THE EFFECTIVENESS OF REDESIGNING COLLEGE ALGEBRA WITH A HEAVY FOCUS ON INSTRUCTIONAL TECHNOLOGY

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ABSTRACT

Low success rates in college algebra have been an ongoing problem, and mathematics education researchers have continually looked for ways to improve student performance and learning (Aichele, Francisco, Utley, & Wescoatt, 2011; Gordon, 2008; Thompson & McCann, 2010; Twigg, 2011). This study examined the effectiveness of the pilot semester, spring 2012, of a technology-intensive course redesign of college algebra as compared to a traditional lecture approach at a mid-sized, diverse, urban university in the Midwest. Final exam performance was the main measure for assessing student learning outcomes and for testing thirteen hypotheses; DFW rate, the proportion of students withdrawing or earning a grade of D or F, was used for testing one hypothesis. Between the two instruction types, the researcher used a quasi-experimental study to compare overall performance on the final exam, performance on the conceptual and procedural questions of the final exam, performance on the individual questions of the final exam, and DFW rates in the course. Overall final exam performance was also compared within each gender, between genders, within two races/ethnicities, and between races/ethnicities. Additionally, performance on the conceptual and procedural questions was compared within each gender and within two races/ethnicities. Final exams were taken by 170 students, 73 students in the redesign approach and 97 students in the traditional approach. T-tests, analyses of covariance, and two-proportion z-tests were used to investigate the hypotheses. In most hypotheses, there were no statistically significant differences between the two types of instruction. One significant difference was found between African-Americans and Caucasians in both the redesign and traditional sections; however, the covariate, American College Testing (ACT) Mathematics Sub-score accounted for the difference, meaning that type of instruction had no effect. Also, a large difference ($p = 0.0026$) in favor of students in the redesign occurred on one question of the final exam on which students solved a system of linear equations. Lastly, a large difference in course success was observed in DFW rates in favor of the seasoned, traditional lecture approach. The DFW rate was 41% for the redesign approach, but the DFW rate was only 21% for the traditional lecture approach.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Graduate Studies, have examined a dissertation titled "The Effectiveness of Redesigning College Algebra with a Heavy Focus on Instructional Technology," presented by Mark A. Brown, candidate for the Doctor of Philosophy degree, and certify that in their opinion it is worthy of acceptance.

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CONTENTS

TABLES

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CHAPTER 1

INTRODUCTION

Background Information

During the academic-year of 1992-1993, the researcher was a graduate teaching assistant in mathematics at a Midwestern university and taught two sections of college algebra each semester. On the first day of class in one of those sections a student asked for permission to speak to the rest of the class. After permission was granted, the student proceeded to encourage the class to take the class seriously. The student then informed her classmates that she was taking college algebra for the seventh time and that she did not want them to experience the same failure. Although certain aspects of this story may be unique, the frustration with college algebra is a common occurrence in colleges and universities throughout the United States. The existence of the frustration is supported by the fact that nearly 50% of students in college algebra earn a grade of D or F or withdraw from the course (Gordon, 2008). Because of its high DFW rate—the proportion of students who either withdraw or earn a grade of D or F—college algebra is blamed for negatively affecting one university's recruiting efforts (Bennett, Manspeaker, Natarajan, & Paulhus, 2011) and is the main reason for another institution's failure to retain students (Gordon, 2008). Furthermore, the high DFW rate in a course results in many students not completing their bachelor's degrees, resulting in a negative impact on the nation's economy (de Alva & Schneider, 2011). Parenthetically, the abovementioned student dropped the class after two weeks.

Educators are continually seeking the most effective ways to impact student learning while government leaders are trying to find ways to overcome budget shortfalls. These shortfalls often result in significant cuts to federal and state education budgets, thus making it more difficult for educators to research and implement the most successful teaching practices. Persistent educators, however, often find ways to positively influence student learning whether or not satisfactory funding is available. Organizations, such as the National Center for Academic Transformation (NCAT), seek creative ways to implement effective instruction and reduce expenses at the same time. NCAT, known as the "experts in improving learning and reducing costs in higher education" (The National Center for Academic Transformation, 2012c), has supported the implementation of course redesigns in the following areas: mathematics, sciences, social sciences, humanities, and professional studies. A majority of the course redesigns have been in mathematics (The National Center for Academic Transformation, 2012i). NCAT aspires to use information technology in their course redesigns to improve student learning while reducing costs. They use a four-stage iterative process to accomplish their goals. This cyclical process includes (1) proof of concept, (2) analysis, (3) communication, and (4) scale. (The National Center for Academic Transformation, 2012m). A more thorough description of the process is described in Chapter 2.

To initially test the effectiveness of course redesigns in which learning is improved and expenses are reduced, Dr. Carol Twigg, President and Chief Executive Officer of NCAT, created the Program in Course Redesign. The program was backed by an 8.8 million dollar grant from Pew Charitable Trusts, and from 1999 to 2004, courses at 30 diverse colleges and universities were redesigned with the help of NCAT. Twenty-five of the 30 redesigns showed significant improvement in student learning as compared to the traditional courses, and the remaining five showed no difference. Furthermore, the institutions reduced costs by an average of 37% (The National Center for Academic Transformation, 2012n). Since the Program in Course Redesign, NCAT has continued to support institutions throughout the country that wish to transform certain courses. Overall, results of the course redesign programs supported by NCAT have been positive.

The primary model supported by NCAT in the redesigns of the mathematics courses is the emporium model. The emporium model "eliminates all class meetings and replaces them with a learning resource center featuring online materials and on-demand personalized assistance, using a) an open attendance model or b) a required attendance model depending on student motivation and experience levels" (The National Center for Academic Transformation, 2012j). The mathematics courses redesigned with this model include developmental mathematics, college algebra, pre-calculus, and linear algebra. Furthermore, the implementation has occurred and is occurring at both four-year universities and two-year community colleges. One of the four-year universities, the University of Missouri-Kansas City (UMKC), piloted a modified emporium model with approximately half of its college algebra students during the spring semester of 2012.

UMKC is a diverse, urban university with more than 13,000 students (UMKC, 2011). The university resides in Kansas City, Missouri, a city with more than two million people in its metropolitan area (U.S. Census Bureau, 2011). The university's mathematics department plans to fully implement the model during the academic year of 2012-2013, and they are expecting a 35% reduction in the cost of delivering college algebra via the emporium model as compared to the traditional lecture model (UMKC Department of Mathematics and

Statistics, 2011). The mathematics department also anticipates improvement in student learning consistent with other programs that have implemented course redesigns supported by NCAT.

During the previous four academic years at UMKC, enrollment in college algebra has increased. In the 2007-2008 academic year 293 students were enrolled in college algebra. Then 320 students were enrolled in 2008-2009, 379 students in 2009-2010, and 453 students in 2010-2011 (UMKC Department of Mathematics and Statistics, 2011). The individual sections of college algebra have been taught predominantly by graduate teaching assistants in classrooms with 35 to 40 students each, and traditional lecture has been the main mode of instruction. "Often the sections are taught by different instructors, whose teaching methods, areas of emphasis, and degree of rigor can vary considerably, resulting in course 'drift'" (UMKC Department of Mathematics and Statistics, 2011, p. 3). As stated earlier, the classroom dynamics will change in 2012-2013 with students experiencing two 75-minute lab sessions each week. The lab time is intended to encourage active learning and collaboration among students. Students will interact with the text, view animations, and engage in group projects (UMKC Department of Mathematics and Statistics, 2011). Thiel, Peterman, and Brown (2008), address the importance of active learning versus passive learning as follows: "The essence of learning math is doing math, rather than passively listening" (p. 46). Furthermore, each week students will attend one 50-minute classroom session with 100-150 students. One instructor will be teaching all large sections, thus providing consistency in content emphasis and rigor (UMKC Department of Mathematics and Statistics, 2011);

however, different graduate teaching assistants will be leading with the help of undergraduate assistants each of the two 75-minute lab sessions with approximately 50 students per session.

Traditionally, UMKC has sought to effectively reach all students. For example, students at UMKC who enroll in courses in which learners historically struggle to succeed, may use Supplemental Instruction (SI). Developed in 1973 by Deanna Martin at UMKC, "SI utilizes a non-remedial, collaborative approach to learning that increases student performance and retention by offering peer-led, regularly scheduled, out-of-class review sessions" (Pemberton, 2011). Additionally, SI is provided for students in low pass-rate courses in all content areas. In college algebra at UMKC, Supplemental Instruction takes the form of Video-based Supplemental Instruction (VSI). VSI is available for students who need to learn at a slower pace than what is taught in the traditional classroom. In this approach the students watch a mathematics teaching professor present the material on a recorded video. Additionally, a trained facilitator stops the video at key times to allow for discussion and practice. The students spend 5-10 hours each week with the facilitator in lieu of three lecture hours in a traditional classroom, thus allowing for more time to process concepts (UMKC Center for Academic Development, 2012).

Statement of the Problem

Even though many institutions, UMKC included, have continually sought ways to improve student learning, a crisis still exists. Specifically, poor student performance has long been and still is an issue in college algebra courses across the United States. The percentage of students withdrawing or earning a grade of D or F (DFW rate) is of constant concern considering the national DFW rate in college algebra is nearly 50% (Gordon, 2008). For some populations the DFW rate has been as high as 90% in college algebra (Brewer & Becker, 2010). At one state university, not UMKC, in the Midwest the DFW rate has historically been between 34% and 45%. Even though this is below the national average, it is still high compared to most of the other freshman courses. As stated earlier, the attendance rate in the large lectures at this university has even dropped below 20% at times, and the university's New Student Services office claims that the reputation of the college algebra course has negatively affected recruitment (Bennett, Manspeaker, Natarajan, & Paulhus, 2011). Over the last two academic years at UMKC, the DFW rate has averaged roughly 30%. Relative to the national average and to the aforementioned universities, the rate is good; however, the UMKC Department of Mathematics and Statistics has improvement of retention as a primary goal in their college algebra course redesign. They believe lowering the DFW rate will accomplish this goal and will improve overall academic success (UMKC Department of Mathematics and Statistics, 2011).

The low passing rate in college algebra has kept many students from completing their degrees, and is, therefore, a source of frustration for many students. For example, at one of the largest two-year colleges in the country, college algebra has been determined to be the main reason the school is losing students (Gordon, 2008). The completion of bachelor's degrees has also had a strong economic impact. According to a recent study (de Alva & Schneider, 2011), individual lifetime earning potential for people with bachelor's degrees compared to those without bachelor's degrees is improved by an average of more than $230,000 for less selective schools and by an average of over $500,000 for more selective schools.

Expenses associated with administering college algebra are a concern in addition to the issue of poor performance in college algebra. The high costs are a result of the large number of students required to take college algebra for completion of the bachelor's degree. Although college algebra brings in considerable income because of the large class sizes, the expenses can be reduced further by increasing class size even more. A potential problem then exists due to less available individual attention for students. This problem might be overcome by a modified emporium model course redesign like the one at UMKC. In this approach a master teacher provides standardized instruction accompanied by lab sessions where students receive focused, needs-based instruction by means of effective software and knowledgeable lab assistants.

Definition of Terms

Throughout this dissertation, reference is made to two different methods of teaching college algebra. One method is a traditional approach, and the other method is a technology-heavy approach referred to as a course redesign. These methods and a few other terms are defined below. After the definitions, information is provided about the relationship that some of the terms have with this study.

The **College Algebra Entrance Exam** is an exam used to determine if students are ready for college algebra. The exam, created by the mathematics department at UMKC, consists of twenty questions from Elementary Algebra and Intermediate Algebra.

C**onceptual knowledge and learning** are defined together. According to Even and Tirosh (2002), Hiebert and Carpenter (1992) defined conceptual knowledge as "knowledge that is rich in relationships" (p. 224). Students gain conceptual knowledge when the new idea or relationship makes the whole cognitive structure more stable (Even & Tirosh, 2002). Conceptual learning in mathematics "focuses on ideas and on generalizations that make connections among ideas, in contrast to learning that focuses only on skills and step-by-step procedures without explicit reference to mathematical ideas" (Ashlock, 2006, p. 228).

C**ourse redesign** refers to instruction adapted from the emporium model which originated at Virginia Tech University (Twigg, 2011). It is a model supported by the National Center for Academic Transformation.

The **DFW rate** is the proportion of students who either withdraw or earn a grade of D or F.

The **emporium model** is a mode of instruction in which all class meetings are replaced with a learning center that features online resources and immediate personalized assistance (The National Center for Academic Transformation, 2012g). As described in the previous definition, the course redesign at UMKC was an adaptation of the emporium model.

Item analysis in this study refers to comparing student performance between the traditional approach and the course redesign on the final exam item-by-item. This is different from the typical use of this term as "a set of procedures for determining the difficulty, validity, and the reliability of each item in a test" (Gall, Gall, & Borg, 2007b, p. 643).

MyMathLab® is an online resource from Pearson Education that accompanies the textbook being used in UMKC's college algebra course. It "engages students in active learning—it's modular, self-paced, accessible anywhere with Web access, and adaptable to each student's learning style—and instructors can easily customize MyMathLab® to better meet their students' needs" (Pearson Education, 2012).

NCAT is an acronym for the National Center for Academic Transformation. The organization is "an independent, not-for-profit organization that provides leadership in using information technology to redesign learning environments to produce better learning outcomes for students at a reduced cost to the institution" (The National Center for Academic Transformation, 2012n).

Procedural knowledge and learning are defined together. According to Even and Tirosh (2002), Hiebert and Carpenter (1992) defined procedural knowledge as "a sequence of actions that can be learned with or without meaning" (p. 224). As indicated by Ashlock (2006), "procedural learning in mathematics focuses on learning skills and step-by-step procedures. In practice, it does not always include understanding mathematical concepts and principles involved" (p. 230).

The **traditional approach** to teaching college algebra referred to in this study is a lecture-based approach. The students meet for three 50-minute lectures each week, and the instructors, who are graduate teaching assistants, can assign online or on-paper homework.

Relationship of Terms with Study

In the spring semester of 2012 three traditional approach sections were offered, and each of these sections was taught by a different instructor. The students could have purchased access to MyMathLab® in order to submit homework or to receive computer-assisted instruction. Addtionally, the group of students taking college algebra with the traditional approach was compared to the group experiencing the NCAT-supported course redesign. In this particular redesign, the three weekly 50-minute lectures were replaced by two 75-minute computer lab sessions which occurred on Wednesdays and Fridays. In the lab sessions, students received computer-assisted instruction using MyMathLab®, and they had graduate and undergraduate teaching assistants to answer their questions. Each lead graduate teaching assistant in the lab also taught a traditional section of college algebra. The students spent most of their time doing mathematics and receiving immediate help when encountering a problem. Additionally, the students met for one 50-minute session each Monday. The 50-minute session was taught by an experienced faculty member who was also the college algebra coordinator at the university; its purpose was to preview big ideas and upcoming tasks and to address specific content in which the students were having difficulty (The National Center for Academic Transformation, 2012f).

On the College Algebra Placement Exam, students had to answer at least 15 out of 20 questions correctly in order to be placed into college algebra. The students took the exam online, and they could have taken a newly generated exam as many times as necessary to pass (UMKC Department of Mathematics and Statistics, 2012).

The terms conceptual knowledge and learning and procedural knowledge and learning were defined to assist in classifying final exam questions in college algebra as either conceptual or procedural questions. Two of the research questions in this study pertain to conceptual and procedural questions.

Purpose of the Study

The purpose of the study was to determine the effectiveness of a less expensive, research-backed, course redesign of the teaching of college algebra as compared to the traditional lecture approach. The researcher assessed the effectiveness of the course redesign on student learning by comparing overall scores on the final exams for the two groups using a quantitative, observational study. Observational study refers to the fact that a true experimental design was not done. In an experimental study students in the two groups would be randomly assigned to the treatment group or the control group; however, students in this study were able to self-select the type of instruction they would receive. Educational researchers often refer to this type of observational study as a quasi-experimental study. In addition to comparing overall performance on the final exam, an item analysis, as defined in the definition-of-terms section, was conducted. Then a comparison of performance on question types, conceptual and procedural, of the final exam was made. Furthermore, attention was given to overall final exam performance based on race/ethnicity and gender. Final exam scores were compared within each race/ethnicity and within each gender.

