through Spring 2018, as the curriculum and approach for College Algebra changed after Spring 2002. Students in the first group were enrolled in a traditional College Algebra course using a standard textbook between Fall 1986 and Spring 2002. Students in the second group were enrolled in a Modeling-Based College Algebra course using an explorations textbook between Fall 2002 and Spring 2018. The transcripts of these students list a letter grade of A, B, C, D, F, or W for College Algebra on their transcript for a semester during the specified appropriate time period. Students with an incomplete, I, on their transcripts were not included. Students who withdrew from the class without the course showing on their transcript were also omitted from this study. The university offered few, if any, College Algebra courses in the summer; thus, the study was restricted to only spring and fall semesters. The independent variable is the curriculum used in the two College Algebra courses. The dependent variables are final grade (4.0 scale), D/F percentage, withdrawal percentage, and final grade in the next mathematics class (if it exists). Final grades in the College Algebra class and final grades in the next mathematics class were listed as A, B, C, D, F, or W. The letter grades were assigned grade point values with A = 4, B = 3, C = 2, D = 1, F = 0, and W was not assigned a numerical value. Other variables that were examined include age of students during the term College Algebra was taken, gender, ethnicity, and instructor of the class.

Ethical consideration of the data was carefully examined. Individual student identities were protected and never disclosed; no names, student ID numbers, or dates of birth were shown to the researcher. Student ID numbers were masked using a linear encryption model by the administrative computer support specialist. This was done to allow the researcher to identify which students had taken College Algebra more than once as well as to determine which students took a next subsequent mathematics course without sacrificing the security of the students' identities. This masking was also necessary to assure independence of the two groups. Any students who were listed in both groups were removed to ensure independence of the groups. The research proposal was submitted to and approved by the Research Review Board (RRB) at the university under study and the Institutional Research Board (IRB) at the University of Missouri–Kansas City prior to conducting research. Both compliance groups determined that this project did not constitute human subjects research according to the Department of Health and Human Services regulatory definitions (Appendices E-G). The researcher intended to collect dates of birth to control for the effect of age on final grade but was advised not to collect this data by the Family Educational Rights and Privacy Act (FERPA) representative at the university and the IRB reviewer. Instead, current age and date of term was provided, and the researcher used those data to approximate the age of each student (within one year) at the time of enrollment in the College Algebra class. Also, the name of the university in the study was kept private, referred to as the university of study in all references.

Demographic Information

Data were collected from the university database for 4,532 students who enrolled in College Algebra in spring or fall semesters during the time interval Fall 1986 through Spring 2002. Data were also collected from the university database for 3,804 students who enrolled in College Algebra in spring or fall semesters during the time interval Fall 2002 through Spring 2018. The ages of the students in the first group ranged from 17 to 57, with an average age of 20.50 and a standard deviation of 3.04. The median age was 20, and the mode age was 19. The ages of the students in the second group ranged from 16 to 65, with an average age of 20.11 with a standard deviation of 3.67. The median age was 19, and the mode age was 18. The summary statistics of the age distribution for each group of students is displayed in Table 4.

Table 4. Population of College Algebra Students by Age

		n	Mean	SD	Median	Mode
Age						
	Traditional	4,532	20.50	3.04	20	19
	Modeling-Based	3,804	20.11	3.67	19	18

The population for the entire University is represented by 63.7% female and 36.3% male. The gender breakdown for the Fall 2018 semester for the main campus of the university was 56% female and 44% male. The Fall 2018 population on the main campus was 2,633 students. There were 2,412 females and 2,120 males in the Traditional College Algebra group, and there were 1,838 females and 1,966 males in the Modeling-Based College Algebra group. This equated to a ratio of 53.2% females to 46.8% males in the Traditional College Algebra group and a ratio of 48.3% females to 51.7% males in the Modeling-Based College Algebra group.

Table 5. Population of College Algebra Students by Gender

	College Algebra			Main Campus		
	Female	Male	Total	Female	Male	Total
Traditional 1986-2002	2,412 (53.2%)	2,120 (46.8%)	4,532 (100%)	7,070 (56.6%)	5,432 (43.4%)	12,502 (100%)
Modeling-Based 2002-2018	1,838 (48.3%)	1,966 (51.7%)	3,804 (100%)	5,360 (53.7%)	4,628 (46.3%)	9,988 (100%)

It was of interest to note that the gender ratio for Modeling-Based College Algebra was not only different from the gender ratio for the main campus but also that there were more males than females who enrolled in the Modeling-Based course even thought it was the only college algebra course available.

Ethnicity for the entire university and for the Modeling-Based College Algebra group is listed in Table 6. This information was queried from the current university student database, Colleague®. The data from the previous university student database, an earlier version of Colleague®, was converted to Microsoft® Access®. Some of the fields did not transfer successfully during the conversion so the Access® database does not contain the ethnicity records for the Traditional College Algebra group. The ethnicity breakdown for the university as a whole was White (68.9%), Black or African American (4.7%), Hispanic/Latino (2.2%), Non-Resident Alien (1.4%), American Indian or Alaska Native (0.8%), Asian (0.6%), Native Hawaiian or Other Pacific Islander (0.2%), and Ethnicity Unknown (21.3%). The students in the Modeling-Based College Algebra group self-identified as White (83.0%), Black or African American (9.8%), Hispanic/Latino (2.8%), American Indian or Alaska Native (1.2%), Asian (0.8%), Native Hawaiian or Other Pacific Islander (0.3%), and Ethnicity Unknown (2.2%). The percentage of Modeling-Based College Algebra students who identified as Black or African American was more than double that of the university as a whole. There were no students in the Modeling-Based group who identified as Non-Resident Alien compared to the 1.4% of the university.

Table 6. Population of College Algebra Students by Ethnicity

		University %	Modeling-Based %
Ethnicity			
	White	68.9	83.0
	Black or African American	4.7	9.8
	Hispanic/Latino	2.2	2.8
	Non-Resident Alien	1.4	0
	American Indian or Alaska Native	0.8	1.2
	Asian	0.6	0.8
	Native Hawaiian or Other Pacific Islander	0.2	0.3
	Ethnicity Unknown	21.3	2.2

Two full-time professors taught sections of both Traditional and Modeling-Based College Algebra courses. To control for the effect of instructor bias, students for each professor were separated into subgroups. Instructor 1 taught 195 students in Traditional College Algebra and 1,403 students in Modeling-Based College Algebra. There were 563 Traditional College Algebra students and 519 Modeling-Based College Algebra students taught by Instructor 2. Each of the four research questions were addressed for each instructor subgroup.

Table 7. Population of College Algebra Students by Instructor

		Traditional	Modeling-Based	Total
Instructor				
	Instructor 1	195 (12.2%)	1,403 (87.8%)	1,598 (100.0%)
	Instructor 2	563 (52.0%)	519 (48.0%)	1,082 (100.0%)

Table 8 provides final course grade distribution summaries for the Traditional College Algebra and Modeling-Based College Algebra courses. The final course grade distribution of A, B, C, D, F, and W grades were 903, 937, 997, 569, 489, and 637, respectively, for the 4,532 students in the Traditional College Algebra course. The final course grade distribution of A, B, C, D, F, and W grades for the 3,804 students in the Modeling-Based College Algebra course was 959, 945, 832, 444, 331, and 293, respectively. Noticeable differences between the groups were the percentage of A students, 25.2% Modeling-Based to 19.9% Traditional, and the percentage of students who withdrew, 7.7% Modeling-Based to 14.1% Traditional. The mean final course grade for Traditional students was 2.307 and the mean final course grade for Modeling-Based students was 2.515, on a four-point scale. Both mean final course grades are within the range of a grade of C.

Table 8. Final Course Grade of College Algebra Students

Final Course Grade	Traditional	Modeling-Based
A	903 (19.9%)	959 (25.2%)
B	937 (20.7%)	945 (24.8%)
C	997 (22.0%)	832 (21.9%)
D	569 (12.6%)	444 (11.7%)
F	489 (10.8%)	331 (8.7%)
W	637 (14.1%)	293 (7.7%)
Total	4,532 (100.0%)	3,804 (100.0%)

Research Questions

The plan was to use the Student *t*-test comparing two independent samples to determine if there was a statistically significant difference in the mean final grade for the two courses. The average final grade of the Modeling-Based College Algebra students was compared to the average final grade of the traditional College Algebra students. The average final grade was based on the numbers of A, B, C, D, and F grades for each group. The Student *t*-test is a parametric statistic that determines the level of significance of the differences between two groups. Before employing this test, four assumptions needed to be verified for the distribution of each group. 1) The two samples were independent.

2) The data values of each group represented a random sample from the population under study. 3) The distribution of the mean was normal. 4) The variances of the two groups were similar. The significance level, also known as alpha, is the probability of rejecting the null hypothesis when the null hypothesis is true. The significance level $\alpha = 0.05$ was used for all tests in this study.

The two samples were verified to be independent by comparison of the masked student identifiers for the two groups, and students listed in both groups were removed from the study. There were 113 students who were omitted to guarantee independence. Since the data represented all of the students in the time intervals except for those removed for independence, the assumption of random sample from the population is satisfied. To test for equality of variances, Levene's Test was utilized. The variance in final course grade for the Traditional College Algebra students was 1.72234, and the variance in final course grade for the Modeling-Based College Algebra students was 1.61531. Levene's Test returned $F = 3.736$ with significance 0.053. Two distributions are assumed to have equal variances if the significance is greater than 0.05 using Levene's Test. The p-value is slightly larger than 0.05 so the two groups have similar variances. The remaining assumption is that the distribution of the mean was normal.

Table 9. Levene's Test for Equality of Variances

	F	p-value
Levene's Test	3.736	.053*

* Indicates statistical significance (p-value > .05)

Graphs such as histograms, boxplots, and normal quantile-quantile (Q-Q) plots are commonly used to test for normality. For each figure shown below, the graph labeled 1.00 represents the Traditional group and the graph labeled 2.00 represents the Modeling-Based group. The histograms are shown in Figure 1. The distributions appear nonnormal, with negative skewness in both distributions. The boxplots are shown in Figure 2. The boxplots do not show outliers, and the Traditional distribution seems normal. But the Modeling-Based distribution appears nonnormal. The normal Q-Q plots are shown in Figure 3. These quantile-quantile plots support normality of the distributions.