The study is based on archived data from a course that was offered at UMKC during the spring 2012 semester. Note that the purpose of this study was not to evaluate the difference in expenses of the two approaches. While much of the motivation for teaching college algebra with the course redesign is to reduce costs, this study was proposed to assess the impact on student learning of the course redesign compared to the traditional lecture approach.

Research Questions

The first two research questions were intended to address the question of overall effectiveness of the course redesign in the teaching of college algebra as compared to the traditional lecture-based approach.

1. Is there a difference in student scores on the comprehensive college algebra final exam for the course redesign versus the traditional approach?
2. Is there a difference in DFW rate in college algebra for the course redesign versus the traditional approach?

The third research question was formulated to assess the effectiveness of the course redesign based on factors of gender and race/ethnicity.

3. Is there a difference in student scores on the college algebra final exam for the course redesign versus the traditional approach within each gender, within each race/ethnicity, between genders, and between races/ethnicities?

Because different methods of teaching may be better for different concepts, the researcher also evaluated the approaches based on question type. Therefore, in addition to assessing the overall success of the course redesign versus the traditional approach, the two methods were compared on conceptual and procedural questions separately, and the factors of gender and race/ethnicity were considered separately on both conceptual and procedural questions. Finally, item analysis was done by making comparisons between the traditional approach and the course redesign on the individual questions. Accordingly, the fourth, fifth and sixth questions were:

4. Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach?

5. Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach within each gender and within each race/ethnicity?
6. Is there a difference in student scores on each individual question on the comprehensive final exam for the course redesign versus the traditional approach?

Research Hypotheses

From the six research questions, several research hypotheses and their corresponding null hypotheses were created.

1. The mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
2. The DFW rate for students initially enrolled in the course redesign for college algebra is less than the DFW rate for students enrolled in the traditional approach.
3. Within each gender the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
4. Within each race/ethnicity the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
5. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between genders.

6. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between races/ethnicities.
7. The mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
8. The mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
9. Within each gender the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
10. Within each gender the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
11. Within each race/ethnicity the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
12. Within each race/ethnicity the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.

13. The proportion of students correctly answering each multiple-choice question is greater for students enrolled in the course redesign than it is for students enrolled in the traditional approach.
14. The mean score on each short-answer question for students enrolled in the course redesign is greater than the mean score on each short-answer question for students enrolled in the traditional approach.

Null Hypotheses

1. There is no difference between the mean final exam score for students enrolled in the course redesign for college algebra and the mean final exam score for students enrolled in the traditional approach.
2. There is no difference in the DFW rate for students initially enrolled in the course redesign for college algebra and the DFW rate for students enrolled in the traditional approach.
3. Within each gender there is no difference between the mean final exam score for students enrolled in the course redesign for college algebra and the mean final exam score for students enrolled in the traditional approach.
4. Within each race/ethnicity there is no difference between the mean final exam score for students enrolled in the course redesign for college algebra and the mean final exam score for students enrolled in the traditional approach.
5. There is no difference in the mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach between genders.

6. There is no difference in the mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach between races/ethnicities.
7. There is no difference between the mean score on the conceptual questions of the final exam for students enrolled in the course redesign and the mean score on the conceptual questions for students enrolled in the traditional approach.
8. There is no difference between the mean score on the procedural questions of the final exam for students enrolled in the course redesign and the mean score on the procedural questions for students enrolled in the traditional approach.
9. Within each gender there is no difference between the mean score on the conceptual questions of the final exam for students enrolled in the course redesign and for students enrolled in the traditional approach.
10. Within each gender there is no difference between the mean score on the procedural questions of the final exam for students enrolled in the course redesign and for students enrolled in the traditional approach.
11. Within each race/ethnicity there is no difference between the mean score on the conceptual questions of the final exam for students enrolled in the course redesign and for students enrolled in the traditional approach.
12. Within each race/ethnicity there is no difference between the mean score on the procedural questions of the final exam for students enrolled in the course redesign and for students enrolled in the traditional approach.

13. There is no difference between the proportion of students enrolled in the course redesign correctly answering each multiple-choice question and the proportion of students enrolled in the traditional approach.
14. There is no difference between the mean score on each short-answer question for students enrolled in the course redesign and for students enrolled in the traditional approach.

Significance of the Study

The high DFW rate in college algebra across the United States has long been and continues to be a major concern. Educators and education researchers are persistently studying ways to improve student learning in college algebra and, therefore, reducing the DFW rate. In this study the researcher assessed the effectiveness of an NCAT-supported, modified emporium model course redesign at UMKC as compared to the traditional lecture approach. The research provides analysis of results to help UMKC determine if the course redesign is positively impacting students. Also, NCAT requires the results of this study to be disseminated by providing links to descriptions, including results, of their course redesigns on their website (The National Center for Academic Transformation, 2012i). Other institutions can use the results from NCTA-supported course redesigns to determine whether they should use an emporium model for improving learning in college algebra. In reading through the results of NCAT's college algebra redesigns, this researcher only found results on overall performance. Therefore, this study, by considering student performance on the final exam item-by-item, contributes additional information to the literature. Possibly, the course redesign is better than the traditional approach for student learning with some algebraic concepts and not with others. Furthermore, this study adds to the literature by analyzing performance within and between genders and within and between races/ethnicities at a diverse, urban university.

Delimitations and Limitations of the Study

The researcher desired to generalize the results of this study to college algebra courses in all universities and colleges. In order to generalize, the study must have external validity which is "the extent to which the results of a research study can be generalized to individuals and situations beyond those involved in the study" (Gall, Gall, & Borg, 2007b, p. 640). The main threat to external validity was that the proposed study occurred at a single, urban, four-year public university in the Midwest. The results may have been different, for instance, at a private, rural, four-year institution in the Northeast. Additionally, this study only looked at the results from a single semester as opposed to a longitudinal study, and it is the first time the institution, UMKC, implemented the course redesign. The purpose of this study, however, was to begin the process of evaluating the effectiveness of an emporium model course redesign in college algebra at UMKC. Therefore, it remains important to educational researchers.

Threats to internal validity also existed. Internal validity in experiments is "the extent to which extraneous variables have been controlled by the researcher, so that any observed effects can be attributed solely to the treatment variable" (Gall, Gall, & Borg, 2007b, p. 642). One threat to internal validity was the lack of random assignment to the groups. Students were allowed to choose the section of college algebra in which to enroll. The result of student choice could be non-equivalent ability levels for the groups at the start of the semester. The researcher overcame this threat by comparing preparedness for success in college algebra at the start of the semester; then determining the statistical analysis used based on the preliminary testing. Details of the statistical methods are described in Chapter 3. The results of the study may also be hindered by the absence of a pre-test; however, scores on the required entrance exam, scores on the mathematics section of the ACT, and cumulative high school grade point averages were used to test if the treatment and control groups were equivalent.

Since the same graduate teaching assistants were teaching the traditional sections of college algebra as were assisting students in the lab sessions of the course redesign, confounding of variables needs to be considered as an additional threat to internal validity. Confounding could have taken place had the teaching assistants, either intentionally or unintentionally, influenced the outcomes by desiring one method to show better results than the other. The teaching assistants and their pedagogical decisions would have then been the confounding variable. It is the researcher's opinion, however, that using the same instructors in both methods increased internal validity by controlling for instructor differences.

Another potential threat to internal validity was the increased instructor-contact time for students in the course redesign. In the traditional approach students received 150 minutes (3 sessions of 50 minutes each) of instruction time; however, in the course redesign students received 200 minutes (2 sessions of 75 minutes each and 1 session of 50 minutes) of instructor contact time. Therefore, any improvement in student learning could potentially be attributed to more combined time in the classroom and laboratory rather than to the type of instruction. While this is cause for concern, the modified emporium model being used at

UMKC with the extra instruction time was what the researcher desired to compare to the traditional approach. The researcher is of the opinion that the analysis of the modified emporium model, as opposed to a strict emporium model, adds more to the literature by determining if a particular variation is effective in improving student learning. Furthermore, even though the modified emporium model had additional meeting time, it was still less expensive than the traditional approach as outlined in the final plan submitted to NCAT by the university's mathematics department (2011).

CHAPTER 2

REVIEW OF LITERATURE

This literature review contains five major sections. The first addresses the current state of college algebra. It includes a discussion of (1) the impact of the high DFW rate in college algebra and (2) the results of several studies that speak to the effect of different variables on student learning outcomes in college algebra. The second major section is a review of the impact of the National Center for Academic Transformation (NCAT) on the teaching of college algebra; it includes a description of NCAT's processes and programs, a description of the emporium model as used in college algebra courses, and a summary of the results of multiple course redesigns that have been financially supported by NCAT. Because the emporium model uses computer technology, the third major section of the literature review addresses Computer-Assisted Instruction (CAI). This section consists of a brief history of CAI and the current uses of CAI in college algebra. The fourth section addresses college algebra curriculum reform including recommendations from several prominent mathematics organizations. It contains a brief section on curriculum change and design not specific to mathematics, and it finishes with the results of several studies on college algebra curriculum changes. A brief review of equity issues in mathematics as related to college algebra is given in the final section.

Current State of College Algebra

A large number of students are not succeeding in college algebra, and lack of student success in college algebra is one reason students do not complete their associate or bachelor degrees. Additionally, since many students are not succeeding in college algebra, enrollments in remedial courses are higher than they were previously; enrollment in remedial courses has been linked to students' dropping out of college (Thompson & McCann, 2010). This section on the current state of college algebra has two subsections. The first addresses the student and the economic impact of the high DFW rate in college algebra; the second subsection discusses the effects of several variables on student learning outcomes in college algebra.

Student and Economic Impact

Students are earning a grade of D, F or W in college algebra at an unacceptable rate. Gordon (2008) places the DFW rate at nearly 50% for all students throughout the country, whileThompson and McCann (2010) state the rate to be approximately 40%. Whether the rate is 40%, 50%, or anywhere between 40% and 50%, too many students are not succeeding in college algebra. The high DFW rate leads to frustration for students, especially considering that college algebra is often a gateway course for many undergraduate programs. In 2002, a conference on reform in traditional college algebra was held at the United States Military Academy. At the conference Don Small estimated that approximately 200,000 students each semester were not successfully completing the course (Marshall & Riedel, 2005). Furthermore, at some institutions, such as Northern Arizona University, nearly half of these non-passing students were expected to drop out of college entirely (Beaudrie, 2002).

Because of the large number of unsuccessful students, the economy is greatly affected. When considering private and public college tuition and state subsidy for the public institutions, "students and taxpayers are paying at least $240,000,000 per year for College

Algebra courses that students do not pass" (Marshall & Riedel, 2005, p. 55). In their article, "Who Wins? Who Pays? The Economic Returns and Costs of a Bachelor's Degree," de Alva and Schneider (2011) explain the benefits to the nation's economy of students passing college algebra and completing their bachelor's degrees. First, students earn higher wages with a bachelor's degree than they do with only a high school diploma. Lifetime wages are increased with a bachelor's degree by an average of "more than $230,000 at less selective not-for-profit colleges…to well over $500,000 at the most competitive public or not-for-profit institutions" (de Alva & Schneider, 2011, p. 1). Second, when considering taxes paid on the higher incomes and considering state subsidies that support higher education, the economy benefits as a whole. Estimates show that taxpayers benefit $6,000 per bachelor's degree (de Alva & Schneider, 2011). Additionally, even though the economic impact of failure in college algebra is quite significant, "the real waste is measured in human disappointment" (Marshall & Riedel, 2005, p. 55).

The unacceptable DFW rates, the significant economic impact, and the human disappointment should provide motivation for mathematics education researchers to study the effects of any variable that could improve student performance on learning outcomes. This study was designed to assess the effectiveness of instructional technology on student learning in college algebra.

Miscellaneous Research in College Algebra

College algebra instructors and mathematics departments are always seeking to determine the most effective ways to improve student learning—evidenced by the abundance of studies that have been done about college algebra. The purpose of this subsection is to provide examples of the variety of studies that have occurred in college algebra. Some of the studies had more direct ties to this study than others, but they are all discussed in order to give a more complete picture of the current state of college algebra.

Academic institutions throughout the United States have attempted and continue to attempt to solve the problem of the high DFW rate and the problem of the expense in the teaching of college algebra. For example, the mathematics department at the University of Missouri-Saint Louis (UMSL) changed from three hours of lecture each week in the teaching of college algebra to one hour of lecture combined with two computer lab sessions. The lab sessions were required for students earning less than 80% on homework, quizzes and tests (Thiel, Peterman, & Brown, 2008). The National Center for Academic Transformation (NCAT) supported the changes at UMSL and has supported similar programs at other universities. The results have been quite positive as: (1) student learning has increased or remained steady in all of the universities and (2) costs have been reduced by an average of 37% (The National Center for Academic Transformation, 2012n). The college algebra course redesign piloted at UMKC in the spring semester of 2012 is similar to the redesign that took place at UMSL. Additional NCAT-supported studies are discussed later in this chapter.

In addition to the types of course redesigns described above, colleges and universities have tried many different approaches to improve performance on student learning outcomes and to improve the DFW rate. One approach some universities have used is to add extra class sessions to help students. For example, Wichita State University has had two extra contact hours per week for many students in their college algebra classes to give a total of five hours per week (Wichita State University, 2012). In the course redesign investigated in this study, there were fifty more minutes of instructor contact time per week than was used in the traditional lecture sections. A second approach for some universities has been to provide Supplemental Instruction (SI), instruction that is learner-centered as opposed to teacher-centered. In college algebra at Albany State University in Georgia, a study was done to compare a college algebra class with required SI one time per week to a class taught by the same instructor in which no additional session was required. This particular study found there to be no difference (Porter, 2010). In college algebra at UMKC, Supplemental Instruction takes the form of Video-based Supplemental Instruction (VSI). In VSI students watch recorded lectures with a facilitator to help the students process the content (UMKC Center for Academic Development, 2012). A third approach was to change the college algebra curriculum to be more relevant to students. With the support of the National Science Foundation and the Calculus Consortium for Higher Education, the Mathematical Association of America published the book, "Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra" (Ganter & Haver, 2011). One particular section focused on a college algebra course at Virginia Commonwealth University (VCU) that is modeling-based. At VCU the DFW rate from 2004-2006 was 38% in their traditional college algebra courses. When they changed to a modeling approach in the fall of 2008, the DFW rate dropped to 22.1% (Ellington & Haver, 2011).

Studies have also been performed to test the effectiveness of seemingly trivial adjustments; however, if the change, no matter how small, improves performance, then that adjustment is valuable. One study examined the relationship between class scheduling and student achievement in college algebra by comparing performance in three-days-per week courses versus two-days-per week classes versus one-day-per-week classes. The researchers found that the one-day-per-week group scored consistently lower than the other groups on unit tests and final examinations (Gallo & Odu, 2009). Another study compared teaching college algebra in the morning versus the evening. The researcher found that students in the morning sessions had higher success rates on the final exam than students in the evening sessions, but there was no significant difference in retention rate (Lazari, 2009). In a third study a researcher compared the success rates by looking at course grades for students in a 16-week offering of college algebra versus an 8-week offering of college algebra. No significant difference was found in course grades when comparing these two groups overall. Furthermore, the study found no difference within genders, within ethnicities, and within ages except for the Asian, Pacific Islanders and for the age group 23-30. Both of these groups performed better in the 16-week course (Reyes, 2010).

Because online homework was part of the course redesign in this study, the following study by Brewer and Becker is described. Focusing on underprepared and repeating college algebra students, Brewer and Becker (2010) conducted a study on online homework effectiveness at a large, western community college. Both the treatment (using an online homework system) group students and the control (doing traditional, textbook homework) group students of this quasi-experimental study were assigned homework with similar skill-based questions, concept-based questions, degree of difficulty, depth of content coverage and breadth of content coverage. Final exam scores were compared at the end of the semester after first determining similarity in pre-test scores, and an independent sample t-test indicated that no significant difference was present on the final exam scores between the two groups. The researchers also tested whether students with a low level of preparation were affected differently by the different types of homework than were the students with a high level of preparation. Within the group of low level of preparation students, final exam scores were significantly higher for those using online homework than for those doing traditional, textbook homework; but there was a reversed, though insignificant difference within the group of high level of preparation students. Finally Brewer and Becker analyzed the effects of online homework versus traditional homework with first-time college algebra students and repeating college algebra students. There was not a statistically significant difference within either group; however, the final exam average was greater for both first-time students (65% versus 62%) and repeating students (66% versus 57%) who used online homework versus traditional, textbook homework. In summary, in comparing online homework effectiveness versus textbook homework, no significant difference was found in final exam scores or when contrasting first-time and repeating students; however, low level of preparation students who used the online homework performed significantly higher on the final exam than low level of preparation students who used traditional, textbook homework.