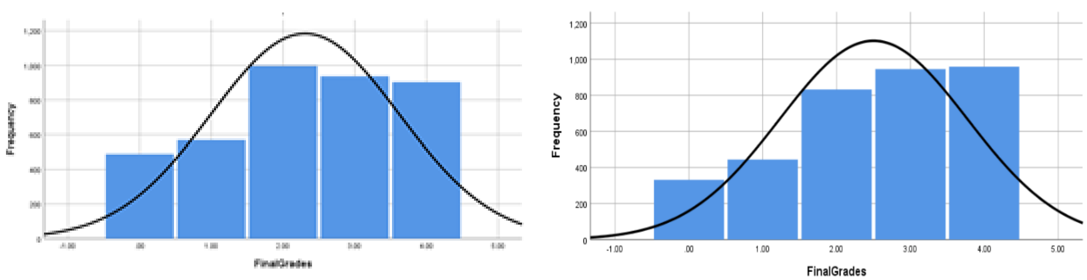

Figure 1. Histograms of College Algebra Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

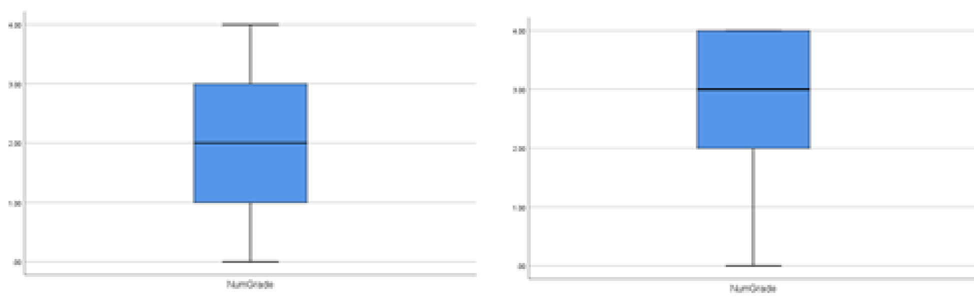

Figure 2. Boxplots of College Algebra Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

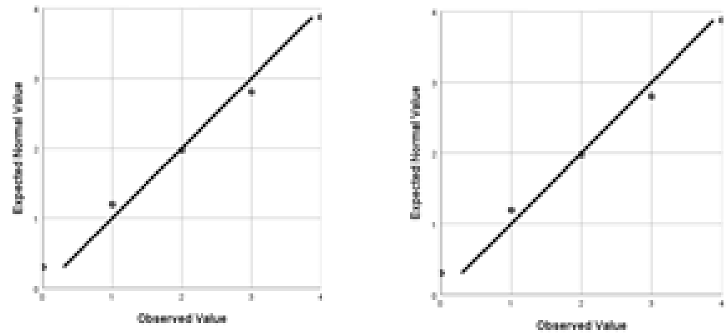

Figure 3. Normal Q-Q Plots of College Algebra Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

There are many statistical tests for normality that can supplement the assessment of normality already seen through graphical representation. The two most frequently used normality tests are the Shapiro-Wilk Test and the Kolmogorov-Smirnov (K-S) Test. The Shapiro-Wilk Test is a parametric test whose null hypothesis is that the sample was drawn from a normal distribution. Shapiro-Wilk test is a powerful test, but it becomes less powerful with larger sample sizes (Yazici & Yolacan, 2007). Typically, the Shapiro-Wilk Test is used for sample size up to $n = 50$. The Kolmogorov-Smirnov Test is a nonparametric test whose null hypothesis is that the data come from a specified distribution, such as the normal distribution. The SPSS test incorporated the Lilliefors correction for the K-S Test for these distributions. The p-value was .000 for each group in each of the two tests; therefore, the null hypothesis is rejected, and the distributions are said to be nonnormal.

Table 10. Tests of Normality of College Algebra Student Grade Distributions

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	*p*-value	Statistic	df	*p*-value
Traditional	.174	3,895	.000*	.895	3,895	.000*
Modeling-Based	.195	3,511	.000*	.883	3,511	.000*

* Indicates statistical significance (*p*-value < .05)

Two other statistical measures that characterize the shape of the distribution are skewness and kurtosis. Skewness is the measure of symmetry in a distribution or the lack thereof. If a curve is shifted to the left or to the right, the distribution is considered skewed. The skewness of an approximately normal distribution is close to 0. If the skewness is between -0.5 and 0.5, the distribution is approximately symmetric. The skewness statistic for the Traditional group was -0.297 and the skewness statistic for the Modeling-Based group was -.476. Both distributions are approximately symmetric. Kurtosis measures the amount of probability in the two tails. In SPSS, the kurtosis of an approximately normal distribution is close to 0. The kurtosis statistic for the Traditional group was -0.995 and the skewness statistic for the Modeling-Based group was -.799. Negative values of kurtosis indicate that a distribution has fewer extreme values. A distribution that has negative kurtosis values is called platykurtic. Both distributions are platykurtic. This is not surprising as the grade distribution was discrete with only five possible values. Both distributions have kurtosis values greater than -1 which are in an acceptable range for most statistical uses.

Table 11. Skewness and Kurtosis of College Algebra Student Grade Distributions

	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
Traditional	-.297	.039*	-.995	.078
Modeling-Based	-.476	.041*	-.799	.083

* Indicates statistical significance (*p*-value < .05)

The normal Q-Q plot supports normality, and the skewness and kurtosis values are in range for a normal distribution. The boxplot, histogram, Shapiro-Wilk value, and the Kolmogorov-Smirnov value all support the fact that the distribution is not normal. However, the normality assumption is not as vital to the power of the two-sample *t* test if the sample size is large. Studies have shown that the *t* test has extremely acceptable Type I error rates with analysis of two large samples that are skewed in the same direction but can have much greater deviation in Type I error rates when the distributions are skewed in opposite directions (Delaney & Vargha, 2000; Skovlund & Fenstad, 2001). The distribution of final grades in the Traditional College Algebra course and the distribution of final grades in the Modeling-Based College Algebra course are both skewed negatively. Therefore, a two-sample *t* test can be used to analyze the difference in final grades. The null hypothesis states that there is no difference in the means of the two groups, and a *p*-value less than .05 rejects the null hypothesis in favor of the alternate hypothesis that the difference is statistically significant. The mean final course grade for Traditional students was 2.307 and the mean final course grade for Modeling-Based students was 2.515, on a four-point scale. The *p*-value is .000 rounded to three decimal places. Thus, the mean final grade in the Modeling-based College Algebra course is statistically significantly different from the mean final grade in the traditional College Algebra course.

Table 12. Independent Samples T Test of College Algebra Student Grade Distributions

	t	*df*	*p*-value
Independent Samples T Test	-6.427	7,404	.000*

* Indicates statistical significance (p-value < .05)

Although the *t* test is robust with respect to nonnormality with large, similar distributions, some might not deem it appropriate to use the *t* test with this data. The Mann-Whitney U Test is a nonparametric two-sample independent test that tests the difference between medians of samples and does not have the assumption of normality. This test is also commonly referred to as the Wilcoxon Rank Sum Test or the Wilcoxon Mann-Whitney Test. The null hypothesis of the test is that the two samples come from the same population. There are three assumptions for the Mann-Whitney test. 1) The variable is continuous or ordinal. Grades can be ordered meaningfully. 2) There are two categorical, independent groups. The Traditional group and the Modeling-Based group are independent. 3) There is no dependence of observations. No student is in both groups. The p-value of .000 is significant, meaning that the samples do not come from the same population. Thus, the median final grade in the Modeling-based College Algebra course is statistically significantly different from the median final grade in the traditional College Algebra course.

Table 13. Mann-Whitney U Test of College Algebra Student Grade Distributions

	n	*z*	*p*-value
Mann-Whitney U Test			
	7,406	-6.355	.000*

*** Indicates statistical significance (*p*-value < .05)**

Another method of measuring the difference in success between the two curriculum/approaches is to compare the proportions of A/B/C grades. There were 2,837 students with A/B/C grades out of the 3,895 Traditional College Algebra students with A/B/C/D/F grades, and there were 2,736 students with A/B/C grades out of the 3,511 Modeling-Based College Algebra students with A/B/C/D/F grades. The Two-Sample Test of Proportions was conducted for the 72.8% and 77.9% proportions. The difference was statistically significant with a test statistic $z = -5.07$ and a p-value = .000.

Table 14. Two-Sample Test of Proportions for A/B/C Final Grades

	p^a	X^b	*n*	*z*	*p*-value
A/B/C Grades				-5.07	.000*
Traditional	.7284	2,837	3,895		
Modeling-Based	.7793	2,736	3,511		
Total	.7525	5,573	7,406		

*** Indicates statistical significance (*p*-value < .05); a: proportion; b: number of successes**

A Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the percentage of D/F grades. The proportion of D/F grades of the Modeling-Based College Algebra course was compared to the proportion of D/F grades of the traditional College Algebra course. The proportion was calculated as the ratio of the number of students with a D or F on their transcript to the total number of students who received a grade of A, B, C, D, or F. This test, also called the two-proportion z-test, determines the level of significance of the difference in proportions between two groups. Before employing this test, three assumptions were verified. 1) The data values of each group represented a random sample from the population under study. Since the data represented all of the students in the time intervals except for those removed for independence, the assumption of random sample from the population is satisfied. 2) The samples were independent. The two samples were verified to be independent by comparison of the masked student identifiers for the two groups, and students listed in both groups were removed from the study. 3) Each sample included at least 10 successes and 10 failures. There were 1,058 D/F grades and 2,837 A/B/C grades in the Traditional group, and there were 775 D/F grades and 2,736 A/B/C grades in the Modeling-Based group. The Traditional group had a proportion of 0.2716, and the Modeling-Based group had a proportion of 0.2207. The p-value was 0.000 rounded to three decimal places, so the null hypothesis was rejected. Thus, the percentage of D/F grades in the Modeling-based College Algebra course was statistically significantly different than the percentage of D/F grades in the traditional College Algebra course.

Table 15. Two-Sample Test of Proportions for D/F Final Grades

	p^a	X^b	n	z	p-value
D/F Grades				5.07	.000*
Traditional	.2716	1,058	3,895		
Modeling-Based	.2207	775	3,511		
Total	.2475	1,833	7,406		

* Indicates statistical significance (p-value < .05); *a*: proportion; b: number of successes.

Another Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the percentage of W grades. The proportion of W grades of the Modeling-Based College Algebra course was compared to the proportion of W grades of the traditional College Algebra course. The proportion was calculated as the ratio of the number of students with a W on their transcript to the total number of students who received a grade of A, B, C, D, F, or W. The three assumptions for the two-sample proportion test were verified. There were 637 W grades and 3,895 A/B/C/D/F grades in the Traditional group, and there were 293 W grades and 3,511 A/B/C/D/F grades in the Modeling-Based group. The Traditional group had a proportion of 0.1406, and the Modeling-Based group had a proportion of 0.0770. The p-value was 0.000 rounded to three decimal places, so the null hypothesis was rejected. Thus, the withdrawal percentage in the Modeling-based College Algebra course was statistically significantly different from the withdrawal percentage in the traditional College Algebra course.