Marshall and Riedel (2005) investigated the National Science Foundation funded project, Excellence through Mathematics Communication and Collaboration ($E = mc^2$). The goal of the project was to increase reading and writing ability as part of the mathematics learning process using ten teamwork and video-based assignments. Each out-of-class, 30-45 minute assignment consisted of a 15-20 minute video and worksheets with teamwork activities designed to address the following ten areas: working in teams, getting more out of homework, resources to succeed in mathematics, relating to your instructor, how to get the most out of class time, speaking and writing mathematics, understanding learning styles, how to prepare for tests and exams, understanding mathematical thought/logic, and where to go after the course. The treatment group of students in four college algebra classes experienced the abovementioned assignments while the control group of students in four different college algebra classes did not. Four instructors were involved in the study, and each instructor taught one class with the $E = mc^2$ materials and one class without the materials. The in-class activities and other out-of-class assignments were the same for both the treatment and control groups. The researchers claim the following observations: (1) the students in the treatment group earned better grades and tended to withdraw less often in follow-up mathematics courses than the control group students, (2) the students in the treatment tended to be more interactive in class than the students in the control group, and (3) the treatment students had a much higher ratio of positive responses to negative responses (5.9 versus 2.2) on a student opinion survey.

In another study, Fike and Fike (2007) investigated the effects of instructor background and employment status on student performance in developmental mathematics courses at a community college. By means of multivariate analysis, the study showed that the educational background of instructors was associated with final course grades. Faculty with graduate degrees produced better student outcomes than faculty without graduate degrees. Contrastingly, whether a faculty member was part-time or full-time did not produce a significant difference in student learning outcomes. Even though the study was done in developmental mathematics rather than college algebra, the results are still relevant as students move from developmental classes to college algebra classes.

In some of the aforementioned studies, the independent variable appeared to affect student learning while in other studies there was not a significant difference in student learning. In general there appears to be no single variable that gives success. Additionally, though not all of the studies relate directly to this researcher's study, the variety in these studies suggests a sense of desperation in trying to discover anything and everything that will improve student performance in college algebra. Lazari (2007) states, "there is still a need for new ways in which to help more students succeed" (p. 73). While acknowledging the Mathematical Association of America (2006) and Hoyt and Sorensen (2001), Brewer and Becker (2010) also support the urgency for change with the following quote about the high DFW rate in college algebra: "It is critical for educators to explore every possible path to change this dismal outcome" (p. 354). In the current study, the researcher explored one of the possible paths to improve student learning in college algebra, namely, a modification of NCAT's emporium model.

National Center for Academic Transformation

The National Center for Academic Transformation (NCAT) provides leadership for institutions in redesigning courses to improve student learning at a lower cost by using instructional technology. Dr. Carol Twigg, an internationally recognized expert in using information technology to improve higher education, leads NCAT as President and CEO. With the support of an extensive grant, Dr. Twigg created the Program in Course Redesign (The National Center for Academic Transformation, 2012n). This program and other NCAT programs are described below within NCAT's four-stage iterative process. Following the explanation of the process and programs is a description of the emporium model and then a discussion of the results of NCAT supported course redesigns specific to college algebra.

Process and Programs of NCAT

"The National Center for Academic Transformation works through a four-stage iterative process to advance the use of information technology in improving student learning and reducing instructional costs" (2012m). This cyclical process includes (1) proof of concept, (2) analysis, (3) communication, and (4) scale.

NCAT originates innovative programs and uses the outcomes of the new programs as proof of concept. The first of the programs was the Program in Course Redesign (PCR). Conducted from 1999-2003 and funded by Pew Charitable Trusts, PCR consisted of 30 colleges and universities with a concentration on introductory courses with large enrollments and with only one of the redesigned courses being college algebra. Large-enrollment courses were selected as the focus in order to "have the potential of impacting significant student numbers and generating substantial cost savings" (The National Center for Academic Transformation, 2012g). The second innovative program was the Roadmap to Redesign (R2R) which was partially funded by the Fund for the Improvement of Postsecondary Education (FIPSE) from the United States Department of Education. Functioning from 2003-2006, R2R involved 16 universities and colleges. Of the 16 redesigns, seven were in pre-calculus mathematics, and of the seven pre-calculus redesigns, five were in college algebra. Following PCR, "R2R partnered experienced, successful institutions with new institutions, using a streamlined redesign methodology" (The National Center for Academic

Transformation, 2012l). Also partially funded by FIPSE, Colleagues Committed to Redesign (C^2R) became the third program as proof of the redesign concept. From 2006-2010 twenty-eight educational institutions redesigned courses to improve quality of instruction and to reduce expenses. Six of these were in college algebra (The National Center for Academic Transformation, 2012b). The fourth program, Changing the Equation, began in 2010 and is scheduled to continue to 2013. Sponsored by the Bill and Melinda Gates Foundation, Changing the Equation is engaging mathematics departments in 38 community colleges to redesign their developmental mathematics courses. It is estimated that the 38 redesigns are impacting more than 120,000 students annually (The National Center for Academic Transformation, 2012a).

After the proof of concept stage, NCAT moves to the analysis stage. A sample product of the analysis stage is an article written by Twigg at the completion of the Program in Course Redesign that analyzes the results and summarizes the lessons learned from the program. The article is entitled *Improving Learning and Reducing Costs: New Models for Online Learning* (2003). In this article she analyzes the five models used: the supplemental model, the replacement model, the emporium model, the fully online model, and the buffet model. All five models possess the following characteristics: whole course redesign, not just a few class periods are redesigned; active learning, lectures are replaced with various activities; computer-based learning resources, instructional software and web-based resources are used; mastery learning, greater flexibility is added as to when students can engage in the course; on-demand help, students receive immediate help; and alternative staffing, faculty are able to focus on the academic aspects of the courses rather than logistical tasks. With the emporium model being the exception, the models are addressed in this section on the process and programs of NCAT. Since a modification of the emporium model is the focus of this dissertation, the emporium model will be discussed in greater detail in its own section.

The supplemental model involves a variety of enhancements while keeping the basic structure, particularly in terms of number of class meetings, of the traditional course. For example, at the University of New Mexico (UNM) and at Carnegie Mellon University (CMU) traditional lecture remained, and a variety of computer-based activities were added. At UNM students augment the lectures and text material with a CD-ROM containing interactive activities, simulations, and movies. In the general psychology class where this was done, the DFW rate decreased from 42% with the original structure to 18% when adding the supplements. In a statistics course at CMU changes were made to the laboratory sessions while the lecture sessions stayed intact. The redesign course used an intelligent tutoring system, SmartLab, to help students understand concepts. SmartLab brought students a level of statistical literacy that seemed impossible to accomplish in the course before its redesign (Twigg, 2003). Other enhancements in the Supplemental Model included students using technology to prepare for class, thus allowing for less lecture time in the general class meetings. In a biology class at the University of Massachusetts-Amherst, for example, attendance has improved from 67% to 90%, exam questions involve much more problem solving and reasoning, and exam scores have improved (Twigg, 2003).

In the replacement model face-to-face time is replaced with online, interactive learning activities for students. At the University of Wisconsin at Madison the redesign of chemistry took the form of replacing one of two lecture sessions and one of two discussion sessions with web-based resources. The resources consisted of 37 interactive modules developed by the university chemistry department faculty who had substantial experience developing interactive materials (Twigg, 2003). The redesign resulted in cost savings (The National Center for Academic Transformation, 2012d), but there was no significant impact on student learning (The National Center for Academic Transformation, 2012e).

The fully online model is seldom used by the NCAT-supported course redesigns. When it is used, the focus is on reducing instructor time commitment while still delivering the course content. In four pre-calculus courses at Rio Salado College (RSC), Academic Systems' mathematics software and a nonacademic course assistant were provided for the instructor. The course assistant handled 90% of all interactions with students since 90% of the interactions were nonacademic. The instructor was then able to focus on academic issues and to handle larger classes, resulting in reduction of costs. Furthermore, because of the technology, students were able to receive immediate feedback, and the instructor was able to easily track student progress. In the pre-calculus courses at RSC the DFW rate improved from 41% to 35% (Twigg, 2003).

One of the troublesome areas for each of the aforementioned models is that instruction, though potentially leading to improvement of student learning and to reduction of expenses, tends to be done in one way. Students need to receive individual instruction rather than instruction designed for the masses, and they should have options for learning within each course (Twigg, 2003). At The Ohio State University (OSU) the buffet model was used to redesign introductory statistics courses to allow students to choose the method that works best for them. OSU students could choose from learning opportunities which included lectures, individual discovery laboratories, individual and group review, small-group study sessions, videos, training modules, oral and written presentations, active large-group problem-solving activities, homework assignments, individual projects, and group projects (Twigg, 2003). With 31% reduction in costs and improvement in course retention (The National Center for Academic Transformation, 2012h), the redesign using the buffet model appears to be successful.

The in-depth analysis NCAT conducted for the five models used in PCR was also done for the other NCAT programs. After a thorough analysis and progressing to the third stage, the information was disseminated so other institutions could learn from the successes and mistakes.

The third stage of NCAT's iterative process is communication. They value the role of dissemination of results and lessons learned. They publish a quarterly newsletter that updates its readers of redesigned learning environments, and they post articles and monographs on their website (The National Center for Academic Transformation, 2012m). NCAT also has a membership organization, The Redesign Alliance, "whose mission is to advance the concept of course redesign throughout higher education to increase student success and access while containing or reducing instructional costs" (The National Center for Academic Transformation, 2012k). The goal of the alliance is to build a community of organizations committed to large-scale redesign of courses. The Redesign Alliance consists of 24 educational institutions and six corporate members; the mid-sized, Midwest, diverse, urban institution in this study is one of the educational institutions in the Redesign Alliance.

Finally, NCAT adds to the communication stage by posting what others are saying about their redesign efforts. For example, one posted publication by the Secretary of Education's Commission on Higher Education urges educational institutions to use technology-based programs similar to what NCAT is doing (U.S. Department of Education, 2006).

Scaling the proof of concept is the fourth stage in NCAT's iterative process. By working with individual institutions or groups of institutions, NCAT scales the proof of concept "to impact greater numbers of students, faculty members and institutions and achieve significant educational change" (The National Center for Academic Transformation, 2012m). One example of a group of institutions in the scaling phase is the Missouri Public Four-Year Universities. NCAT's work with this group began in 2010 and will continue through 2013. Thirteen Missouri schools, including UMKC are taking part in this major course redesign.

Even though the scaling stage is the fourth of four stages, it is not an end to the process. The process is iterative, meaning NCAT is continually cycling through the stages of proving the concept, analyzing the results, communicating the outcomes, and scaling the proof of concept.

The Emporium Model

The emporium model is one NCAT model that receives extensive attention. The model and its name originated at Virginia Tech University in 1997, and it remains active today. The model and the associated facility were designed to improve learning outcomes for thousands of students in large-enrollment mathematics classes. Today, the Math Emporium at Virginia Tech is an open, 60,000-square-foot laboratory that services more than 8,000 mathematics students each semester with its 550 Macintosh computers. It supports an assortment of activities including, "active, independent learning through locally developed, self-paced online math courses designed to let students learn on their own schedules, while providing immediate feedback and sufficient structure to ensure students understand expectations and meet required milestones" (Robinson & Moore, 2006). Another fundamentally important activity is "one-on-one coaching by professors, graduate students, and advanced undergraduates who are available 15 hours a day to assist students having difficulty with material, in a comfortable, less-threatening environment than a faculty office" (Robinson & Moore, 2006, p. 42.3).

The NCAT website (2012g) says, "The emporium model eliminates all class meetings and replaces them with a learning resource center featuring online materials and on-demand personalized assistance." In the article, *The Math Emporium: A Silver Bullet for Higher Education*, Twigg (2011) provides four core principles that make the emporium model so successful. First, students spend much of their time actively doing mathematics rather than passively listening to someone lecture about mathematics. The instructional software enables them to spend more time on mathematical tasks. Second, students expend more of their energy trying to understand things they don't understand and less effort on the topic they have mastered. Since the software individualizes instruction, students are better able to focus on areas of difficulty than they would be if they were listening to a lecture. The third principle that makes the model effective is the immediate support students receive when they encounter troubles. The immediate assistance comes from either the computer software, the other students in their pod of four to six, the teaching assistants, and/or the instructor. Fourth, "students are required to do math" (Twigg, 2011, p. 27). By participating in lab activities, group discussion, and homework, all of which are required to receive credit, students must do mathematics in order to earn the credit. At the University of Alabama attendance was required in the fall semester of 2000, not required in the spring of 2001, and then required again in the fall of 2001. Performance declined from fall of 2000 to the spring of 2001; performance then improved significantly the following fall. In the fall of 2001 students were also allowed to improve test grades by spending an additional 10 hours in the lab covering material they had failed (Twigg, 2011).

In the current comparison study of two methods of instruction administered during the spring semester of 2012 at a mid-sized, Midwest university, the emporium model is modified for the piloted, redesigned college algebra classes. The traditional college algebra sections contain three 50-minute lecture sessions; however, in the redesign sections the lectures are replaced by two mandatory 75-minute lab sessions and one 50-minute class meeting. The two lab sessions provide the students opportunity to actively engage in mathematics, and the additional class meeting gives the primary instructor time to review key concepts and preview new ideas (UMKC Department of Mathematics and Statistics, 2011).

Results of NCAT-Supported Course Redesigns in College Algebra

NCAT (The National Center for Academic Transformation, 2012i) has supported or is supporting over 150 course redesigns with more than half of the redesigns in mathematics courses, and 22 of the participating institutions have redesigned or are redesigning college algebra. Overall, results of the course redesigns have positively reflected the efforts of NCAT. Expenses have been substantially reduced because of the redesigns, ranging from

12% to 77% reductions, and most of the redesigns save the institutions between 30% and 50% as compared to traditional methods. Learning outcomes are either improving or staying the same when considering statistical significance. Also, retention is improving or remaining the same with two exceptions. While both of these exceptions had an increase in DFW rate (58% to 72% and 44% to 56%), one of the exceptions had better final exam scores; the other institution had no difference in test scores. In NCAT-supported redesigns in college algebra, the emporium model and the replacement model are being used exclusively. Generally, schools redesigning college algebra with an emporium model had greater success than those using a replacement model.

Twigg (2011) analyzd several emporium model redesigns in the article, *The Math Emporium: A Silver Bullet for Higher Education*. At the University of Alabama a redesigned intermediate algebra course generated such significant improvement that the university has redesigned college algebra. In a four-year timeframe, the success rate (course grade of C or better) in intermediate algebra improved from 40.6% when the traditional lecture approach was used to 78.8% as the emporium model was implemented. Additionally, cost per student was reduced by 30%. The University of Idaho also piloted the emporium model in both intermediate algebra and college algebra with a 31% savings. Even though the improvement at the University of Idaho was not as large as the improvement at the University of Alabama, the increase in the student success rate was significant. In 2004, Louisiana State University (LSU), like Idaho and Alabama, redesigned college algebra using the model provided by Virginia Tech. LSU, considering their 36% savings, had a goal of at least maintaining the student success rate of 64%. By the end of 2006, their success rate climbed to 75%, and they experienced the lowest-ever drop rate of 6%. Furthermore, the final exam median in the fall of 2006 was the highest ever at 78%. Twigg (2011) also commended Alcorn State University for improvement on the final exams in college algebra. The students in the traditional format in the fall of 2008 averaged 55.89 on the mid-term and final exam combined while the students in the redesigned format in the fall of 2009 averaged 66.16; however, the DFW rate was 58% for the traditional format and 72% for the course redesign (The National Center for Academic Transformation, 2012i). Overall, the emporium model appears to improve student learning which Twigg (2011) attributed to the simple message: "Students learn math by doing math, not by listening to someone talk about doing math" (p. 26).