Table 16. Two-Sample Test of Proportions for W Final Grades

	p^a	X^b	n	z	p-value
W Grades				9.18	.000*
Traditional	.1406	637	4,532		
Modeling-Based	.0770	293	3,804		
Total	.1116	930	8,336		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

The plan was to use the Student t-test comparing two independent samples to determine if there was a statistically significant difference in the mean final grade of the next subsequent mathematics class for the two courses. The average final grade of the next subsequent mathematics class for the Modeling-Based College Algebra students was compared to the average final grade of the next subsequent mathematics class for the traditional College Algebra students. The average final grade was based on the numbers of A, B, C, D, and F grades for each group. The normality assumption was not supported graphically by the histogram (negative skewness), the boxplot (outliers), and the normal Q-Q plot. The Mann-Whitney U Test was used instead of the Student two-sample t-test, with results $z = -.991$ and p-value = .322. The null hypothesis was not rejected since the p-value was greater than .05. The median final grade in the next math class for students in the Modeling-based College Algebra course was higher than but not statistically significantly different from the median final grade in the next math class for students in the traditional College Algebra course.

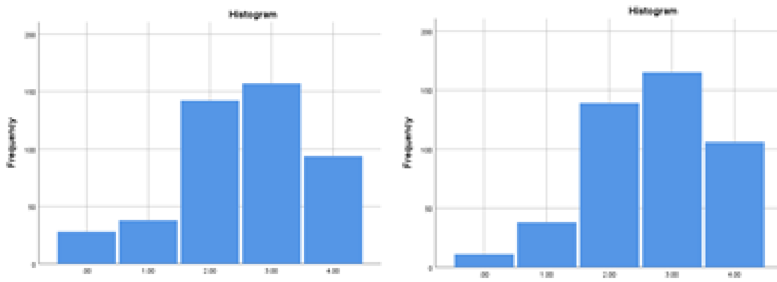

Figure 4. Histograms of Next Course Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

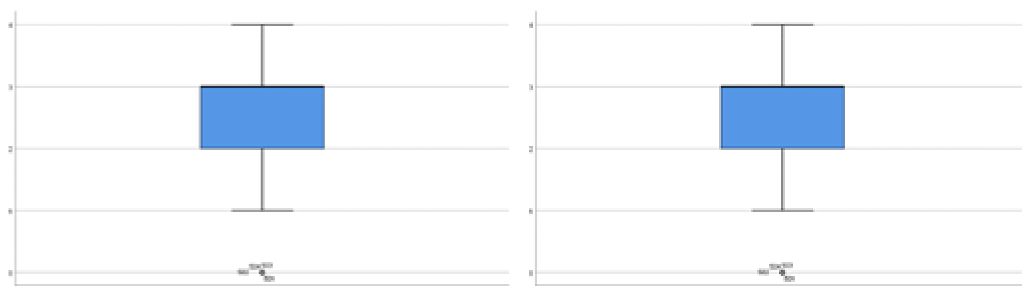
Figure 5. Boxplots of Next Course Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

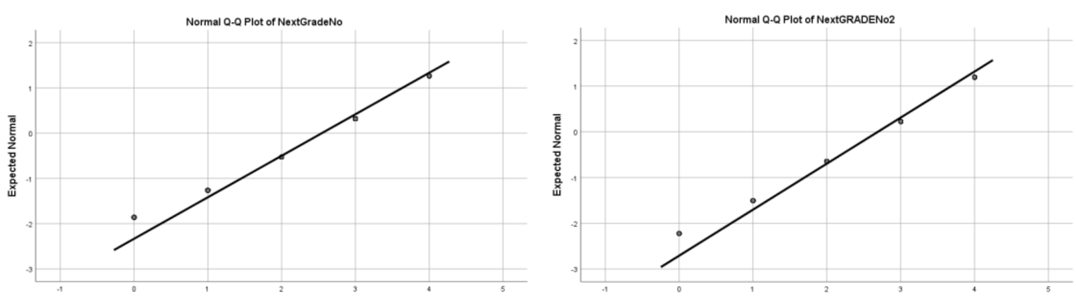

Figure 6. Normal Q-Q Plots of Next Course Student Grade Distributions (Left: Traditional, Right: Modeling-Based)

Table 17. Mann-Whitney U Test of Next Course Student Grade Distributions

	n	z	p-value
Mann-Whitney U Test			
	1,043	-.991	.322

There were 404 students with A/B/C grades in the next math course out of the 512 Traditional College Algebra students with A/B/C/D/F grades in the next math course, and there were 434 students with A/B/C grades in the next math course out of the 531 Modeling-Based College Algebra students with A/B/C/D/F grades in the next math course. The Two-Sample Test of Proportions was conducted for the 78.9% and 81.7% proportions. The difference was not statistically significant with a test statistic $z = -1.15$ and a p-value = .251.

Table 18. Two-Sample Test of Proportions for A/B/C Final Grades in the Next Math Course

	p^a	X^b	n	z	p-value
A/B/C Grades				-1.15	.251
Traditional	.7891	404	512		
Modeling-Based	.8173	434	531		
Total	.8035	838	1,043		

a: proportion; b: number of successes

Effect of Subgroups on Research Hypotheses

After addressing the research questions, it was of interest to investigate the success in each course of subgroups of the population of study. Specifically, how did students of different ages, genders, and ethnicities perform in Traditional College Algebra and in Modeling-Based College Algebra? In an attempt to control for instructor bias, the final course grades in College Algebra for two full-time professors at the university were studied. The success in the next mathematics course was also broken down by the name of course.

The student data for both Traditional College Algebra and Modeling-Based College Algebra were split into two age groups, students under 25 years of age and students age 25 years and older. Typically, students under 25 years of age are called traditional students and students 25 years of age and older are referred to as nontraditional students (Bean & Metzner, 1985). Due to the nonnormality of the data, a Mann-Whitney U Test was computed for each age group to determine if there was a statistically significant difference in the College Algebra course grades. For the under 25 age group, the Mann-Whitney U Test statistic was $z = -5.650$ with a p-value = .000 rounded to three decimal places. This supports the hypothesis that the difference was statistically significant for the 6,761 students who were under 25 years of age. For the 623 students in the age group of 25 years and older, the test statistic was $z = -1.273$ with a p-value = .203 rounded to three decimal places. This p-value is greater than .05 so the difference in College Algebra course grade was not statistically significant.

Table 19. Mann-Whitney U Test of College Algebra Student Grade Distributions with Respect to Age

	n	z	p-value
Mann-Whitney U Test			
Under 25	6,761	-5.650	.000*
25 and older	623	-1.273	.203

* Indicates statistical significance (p-value < .05)

A Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the percentage of D/F and W grades with respect to age. The National Center for Education Statistics (NCES) defines the traditional age of college students as under 25 years of age and nontraditional age as 25 years of age and older (McFarland et al., 2019). For students of less than 25 years of age, there were 1,001 D/F grades in 3,688 A/B/C/D/F grades for the Traditional group and 733 D/F grades in 3,372 A/B/C/D/F grades for the Modeling-Based group. The proportions were 0.2714 to 0.2174, and the difference was statistically significant. The students who were 25 years or older had 52 D/F grades in 192 A/B/C/D/F grades for the Traditional group and 32 D/F grades in 122 A/B/C/D/F grades for the Modeling-Based group. The proportions for the older group were 0.2708 to 0.2623, and although the proportion of D/F grades were lower for the Modeling-Based group, the difference was not statistically significant. Similarly, the younger students had a statistically significant difference in W course grades, but the difference in W grades for the older students was not statistically significant.

Table 20. Two-Sample Test of Proportions for D/F Final Grades with Respect to Age

D/F Grades	p^a	X^b	n	z	p-value
Under 25				5.27	.000*
Traditional	.2714	1,001	3,688		
Modeling-Based	.2174	733	3,372		
25 and Older				0.17	.868
Traditional	.2708	52	192		
Modeling-Based	.2623	32	122		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

Table 21. Two-Sample Test of Proportions for W Final Grades with Respect to Age

W Grades	p^a	X^b	n	z	p-value
Under 25				9.34	.000*
Traditional	.1357	579	4,267		
Modeling-Based	.0708	257	3,629		
25 and Older				-0.56	.575
Traditional	.2320	58	250		
Modeling-Based	.2561	42	164		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

Another Mann-Whitney U Test was calculated to measure the difference in final course grades for females in College Algebra for each curriculum/approach. The test statistic was $z = -5.353$ with a p-value = .000 rounded to three decimal places. This supports the hypothesis that the difference in College Algebra course grades was statistically significant for the 3,819 females studied. The Mann-Whitney U Test statistics for males was $z = -5.195$ with a p-value = .000 rounded to three decimal places. The difference in College Algebra course grade was also statistically significant for the 3,586 males studied.

Table 22. Mann-Whitney U Test of College Algebra Student Grade Distributions with Respect to Gender

	n	z	p-value
Mann-Whitney U Test			
Female	3,819	-5.353	.000*
Male	3,586	-5.195	.000*

* Indicates statistical significance (p-value < .05)

A Two-Sample Test of Proportions was run to determine whether there was a statistically significant difference in the percentage of D/F and W grades with respect to gender. The proportion of D/F grades for female students in the Traditional College Algebra group was 0.2145, and the proportion was 0.1692 for the Modeling-Based College Algebra female students. The proportions of D/F grades for male students in the Traditional College Algebra and Modeling-Based College Algebra courses were 0.3297 and 0.2692, respectively. The differences in D/F grades were statistically significantly different for both genders. Similarly, both genders had a statistically significant difference in W course grades.

Table 23. Two-Sample Test of Proportions for D/F Final Grades with Respect to Gender

D/F Grades		p^a	X^b	n	z	p-value
Female					3.51	.000*
	Traditional	.2145	454	2,117		
	Modeling-Based	.1692	288	1,702		
Male					3.98	.000*
	Traditional	.3297	602	1,826		
	Modeling-Based	.2692	487	1,809		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

Table 24. Two-Sample Test of Proportions for W Final Grades with Respect to Gender

W Grades		p^a	X^b	n	z	p-value
Female					5.13	.000*
	Traditional	.1219	294	2,411		
	Modeling-Based	.0740	136	1,838		
Male					7.99	.000*
	Traditional	.1618	343	2,120		
	Modeling-Based	..0799	157	1,966		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

No analysis can be conducted on the difference in final course grades in the two College Algebra courses with regard to ethnicity since the ethnicity data were not available for the Traditional College Algebra students. However, statistical tests can determine if ethnicity affects final grades in the Modeling-Based College Algebra course. The Independent-Samples Kruskal-Wallis Test is the nonparametric alternative to the

One-Way Analysis of Variance (ANOVA) test. A nonparametric test is necessary since the data distribution is not normal. The test determines whether the medians of two or more groups are different. The null hypothesis is that the population medians are equal, and a *p*-value less than .05 represents a statistically significant difference between the groups. The ethnicity groups were coded using 1 for White (WH), 2 for Black or African American (BK), 3 for Hispanic/Latino (HI), 4 for Non-Resident Alien (NR), 5 for American Indian or Alaska Native (AN), 6 for Asian (AS), 7 for Native Hawaiian or other Pacific Islander (HP), and 8 for Ethnicity Unknown (UN).

The Kruskal-Wallis Test statistic was $H = 119.055$ with a *p*-value = .000 rounded to three decimal places. The *p*-value shows there is a difference in two or more of the ethnic groups, but the test does not state which groups have different median Modeling-Based College Algebra final grades. A graphical representation of the difference in medians is shown in Figure 7.