In addition to considering student achievement, Bishop (2010) considered the effects of an emporium model redesign on students' attitudes. While there was no significant difference in achievement scores, Bishop found that student attitudes were significantly better for the traditional lecture group than for the emporium group as measured by the Attitudes Toward Mathematics Inventory. Students' attitudes were measured both at the beginning and the end of the course, and Analysis of Covariance was used to control for any difference in attitudes at the beginning of the course. Bishop stated that lower attitude scores may be attributed to lack of computer skills in the rural, low socioeconomic area where the study took place. Bishop added that studies on attitudes in computer-based algebra instruction have been mixed and that more research needs to be done on student attitudes.

Even though NCAT has discouraged emulation of the replacement model at some institutions, one study found a replacement model to be effective in college algebra

(Thompson & McCann, 2010). The study was quasi-experimental with six two-year college faculty members participating. Each instructor was assigned to teach both types of instruction, the traditional lecture approach and the replacement model approach. Furthermore, existing sections of college algebra were randomly assigned to control and treatment groups. The Analysis of Covariance results found that college algebra students who experienced a technology-based, replacement model scored significantly higher in average cognitive performance than the college algebra students who experienced a traditional lecture approach. Additionally, replacement model students reported significantly lower mathematics anxiety and significantly greater levels of academic confidence.

Determining the best instructional methods is difficult at best. At times one model, the emporium model for example, tends to produce the best results. At other times a different model, the replacement model for example, shows better results. Once again, the purpose of this dissertation research is to add to the literature by analyzing a modification of the emporium model.

Computer-Assisted Instruction

As technology advances, its uses quickly multiply, and one area that has benefited from these fast-growing technological advances is education. Computer-assisted instruction (CAI), as its name suggests, is any computer program used for teaching students. CAI can also be organized into several categories: practicing, tutoring, simulating, gaming, testing, informing, and communicating (Hatfield, 1984). The instructional methods, including the emporium model and its modifications, described by NCAT are heavily impacted by the use of some form of CAI. Therefore, this study, by comparing a modified emporium model, adds to the literature regarding the effectiveness of CAI, specifically in the college algebra classroom.

Brief History of CAI

During the 1950's and 1960's, the idea of education for all grew, and the variation in student abilities became prevalent, necessitating individualized instruction. Some publishers tried to individualize mathematics instruction by producing large texts with modules of questions that would accommodate all possible chains of responses. Since the texts were too cumbersome, the attempts by the publishers to produce such materials failed; however, with the beginning of the computer, the chains of questions could be invisible and not so cumbersome (Kelly, 2003). Implementation of computer-assisted instruction (CAI) in the 1960's occurred on mainframe computers. Most of the early CAI programs consisted of drill-and-practice or tutor simulation. Unfortunately, "most of these programs failed to achieve the promised results because they offered little more than a book with an automatic page-turning function" (Kelly, 2003, p. 1049).

In 1971, the National Science Foundation supported two CAI projects: Time-shared Interactive Computer Controlled Information Television (TICCIT) and Programmed Logic for Automatic Teaching Operation (PLATO) (Kelly, 2003). TICCIT did not produce good results considering only 16% of students successfully completed the mathematics courses compared to 50% in the lecture sections (Alderman, 1978); however, Rahmlow, Fratini,and Ghesquiere state that PLATO could be considered "the first significant attempt to implement the computer in mathematical instruction" (as cited in Kelly, 2003, p. 1050). Based out of the University of Illinois, Urbana-Champaign, PLATO utilized game and simulation in an attempt to increase motivation and to teach fundamental concepts and problem-solving skills. Instructors were allowed to author their own materials creating inconsistent quality; therefore, evaluation of PLATO was mostly inconclusive even though some sites had tremendous success. The success at these sites demonstrated potential benefits for using CAI (Kelly, 2003).

With the advent of microcomputers in the late 1970's, computers were introduced to classrooms throughout the 1980's and were used as a tool for calculations and manipulations, as a tutor for addressing individual needs, and as a tutee for exploration and discovery (Kelly, 2003). In the preface of the 1984 National Council of Teachers of Mathematics (NCTM) Yearbook, Hansen (1984) stated the computer is "here to stay." He also indicated that there was a shortage of good CAI software and a lack of sufficient research on CAI. Since 1984 and with the increased use of CAI, the software has continued to develop and research has increased. In order to make the research on technology more valuable, Zbiek, Heid, Blume, and Dick (2007) recommend identifying "constructs important to the teaching and learning of mathematics in technological environments" (p. 1202). Though not listed as one of their constructs related to the role of technology in mathematics education, they attach importance to making careful distinctions between technical mathematical activity and conceptual mathematical activity. Parenthetically, the descriptions of technical activity and conceptual activities by Zbiek, Heid, Blume, and Dick, are analogous, respectively, to the descriptions of procedural learning and conceptual learning provided in Chapter 1. This researcher believes distinguishing the role of technology with procedural activities versus the role of technology with conceptual activities makes a good construct because technology might prove to be useful with one type of question but to be detrimental with another type of question. Therefore, the following research question occurred in this study: Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach?

Current Use of CAI in College Algebra

Currently, several software packages are available to assist students in learning college algebra content. A few examples include MyMathLab®, Hawkes Learning Systems, **A**ssessment and **LE**arning in **K**nowledge **S**paces (ALEKS®), and WebAssign®. MyMathLab® is a group of online resources associated with textbooks from Pearson Education. The publishers describe it as engaging "students in active learning—modular, self-paced, accessible anywhere with Web access, and adaptable to each student's learning style" (Pearson Education, 2012), and once MyMathLab® is an NCAT-approved technology that was used in the course redesign of this study. Hawkes Learning Systems also produces instructional software to complement their textbooks and is also NCAT-approved. Their "software enables students to have unlimited practice and homework problems. It also has access to definitions, objectives and examples like a textbook" (Hawkes Learning Systems, 2012). ALEKS® is a stand-alone learning system used to support any publisher's textbook in a variety of content areas including college algebra. As an artificially intelligent system, "ALEKS® uses adaptive questioning to quickly and accurately determine exactly what a student knows and doesn't know in a course. ALEKS® then instructs the student on the topics she is most ready to learn" (ALEKS, 2012). The Web-based system also reassesses the learner to ensure retention of concepts, and it is always available for one-on-

one instruction (ALEKS, 2012). WebAssign® is another technology tool used in the teaching and learning of college algebra. It is often bundled with a textbook to give students instant feedback on performance, to offer students extensions of their assignments, and to automatically grade assignments for students and instructors (WebAssign, 2012). According to instructor, Dave Corsetti, "WebAssign is educational technology at its best. It helps teachers assess students in a variety of ways and gives them an easy-to-use tool to improve critical thinking and problem solving skills" (WebAssign, 2012).

Overall, research suggests that CAI, when done properly, improves student learning as measured by course retention and by final exams. Also from the research, lessons are being learned by mathematics educators about effective practices when using CAI. For example, four Oklahoma State University (OSU) education researchers sought to find learning components of CAI that students find beneficial (Aichele, Francisco, Utley, & Wescoatt, 2011). In the fall of 2008, OSU redesigned 8 of 27 college algebra sections with the support of NCAT's program, Colleagues Committed to Redesign. In performing a qualitative analysis of the redesign, the researchers asked the participants to advise future students on the best way to learn college algebra in the MyMathLab® computer environment. The most beneficial resource as perceived by the students is the "view an example" feature in MyMathlab®, the second most beneficial resource are the human tutors in the computer lab, and the third most beneficial resource is the "help me solve this" feature of MyMathlab®. In a different study, a mixed quantitative and qualitative study, Ye and Herron (2010) compared a computer-based college algebra course to a traditional college algebra course. They found no statistically significant difference in final exam scores and no significant difference in student attitudes between the two groups. They did, however, find a significant positive relationship between the number of hours students used the available technology and the final exam scores. Grimes and Niss (1989) also report increased study time, though in economics education, to be important when utilizing CAI.

Using CAI has resulted in both positive and negative outcomes. First, at a community college in the Southeast, Wynegar and Fenster (2009) evaluated four different delivery systems. They compared some sections of a traditional lecture method, some sections with CAI, some sections with an online delivery method, and one section that used television. They controlled for instructor differences and found that the traditional lecture sections had the highest grade point average and one of the lowest failing rates. As a contrasting example, Hagerty, Smith, and Goodwin (2010), analyzed the results of a redesigned college algebra course at Black Hills State University (BHSU). The redesign at BHSU used ALEKS®, historical development of concepts modules, whole class discussions, cooperative activities, relevant application problems, and many fewer lectures. Hagerty, Smith, and Goodwin (2010) illustrate the improvement made by changing from the traditional lecture method to the redesigned method:

> This resulted in a 21% increase [sic] in passing rate (from 54% to 75%), a 300% increase in enrollment in the next mathematics course in the program (trigonometry), a 25% improvement in attendance, and a statistically significant increase in Collegiate Assessment of Academic Proficiency (CAAP, a nationally normed test) scores (p. 418).

The researchers caution that the improved performance could be due to increased emphasis on improving college algebra and not necessarily the precise method used. This researcher believes the results of the study by Wynegar and Fenster may have shown the traditional method to be better because the implementation lacked passion. It appears as though they threw several instructional methods together without the necessary investment to make it effective. Implied in this discussion is that more research would be beneficial.

A different group of researchers analyzed the impact of CAI in a specific algebraic topic, the relationship between particular types of formulas (transformations of basic functions) and their respective graphs (Ninness, et al., 2005). In this study, an introductory lecture of the topic was followed by CAI. In the first of two experiments, five out of fifteen participants demonstrated nearly perfect performance on original tasks. In the second experiment, the remaining ten students received remedial training by computer-assisted instruction focused exclusively on the types of errors that were identified. All participants significantly reduced their errors as compared to their performance in the first experiment. This article provides evidence that CAI may be a good thing especially when connected with lecture. Since the course redesign assessed in this study is a modified emporium model with a small, active lecture component within one 50-minute class session each week, the researcher adds to the literature in regards to the potential benefit of combining lecture and CAI.

College Algebra Curriculum Reform

Since the end of World War II, the population of the United States has more than doubled (Gordon, 2008). As of 2008, college enrollments had increased roughly ten-fold compared to the enrollments immediately following the war. Therefore, the proportion of the United States population who attend college has increased dramatically. In talking about students in the post-war era, Gordon (2008) states, “From a mathematical perspective, they were an elite group who had mastered a high level of proficiency in traditional high school mathematics, particularly algebraic manipulation" (p. 519). Today, because the proportion of students attending college is significantly higher, college students as a group are not necessarily considered elite.

One implication of the change in student demographics is that the students taking college algebra have different needs today than they did post-World War II. In the past many of the students in college algebra were taking the course to prepare for the algebraic skills needed in calculus. Now most of the students are taking college algebra as a terminal mathematics course, and they have no intention of majoring in a mathematically intensive field. For example, in a study of ten private and public universities in Illinois, only 10-15% of the students enrolled in college algebra intended to major in a field requiring calculus (Herriott & Dunbar, 2009), and many of the students intending to take calculus change their plans after not succeeding in college algebra (Gordon, 2008). At the University of Nebraska-Lincoln enrollment patterns were tracked for more than 16 years by Dunbar (2006; as cited in Herriott & Dunbar, 2009). He found that only 10% of the students who pass college algebra go on to take calculus I. Because nearly 50% of students don't pass college algebra with an A, B, or C, roughly 5% of the students who originally enrolled in college algebra actually take calculus. Additionally, at the University of Houston-Downtown, only 3-4% of more than 1000 college algebra students go on to take Calculus I (Gordon, 2008). Therefore, given that so few students go on to take calculus, a change in the curriculum to meet the needs of the vast majority of students should be seriously considered. Gordon (2004) recommends a change in the mathematics curriculum as follows:

> Courses below calculus need to be refocused to emphasise conceptual understanding and realistic applications via mathematical modelling rather than an overarching focus on developing algebraic skills that may be needed for calculus. Without understanding the concepts, students will not be able to transfer the mathematics to new situations or to use modern technology wisely or effectively. Without a modelling approach, students do not recognise the mathematics when it arises in courses in other fields. And, in an era when any routine operation can be performed at the push of a button, courses that make development of algebraic skills the primary objective are producing nothing more than imperfect organic clones of existing technology (p. 37).

In the following three subsections, the researcher discusses recommendations for the college algebra curriculum from leading mathematics organizations, curriculum change and design in general, and results of curriculum reform in college algebra. Although this researcher is not investigating a curriculum reform in this study, the section on college algebra curriculum reform is provided to create a broader picture of the state of college algebra than what was given in the first section of the literature review. Finally, because curriculum reform is not being investigated, the following subsections give an overview without much elaboration.

Recommendations from Prominent Mathematics Organizations

Mathematics organizations such as the National Council of Teachers of Mathematics (NCTM), the Mathematical Association of America (MAA), the American Mathematical Association of Two-Year Colleges (AMAYTC), and the Contemporary College Algebra (CCA) program, have made recommendations for the teaching of mathematics. NCTM (2009) states: “A high school mathematics program based on reasoning and sense making will prepare students for citizenship, for the workplace, and for further study” (p. 3). In order to fulfill the purpose, NCTM urges five process standards in addition to the content standards. The five process standards are problem solving, reasoning and proof, communication, connections, and representations (2000). Likewise, the National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO) ((2012) created the Common Core State Standards for Mathematics (CCSSM) to provide guidelines for both process and content. Their process standards, denoted as Standards for Mathematical Practice, are (1) make sense of problems and persevere in solving them, (2) reason abstractly and quantitatively, (3) construct viable arguments and critique the reasoning of others, (4) model with mathematics, (5) use appropriate tools strategically, (6) attend to precision, (7) look for and make use of structure, and (8) look for and express regularity in repeated reasoning.

The CCSSM and the standards from NCTM are specific to K-12 mathematics; however, the MAA, AMATYC, and the CCA program have similar recommendations for college mathematics; their recommendations are for college algebra courses to go beyond algebraic manipulation and to focus on students experiencing meaningful mathematics through problem solving, modeling, and data analysis. In 2004 the MAA published a curriculum guide with recommendations for all areas of mathematics and mathematics education. Specific to courses not intended for mathematics majors, such as college algebra, the curriculum guide recommends designing the courses to help students in: "creating, solving, and interpreting basic mathematical models; making sound arguments based on mathematical reasoning and/or careful analysis of data; and effectively communicating the substance and meaning of mathematical problems and solutions" (Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America, 2004, p. 37). AMATYC created a document entitled, *Beyond Crossroads*, which provides principles and standards for college mathematics. A few of the principles consistent with reform are inquiry, quantitative literacy, and relevance. Additionally, example standards for intellectual development are problem solving, modeling, reasoning, connecting with other disciplines, communicating, technology, and linking multiple representations (Blair, 2006). Finally, the recommendations from Contemporary College Algebra (2012) in their philosophy and goals reinforce the principles and standards of both MAA and AMATYC and add small-group work, confidence, and enjoyment.