Table 25. Independent-Samples Kruskal-Wallis Test of Modeling-Based College Algebra Student Course Grades with Respect to Ethnicity

	n	*H*	*p*-value
Kruskal-Wallis Test	3,511	119.055	.000*

* Indicates statistical significance (*p*-value < .05)

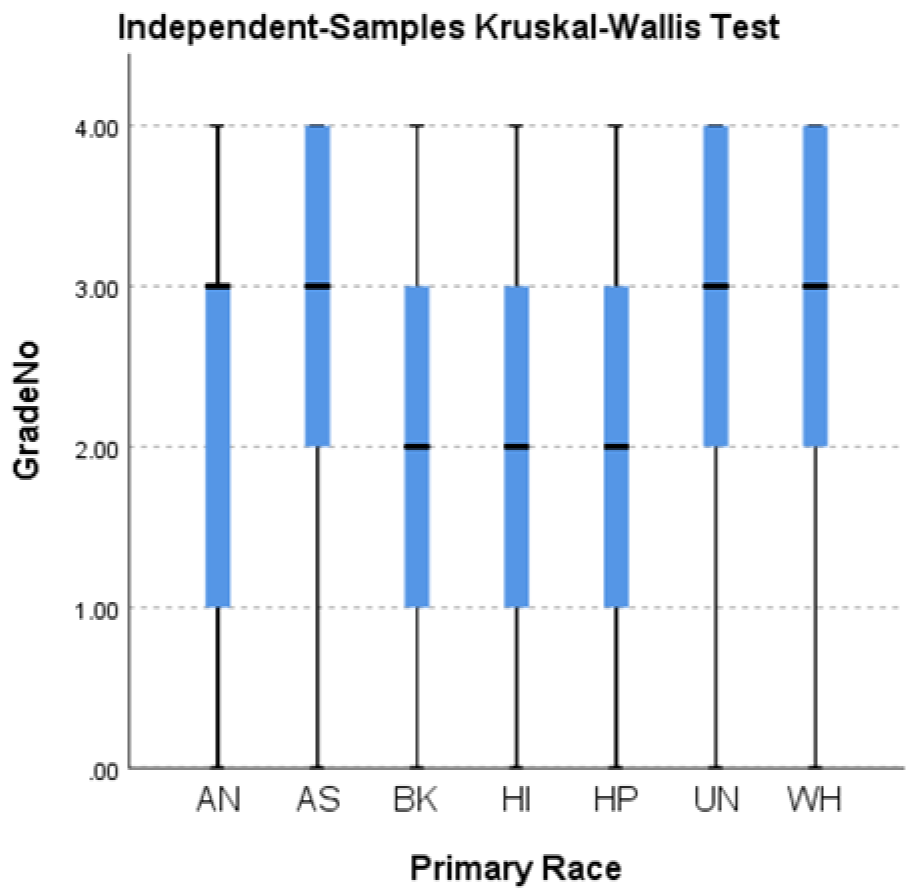

Figure 7. Independent-Samples Kruskal-Wallis Test of Modeling-Based College Algebra Student Course Grades with Respect to Ethnicity

Dunn's Multiple Comparison Test is a post hoc nonparametric test that can be run after the Kruskal-Wallis Test to conduct pairwise comparisons between the different groups. Results of the Dunn's Test revealed that the median Modeling-Based College Algebra final grade for Black or African American students was statistically significantly different than the median course grades for students who were White, Asian, or Ethnicity Unknown.

Table 26. Dunn's Multiple Comparison Test of Modeling-Based College Algebra Student Course Grades with Respect to Ethnicity

Dunn's Test	*Sample 1 - Sample 2*	*Test Statistic*	*Standard Error*	*p-value*	*Adjusted p-value*
	BK-HP	-142.826	332.606	0.668	1.000
	BK-HI	-297.760	112.474	0.008	0.170
	BK-AN	461.715	161.081	0.004	0.087
	BK-UN	-564.971	123.646	0.000	0.000*
	BK-WH	-594.739	56.441	0.000	0.000*
	BK-AS	701.822	193.635	0.000	0.006*
	HP-HI	154.934	342.887	0.651	1.000
	HP-AN	318.889	361.757	0.378	1.000
	HP-UN	-422.145	346.712	0.223	1.000
	HP-WH	-451.914	328.796	0.169	1.000
	HP-AS	558.996	377.380	0.139	1.000
	HI-AN	163.955	181.362	0.366	1.000
	HI-UN	-267.211	149.108	0.073	1.000
	HI-WH	-296.979	100.650	0.003	0.067
	HI-AS	404.062	210.806	0.055	1.000
	AN-UN	-103.256	188.494	0.584	1.000
	AN-WH	-133.025	153.059	0.385	1.000
	AN-AS	-240.107	240.283	0.318	1.000
	UN-WH	-29.768	112.996	0.792	1.000
	UN-AS	136.851	216.972	0.528	1.000
	WH-AS	107.082	187.014	0.567	1.000

A Mann-Whitney U Test was conducted for each of two professors who taught multiple sections in both College Algebra courses. These professors were the only instructors to teach both Traditional College Algebra classes and Modeling-Based College Algebra classes. Both instructors saw higher final grades in the Modeling-Based College Algebra course, but only the second instructor saw a statistically significant difference in the grades of the two approaches.

Table 27. Mann-Whitney U Test of College Algebra Student Grade Distributions with Respect to Instructor

	n	z	p-value
Mann-Whitney U Test			
Instructor 1	984	-.834	.405
Instructor 2	1,496	-3.073	.002*

* Indicates statistical significance (p-value < .05)

The difference in median final grade in the next math class was not statistically significant for the two groups. The difference in percentages of A/B/C grades was also statistically significant. It is important to look at common courses that students do take as their next course and look at the differences within the subgroups. Business Statistics, Business Calculus and Calculus I showed no statistically significant difference in A/B/C grade percentages for the two College Algebra groups. There was a statistically significant difference in A/B/C grade percentages, though, for Discrete Math with test statistic z = -2.33 and a p-value = .020.

Table 28. Two-Sample Test of Proportions for A/B/C Final Grades in the Next Math Course with Respect to Next Course Name

A/B/C Grades	p^a	X^b	n	z	p-value
Discrete Math				-2.33	.020*
Traditional	.6500	26	40		
Modeling-Based	.8545	47	55		
Business Statistics				-.47	.641
Traditional	.7973	59	74		
Modeling-Based	.8302	44	53		
Business Calculus				.52	.601
Traditional	.9083	218	240		
Modeling-Based	.8945	246	275		
Calculus I				.77	.443
Traditional	.8559	101	118		
Modeling-Based	.8190	95	116		

* Indicates statistical significance (p-value < .05); a: proportion; b: number of successes

Summary

The purpose of this study is to determine if students had greater success in Modeling-Based College Algebra than in Traditional College Algebra and if the Modeling-Based students achieved greater success in the next subsequent mathematics course. Success in the College Algebra was measured using course final grade, percentage of D/F grades, and percentage of withdrawals. The results of each hypothesis test are listed below.

1. The Mann-Whitney U Test produced a test statistic of $z = -6.355$ with p-value = .000; the results support the research hypothesis. The median final grade in the Modeling-based

College Algebra course was statistically significantly different from the median final grade in the traditional College Algebra course.

2. The percentage of D/F grades for Traditional College Algebra students was 1,058/3,895 = .2716, and the percentage of D/F grades for Modeling-Based College Algebra students was 775/3,511 = .2207. The Two-Sample Test of Proportions produced a test statistic of $z = 5.07$ with p-value = .000; the results support the research hypothesis. The percentage of D/F grades in the Modeling-based College Algebra course was statistically significantly different than the percentage of D/F grades in the traditional College Algebra course.
3. The percentage of withdrawals for Traditional College Algebra students was 637/4,532 = .1406, and the percentage of withdrawals for Modeling-Based College Algebra students was 293/3,804 = .0770. The Two-Sample Test of Proportions produced a test statistic of $z = 9.18$ with p-value = .000; the results support the research hypothesis. The withdrawal percentage in the Modeling-based College Algebra course was statistically significantly different from the withdrawal percentage in the traditional College Algebra course.
4. The Mann-Whitney U Test produced a test statistic of $z = -.991$ with p-value = .322; the results fail to support the research hypothesis. The median final grade in the next math class for students in the Modeling-based College Algebra course was not statistically significantly different from the median final grade in the next math class for students in the traditional College Algebra course.

Additional statistical analysis was conducted on various subgroups of the College Algebra students. How did students of different ages, genders, and ethnicities perform in Traditional College Algebra and in Modeling-Based College Algebra? The final course grades in College Algebra for two full-time professors at the university was also studied.

1. The students were divided by age groups of under 25 and 25 and older. A Mann-Whitney U Test was performed on each age subgroup. The median final grade for students under the age of 25 showed a statistically significant difference, but the median final grade for students age 25 and older did not show statistical significance. Similarly, the two-sample test for proportions showed statistical significance for the group under 25 years of age for both D/F and W percentages, but the older group did not have statistical significance for either D/F or W percentages.
2. A Mann-Whitney U Test was performed on both gender subgroups. The median final grade showed a statistically significant difference for both male and female subgroups. Likewise, the Two-Sample Test for Proportions showed statistical significance for females and males for both D/F and W percentages.
3. A Kruskal-Wallis Test was performed on the median Modeling-Based College Algebra final course grade for ethnicity. The results showed a statistically significant difference between one or more ethnicity subgroups. A Dunn's Test was performed post hoc to conduct a pairwise comparison between ethnicity subgroups. The results showed statistically significant differences for Black or African American students with White students, Asian students, and Ethnicity Unknown students.
4. A Mann-Whitney U Test was conducted for each of the professors who taught sections of both College Algebra courses. Both instructors saw higher final grades in the Modeling-Based College Algebra course, but there was only a statistically significant difference in median final College Algebra grades for the second instructor.
5. The Two-Sample Test for Proportions was conducted for the difference in A/B/C grade percentages for the two College Algebra groups with no statistical significance.

Similarly, there was no statistical significance for the difference in A/B/C grade percentages for Business Calculus and Calculus I. However, Discrete Math showed statistical significance for the difference in A/B/C grade percentages.

CHAPTER 5

DISCUSSION

Summary of the Study

Concerned with the high D/F rates, high W rates, low success rates, and overall student dissatisfaction with College Algebra as it was taught at that time, the mathematics department at a small, Midwestern university modified their existing College Algebra course that was very traditional in nature to create a Modeling-Based College Algebra course to address those concerns. The purpose of this study was to investigate student success in the two College Algebra courses that were taught on the main campus at the university over a period of thirty-two years. College Algebra was taught as a traditional course using a standard algebra textbook between Fall 1986 and Spring 2002. The students who were enrolled in this course on the main campus of the university formed the first group. College Algebra was taught as a Modeling-Based course using an exploratory algebra textbook between Fall 2002 and Spring 2018. The students who were enrolled in this course on the main University campus formed the second group. Any students who have transcript grades for College Algebra in the first time period and then repeated College Algebra during the second time period were removed from the study to ensure independent samples. The transcripts of students in the study listed a letter grade of A, B, C, D, F, or W for College Algebra for a semester during one of the two specified time periods. Students with an incomplete, I, on their transcripts and those who withdrew from the class without a transcript grade were also not included. The Traditional College Algebra group consisted of 4,532 students, and there were 3,804 students in the Modeling-Based College Algebra group. The independent variable was the curriculum used in the traditional College Algebra course and the modeling-based College Algebra course. The dependent variables were final grade (4.0 scale), D/F percentage, withdrawal percentage, and final grade in the next math class (if it exists).

To measure the effectiveness of the change in curriculum/approach in terms of success in the algebra course as well as success in a subsequent mathematics course, two research questions were considered.

1. Is there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the College Algebra course? An Independent Sample T Test was originally planned for the analysis of the difference in means of the two College Algebra courses but had to be replaced by the Mann-Whitney U Test for the analysis of the difference in medians due to the nonnormality of the distributions. The Mann-Whitney U Test tested for significance of the difference in College Algebra course final grades for curriculum/approach. The two-sample test for proportions was used to test for significance of the difference in percentages of D/F grades. A two-sample test for proportions was also used to test for significance of the difference in percentages of W grades.
2. Is there a difference in the College Algebra course approach/curriculum (modeling-based vs. traditional) in terms of student success in the subsequent mathematics course? A Mann-Whitney U Test tested for significance of the difference in a subsequent mathematics course final grades for curriculum/approach.

Findings of the Study

The first research hypothesis was constructed to test the statistical significance of the difference in mean final grades of the Traditional College Algebra course and the Modeling-Based College Algebra course. The results of the Independent Sample T Test confirmed that there was a statistically significant difference in the mean final grades. With concerns regarding nonnormality of the distributions, the researcher also conducted a Mann-Whitney U Test to test the difference in median final grades. The difference in the median final grades was also statistically significant as the *p*-value was .000. Both tests confirmed that the students in the Modeling-Based College Algebra course achieved a higher final grade than the students enrolled in the Traditional College Algebra course.

The second research hypothesis was developed to test the statistical significance of the difference in the percentage of D/F grades of the two courses. There were 1,058 (27.16%) and 775 (22.07%) D/F grades given to Traditional College students and Modeling-Based College Algebra students, respectively. A Two-Sample Test of Proportions showed a statistically significant difference in the proportions of D/F grades, with a test statistic of $z = 5.07$ and a *p*-value = .000. This means that a lower percentage of students in the Modeling-Based College Algebra course received D/F grades than in the Traditional College Algebra course.

The third research hypothesis was similar to the second research hypothesis and was developed to examine the difference in the percentage of withdrawals of the two courses. There were 637 (14.06%) students and 293 (7.70%) students who withdrew from the Traditional College course and the Modeling-Based College Algebra course, respectively. A Two-Sample Test of Proportions showed a statistically significant difference in the proportions of withdrawals, with a test statistic of $z = 9.18$ and a *p*-value = .000. This means that a lower percentage of students withdrew from the Modeling-Based College Algebra course than from the Traditional College Algebra course.

For the fourth and final research hypothesis, a Mann-Whitney U Test was conducted to test whether the difference in final grade in the next math class for students in the Modeling-Based College Algebra course was statistically significantly different from the final grade in the next math class for students in the traditional College Algebra course. The test statistic was $z = -.991$ with a p-value $= .322$. Thus, the difference in the median final grades of the next math class was not statistically significant. This means that there was not a significant difference in the grades earned in the next mathematics class based on which type of College Algebra the student had taken. But the test statistic was negative, showing that the median final grade in the subsequent mathematics course for Modeling-Based College Algebra students was higher than their Traditional College Algebra counterparts.

Analyses were also run on subgroups of the students under study. Students were divided by age in two groups, those under the age of 25 years and those 25 years of age and older. A Mann-Whitney U Test showed statistical significance for the difference in median final grade between traditional age students in the two College Algebra courses. This means that traditional age students received higher final grades in Modeling-Based College Algebra than in Traditional College Algebra. A second Mann-Whitney U Test did not confirm statistical significance for the older group of students. Therefore, there was no difference in final grades for the nontraditional age students no matter what type of College Algebra was taken. Similarly, a pair of Two-Sample Test for Proportions showed statistically significantly different proportions for D/F and W grades for the younger group but not for the older group. As before, this means that the younger students had lower percentages of D/F/W grades for the Modeling-Based approach than the Traditional approach. There was no change in the percentages of D/F/W grades for the older students between the two College Algebra courses.

The students were also divided by gender, and two Mann-Whitney U Tests were performed. There was a statistical significance for the median final grade for both female and male students. Therefore, female Modeling-Based students earned higher grades than female Traditional students, and male Modeling-Based students earned higher grades than male Traditional students. The Two-Sample Test for Proportions showed statistical significance for females and males for both D/F and W percentages. Hence, both females and males had fewer D/F/W grades in Modeling-Based College Algebra than in Traditional College Algebra.

The students were divided by ethnicity, and a Kruskal-Wallis Test was performed on the median final grades in Modeling-Based College Algebra for ethnicity. The results showed statistically significantly different medians for more than one ethnicity subgroup. The results of a Dunn's Test showed statistically significant differences for Black or African American students with White students, Asian students, and Ethnicity Unknown students, thus showing us that the Black or African American students in the Modeling-Based course had lower final grades compared to the final grades of White, Asian, and Ethnicity Unknown Modeling-Based students.

A Mann-Whitney U Test was conducted for Instructor 1 and Instructor 2 who were the only instructors who taught sections of both College Algebra courses. The test showed higher final grades for the Modeling-Based College Algebra course for both instructors, but only Instructor 2 saw a statistically significant difference in median final College Algebra grades.

Implications for Practice

The results of this study confirmed what the mathematics faculty at the university of study envisioned when they modified their existing Traditional College Algebra course into a Modeling-Based College Algebra course. This is evident by the statistically significant increase in student success as measured by average grade in the course, which supports the findings of

Ellington (Ellington, 2005). The percentage of A/B/C grades for College Algebra students improved from the Traditional era to the Modeling-Based era, and the difference was statistically significant. This result supports the findings of the study by Ellington (2005) who found a statistical significance in the difference of A/B/C grade percentages. The results also showed statistical significance in the decrease in D/F and W percentages. With fewer withdrawals, more students have the opportunity to succeed, and fewer D/F grades allow more students to be successful in the A/B/C range. College Algebra has been a stumbling block for many students entering college (Edwards et al., 2011; Haver et al., 2007; Herriott, 2003; Herriott & Dunbar, 2009). An important finding of this quantitative study is that more students succeed in Modeling-Based College Algebra than in Traditional College Algebra.

Although the mathematics department was not as much concerned about increasing success in a subsequent math course after College Algebra as it was in improving the algebra course itself, the Mann-Whitney U Test results showed that, overall, students did better in the subsequent math course after taking the Modeling-Based College Algebra course than those from the Traditional College Algebra course. The difference was not statistically significant, but the fact that the students in Modeling-Based approach did better than the students in the earlier approach was an added bonus to their algebra reform efforts.

However, the success in the subsequent mathematics course varied greatly by the course. The percentage of A/B/C grades decreased from the Traditional era to the Modeling-Based era for both Business Calculus and Calculus I. The difference was not statistically significant. Again, the math department at the university was pleased with the fact that the change in curriculum and approach did not statistically alter the level of academic performance in the next math course. This positive difference could suggest that the Traditional College Algebra curriculum or approach is slightly better at preparing students for either of the two Calculus courses. On the other hand, it could indicate that the two calculus courses focus more on procedures than on a real-world focus. This differs from the findings of Ellington (2005). Ellington (2005) found that students in Traditional College Algebra did significantly better in Precalculus than students in Modeling-Based College Algebra whereas the Traditional students in this study did somewhat better but not statistically significantly better than the Modeling-Based students in Calculus, a higher mathematics course than Precalculus. The difference in percentages of A/B/C grades for Business Statistics was a small, negative difference which means that the Modeling-Based College Algebra students did better, but not statistically significantly better, than the Traditional College Algebra students. The difference in percentages of A/B/C grades for Discrete Math showed a statistical significance. This evidence supports the researcher’s notion that the curriculum and approach of the Modeling-Based course is better preparation for Discrete Math than that of the Traditional course. This might also indicate that the Modeling-Based course is better preparation for non-STEM majors since these non-STEM students typically do not enter into the calculus sequence. For subsequent mathematics courses other than Discrete Math, the Modeling-Based College Algebra course prepared students just as well as the Traditional College Algebra course. And for Discrete Math, students in the Modeling-Based course were better prepared than the students in the Traditional course.

The difference in average final grade between the two College Algebra groups was statistically significant for the traditional age subgroup, students under the age of 25 years. The average final grade was higher for the nontraditional age subgroup for the Modeling-Based group than the Traditional group, but not statistically significantly higher. The integrated use of technology may be more familiar for the younger age subgroup, and that might be a factor in why there is a difference between the age subgroups. The researcher expected that students in the older subgroup would draw from their expectably considerably more life experiences as the students work with data in real world situations, and that would have been a positive factor for the older subgroup to thrive in the Modeling-Based classroom. However, it is also possible that students in the older age group used study techniques that made them successful, no matter what the curriculum was.

Another interesting discovery was that a greater percentage of students 25 years of age and older withdrew from the Modeling-Based College Algebra course than the Traditional College Algebra course. These trends have also been documented by previous research (Burgess & Samuels, 1999; Calcagno et al., 2007). As mentioned earlier, this could be a reflection of the extensive use of technology in the Modeling-Based course and the unfamiliarity of older students with technology in general.

The Modeling-Based curriculum and approach worked well for both males and females as they both had statistically significantly higher average final grades with lower D/F and W percentages for that College Algebra group. The statistical analysis of the subgroups did reveal a great difference between females and males in College Algebra in terms of final grades, D/F percentages and withdrawal percentages. Female students had higher final grades than male students in both College Algebra courses. Female students also withdrew and earned D/F grades at a lower percentage than male students in both courses. This supports the research findings of several recent studies (Lorah & Ndum, 2013; Struik & Flexer, 1984; Van Nelson & Leganza, 2006).

Statistical analysis of the difference in final course grades in the two College Algebra courses with regard to ethnicity was not possible due to the absence of ethnicity data in the old database for the Traditional College Algebra students. But analysis was done on the Modeling-Based College Algebra group by itself. The students were divided by ethnicity, and a Kruskal-Wallis Test was performed. The results showed statistical significance. The results of a post hoc test showed statistically significant differences for Black or African American students compared to White, Asian, and Ethnicity Unknown students, which supports the findings of Lorah and Ndum (Lorah & Ndum, 2013). The Black or African American students had lower final grades than White, Asian, and Ethnicity Unknown students in Modeling-Based College Algebra.