Curriculum Change and Design

In order to implement the recommendations from the various mathematics organizations in college algebra, the current and predominant traditional curriculum has to be reformed. No simple answers exist as to how this change should be accomplished, but there are models available. For example, when making change, Lynn Erickson (2008) recommends systems thinking as described by Senge (1990). Senge suggests five disciplines for instigating change. The first four disciplines are Personal Mastery, Mental Models, Building Shared Vision, and Team Learning; and these are integrated through Systems Thinking, the fifth discipline. Systems Thinking is a conceptual framework for understanding the interrelated patterns of change within and among the other disciplines. Personal Mastery is the discipline of continually understanding personal vision and seeing reality objectively. Mental Models relates to understanding how deeply ingrained beliefs or images influence worldview. Building Shared Vision is "the capacity to build and hold a shared picture of the future we seek to create" (Senge, 1990, p. 9). It also implies commitment rather than compliance. Finally, Team Learning is the ability to genuinely communicate together without hastily making assumptions, and it involves understanding team dynamics. In education the team should include all parties: teachers, administrators, parents, school board member, teacher educators, etc. To illustrate the importance of Systems Thinking when bringing about change, Erickson (2008) states:

> A major difficulty in the restructuring of schools is a lack of the five disciplines in action. People work in their own comfort zones, and each person tinkers with a piece of the whole. A coordinated, systemic plan for change is too often absent. Policy makers insist on tests; assessment people comply. Principals encourage teachers to focus on raising test scores; teachers comply. A plethora of new buzzwords and innovations sweep into classrooms but are seldom evaluated for their contributions to increased student success. Teachers and principals request time to dialogue, plan and design effective programs, but there is a breakdown in the system: this essential need remains but a whisper at the budget and policy tables. Educators fear that parents would never support the scheduling change. Parents need to be informed as to the complexity of the changes being asked of us. We must gain their support for these reasonable requests for planning time (pp. 17-18).

Erickson (2008) recommends three additional ideas for implementing curriculum reform. Firstly, she supports concept-based curricula as opposed to traditional curricula. In the traditional curricula, the focus is on memorization and practice of skills (2008). In concept-based curricula the learner finds relevance, makes connections, finds patterns, and transfers knowledge (Erickson, 2007, p. 34). Furthermore, a concept-based curriculum is the curriculum for which NCTM, MAA, AMATYC, and CCA, all advocate. Secondly, Erickson (2008) supports a national model for concept-based curricula with the exception that the model would not become a mandate. She believes the national and state standards are only curricular frameworks and that "the next step is to provide solid models for classroom curricula" (p. 13). Thirdly, Erickson (2008) advises using Professional Learning Communities (PLCs). PLCs should have the following attributes: supportive and shared leadership, collective learning, shared values and vision, supportive conditions, and shared personal practice (Hord, 1997); and in order to create a PLC "focus on learning rather than teaching, work collaboratively, and hold yourself accountable for results" (DuFour, 2004, p. 6).

Results of Curriculum Reform in College Algebra

After a Contemporary College Algebra conference at the United States Military Academy and after the publication of MAA's 2004 Curriculum Guide, a grant from the National Science Foundation was awarded to the Committee on the Undergraduate Program in Mathematics (CUPM) Subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY). The subcommittee, acting as a Professional Learning Community, was given the task to solicit partner discipline recommendations for college algebra and to report on reform efforts. Many schools applied to participate in a pilot study on using a modeling, concept-based approach in college algebra; however, only 11 institutions were accepted due to limited funding (Ganter & Haver, 2011). Nine of the institutions conducted a comparative study in the spring and fall semesters of 2006. The comparison was between the traditional lecture approach and the modeling approach. When comparing the modeling approach to the traditional approach; five of the 9 institutions showed better (lower) DFW rates, two showed worse DFW rates, one showed no difference in DFW rates in both semesters, and one was worse in the spring semester and better in the fall semester. Of the two institutions that didn't participate in the study, one had instructors who didn't stay committed to change and the other had a different vision of reform (Edwards, 2011). Qualitatively speaking, several factors may have prevented the piloted programs from being more effective. These factors include, but are not limited to, the following: more work for the instructors, more work for the students, and lack of efficacy of the instructors. Additionally, since each institution implemented the modeling approach differently, the effectiveness of the method was difficult to measure (Edwards, 2011), and further research would be beneficial. Finally, each institution would have benefited from a well-functioning Professional Learning Community in which shared vision was present.

Even though this dissertation study did not include an analysis of a modeling approach to college algebra, the information in this section on curriculum reform is important in understanding the current state of college algebra since curriculum reform has been occurring at several institutions (Ganter & Haver, 2011). Furthermore, the focus on conceptual understanding recommended by many mathematics organizations is studied by this researcher by comparing scores on conceptual questions on the final exam between students in a modified emporium model and students receiving the traditional lecture approach.

Brief Review of Equity in College Algebra

"Mathematics can and must be learned by all students" (National Council of Teachers of Mathematics, 2000, p. 13). This mantra of NCTM embodies the equity principle for school mathematics which states, "excellence in mathematics education requires equity—high expectations and strong support for all students" (p. 12). This section on equity contains a subsection with an overview of gender and a subsection with an overview of race/ethnicity. These discussions on gender and race/ethnicity are part of the literature review in order to provide background information for analyzing the research questions that evaluate the effectiveness of the course redesign within and between gender and within and between race/ethnicity.

Gender

Researchers have often observed a gender gap in mathematics with males outperforming females. One of the pioneers in documenting gender differences in mathematics education is Elizabeth Fennema, who began writing about gender inequity in the 1970's (Vale & Leder, 2004). After analyzing numerous studies, Fennema (1976) reported at the annual meeting of the American Educational Research Association that in many studies which reported that males had more mathematical ability than females, that males were studying more mathematics than females. She hypothesized that if both boys and girls would spend equal time studying mathematics, then the gender differences in mathematical performance would dissolve. Over the years, Fennema, often in collaboration with others, has also studied differences in attitudes between males and females. For example, Hyde, Fennema, Ryan, Frost, and Hopp (1990) performed a meta-analysis on mathematics attitudes and affect between genders. Though the differences were not great, girls had more negative attitudes about mathematics than boys. Furthermore, "gender differences in self-confidence and general mathematics attitudes are larger among high school and college students than among younger students" (p. 299). The following paragraphs provide additional information about the gender gap in both performance and attitudes.

Since the 1970's, the amount of mathematics taken by girls has increased significantly, and the research is showing that the gender gap has decreased. In one multinational meta-analysis Else-Quest, Hyde, and Linn (2010), determined that "on average, males and females differ very little on mathematics achievement" (p. 125); however, males tend to have more positive attitudes and affect than females. Another finding from the meta-analysis is that lack of significant difference in mathematics achievement should be qualified by the variability that exists between nations. In countries where women are denigrated, the gap in mathematics performance is significant. More evidence that the gender gap in the United States has nearly closed is provided by the National Assessment of Educational Progress (NAEP). In the 2011 results for Grade 8 Mathematics scaled scores, the national average for boys is slightly higher than for girls, but the confidence intervals of the scores overlap indicating that the difference is not significant. The same can be stated for the 2009 results for Grade 12. Interestingly, in 2005, the Grade 8 results were such that boys scored significantly higher than girls, the confidence intervals did not overlap. An implication might be that the same group of students who had a significant difference in 2005 closed the gap, albeit slightly, by 2009 (NAEP State Comparisons, 2012). The reason for this gap closure is uncertain, but as Else-Quest, Hyde, and Linn (2010) posit, "factors that have more direct influences on children's learning—for example, quality of instruction and curriculum—may serve to mediate the effect of gender inequity on math achievement" (p. 125).

In order to close the gender gap, some mathematics educators have suggested using principles in line with feminist pedagogy. For example, Jacobs and Becker (1997) recommend four principles for teachers desiring to build a gender-equitable classroom. First, teachers should build knowledge by applying students' personal experiences. This type of instruction should give students reasons to learn what they are learning, should be active rather than passive, and should involve applications. Second, writing should be an integral part of the mathematics classroom. “Sharing writing with other students allows one to listen to others’ reasons and ideas and learn from the variety of approaches that might be taken on any one problem situation. Writing emphasizes the process, not just a correct answer” (p. 110). Third, teachers make effective use of cooperative learning. If they are allowed to experience connectedness with others, many females will be more successful. Jacobs and Becker state: “In groups, students develop and support their own justifications, struggle for solutions to problems, and share problem solving. More-challenging problems can be chosen because a group has the benefit of several minds working toward a solution” (p. 111). Fourth, teachers should develop a community of learners. In this setting, the teacher and the students learn from each other. Even though these four principles are for feminist pedagogy, many males will benefit as well.

With the increased use of technology in the classroom, consideration should be given to the relationship between computer-based instruction and gender equity. In one study, Vale and Leder (2004) consider student views, compared by gender, on the use of computers in the mathematics classroom. Though the participants in the study are middle level students and a lot of change occurs between the middle years and college, it provides insight for instructors at the college level. The participants in general were positive about the use of technology in learning, and they “considered it a natural learning environment for the 21^{st} century” (p. 308). The boys and girls were alike in their beliefs about their abilities to be successful with computers in mathematics, but the girls were less positive about the actual use of computers.

Vale and Leder also found that males and females viewed differently the purpose of computers in their classes: “Girls were more likely to be concerned about success in computer-based mathematics whilst boys were more likely to be concerned about relevance and pleasure” (p. 307). Therefore, instructors need to be mindful of the differences when motivating students with computers in the classroom. In this researcher’s study, performance on the final exams in the technology-enhanced, modified emporium model will be compared within each gender to performance on the final exams in the traditional lecture approach.

Race/Ethnicity

In Chapter 1of this dissertation, it was stated that one subpopulation had a DFW rate of roughly 90% in college algebra (Brewer & Becker, 2010). The DFW rate being that high is unacceptable; therefore, education researchers are seeking ways to improve student learning for all races/ethnicities. Addressing the seriousness of mathematics education for students in urban and rural communities, Robert Moses (Moses & Cobb Jr., 2001, p. 5) stated, “I believe the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961” (as cited in Schoenfeld, 2004, p. 255). African-Americans and Hispanics receive attention in the research because performance in college is often worse than it is for Caucasians. The following data gathered from over 30 states by Complete College America (2012) demonstrate some comparisons between the aforementioned groups: (1) in public two-year colleges remediation is needed by 67.7% of African-Americans, 58.3% of Hispanics, and 46.8% of Caucasians, (2) in public four-year colleges remediation is needed by 39.1% of African-Americans, 20.6% of Hispanics, and 13.6% of Caucasians, (3) for those needing remediation in public two-year colleges, remediation and the associated college-level courses are not completed in the first two years of college by 85.6% of African-Americans, 76.2% of Hispanics, and 76.9% of Caucasians, (4) for those needing remediation in public four-year colleges, remediation and the associated college-level courses are not completed in the first two years of college by 69.5% of African-Americans, 64.6% of Hispanics, and 63.6% of Caucasians.

Using the above statistics from Complete College America, the researcher calculated additional percentages. First, for all students in public two-year colleges, associated college-level courses for which remediation is often necessary by many students are not completed in the first two years of college by 58.0% of African-Americans, 44.4% of Hispanics, and 36.0% of Caucasians. Second, for all students in public four-year colleges, associated college-level courses for which remediation is often necessary by many students are not completed in the first two years of college by 27.2% of African-Americans, 13.3% of Hispanics, and 8.6% of Caucasians.

The subsequent paragraphs discuss pedagogical recommendations and results of studies of effective pedagogy for African-Americans and Hispanics beginning with cooperative learning. Next, NCAT-supported redesigns, the achievement gap, the complementary learning model, and English learners are discussed briefly.

"Traditionally, mathematics instruction has addressed the needs of the analytic, field-independent, individual learner. Students were instructed in ways that encouraged them to focus on detail and use sequential or structured thinking" (Malloy, 2004, p. 8). The problem for many students is that they learn in ways different from what has traditionally been done.

In referencing Lee Stiff (1990), Malloy (2004) stated, “many students learn in ways characterized by factors of social or affective emphasis, harmony with their community, holistic perspectives, field dependence, expressive creativity, and nonverbal communication” (p. 8). Geneva Gay (2000) added, “cooperation, collaboration, and community are prominent themes, techniques, and goals in educating marginalized, Latino, Native, African, and Asian-American students” (p. 158). Malloy, Stiff, and Gay were strongly recommending the use of cooperative/collaborative learning in the classroom.

Fullilove and Treisman (1990), discuss the importance of using group dynamics to help African-Americans succeed. The University of California, Berkeley developed the Mathematics Workshop Program (MWP) to help African-American students succeed in freshman-level college mathematics. MWP was billed as an honors program, and since UCB attracts the best of California’s African-American high school graduates, MWP includes quality students. Quality students refers to the fact that the University of California, Berkley “comprise the best and brightest of California’s graduating high school seniors” (Fullilove & Treisman, 1990, p. 467) The program was developed after researchers noticed that the most successful minority students, Asians, were often studying together; therefore, MWP has a strong cooperative learning component in which groups of 5-7 students work together twice each week for approximately two hours each time they meet. The data show that MWP African-American students performed drastically better in a freshman-level mathematics course than non-MWP African-American students even though both groups included students of similar abilities.

NCAT-supported redesigned courses may also be effective for African-American and Hispanic students. At the University of Alabama in an emporium model redesign of intermediate algebra, the results showed an increase for overall student success rate (earning a C- or better) compared to the traditional approach; however, results were much more drastic when comparing African-American freshmen to Caucasian freshmen. Even though the African-American freshmen scored significantly lower on placement exams than Caucasian freshmen, their success rate in the course was significantly higher. "In fall 2000, 71.4 percent of African-American freshmen were successful, versus 51.8 percent of Caucasian freshmen; in fall 2001, it was 70 percent versus 65.3 percent" (Twigg, 2011, p. 29). In an emporium redesign in intermediate algebra at the University of Idaho, the effects of the redesign were examined for Hispanic students who were part of the College Assistance Migrant Program (CAMP). The CAMP students had a pass rate of 80 percent in the redesigned course compared to the previous pass rate of 70 percent in the traditional lecture course. Twigg (2011) stated that the keys to success for students at both the University of Alabama and the University of Idaho were: (1) students spending enough time on task, and (2) students receiving prompt, individualized help. The researcher in this study considers the effects of a modified emporium model within race/ethnicity for students in college algebra.

Another concern in education is the achievement gap between races/ethnicities. In a group of studies performed by NCAT, Twigg (2005) reported on a group of fifteen studies of course redesign at universities that serve a large population of underserved students. She states, "the good news is that these 15 institutions that have large numbers of the target student populations increased learning and success. The bad news is that while 'all boats rose,' the achievement gap among some groups of students remained" (p. 12).

In a college algebra course at Central State University, a Historically Black College and University in Ohio, a study was done to evaluate the effect of a complementary learning model with a computer-based learning environment. The complementary learning model at Central State consisted of a caring teacher, peer tutors, cooperative learning, positive feedback, and professional development sessions for the students. Kendricks (2011) found a 15% increase in student success (C or better) in the redesigned course compared to student performance in the traditional course. She then compared this to 10% gains nationally for computer-based environments like the NCAT-supported redesigns. The implication was that the addition of a complementary learning model might help decrease the achievement gap.

A difficulty in working with some minority groups is the issue of language. The concern is growing as the population of English learners, people whose first language is something other than English, is growing rapidly; the rapid growth is especially happening among Spanish-speaking students. For students whose first language is different from the language of the classroom, difficulties, beyond learning the content, exist. Judit Moschkovich (2011) provided the following guidelines for teaching English learners: "(1) focus on students' mathematical reasoning, not proficiency in English, (2) treat home language and everyday experiences as resources, not obstacles, (3) build on student reasoning and connect student reasoning to mathematical concepts" (p. 20). In relation to using the first language as a resource, Flores (1997) suggested not shortchanging students by emphasizing all aspects of mathematical discourse. During a time of mathematical discourse, if a student needs to speak in their first language, then the teacher should allow it while also encouraging the student to repeat in English. Even though English learners often come from cultural backgrounds that value cooperative learning, “group work may actually put Latinos at a disadvantage” (Khisty, 1997, p. 98) because the status differentials that come from classroom social conditions can lead to inferiority and low expectations. To overcome this potential disadvantage and to make group work effective, Khisty recommended “the teacher must pay close attention to how students speak with one another and note possible confusions that later should be checked and clarified” (p. 99). Additionally, to acquire the language students must repeatedly hear the language in context (Khisty, 1997).

The discussion on race/ethnicity in college algebra has related to effective teaching practices and reported results, but Danny Martin (2009) says the research focus for race/ethnicity in mathematics education needs to change. He argues that since race is socially constructed, research should focus on analyzing inequalities between races in mathematics through the socially constructed character of race; it shouldn’t focus only on static categories for the purpose of disaggregating data. Parks and Schmeichel (2012) add:

> Many studies published in mathematics education, including both those that discuss race and ethnicity in some way and those that do not, have worked to create a dominant discourse around race and ethnicity that emphasizes within-group similarities and downplays power relations, shifting identities, and recognition of race and ethnicity in diverse contexts (p. 249).