Limitations of the Study

The most significant limitation of the study was the use of archived data. The archived data was collected for the use of the university at the time the students were enrolled and not specifically generated for this study. The only quantitative measure of student success available through the archived data was the final course grade which was part of the university transcript information. As a result, there were many variables that could not be explored or investigated. It would have been great to compare success on specific questions on a common final exam. Being able to measure student perceptions of each College Algebra course through surveys or personal interviews would add another dimension to the study. A follow-up survey to collect students' thoughts on how well the College Algebra course prepared them for the next subsequent mathematics course could provide additional insight.

One of the most significant limitations of the study was the incomplete academic records for the students in the database of the university of study. Some fields were missing or not recoverable for the records of students who last attended the university before 2002. An example of this is the lack of ethnicity classification for those students. As a result, the researcher could not analyze the impact of the new curriculum and approach for College Algebra upon the different ethnic groups. Another example of this is the lack of high school academic information that would allow the researcher to control for prior academic experience such as high school grade point average (GPA), American College Testing (ACT) test scores or Scholastic Assessment Test (SAT) test scores, number of years of high school mathematics courses, and university-specific placement test scores.

Another limitation of the study was the autonomy given to instructors for both College Algebra courses. There was no baseline or other measure to standardize each section of each course. Textbooks varied greatly in scope and presentation between the two College Algebra courses. Instructors had the academic freedom to choose how they delivered the material, what homework and test assignments looked like, how those assignments were graded, and the weights for each assignment category. Two professors taught multiple sections in both College Algebra courses, and some additional testing was done on their sections in an attempt to look for possible instructor bias. The Modeling-Based College Algebra final grades were higher than the Traditional College Algebra final grades for both professors, which support the findings for the overall study and reduce the concern of possible instructor bias.

A limitation of the study was the grading structure for the two courses. Unit tests accounted for 40% of the final grade in both courses. The final exam in Traditional College Algebra was worth 25% compared to 20% for Modeling-Based College Algebra. Quizzes and homework amounted to 35% of the Traditional grade, which compared to 40% of the Modeling-Based grade coming from assignments, lab reports, and participation. Paper quizzes were given in the Traditional course whereas iClicker™ questions were used for participation and assessment in the Modeling-Based course. The Modeling-Based classroom required active participation which is also why participation points were given to maximize student involvement.

The university of study is a rural, private, Midwestern university with limited diversity of age, ethnicity, and cultural background. The data collected in the study is pertinent to the university of study and others like it but may not be as applicable to other college and universities with vastly different demographics.

Recommendations for Future Research

The role of College Algebra is under close scrutiny in the American academic community (Edwards et al., 2011; Ganter & Haver, 2011; Gordon, 2016). There is a definite need for future research on this topic. College Algebra still serves a significant role as a prerequisite course for other mathematics courses. Based on the findings of this study, Modeling-Based College Algebra and Traditional College Algebra equally prepare students for the next mathematics course, yet Modeling-Based College Algebra provides a better academic experience for students who will not take another course beyond College Algebra. Research into best practices of curriculum topics and instructional modalities for Modeling-Based College Algebra is warranted.

Further research studies could include a robust analysis of a number of variables that measure or predict student success in Modeling-Based College Algebra or a similar first-year college mathematics course. Predictor variables for student success in this could include, but not be limited to, age, gender, ethnicity, socio-economic status, high school GPA, number of years of high school mathematics course, high school mathematics GPA, ACT scores, SAT scores, and university-specific placement test scores. Measures of student success could include final grade, grade on common tests, grade on specific questions on a common test, and perception surveys.

Further research could include studies of Modeling-Based College Algebra courses where the same textbook was used, which was a limitation of this study. Research could investigate the effect of instructional modes such as online instruction or mixed-mode (blended) instruction on academic achievement in Modeling-Based College Algebra. Research could also be furthered by analyzing the effect of instructional delivery methods such as the flipped classroom, guided inquiry learning, online mathematical homework systems, replacement model, supplemental instruction, technology-based instruction, and the emporium model on student success in Modeling-Based College Algebra.

Additional future research could explore if there is a difference in student success depending on the semester in which students took College Algebra. Specifically, it would be of interest to the academic research community to look for a difference in student success for those who took the course their first semester in college versus those who took it in a later semester.

This study looked at the success of Modeling-Based College Algebra and Traditional College Algebra students in the next subsequent math course. Future studies could utilize a similar approach to compare the success of the students from each type of College Algebra who went on to take higher level STEM courses to see if there was a difference.

The setting for this study was a rural, private, Midwestern university with limited diversity of age, ethnicity, and cultural background. Settings for further research could include urban, public universities, colleges, and community colleges which would have greater diversity of age, ethnicity, and cultural background. Quantitative research could examine the interaction within and between age, ethnicity, and cultural background on student success in Modeling-Based College Algebra within the different instructional modes and delivery methods. Qualitative research could be conducted through surveys and personal interviews. Questions could be asked about their perceptions of the Modeling-Based College Algebra course, the preparation the course provided for the next subsequent math course, the level of math anxiety they experience, level of self-confidence in their ability to do mathematical processes, and level of self-confidence in their ability to successfully complete the course.

Conclusion

The results of this study show that students at the rural, private, Midwestern university being researched performed statistically significantly better, in terms of course final grade and A/B/C percentage, in Modeling-Based College Algebra compared to students in Traditional College Algebra. Additionally, the Modeling-Based students had fewer D/F grades and lower withdrawal rates than the Traditional students. There was no statistical significance for course final grade in the next subsequent math course between the two College Algebra groups. Both gender subgroups, females and males, had higher course final grades, greater A/B/C percentages, lower D/F percentages, and fewer withdrawals in Modeling-Based College Algebra than in Traditional College Algebra. Traditional age students (under 25 years of age) had higher course final grades and lower D/F/W percentages in the Modeling-Based course than in the Traditional College Algebra course. There was no difference in course final grade or D/F/W rates for the non-traditional age students. Ethnicity subgroups could not be compared between the two College Algebra groups due to missing information, but analyses of Modeling-Based College Algebra students with respect to ethnicity showed that Black or African American students had statistically significantly lower final course grades than White, Asian, and Ethnicity Unknown students in the Modeling-Based College Algebra course.

This research provides data from a longitudinal study of Modeling-Based College Algebra from 1986 to 2018. The sample sizes were quite large, with 4,532 students in Traditional College Algebra from 1986 to 2002 and 3,804 students in Modeling-Based College Algebra from 2002 to 2018. The samples were of similar size as well, which results in higher power of the statistical tests and greater significance to the findings of this study. The results show the benefit of offering a Modeling-Based curriculum/approach to College Algebra as it leads to better results for students in the College Algebra course and it does not impede the success of those students in their next subsequent math course. The results affirm the decision of the mathematics department at the university of study to modify College Algebra to its current Modeling-Based curriculum and approach. The department hoped to have one course that would provide a good academic experience for students who would not take another math course and yet still prepare underprepared students adequately for the next course. The course is doing what the department hoped that it would do.

Key takeaways of the study are recapped below.

1. Students were more successful in Modeling-Based College Algebra.
2. Fewer students withdrew from Modeling-Based College Algebra.
3. Students who took Modeling-Based College Algebra did better in Discrete Mathematics than Traditional College Algebra students.
4. There was no statistical difference in success in the next math course.
5. Younger students benefitted from the Modeling-Based approach, but older students dd not.
6. Both genders benefitted from the Modeling-Based course.
7. Black or African-American students earned lower grades in Modeling-Based College Algebra than several other ethnic groups.

APPENDIX A

COURSE MODIFICATION PROPOSAL

Title: College Algebra	Course Number: MAT 1143
Offered: Every semester	Credit Hours: 3

Course Description

A three hour course that explores the use of algebra in the real world. This exploration takes place by examining the concept of function. Conceptual understanding of linear, exponential, logarithmic, quadratic, and other polynomial functions is grounded in the collection and statistical analysis of real world data. Functions will be used to solve real world problems using modeling techniques. The concept of function is also explored in detail using analytic geometry.

Prerequisites

Satisfactory scores on the prealgebra and intermediate algebra portions of the Enhanced ACT Examinations or a minimum grade of “C” in MAT 0123 – Intermediate Algebra.

Specific Modification

The content of the course will be modified to include a section on the statistical analysis of data and a more focused study of functions both algebraically and geometrically. The presentation of the content will be modified to be more exploration oriented. This means that the course will be less focused on learning a set of discrete mechanical rules and more focused on the conceptual understanding of algebra and its applications.

Rationale

The impetus for modifying College Algebra was the need to meet the requirements for general education mathematics courses as defined by the Missouri Coordinating Board of Higher Education. The CBHE has said that a general education mathematics course should explore concepts of algebra, geometry, and statistics. The course is also required to have the same prerequisites and level of rigor as a traditional College Algebra course. This meant that either College Algebra would have to be modified or the Survey of Mathematics (MAT 1133) would have to be brought up to the same level of rigor as College Algebra. It seemed as though the best option was to modify College Algebra and thus eliminate the need for the Survey of Mathematics course.

The CBHE requirements gave the mathematics department the jump-start to do what we have felt needed to be done for a long time. College Algebra needed to be improved to be a better terminal mathematics course for the many students who will never take another mathematics course. Of course, for students who intend to further their mathematical knowledge, the movement into Pre-Calculus, Business Calculus, or Calculus must still be a possibility. The proposed changes in College Algebra will meet these needs and will allow us to eliminate the Survey of Mathematics (MAT 1133).

The change in content, as suggested by the CBHE, allows College Algebra to focus on the concepts of algebra while utilizing the connections with geometry and statistics. Connections are an important part of the study of mathematics (NCTM, 2000). The focus will be on the unifying topic of function, which is important whether further study in mathematics will occur, or not.

The changes also provide an opportunity to change the method of presentation of College Algebra. The modified College Algebra will be exploration based and will require students to be more actively involved in the learning process. This will occur through the use of real world data to develop the concept of function. Students will be involved in "laboratory" type explorations that will help them construct their understanding of algebraic concepts. This is in line with the many recent recommendations for mathematics teaching to be more student centered as opposed to teacher centered (NCTM, 2000; MAA, 1991; NRC, 1989). While this type of instruction is crucial for students who will not study further in mathematics, it is also important for students who will go on to Calculus. The National Research Council (1991) reported in <u>Moving Beyond Myths: Revitalizing Undergraduate Mathematics</u> that "Undergraduate [courses], in which students experience the open-ended exploratory nature of mathematical investigation, is one of the proven means of launching students on successful careers in the mathematical sciences" (p. 35).

The content and methodology of the proposed College Algebra course combine to create a course that develops the mathematical skill students need within the context of real world situations. This approach has been utilized in universities across the United States in recent years. One such example is the University of Missouri-Columbia where a new College Algebra course was instituted about 5 years ago. The results indicate a successful implementation. The dropout rate in the College Algebra course has decreased over 25%. The percent of deficient grades has dropped over 25% and the student and teacher evaluations of the course have become much more positive. Students appreciate the focus on understanding and relevance in the new course. These positive attitudes occur despite the fact that at MU the course is still worth only 3 hours while student must attend 5 days a week for 50 minutes.

Another important consideration is the impact on course offerings when the Survey of Mathematics course is eliminated. Currently we offer 5 sections of College Algebra and 1 section of Survey of Mathematics in the fall, and 2 sections of College Algebra and 1 section of Survey of Mathematics in the spring. When Survey of Mathematics is eliminated 6 sections of College Algebra will offered in the fall and 3 sections will be offered in the spring, therefore staffing and the number of sections available to students will not change.

Budget considerations influenced our decision regarding how to integrate the "laboratory" explorations into a three-hour course. A consideration was made to add a 1-hour lab session per week, but because of lack of staffing this plan was discarded. (A 1-hour lab would necessitate 2 lab sections for each of the 9 sections offered yearly. This would translate into 18 lab hours or 12 load hours per year added to the mathematics department load.) Instead the six explorations will take place in two settings. Three of the explorations will take place within the normal weekly class time. The other 3 explorations will take place during evening hours in the Math Tutor Room. Mathematics majors staff this room 3 to 4 nights per week. Three times during the semester, College Algebra students will be required to attend exploration sessions at the Tutor Room. There are several advantages to this feature of the course. One is that the three explorations that occur outside of class time, free up some in class time. Also the mathematics majors, many of whom are future teachers, will gain some experience leading this type of activity. This process will be evaluated after a year and may be altered depending on its success. Of course, this process will be difficult, if not impossible, to imitate at off campus centers. Thus, at off campus centers, all explorations will have to be done during normal classroom sessions. The course outline may easily be altered to allow for this to occur. One reason the indicated text was chosen for this course is that it provides excellent guidance and models for instructors to pace the course. The materials that accompany the text will provide off campus instructors the needed resources to alter the course.

A final consideration regards the increased utilization of graphing calculators required by the text selected for this course. This is an area that will have to be addressed as the course is implemented. The plan is to begin by using the classroom set of calculators already owned by the mathematics department in conjunction with calculators that many students bring to class. If this presents problems, consideration will be made in the future to require students to purchase graphing calculators. It should be noted that the purchase of calculators by students taking college algebra is already required by many other colleges in Missouri.

In summary, the modifications to College Algebra, are intended to meet the CBHE requirements for general education mathematics courses. But, more importantly, the changes are intended to make College Algebra a course where students see and experience the importance and power of mathematics.

Mathematical Association of America, 1991, A Call for Change: Recommendations for the Preparation of Teachers of Mathematics.

National Council of Teachers of Mathematics, 2000, Principles and Standards for School Mathematics, NCTM: Reston, VA.

National Research Council, 1989, Everybody Counts: A Report to the Nation on the Future of Mathematics Education, National Academy Press: Washington, DC.

National Research Council, 1991, Moving Beyond Myths: Revitalizing Undergraduate Mathematics, National Academy Press: Washington, DC.

APPENDIX B

COURSE TOPIC LIST

Topics Taught in Traditional College Algebra **Not** Taught in Modeling-Based College Algebra

Polynomials and Special Products	Synthetic Division
Factoring	Finding Roots of Rational Functions by hand
Fractional Expressions	Graphing Rational Functions by hand
Absolute Value Equations and Inequalities	Two-Variable Linear Systems
Solving Quadratic Equations by Completing the Square	Multivariable Linear Systems
Finding Roots of Polynomial Functions by hand	Sequences and Summation Notation
Graphing Polynomial Functions by hand	Arithmetic Sequences
Polynomial Division	Geometric Sequences

Topics Taught in both Traditional College Algebra and Modeling-Based College Algebra

Real Numbers, Exponents, and Radicals	Translations
Graphical Representation of Data	Combinations
Graphs	Inverse Functions
Linear Equations	Quadratic Functions
Modeling with Linear Equations	Power Functions
Solving Quadratic Equations by the Quadratic Formula	Exponential Functions and Their Graphs
Complex Numbers	Logarithmic Functions and Their Graphs
Linear Inequalities	Properties of Logarithms
Lines in the Plane and Slope	Exponential and Logarithmic Equations
Functions	Exponential and Logarithmic Models
Analyzing Graphs of Function	Solving Systems of Equations

Topics Taught in Modeling-Based College Algebra **Not** Taught in Traditional College Algebra

Introductory Statistics	Average Rates of Change
60 Second Summary	Scientific Notation
Concavity	Tabular Data

APPENDIX C

TRADITIONAL COLLEGE ALGEBRA SYLLABUS

MAT 1143-COLLEGE ALGEBRA

Text: College Algebra. Larson and Hostetler. 5th ed. Houghton Mifflin Publishing, 2001.

Catalog Description: The real number system and algebra developed using terminology of a set, complex numbers, exponents, radicals, inequalities, sequences, and series, introduction of theory of equations. Prerequisite: Satisfactory scores on the prealgebra and intermediate algebra portions of the Enhanced ACT Examination or a minimum grade of "C" in MAT 0123-Intermediate Algebra.

Course Description: A study of the real number system, elementary algebra, complex numbers, functions, exponents, logarithms, inequalities, and sets of equations.

Course Goals:

1. The student can use the properties of real numbers in the solution of problems.
2. The student can manipulate effectively with exponents, exponential notation and radicals.
3. The student can graph and interpret polynomial functions and relations.
4. The student can simplify and expand algebraic expressions quickly and use the techniques of special products and factoring.
5. The student can use the axioms, definitions and other properties of real numbers to solve linear and quadratic equations and inequalities.
6. The student can apply the concepts, skills, and generalizations of algebra to solve application problems using single equations and inequalities, systems of equations and inequalities and the language of variation.
7. The student can recognize and analyze arithmetic and geometrical progressions and expand binomials.

Organization and Evaluation:

A. Grade Determination:

1. Grades will be determined by performance on quizzes, homework, exams, and the final exam. Homework, quizzes, and exams will be structured to determine student's knowledge in the content of the course objectives. There will be:

a.	Quizzes and Homework	350 pts
b.	Tests(4 @ 100 pts each)	400 pts
c.	Final Exam	250 pts

2. The student's letter grade will be determined by the quality of work produced on the requirements listed above. The letter grade determination will follow the guidelines as listed below.

90 - 100%	A
80 - 89%	B
70 - 79%	C
60 - 69%	D
Below 60%	F

3. Students who perform poorly usually do so for at least one of the following two reasons:
   a. The student's mathematical background is such that prerequisite skills are not naturally demonstrated by the student making it difficult for the student to master new material at the pace with which it is presented. Students with insufficient background should consider taking MAT 0123-Intermediate Algebra to strengthen their background.
   b. The student's attendance and homework completion is sporadic, making it difficult for the student to master new material at the pace with which it is presented.

B. General Information:

1. **Attendance:**
"The University believes that students are primarily responsible for attendance. A student should recognize that many of the vital aspects of a college experience cannot be fully realized when class attendance is irregular. It is the expectation of the University that students will attend all class meetings and complete all activities assigned by the instructor for the class. Each instructor will provide students with written statements in the course syllabus with

respect to class attendance requirements." [SBU attendance policy]

Attendance will be taken on a regular basis. Days, other than review days, where over 30% of the class is absent WILL have homework collected for grading. Course activities and assignments not completed because of absences may adversely affect a grade for the course. After the ninth (9^{th}) absence (which is 20% of the class meetings), NO make-up work is allowed.

2. **On-line Information:**
A course website will be prepared at { HYPERLINK http://bearcat.sbuniv.edu/~khopkins/mat1143/ }. Here you can find the syllabus and other information. The most important information there will be the up-to-date lecture schedule, daily assignments made, upcoming quiz information, and upcoming exam information. Students absent from class should check the website to see what was missed during class so they will be prepared for the next class.

A tutorial is available online at http://www.smarthinking.com/partners/houghton/buyindex.cfm. A password key was included with your textbook if it was purchased new this year.

3. **Quizzes and Homework Assignments:**
Mathematics is participatory and progressive. One must do the majority of assigned problems to learn the material. The next lecture usually depends on previous material and so will make more sense to students who keep up DAILY with the homework. Therefore students should attempt most of the assigned problems and be prepared to ask questions at the next lecture. Homework assignments (problems) may be collected, with selected grading of problems, at any class meeting. These pop hand-in assignments missed because of class absences generally cannot be handed in at a later date. At least half of the homework must have been attempted for any credit to be received on the homework collected.

Quizzes will be announced the class meeting before they will occur. They will generally be 3-4 problems similar to the homework assignments. Quizzes missed and not taken by the time they are graded and returned to the class can be made up only with a valid excuse for the absence (for example: illness, death in family. University activity is also excused but would be known in advance so the quiz could be arranged before the absence occurs).

5. **Lecture Exams:**
An evaluation of each student's knowledge of the lecture material will be obtained from four (4) exams. The material for these exams will be taken from topics which have been assigned in class. Exams missed and not taken by the time they are graded and returned to the class can be made up only with a valid excuse for the absence (for example: illness, death in family. University activity is also excused but would be known in advance so the exam could be arranged before the absence occurs).

6. **Final Exam:**
The final exam in the course is on Tuesday, December 11, at 10:30 a.m. and will include all of the material covered in the course. Students will have the opportunity to show whether they have mastered the material in the course.

7. **Math Tutors:**
Tutors for students enrolled in mathematics classes at SBU are available to help students when they have difficulties understanding topics, concepts, etc. in their mathematics classes. These tutoring sessions are on Monday-Thursday evenings from 6:00 till 10:00 in Taylor 221 (the computer lab). Students may drop in at any time during this time interval. It is advised that if a student is having trouble solving problems and/or understanding a topic they get help as quickly as possible before they fall too far behind. Students wanting to recover lost points due to an absence from a pop homework collection can spend 1/2 hour in the tutor room working on College Algebra homework, have the tutor sign and date that homework, and turn in the signed homework at the next class meeting. This can be used to recover points from up to three missed homework collections.

A tutorial is available online at http://www.smarthinking.com/partners/houghton/buyindex.cfm. A password key was included with your textbook if it was purchased new this year.

APPENDIX D

MODELING-BASED COLLEGE ALGEBRA SYLLABUS

MAT 1143-COLLEGE ALGEBRA

REQUIRED TEXT Explorations in College Algebra, 5th edition, Linda Almgren Kime, Judith Clark, and Beverly Michael published by Wiley. ISBN: 978-0-470-46644-5.

COURSE CATALOG DESCRIPTION: This course explores the use of algebra in the real world. This exploration takes place by examining the concept of function. Conceptual understanding of linear, exponential, logarithmic, quadratic, and other polynomial functions is grounded in the collection and statistical analysis of real world data. Functions will be used to solve real world problems using modeling techniques. The concept of function is also explored in detail using analytic geometry.