The requested change in focus is not part of this study, but this researcher adds to the literature on within-group similarities by comparing the effects of a modified emporium model within race/ethnicity for students in college algebra.

Additional Remarks on Equity

Effective pedagogy related to equity comes down to the use of culturally relevant pedagogy. Brown-Jeffy and Cooper (2011) state that culturally relevant pedagogy "maintains that teachers need to be non-judgmental and inclusive of the cultural backgrounds of their students in order to be effective facilitators of learning in the classroom" (p. 66). Effective teaching for the different cultures by means of culturally relevant pedagogy is best summarized by the following straight-to-the-point statement from Gloria Ladson-Billings (1995), "but, that's just good teaching" (p. 159). Malloy (2004) addresses the idea of culturally relevant pedagogy being "just good teaching" in further detail:

> Historically, educators did not fully examine the role of nonmajority culture on cognition, and thus they did not contextualize their mathematics instruction to these students' learning preferences…Contextualization occurs when mathematics educators consider cultural influences on learning and thus restructure their pedagogy and accommodate their students…the restructuring of pedagogy for all students includes the teacher's (a) acknowledging and using individual students' preferences in acquisition of knowledge, (b) developing activities that promote mathematical discourse within the classroom among students and between students and teacher, (c) valuing students' discourse and verbal knowledge, (d) creating interdependent learning communities within the classroom, and (e) encouraging, supporting, and providing feedback to students as they learn. The accommodation also includes the creation and use of mathematical tasks that require students to "do mathematics," as well as expectations that students can and will achieve conceptual and procedural understanding of the mathematics content… (pp. 8-9).

Parenthetically, this researcher believes culture goes beyond race/ethnicity to include gender, family tradition, religion, and socioeconomic status. Therefore, the contextualization and restructuring for all students addressed by Malloy implies consideration should be given to all aspects of a student's culture.

Once again, this researcher's study considers the effects of a course redesign using technology on student performance in college algebra. In addition to looking at the student population as a whole, the researcher considers whether the redesign is effective for different races/ethnicities and gender.

CHAPTER 3

METHODOLOGY

This chapter consists of a description of the participants, the instruments, and the methodology used for collecting data and analyzing the effectiveness of the course redesign of college algebra as compared to the traditional three-hour lecture course. The quantitative study is observational since it was not practical to randomly assign students to the two methods of instruction; students had the freedom to choose the type of instruction based on instructional preferences and/or scheduling issues. Additionally, the study used causal-comparative design, a non-experimental research design "in which researchers seek to identify cause-and-effect relationships by forming groups of individuals in whom the independent variable is present or absent…then determining whether the group differs on the dependent variable" (Gall, Gall, & Borg, 2007a, p. 306). This observational study generally compared college algebra final exam scores and DFW rates (the dependent variables) between two groups of students. The independent variable was the type of instruction received, instruction via the course redesign using the emporium model or instruction via traditional lecture. Additional analyses were done to look at final exam performance for subgroups of the independent variable and for subsets of the dependent variable. The study specifically sought to answer the following research questions.

1. Is there a difference in student scores on the comprehensive college algebra final exam for the course redesign versus the traditional approach?
2. Is there a difference in DFW rate in college algebra for the course redesign versus the traditional approach?

3. Is there a difference in student scores on the college algebra final exam for the course redesign versus the traditional approach within each gender, within each race/ethnicity, between genders, and between races/ethnicities?
4. Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach?
5. Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach within each gender and within each race/ethnicity?
6. Is there a difference in student scores on each individual question on the comprehensive final exam for the course redesign versus the traditional approach?

Participants

The participants in the study were the students who enrolled in either the traditional lecture approach or the emporium model course redesign of college algebra at the University of Missouri-Kansas City (UMKC). UMKC is a diverse, urban university in the Midwest and enrolls more than 13,000 students in its undergraduate and graduate programs. Approximately 8,000 students are in undergraduate education, and more than 5,000 students are enrolled in graduate programs. UMKC is a regionally accredited institution with more than 50 majors or programs and 125 academic areas (UMKC, 2011).

College Algebra is taken by many students seeking the baccalaureate degree. Typically, approximately 200 students take college algebra each semester. In the spring semester of the 2011-2012 academic year, 193 enrolled in college algebra with 87 students enrolled in the newly redesigned college algebra course, and the remaining 106 students enrolled in a traditional lecture-based college algebra course. Sixty-three percent of the participants were female, and the students ranged from freshmen through seniors. Nearly 46% were Caucasian, approximately 24% were African-American, 10% were Non-Residential International Students, almost 7% were Hispanic, and the remaining students were classified as “other.” Other refers to a combination of American Indians, Asians, Pacific Islanders, persons not specifying race/ethnicity, and persons of two or more races. Data from student performance at the beginning of the semester were also gathered to determine their preparedness for taking college algebra and to compare the preparedness of students between the redesign sections and the traditional sections. These data included scores on the university’s college algebra placement exam, scores on the mathematics section of the ACT, and cumulative high school grade point averages.

Preliminary Data Analysis

Prior to investigating the research questions, the researcher compared preparedness for success in college algebra between students in the redesign approach and students in the traditional approach. Preparedness for success was measured by the following three variables: (1) score on the university college algebra placement exam, (2) ACT Mathematics Sub-score, and (3) overall high school grade point average. The measures of preparedness for success are also investigated within each gender, within African-Americans and Caucasians, between genders, and between African-Americans and Caucasians. The other races/ethnicities were not tested since the sample sizes were small. Furthermore, the analysis was performed within each instructional type, redesign and traditional.

The tests used to perform the preliminary data analysis were multivariate analysis of variance (MANOVA) with k equal to 2, two-way analysis of variance (ANOVA), and t-tests. Finally, as part of the preliminary data analysis, descriptive statistics were calculated, normality was checked, and equality of variances was verified. Most of the statistical analyses in the preliminary data analyses and in the following final data analyses were performed with the Predictive Analytics Software (PASW), also known as Statistical Package for the Social Sciences (SPSS), and some of the statistics were calculated with Microsoft EXCEL.

Final Data Analysis

The results of the preliminary data analysis determined the analysis for testing the following research hypotheses. For a statement of the null hypotheses see Chapter 1.

1. The mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
2. The DFW rate for students initially enrolled in the course redesign for college algebra is less than the DFW rate for students enrolled in the traditional approach.
3. Within each gender the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
4. Within each race/ethnicity the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.

5. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between genders.
6. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between races/ethnicities.
7. The mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
8. The mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
9. Within each gender the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
10. Within each gender the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
11. Within each race/ethnicity the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.

12. Within each race/ethnicity the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
13. The proportion of students correctly answering each multiple-choice question is greater for students enrolled in the course redesign than it is for students enrolled in the traditional approach.
14. The mean score on each short-answer question for students enrolled in the course redesign is greater than the mean score on each short-answer question for students enrolled in the traditional approach.

Most of the research, or alternative, hypotheses were evaluated using t-tests; however, two-proportion z-tests and analysis of covariance were also used.

Procedures

Since the University of Missouri-Kansas City (UMKC) piloted the course redesign of college algebra with support from the National Center for Academic Transformation (NCAT), comparative data analysis of performance between the traditional approach and the course redesign was required. Therefore, data gathering by the Department of Mathematics and Statistics at UMKC started before this study was approved. The researcher was granted access to the data after completion of the spring semester of 2012, after approval by the Social Sciences Institutional Review Board (SSIRB) at UMKC, and after approval from UMKC's Office of Institutional Research.

Upon receipt of the necessary approvals, data were gathered from two different sources by the researcher's advisor. She received the final exams from the mathematics department, assigned a numerical code to each final exam, and then removed the names. Next, the researcher received the final exams and entered the scores on the individual questions into an EXCEL spreadsheet. There were twenty multiple choice questions and five short-answer questions on the final exam. Each short-answer question had multiple parts, but only one score for each question was recorded. After submitting student names with codes to UMKC's Office of Institutional Research, the researcher's advisor obtained the demographic data. The demographic data were then provided to the researcher who merged the information with the final exam data. The data included the following demographics: gender, race/ethnicity, and academic classification. It also included academic information such as college algebra placement exam scores, ACT Mathematics Sub-scores, and cumulative high school grade point averages. Finally, the researcher transferred the merged data to PASW in order to perform the analyses.

Participants did not need to fill out consent documents since names of the students in the two groups were removed from the spreadsheet the researcher received. Even though student performance was tied to the individual's demographic information, confidentiality was, is, and will be guaranteed. Hence, the researcher requested and was granted exemption from using consent forms by the SSIRB at UMKC.

Instrumentation

Three instruments were used for preliminary data analysis, and one instrument, the final exam, was used for addressing the research questions. The three instruments for preliminary data analysis were the UMKC Department of Mathematics and Statistics college algebra entrance examination, the ACT Mathematics Sub-score, and the overall high school grade point average.

The placement exam created by the Department of Mathematics and Statistics is a twenty-question multiple choice test. The test was designed to assess student understanding of number sense and basic algebra, namely, to assess students' preparedness to take a college algebra course. In order to enroll in college algebra a student must answer correctly at least 15 out of 20 questions. The test is taken online, and students are encouraged to not cheat. The discouragement for cheating is that students who cheat would be placed in a class in which they are unlikely to succeed. The topics addressed on the exam are order of operations, operations on decimals and fractions, percentages, roots, evaluation of expressions, solving linear equations, solving for a variable, function notation, integer exponents, factoring quadratic polynomials, linear inequalities, basic graphing skills, word problems, and basic set operations (UMKC Department of Mathematics and Statistics, 2012).

The American College Test (ACT) is a standardized national college admissions examination which assesses English, Mathematics, Reading and Science. The results on the 215-question, multiple-choice, approximately three-hour exam are accepted by all four-year colleges and universities in the United States (ACT, 2012). For the purposes of this study only the mathematics portion was used. "The ACT Mathematics Test is a 60-question, 60-minute test designed to measure the mathematical skills students have typically acquired in courses taken by the end of 11th grade" (ACT, 2012). Twenty-three percent of the test is categorized as Pre-Algebra which includes number, probability and basic statistics. The remaining breakdown of the test is 17% for Elementary Algebra, 15% for Intermediate

Algebra, 15% for Coordinate Geometry, 23% for Plane Geometry, and 7% for Trigonometry (ACT, 2012). Scores range from 1 to 36, and a score of 22 indicates college readiness (ACT, 2008).

Cumulative high school grade point average was also used in the preliminary data analysis to determine whether the course redesign group was equivalent to the traditional group. Each college algebra student's high school grade point average was based on a four-point scale.

As stated earlier, the final exam, as a measure of student learning outcomes, was used to compare the effectiveness of the course redesign to the effectiveness of the traditional lecture approach in college algebra. The exam, available in the Appendix and created by the UMKC Department of Mathematics and Statistics, had twenty multiple choice questions and five short-answer questions, and each of the short-answer questions had multiple parts. A limitation of the final exam was that no attempt was made by the researcher to evaluate the validity or reliability of the final exam. An exam is valid if it measures what it desires to measure, and an exam is reliable if it measures the outcomes consistently. Furthermore, the exam contained both conceptual and procedural questions. After creation of the final exam, the type of question, procedural or conceptual, was determined by the researcher, the exam creator, and one other mathematics educator. To make the determination, the three evaluators of question-types used definitions of procedural knowledge and content knowledge as provided in the definition of terms in Chapter 1. The task was challenging as implied by Hiebert and Carpenter (1992); they suggested that the relationship between the two types of knowledge may vary from "no relationship to a relationship so close that it becomes difficult to distinguish" (p. 78) between them. If there was disagreement as to the question type, the evaluators discussed the disagreement to see if a consensus could be reached. When agreement didn't occur, then the question was not included in either category. The use of three mathematics content experts was to ensure face validity. Face validity is "the extent to which a casual, subjective inspection of a test's items indicates that they cover the content that the test is claimed to measure" (Gall, Gall, & Borg, 2007b, p. 640).

CHAPTER 4

RESULTS

The purpose of this study was to determine the effect on student learning of a technology-heavy course redesign of college algebra compared to the traditional lecture approach typically used for teaching college algebra. The course redesign was a modification of the emporium model as described in Chapter 2. The study took place at the University of Missouri-Kansas City, a mid-sized, diverse, urban university in the Midwest, and the students self-enrolled in the section of college algebra that suited their schedules or interests. Three sections of the traditional course and two laboratory sections of the redesign course were offered; the redesign course also required a large group session which consisted of the students from the two laboratory sections. The data were received from two sources. First, the demographic data, previous-performance data, and course grades were received from the university's institutional research office, and second, the final exams were received from the college algebra instructors.

Data Collected

The data collected from the institutional research office included race/ethnicity, gender, ACT Math Sub-score, college algebra placement exam score, high school cumulative grade point average, college algebra section, and college algebra course grade. The data extracted from the final exams consisted of overall final exam score and individual question score. The breakdown of number of students by gender and race/ethnicity by type of instruction received is in Table 1. In the course redesign, there were 28 males, 44 females, 22 African-Americans, 33 Caucasians, 4 Hispanics, 5 Non-Residential International Students, and 8 other. In the traditional sections, there were 35 males, 62 females, 19 African-Americans, 44 Caucasians, 7 Hispanics, and 15 other. "Other" refers to a combination of American Indians, Asians, Pacific Islanders, persons not specifying race/ethnicity, and persons of two or more races. Demographic information was not available for one person in the redesign group, and demographic information was not available for the students who withdrew or chose not to take the final exam. The remaining data, such as scores and grades, will be summarized and examined in the following two sections: preliminary data analysis and final data analysis.

Table 1 *Demographic Information for Students by Type of Instruction (N=169)*

	Students in Redesign (72 Total)	Students in Traditional (97 Total)	Totals
Males	28	35	63
Females	44	62	106
African-Americans	22	19	41
Caucasians	33	44	77
Hispanics	4	7	11
Non-Residential/International	5	12	17
Other	8	15	23

Preliminary Data Analysis

Before testing the research hypotheses, the researcher performed preliminary data analysis to test whether at the beginning of the semester the students in the course redesign differed from the students in the traditional course in preparedness for success in college algebra. Preparedness for success was measured by the dependent variables, scores on the college algebra placement exam, ACT Math Sub-scores, and cumulative high school grade point averages; the independent variable was the type of instruction. Before performing any tests, the researcher explored the data by calculating the mean, standard deviation, skewness, and kurtosis for each dependent variable within each type of instruction. Also, before calculating the descriptive statistics for the ACT Mathematics Sub-score, one outlier was removed. An African-American female in the redesign group was listed as having an ACT Mathematics Sub-score of one. The researcher believes the score resulted from incorrect data entry or from the student not attempting to answer questions on the test. The data are reported in Table 2. The variation in sample sizes occurred between assessments because not all of the scores were available for every student. The means on each of the three assessments were similar between the two groups with the traditional students scoring slightly higher on all three. On the placement exam, the mean scores were 16.4 for students in the redesign sections and 16.7 for students in the traditional sections. Mean scores for the ACT Mathematics Sub-score were 20.6 and 20.8 for the redesign and traditional sections respectively, and the high school grade point averages were 2.96 for redesign and 3.09 for traditional. For all three assessments, the standard deviations were nearly equal. Finally, the critical ratios for skewness were all less than three, and the critical ratios for kurtosis were all less than two. The researcher assumed normality when the critical ratios were less than three.

Table 2 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success*

Redesign (R)	Placement Exam		ACT Math		High School GPA	
Traditional (T)	R	T	R	T	R	T
N	72	93	44	68	35	61
Mean	16.4	16.7	20.6	20.8	2.96	3.09
Standard Deviation	1.35	1.40	4.24	4.14	0.508	0.513
Skewness	0.778	0.567	0.500	0.295	0.423	-0.123
Standard Error	0.283	0.250	0.357	0.291	0.398	0.306
Critical Ratio	2.75	2.27	1.40	1.01	1.06	0.402
Kurtosis	-0.172	-0.525	0.189	-1.052	-0.854	-0.804
Standard Error	0.559	0.495	0.702	0.574	0.778	0.604
Critical Ratio	0.308	1.06	0.269	1.83	1.10	1.33

Multivariate Analysis of Variance (MANOVA) was used to test the following alternative hypotheses about a significant difference in the measures between the groups. The alternative hypotheses for the preliminary data analysis are numbered P1 through P9 in order to avoid confusion with the alternative, or research, hypotheses of the final data analysis.

P1. There is a difference in the mean score on the college algebra placement exam between students enrolled in the course redesign and students enrolled in the traditional approach.

P2. There is a difference in the mean ACT Mathematics Sub-score between students enrolled in the course redesign and students enrolled in the traditional approach.

P3. There is a difference in high school grade point average between students enrolled in the course redesign and students enrolled in the traditional approach.

Prior to running MANOVA, descriptive statistics were calculated, and Levene's test and Box's test were used to check for homogeneity of variances and homogeneity of the covariance matrix, respectively. For these tests, a sample size of 90 was used since only 90 students had all three measures available for assessing preparedness for college algebra. The means for the 33 students in the redesign sections were 16.15 for the placement exam, 20.33 for ACT Mathematics Sub-score, and 2.96 for high school grade point average; and the means for the 57 students in the traditional sections were 16.65 for the placement exam, 20.70 for ACT Mathematics Sub-score, and 3.12 for high school grade point average. The standard deviations were similar as verified by Levene's tests which did not provide enough evidence to reject homogeneity of variances at an alpha level of 0.05 for any of the dependent variables: the placement exam ($F = 2.360$, $p = 0.128$), ACT Mathematics Sub-score ($F = 0.007$, $p = 0.931$), and high school grade point average ($F = 0.280$, $p = 0.598$); Box's test indicated that the covariance matrix was homogeneous (Box's $M = 7.963$, $F =$

1.273, p = 0.266). Furthermore, the critical errors for skewness and kurtosis as shown in Table 2 indicated the sample was approximately normally distributed with the exception of the high critical ratio for kurtosis for the redesign students on the mathematics section of the ACT, and the distribution of sample means is approximately normally distributed as sample sizes were large. The following four tables contain the aforementioned data. Table 3 shows a few descriptive statistics, Table 4 shows the results of Levene's tests, Table 5 shows some multivariate tests, and Table 6 displays results of between-subjects effects for the MANOVA.

Table 3 *Descriptive Statistics for Students Used in MANOVA (N=90)*

Redesign (R)	Placement Exam		ACT Math		High School GPA	
Traditional (T)	R	T	R	T	R	T
N	33	57	33	57	33	57
Mean	16.15	16.65	20.33	20.70	2.96	3.12
Standard Deviation	1.121	1.382	4.067	3.937	0.489	0.513

Table 4 *Levene's Test for Equality of Variances between Instruction Type on College Algebra Placement Exam Scores, ACT Mathematics Sub-Scores, and High School GPA*

Dependent Variable	F	df1	df2	p-value
Plcmnt Exam	2.360	1	88	0.128
ACT Math	0.007	1	88	0.931
H.S. GPA	0.280	1	88	0.598

Table 5 *Multivariate Tests for Comparing Preparedness for Success Between Instruction Types*

Effect		Value	F	Hyp. df	Error df	p-val.	Partial Eta Sqrd
Instructional Method	Pillai	0.055	1.674	3	86	0.179	0.055
	Wilks	0.945	1.674	3	86	0.179	0.055
	Hotelling	0.058	1.674	3	86	0.179	0.055
	Roy	0.058	1.674	3	86	0.179	0.055

Table 6 *MANOVA for Preparedness for Success, Tests of between-Subjects Effects*

Source	Dep. Var.	Type III Sum Of Squares	df	Mean Square	F	p-val.	Partial Eta Sqrd
Instructional Method	Plcmnt	5.175	1	5.175	3.093	0.082	0.034
	ACT	2.837	1	2.837	0.179	0.674	0.002
	HS gpa	0.542	1	0.542	2.126	0.148	0.024
Error	Plcmnt	147.225	88	1.673			
	ACT	1397.263	88	15.878			
	HS gpa	22.414	88	0.255			

The test indicated no significant difference at an alpha-level of 0.05/24 in the mean vectors for the predictors (F = 1.67, p = 0.179), meaning there was not a significant difference in preparedness for success between students in the two types of instruction. The level of significance, 0.05, was divided by 24 because 24 statistical tests, excluding tests for equality of variances, were run in the preliminary data analysis. Table 5 shows four values calculated for the multivariate test: Pillai's Trace (0.055), Wilks' Lambda (0.945), Hotelling's Trace (0.058), and Roy's Largest Root (0.058). The effect listed in Table 5 is the variable, type of instructional method, either redesign or traditional. The researcher tested whether there was an overall difference in preparedness for success between students in the course redesign and students in the traditional approach. The tests of between-subjects effects, as reported in Table 6, also supported that there was not a significant difference between instructional methods for the three measures of preparedness for success in college algebra. The following results were found: high school GPA ($F = 2.126$, $p = 0.148$), ACT Mathematics Sub-score ($F = 0.179$, $p = 0.674$), and College Algebra Placement Exam ($F = 3.093$, $p = 0.082$). The researcher ran a t-test for the College Algebra Placement Exam since the p-value was relatively small and because only 90 of the 165 placement exam scores were used in the MANOVA. Levene's test again revealed equality of variances ($F = 0.123$, $p = 0.727$), and the t-test, for which no table was produced, indicated no significant difference ($t = -1.173$, $df = 163$, $p = 0.243$).

Within Gender and Within Race/Ethnicity

The researcher also performed preliminary data analysis to test whether at the beginning of the semester the students in the course redesign differed from the students in the traditional course in preparedness for success in college algebra within each gender and within two races/ethnicities, African-Americans and Caucasians. Tests were not performed for the other races/ethnicities because the sample sizes were too small. Once again, preparedness for success was measured by scores on the college algebra placement exam, ACT Mathematics Sub-scores, and cumulative high school grade point averages. This time, however, t-tests were run to test the following hypotheses within each gender and within two races/ethnicities. T-tests were used instead of MANOVA since the sample sizes from which data were available for all three dependent variables for measuring preparedness were small.

P4. Within each gender (or race/ethnicity) there is a difference in the mean score on the college algebra placement exam between students enrolled in the course redesign and students enrolled in the traditional approach.

P5. Within each gender (or race/ethnicity) there is a difference in the mean ACT Mathematics Sub-score between students enrolled in the course redesign and students enrolled in the traditional approach.

P6. Within each gender (or race/ethnicity) there is a difference in high school grade point averages between students enrolled in the course redesign and students enrolled in the traditional approach.

Prior to running t-tests, descriptive statistics were calculated. Table 7 contains results for females, Table 8 for males, Table 9 for African-Americans, and Table 10 for Caucasians.

Table 7 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success for Females*

Redesign (R) Traditional (T)	Placement Exam R	Placement Exam T	ACT Math R	ACT Math T	High School GPA R	High School GPA T
N	44	58	30	48	22	41
Mean	16.3	16.7	19.7	20.9	3.16	3.22
Standard Deviation	1.34	1.42	4.03	4.09	0.457	0.523
Skewness	1.005	0.509	0.549	0.333	0.373	-0.471
Standard Error	0.357	0.314	0.427	0.343	0.491	0.369
Critical Ratio	2.82	1.62	1.29	0.971	0.760	1.28
Kurtosis	0.191	-0.604	0.301	-0.843	-1.078	-0.534
Standard Error	0.702	0.618	0.833	0.674	0.953	0.724
Critical Ratio	0.272	0.977	0.361	1.25	1.13	0.738

The female students in the traditional sections had slightly higher means than the female students in the redesign sections on all three dependent variables. On the placement exam, the mean scores were 16.3 for females in the redesign sections and 16.7 in the traditional sections. Mean scores for the ACT Mathematics Sub-score were 19.7 and 20.9 for females in the redesign and traditional sections respectively, and the high school grade point averages were 3.16 for redesign and 3.22 for traditional. For all three assessments, the standard deviations were similar. The critical ratios for skewness were all less than three, and the critical ratios for kurtosis were all less than 1.3.

Table 8 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success for Males*

Redesign (R) Traditional (T)	Placement Exam R	Placement Exam T	ACT Math R	ACT Math T	High School GPA R	High School GPA T
N	28	35	14	20	13	20
Mean	16.61	16.54	22.5	20.6	2.63	2.84
Standard Deviation	1.37	1.36	4.20	4.35	0.417	0.394
Skewness	0.503	0.689	0.563	0.251	1.229	0.027
Standard Error	0.441	0.398	0.597	0.512	0.616	0.512
Critical Ratio	1.14	1.73	0.943	0.490	2.00	0.053
Kurtosis	-0.234	-0.238	0.594	-1.526	0.728	-0.689
Standard Error	0.858	0.778	1.154	0.992	1.191	0.992
Critical Ratio	0.273	0.306	0.515	1.54	0.611	0.695

The male students in the traditional sections and the redesign sections had relatively similar means on all three dependent variables. On the placement exam, the mean scores were 16.61 for males in the redesign sections and 16.54 in the traditional sections. Mean scores for the ACT Mathematics Sub-score were 22.5 and 20.6 for males in the redesign and traditional sections respectively, and the high school grade point averages were 2.63 for redesign and 2.84 for traditional. For all three assessments, the standard deviations were almost equal, and the critical ratios for skewness and for kurtosis were all less than or equal to two.

Table 9 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success for African-Americans*

Redesign (R) Traditional (T)	Placement Exam R	Placement Exam T	ACT Math R	ACT Math T	High School GPA R	High School GPA T
N	22	19	18	18	13	18
Mean	15.7	16.8	17.7	17.7	2.91	2.90
Standard Deviation	1.08	1.17	3.22	2.35	0.480	0.477
Skewness	1.860	0.808	0.792	1.267	0.897	-0.058
Standard Error	0.491	0.524	0.536	0.536	0.616	0.536
Critical Ratio	3.79	1.54	1.48	2.36	1.46	0.108
Kurtosis	3.463	1.877	-0.916	2.365	0.001	-0.652
Standard Error	0.953	1.014	1.038	1.038	1.191	1.038
Critical Ratio	3.63	1.85	0.882	2.28	0.001	0.628

The African-American students in the traditional sections had slightly higher means on the placement exam than the African-American students in the redesign sections; the mean scores were 15.7 for African-Americans in the redesign sections and 16.8 in the traditional sections. On the ACT Mathematics Sub-score, both the redesign and traditional sections had a mean of 17.7, and the high school grade point averages were nearly the same, 2.91 for redesign and 2.90 for traditional. For all three assessments, the standard deviations were similar. The critical ratios for skewness and kurtosis were all less than three with one exception on the placement exam; the critical ratios were 3.79 for skewness and 3.63 for kurtosis.

Table 10 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success for Caucasians*

Redesign (R)	Placement Exam		ACT Math		High School GPA	
Traditional (T)	R	T	R	T	R	T
N	33	43	19	33	17	26
Mean	16.55	16.40	23.4	22.4	2.93	3.28
Standard Deviation	1.23	1.43	3.76	4.33	0.549	0.503
Skewness	0.104	0.933	0.814	-0.200	0.296	-0.540
Standard Error	0.409	0.361	0.524	0.409	0.550	0.456
Critical Ratio	0.254	2.58	1.55	0.489	0.538	1.18
Kurtosis	-1.234	0.165	0.830	-1.039	-1.309	-0.484
Standard Error	0.798	0.709	1.014	0.798	1.063	0.887
Critical Ratio	1.55	0.233	0.818	1.30	1.23	0.546

The Caucasian students in the redesign sections had slightly higher means than the Caucasian students in the traditional sections on the placement exam (16.55 versus 16.40) and the ACT Mathematics Sub-score (23.4 versus 22.4). For high school grade point average, however, the Caucasians in the traditional approach performed better (2.93 versus

3.28). Once again, on all three assessments, the standard deviations were similar. Finally, the critical ratios for skewness and kurtosis were all less than three for all three assessments.

After analyzing the descriptive statistics, the researcher validated equality of variances for the placement exam, ACT Mathematics Sub-score, and high school GPA, for each of the four groups: female, male, African-American, and Caucasian. Table 11 contains the results of Levene's tests, and Table 12 displays the results of the independent sample t-tests.

Table 11 *Levene's Test for Equality of Variances within Each Gender and Race/Ethnicity*

Group	Assessment	F	df1	df2	p-value
Female	Placement Exam	0.548	1	100	0.461
Female	ACT Math	0.006	1	76	0.940
Female	High School GPA	0.350	1	61	0.556
Male	Placement Exam	0.000	1	61	0.998
Male	ACT Math	1.036	1	32	0.316
Male	High School GPA	0.017	1	31	0.898
Afr-Amer	Placement Exam	0.026	1	39	0.873
Afr-Amer	ACT Math	3.368	1	34	0.075
Afr-Amer	High School GPA	0.189	1	29	0.667
Caucasian	Placement Exam	0.385	1	74	0.537
Caucasian	ACT Math	1.654	1	50	0.204
Caucasian	High School GPA	0.603	1	41	0.442

As shown in Table 11, when comparing instructional types, there was not sufficient evidence to say the variances were not equal for any of the four subgroups: females, males, African-American and Caucasians. The smallest p-value was 0.075 which is greater than 0.05, and the remaining p-values were greater than 0.2.

Table 12 *T-test Results for Comparing Performance on the College Algebra Placement Exam, ACT Mathematics Sub-Score, and High School Grade Point Average within Females, Males, African-Americans, and Caucasians*

Group	Assessment	Mean Difference	Standard Error of Difference	t	df	p-value
Female	Placement Exam	-0.451	0.277	-1.628	100	0.107
Female	ACT Math	-1.162	0.947	-1.228	76	0.223
Female	High School GPA	-0.059	0.133	-0.443	61	0.659
Male	Placement Exam	0.064	0.346	0.186	61	0.853
Male	ACT Math	1.900	1.494	1.272	32	0.213
Male	High School GPA	-0.212	0.144	-1.475	31	0.150
Afr-Amer	Placement Exam	-1.115	0.351	-3.179	39	0.003
Afr-Amer	ACT Math	-0.056	0.939	-0.059	34	0.953
Afr-Amer	High School GPA	0.008	0.174	0.049	29	0.962
Caucasian	Placement Exam	0.150	0.312	0.481	74	0.632
Caucasian	ACT Math	0.974	1.190	0.819	50	0.417
Caucasian	High School GPA	-0.353	0.163	-2.170	41	0.036

The tests indicate there was not enough evidence to say there was a significant difference at an alpha-level of 0.05/24 for any of the three assessments for either females or males. The smallest of the p-values was 0.107 which occurred on the placement exam with females. The test statistic, t, was -1.628, indicating that performance in the redesign group was lower than performance in the traditional group. Since none of the gender-related tests were significant, covariates were not used in the data analysis when testing within gender. Contrary to the results within each gender, the results within African-Americans had one test ($t = -3.179$) with a very small p-value (0.00289). On the college algebra placement exam, the score was higher for the traditional group than for the redesign group. For Caucasians the test with the biggest statistical difference occurred when evaluating high school grade point average for which the traditional group again scored higher ($t = -2.170$, $p = 0.036$). Although, the two tests were not significant at a level of 0.05/24, the researcher chose to use the college algebra placement exam score as a covariate when comparing instructional methods on the final exam scores for African-Americans and to use high school GPA as a covariate when comparing instructional methods for Caucasians. The researcher did not perform analyses with the other races/ethnicities as the sample sizes were too small.

Between Genders and Between Races/Ethnicities

In addition to preliminary analysis within each gender and within two ethnicities, the researcher investigated preparedness for college algebra between genders and between African-Americans and Caucasians. The investigations were performed within each instructional type, and the associated alternative hypotheses were as follows:

P7. There is a difference in the mean score on the college algebra placement exam for students enrolled in the course redesign and students enrolled in the traditional approach between genders (or races/ethnicities).

P8. There is a difference in the mean ACT Math ematicsSub-score for students enrolled in the course redesign and students enrolled in the traditional approach between genders (or races/ethnicities).

P9. There is a difference in high school grade point averages for students enrolled in the course redesign and students enrolled in the traditional approach between genders (or races/ethnicities).