COURSE GOALS AND OBJECTIVES

1. The student can read, interpret, analyze, and synthesize quantitative data.
2. The student can recognize patterns involving a variety of functions.
3. The student can solve problems using algebraic, geometric, and statistical models.
4. The student can recognize the connections between algebraic and geometric concepts and utilize these connections to solve problems.
5. The student can recognize the connections between mathematical models and studies in social and physical sciences and utilize these connections to solve problems.
6. The student can describe the contributions to society from the discipline of mathematics.

COURSE PREREQUISITES: Satisfactory scores on the prealgebra and intermediate algebra portions of the Enhanced ACT Examinations or a minimum grade of "C" in MAT 0123 – Intermediate Algebra.

COURSE PRESENTATION: The focus of class time, in this course, will be on students exploring the concepts of algebra. These explorations may take place in whole class discussion, individual work, group work, or in "laboratory" explorations. Although the teacher will guide class time, students are expected to be active participants during class time.

COURSE REQUIREMENTS AND REGULATIONS (including Attendance Policy-see #2)

1. Students will complete all examinations, including the comprehensive final exam at the end of the course.
2. Students who are absent are responsible for providing, as soon as possible but within a week of their return to class, any documentation needed to have the absence considered justified. Until such documentation is provided the absence is considered unjustified. Make-up exams are given only if the student contacts instructor to make arrangements to do so **<u>before</u>** graded exams are returned and only if absence is justified (for university business, illness, or other emergencies such as a death in the immediate family). All make-up work must be completed within one week of returning to class. Students with unjustified absences over 20% of class meetings (9 absences) will be allowed NO LATE WORK after the 9th absence. This attendance policy falls within the parameters of the University attendance policy found on the last page of the syllabus.
3. Students will participate in class using I-Clickers, working problems while they are being discussed and submitting their answers in a timely fashion. Since the material will be new, proficiency is not expected but thoughtful work is. Most class period will have 5 points for participation. Students who answer all questions and get over 60% correct will get 5 points. Students who answer all questions and get over 30% correct will get 4 points. Students who answer at least 60% of the questions and get at least 30% correct will get 3 points. Students who answer less than 60% of the questions or get fewer than 30% correct, but

still participate in class with the I-clickers will get 2 points. Students with an unjustified absence will receive no participation points for that class period. Students with a justified absence will receive the average of their participation grades for the class period before and after the absence. Remember all absences are considered unjustified until documentation is provided to have the absence considered justified.

4. Students will complete all homework assignments ONLINE. ALL homework assignments will be made in Blackboard and will be graded within Blackboard on submission. Assignments to turn in will be due at 5 pm the class day following the assignment being made (so you can ask questions at the beginning of class on that homework and then complete it after class before 5 pm that day). One point (of the 6 points possible per homework set) will be deducted for every day an assignment is considered late. If a student is absent (whether justified or not), they are still expected to do the assignment for the next class meeting. No late homework from a unit will be accepted after the exam on that unit without prior arrangement (where justification for such an extension will need to be given).
5. Students will complete all explorations, including any requested written responses.

GRADING

		Percentages for letter grades	
Assignments and Lab Reports	200 points (approximately)	90%-100%	A
Participation	200 points (approximately)	80%-89%	B
4 Tests (100 points each)	400 points	70%-79%	C
Comprehensive Final	200 points	60%-69%	D
TOTAL	1000 points	below 60%	F

The instructor reserves the right to curve scores slightly below these percentage cutoffs due to students' performance in the course. If the cutoff for a certain grade is lowered, all students scoring above that cutoff will receive the same grade.

Students who perform poorly usually do so for at least one of the following two reasons:

I. LACK OF EFFORT. The student's attendance, participation, and/or homework completion is sporadic, or the student works through problems without developing an understanding of the problems.

II. The student's mathematical background is such that prerequisite skills are not naturally demonstrated by the student. It is therefore difficult for the student to master new material at the pace with which it is presented. Students with insufficient background should consider taking MAT 0123 – Intermediate Algebra to strengthen their background.

HINTS FOR SUCCESS:

1. DO HOMEWORK IN GROUPS. This way you can help each other plus gain a better understanding of the material through explaining it to others.
2. GET HELP when a concept is unclear.
3. Be regular and prompt in attendance. Seeing problems worked out in a setting where questions are encouraged is very helpful to the learning process. Participate in class. Think through the examples and ask questions when needed.
4. Do the assigned homework. This is the best way to learn algebra. Mathematics is participatory and progressive. The next lecture usually depends on previous material and so will make more sense to students who keep up daily (5 days a week) with the homework. Therefore students should attempt the assigned problems and be prepared to ask questions at the next lecture.

5. Study! The rule of thumb is that a college student should spend *an average* of two hours studying outside of class for every hour spent in class. This means that each student should plan to spend on average a minimum of 6 hours per week studying and working homework problems for this course.
6. Don't fall behind. The pace of the course is determined by the amount of material that needs to be covered in a College Algebra course. Falling behind will only make the pace of new material seem more rapid.
7. Use the 10-minute rule when studying. If you stuck on a problem for 10 minutes, go to the next problem. If you get stuck on a section, either go get help or put the work up and study something else for a while.

Available Help:
There is a tutoring lab available *free of charge* Monday, Tuesday, Wednesday, and Thursday from 6:00 p.m. to 10:00 p.m. in Wheeler 126. My office hours are a time when I am in my office to be available to help you with questions about the course.

DISABILITY STATEMENT
Southwest Baptist University desires to provide all students with optimum learning experiences. If you have a disability that impacts learning in this course, you must inform your instructor in order to receive special assistance.

Academic Integrity: It is expected that all students will behave in a Christ-like fashion and uphold the highest standards of integrity and personal ethics. Students who cheat, plagiarize, misuse SBU computing resources, violate SBU computer usage policy, misrepresent the truth, or make false statements to University faculty, administration or staff will be held accountable for their actions. Such conduct is inconsistent with the Christian lifestyle and Biblical principles (Col. 3:17; I Thess. 5:22; Ex. 20:16; Deut. 5:20; Prov. 6:16-19; 12:22; Psalm 97:10). If student misconduct occurs, the misconduct will be dealt with as described in the SBU Student Handbook. Any student assignment that is plagiarized or is associated with cheating will be assigned a zero.

Faith Integration Statement: The Mission Statement and Vision Statement of Southwest Baptist University explicitly state that University activities are to be Christ-centered and that instruction will be from a Christian perspective. Every attempt will be made to integrate into this course the Christian faith, Christian world view and Biblical values consistent with the Baptist heritage of the University (See University Catalog).

Inclement Weather Policy: In case of inclement weather, the course will meet as scheduled unless the University cancels all classes. Students commuting to school should use their own discretion as to their ability to safely make it to campus for class. As soon as possible, please call or email the instructor if inclement weather keeps you from attending class.

APPENDIX E

UNIVERSITY APPROVAL LETTER

November 4, 2019

UMKC IRB

I am writing as chairman of the SBU Research Review Board (RRB) on behalf of Tim Chappell regarding his Ph.D. research. The RRB of SBU, pursuant to its policies for research on human subjects, has determined that RRB approval is not required for Tim Chappell's research, due to the fact that it is based on archived data and maintains anonymity.

As chairman of the SBU RRB, I approve this data collection.

Craig Masters, Ph.D.
Research Review Board, Chairman
Southwest Baptist University

APPENDIX F

DEPARTMENT APPROVAL LETTER

Nov. 4, 2019

UMKC IRB

Tim Chappell is working on a Ph.D. from University of Missouri-Kansas City. He wishes to conduct a dissertation study comparing grades from the traditional College Algebra course offered at SBU from Fall 1986 to Spring 2002 and the Modeling-Based College Algebra course offered at SBU from Fall 2002 to Spring 2018, as well as to compare grades in the next subsequent math class. The study will use archived data.

As chair of the mathematics department I approve this data collection. Not only do I want to support Tim's research proposal, but I am also eager to see the results that Tim obtains.

Dr. Kevin W. Hopkins

Dr. Kevin W. Hopkins
Chairman, Mathematics Department
Southwest Baptist University

APPENDIX G

IRB APPROVAL LETTER

Fri 2/14/2020 9:11 AM

UMKC eCompliance <umkc-ecompliance@umkc.edu>

IRB Determination Notice Project #2018142 Review #255664

UMKC eCompliance

IRB Determination Notice Project #2018142 Review #255664

Project #2018142
Project Title: A Longitudinal Study of Modeling-Based College Algebra and Its Effect on Student Achievement
Principal Investigator: Rita S Barger
Primary Contact: tpc34d

Dear Investigator,

A member of the UMKC Research Compliance Office reviewed your application and supportive documents. It has been determined that this project does not constitute human subjects research according to the Department of Health and Human Services regulatory definitions. As such, there are no further IRB requirements.

If you have questions, please feel free to contact the IRB office at 816-235-5927 or umkcirb@umkc.edu.

Sincerely,

UMKC Institutional Review Board

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VITA

Tim Chappell attended Southwest Baptist University from 1984 to 1987, where he earned a Bachelor of Science in Mathematics with a minor in Computer Programming. He continued studying mathematics in graduate school at the University of Missouri-Columbia during the 1987-1988 school year. Mr. Chappell transferred to Pittsburg State University the following year and completed a Master of Science in Mathematics with an emphasis in Community College teaching in May 1989. His thesis was titled "Taxicab Trigonometry: A Development of "Circular Functions in the Plane with the L_1 Metric."

After receiving his degree from Pittsburg State University, Mr. Chappell worked at Labette Community College in Parsons, Kansas. His duties there were split between teaching mathematics courses and tutoring in the academic learning center. In fall 1990, Mr. Chappell accepted a full-time teaching position at North Central Missouri College in Trenton, Missouri. In fall 1996, he began teaching at Metropolitan Community College-Penn Valley. During the twenty-two years at Penn Valley, he developed online courses and became the first online coordinator for the mathematics courses in the district. In fall 2018, Mr. Chappell relocated to Bolivar, Missouri to become an assistant professor of mathematics at Southwest Baptist University.

Mr. Chappell has conducted fourteen week-long workshops and three weekend institutes for Missouri mathematics instructors. He has also conducted two week-long institutes and multiple math fairs for high school and college students. He has delivered thirty-three presentations and hosted over thirty webinars through the years. He has always been active in state and national mathematics organizations. He has been very active in AMATYC and has attended more than twenty annual conferences. He has held numerous positions within the state affiliate MOMATYC including serving as President from 1997 to 2000.

Mr. Chappell applied for admission to the University of Missouri-Kansas City in fall 1999. He entered the interdisciplinary Ph.D. program with curriculum and instruction as his primary discipline and mathematics as his co-discipline. He completed his coursework and passed his comprehensive exams in fall 2003. After some time away from the program, Mr. Chappell applied for readmission to the doctoral program in fall 2018. His dissertation focused on the curriculum and instruction of mathematics at the college level.