Initially, the sample sizes, means, and standard deviations from earlier tables were reorganized for easier comparisons between genders. The summary is provided in Table 13. For students in the redesign, females averaged lower than males on the placement exam (16.27 versus 16.61) and on ACT Mathematics (19.73 versus 22.50); however, high school grade point average was higher for females than for males (3.159 versus 2.629). In the traditional approach, females scored better than males on all three assessments: placement exam (16.72 versus 16.54), ACT Mathematics (20.90 versus 20.60), and high school grade point average (3.217 versus 2.841). The standard deviations were similar for all of the groups with the biggest difference occurring on high school GPA in the traditional sections. The standard deviations were 0.523 for females and 0.394 for males.

Table 13 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success between Genders*

Assessment		Redesign Female	Redesign Male	Traditional Female	Traditional Male
College Algebra Placement Exam	N	44	28	58	35
	Mean	16.27	16.61	16.72	16.54
	Standard Deviation	1.336	1.370	1.424	1.358
ACT Math Sub-Score	N	30	14	48	20
	Mean	19.73	22.50	20.90	20.60
	Standard Deviation	4.034	4.202	4.091	4.346
High School Grade Point Average	N	22	13	41	20
	Mean	3.159	2.629	3.217	2.841
	Standard Deviation	0.457	0.417	0.523	0.394

Two-Factor Analysis of Variance (ANOVA) was used for each hypothesis related to gender, and Levene's Test was performed for equality of error variances before ANOVA. The factors were instructional method and gender. For the variable, college algebra placement exam, Levene's test indicated that error variances were equal ($F(3, 161) = 0.193$, p-value = 0.901). Table 14 provides the results of two-way ANOVA for the placement exam.

Table 14 *ANOVA for Placement Exam with Factors of Gender and Instructional Type*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	1.438	1	1.438	0.757	0.386	0.005
Gender	0.225	1	0.225	0.118	0.731	0.001
Instr_Meth*Gender	2.551	1	2.551	1.344	0.248	0.008
Error	305.678	161	1.899			

The effect of gender on the placement exam was not statistically significant (F = 0.118, p-value = 0.731), and the interaction effect of instructional method and gender was not significant (F = 2.551, p-value = 0.248). Based on these results the researcher did not use the college algebra placement exam as a covariate when performing analysis on the final exam between genders.

For the variable, ACT Mathematics Sub-score, Levene's test again indicated that error variances were equal (F(3, 108) = 0.396, p-value = 0.756). Table 15 provides the results of two-way ANOVA for ACT Mathematics. The effect of gender on the ACT Mathematics Sub-score was not statistically significant at an alpha-level of 0.05/24 (F = 2.033, p-value = 0.157), and the interaction effect of instructional method and gender was not significant (F = 3.124, p-value = 0.080). Even though statistical significance was not present, the researcher chose to perform a t-test to compare ACT Mathematics scores between genders for students enrolled in the redesign. Only the redesign group was chosen because the means differed by almost three points in that group while the means were nearly equal in the traditional group. Table 16 displays the results of the t-test.

Table 15 *ANOVA for ACT Mathematics with Factors of Gender and Instructional Type*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	3.098	1	3.098	0.181	0.671	0.002
Gender	34.768	1	34.768	2.033	0.157	0.018
Instr_Meth*Gender	53.412	1	53.412	3.124	0.080	0.028
Error	1846.65	108	17.099			

Table 16 *T-test Results for Comparing ACT Mathematics Scores between Genders*

Mean Difference	Standard Error Difference	t	df	p-value
-2.767	1.323	-2.092	42	0.043

The test statistic for comparing mean ACT Mathematics Scores between genders was -2.092, and the p-value was 0.043. There was not a statistically significant difference when comparing to 0.05/24, but the researcher decided to use ACT Mathematics as a covariate when performing analysis on the final exam between genders within the redesign group. ACT Mathematics was not used as a covariate with the traditional group.

For the variable, cumulative high school grade point average, Levene's test once again indicated that error variances were equal ($F(3, 92) = 1.024$, p-value = 0.386). Table 17 provides the results of two-way ANOVA for High School GPA.

Table 17 *ANOVA for High School GPA with Factors of Gender and Instructional Type*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	0.372	1	0.372	1.678	0.198	0.018
Gender	4.169	1	4.169	18.824	0.000	0.170
Instr_Meth*Gender	0.119	1	0.119	0.538	0.465	0.006
Error	20.376	92	0.221			

The effect of gender on High School GPA was statistically significant at an alpha-level of 0.05/24 ($F = 18.824$, p-value = 0.000), but the interaction effect of instructional method and gender was not significant ($F = 0.538$, p-value = 0.465). Because of the statistical significance, the researcher chose to use High School GPA as a covariate when performing analysis on the final exam between genders within both the redesign and traditional sections.

Sample sizes, means, and standard deviations from earlier tables were also reorganized for easier comparisons between African-Americans and Caucasians. The summary is provided in Table 18.

Table 18 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success between African-Americans (Blacks) and Caucasians (Whites)*

		Redesign		Traditional	
Assessment		Blacks	Whites	Blacks	Whites
College Algebra Placement Exam	N	22	33	19	43
	Mean	15.7	16.6	16.8	16.4
	Standard Deviation	1.08	1.23	1.17	1.43
ACT Math Sub-Score	N	18	19	18	33
	Mean	17.7	23.4	17.7	22.4
	Standard Deviation	3.22	3.76	2.35	4.33
High School Grade Point Average	N	13	17	18	26
	Mean	2.91	2.93	2.90	3.28
	Standard Deviation	0.480	0.549	0.477	0.503

For students in the redesign, African-Americans averaged lower than Caucasians on all three assessments: placement exam (15.7 versus 16.6), ACT Mathematics (17.7 versus 23.4), and high school grade point average (2.91 versus 2.93). For students enrolled in the traditional sections, African-Americans scored higher on the placement exam (16.8 versus 16.4); however, African-Americans scored lower than Caucasians on ACT Mathematics (17.7 versus 22.4) and on high school grade point average (2.90 versus 3.28). The standard deviations were similar for all of the groups with the biggest difference occurring on ACT

Mathematics in the traditional sections. The standard deviations were 2.35 for African-Americans and 4.33 for Caucasians.

Two-Factor Analysis of Variance (ANOVA) was used for each hypothesis related to race/ethnicity, and Levene's Test was performed for equality of error variances before ANOVA. The factors were instructional method and race/ethnicity. In every investigation related to race/ethnicity, the data were restricted to only include African-Americans and Caucasians.

For the variable, college algebra placement exam, Levene's test indicated that error variances were equal ($F(3, 113) = 1.888$, p-value = 0.136). Table 19 provides the results of two-way ANOVA for the placement exam.

Table 19 *ANOVA for Placement Exam with Factors of Race/Ethnicity and Instructional Type*

Source	Type III Sum of Squares	Df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	6.137	1	6.137	3.782	0.054	0.032
Race/Ethnicity	0.910	1	0.910	0.561	0.456	0.005
Instr. Meth.*Race	10.551	1	10.551	6.503	0.012	0.054
Error	183.351	113	1.623			

The effect of race/ethnicity on the placement exam was not statistically significant ($F = 0.561$, p-value = 0.456). Although the p-value was small, the interaction effect of instructional method and race/ethnicity was not significant ($F = 6.503$, p-value = 0.012) at an alpha-level of 0.05/24. Even though statistical significance was not present, the researcher chose to perform a t-test within each instructional group to compare placement exam scores between races/ethnicities. Table 20 shows the results of the t-tests.

Table 20 *T-test Results for Comparing Placement Exam Scores between Races/Ethnicities (African-American Mean minus Caucasian Mean)*

Instructional Type	Mean Difference	Standard Error Difference	t	df	p-value
Redesign	-0.818	0.322	-2.541	53	0.014
Traditional	0.447	0.376	1.193	60	0.237

The test statistic for comparing mean placement exam scores between races/ethnicities in the redesign sections was -2.541, and the p-value was 0.014. There was not a statistically significant difference when comparing to 0.05/24, but the researcher decided to use the placement exam as a covariate when performing analysis on the final exam between races/ethnicities within the redesign group. The placement exam was not used as a covariate with the traditional group as the mean difference did not approach significance (t = 1.193, p-value = 0.237).

For the variable, ACT Mathematics Sub-score, Levene's test again indicated that error variances were equal (F(3,85) = 2.278, p-value = 0.085). Table 21 provides the results of two-way ANOVA for ACT Mathematics.

Table 21 *ANOVA for ACT Mathematics with Factors of Race/Ethnicity and Instructional Type*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	0.009	1	0.009	0.001	0.981	0.000
Race/Ethnicity	662.287	1	662.287	40.585	0.000	0.323
Instr. Meth.*Race	19.033	1	19.033	1.166	0.283	0.014
Error	1387.07	85	16.318			

The effect of race/ethnicity on ACT Mathematics was statistically significant at an alpha-level of 0.05/24 (F = 40.585, p-value = 0.000), but the interaction effect of instructional method and race/ethnicity was not significant (F = 1.166, p-value = 0.283). Because of the statistical significance, the researcher chose to use the ACT Mathematics Sub-score as a covariate when performing analysis on the final exam between races/ethnicities within both the redesign and traditional sections. This decision was made without performing any t-tests since the difference was obvious for both groups.

For the variable, cumulative high school grade point average, Levene's test once again indicated that error variances were equal (F(3,70) = 0.420, p-value = 0.739). Table 22 provides the results of two-way ANOVA for High School GPA.

Table 22 *ANOVA for High School GPA with Factors of Race/Ethnicity and Instructional Type*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Instruction Method	0.516	1	0.516	2.033	0.158	0.028
Race/Ethnicity	0.700	1	0.700	2.754	0.101	0.038
Instr. Meth.*Race	0.568	1	0.568	2.238	0.139	0.031
Error	17.781	70	0.254			

The effect of race/ethnicity on the high school GPA was not statistically significant (F = 2.754, p-value = 0.101). Additionally, the interaction effect of instructional method and race/ethnicity was not significant (F = 2.238, p-value = 0.139). Even though statistical significance was not present, the researcher chose to perform a t-test within the traditional sections to compare high school GPA between races/ethnicities. Table 23 shows the results of the t-test.

Table 23 *T-test Results for Comparing High School GPA between Races/Ethnicities (African-American Mean minus Caucasian Mean)*

Instructional Type	Mean Difference	Standard Error Difference	t	df	p-value
Traditional	-0.381	0.151	-2.524	42	0.015

The test statistic for comparing high school GPA between races/ethnicities in the traditional sections was -2.524, and the p-value was 0.015. There was not a statistically significant difference when comparing to 0.05/24, but the researcher decided to use high school GPA as a covariate when performing analysis on the final exam between races/ethnicities within the traditional group. High school GPA, however, was not used as a covariate with the redesign group as the GPAs were nearly the same (2.91 and 2.93).

Final Data Analysis

The purpose of this research was to compare the effectiveness on student learning of a technology-based course redesign versus traditional lecture in college algebra. To investigate the effectiveness the researcher tested the following alternative hypotheses. The corresponding null hypotheses were stated in Chapter 1.

1. The mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
2. The DFW rate for students initially enrolled in the course redesign for college algebra is less than the DFW rate for students enrolled in the traditional approach.
3. Within each gender the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.
4. Within each race/ethnicity the mean final exam score for students enrolled in the course redesign for college algebra is greater than the mean final exam score for students enrolled in the traditional approach.

5. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between genders.
6. The mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach is different between races/ethnicities.
7. The mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
8. The mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
9. Within each gender the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
10. Within each gender the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
11. Within each race/ethnicity the mean score on the conceptual questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.

12. Within each race/ethnicity the mean score on the procedural questions of the final exam for students enrolled in the course redesign is greater than for students enrolled in the traditional approach.
13. The proportion of students correctly answering each multiple-choice question is greater for students enrolled in the course redesign than it is for students enrolled in the traditional approach.
14. The mean score on each short-answer question for students enrolled in the course redesign is greater than the mean score on each short-answer question for students enrolled in the traditional approach.

The researcher conducted two-sample t-tests to test the first, third, seventh, eighth, ninth, tenth, eleventh, twelfth, and fourteenth hypotheses; two-proportion z-tests to investigate the second and thirteenth hypotheses; and Analysis of Covariance (ANCOVA) to analyze the fourth, fifth, and sixth hypotheses.

Results of Overall Final Exam Comparison

As stated, a two-sample t-test was used to test the first hypothesis that mean final exam scores for students enrolled in the course redesign were greater than in the traditional approach. Table 24 provides summary statistics of final exam scores for all students and for students in each type of instruction group as calculated by PASW. The final exams were each worth 100 points. Notice that the total number of students in Table 1 ($N = 169$) is different than in Table 24 ($N = 170$). This is because demographic data were not available for one of the students who took the final exam.

Table 24 *Summary Statistics for Final Exam Scores (Out of 100)*

	Students in Redesign	Students in Traditional	All Students
N	73	97	170
Mean	59.14	57.93	58.45
Standard Deviation	21.96	20.88	21.30
Minimum	14	18	14
First Quartile	40	41	41
Median	63	56	59
Third Quartile	76	73	76
Maximum	98	98	98

Notice that the mean for the students in the redesign (59.14) was slightly higher than the mean in the traditional sections (57.93). The standard deviations were similar, approximately 22 for the redesign and 21 for the traditional students. For the two groups, the five number summaries of minimum, first quartile, median, third quartile, and maximum values were also similar (14, 40, 63, 76 and 98 for redesign students; 18, 41, 56, 73, and 98 for traditional students); the biggest difference was in the median (63 versus 56).

A t-test was used to check if the difference in final exam means was different between the two groups. The researcher did not use covariates because the preliminary data analysis did not reveal any significant differences between the groups. Before performing the t-test, normality and equality of variances were checked. In testing for normality, skewness and kurtosis were calculated and are shown in Table 25.

Table 25 *Normality of Final Exam Grades by Type of Instruction*

	Redesign		Traditional	
	Skewness	Kurtosis	Skewness	Kurtosis
Statistic	-0.299	-0.952	0.220	-0.838
Standard Error	0.281	0.555	0.245	0.485
Critical Ratio	1.06	1.72	0.90	1.73

For the distribution of final exam grades for the redesign students, the critical ratio for skewness was 1.06 and the critical ratio for kurtosis was 1.72. For the traditional students, the critical ratio for skewness was 0.90 and the critical ratio for kurtosis was 1.73. Therefore, the researcher determined that final exam grades were normally distributed. Second, in checking for equal variances, the researcher used Levene's test for equality of variances. The researcher obtained the following results from PASW as shown in Table 26. Levene's test showed that the variances on the final exam between the redesign and traditional groups were not significantly unequal ($F = 0.581$, $p = 0.447$, $p > 0.05$).

Table 26 *Levene's Test for Equality of Variances between Instruction Groups on Final Exam*

F	df1	df2	p-value
0.581	1	168	0.447

After showing normality and equality in the variances, the researcher conducted the t-test to compare overall final exam performance between the two groups. Though the performance for the redesign students was higher, the difference was not significant at an overall level of significance of 0.05 ($t = 0.365$, $p = 0.358$, $p > 0.05/50$). Therefore, there was not enough evidence to say the course redesign students performed better on the final exam than the traditional course students. See Table 27 for the test results. The level of significance, 0.05, was divided by 50 because 50 statistical tests, excluding tests for normality and for equality of variances, were run in all of the final data analyses.

Table 27 *T-Test Results for Comparing Overall Final Exam Scores between Groups*

Mean Difference	Standard Error Difference	t	df	p-value
1.209	3.308	0.365	168	0.358

Results of DFW Rate Comparison

Out of 183 students enrolled in either type of instruction, 129 earned a C or better and 54 earned a D, F, or W. Out of 78 students enrolled in the course redesign, 46 earned a C or better and 32 earned D, F, or W. Out of 105 students enrolled in the traditional sections, 83 earned a C or better and 22 earned D, F, or W. The abovementioned totals are represented in Table 28 along with the respective proportions. To determine the number of D's, F's, and W's, the researcher included students who did not take the final exam but were still enrolled in the class and were not given a grade of incomplete, and seven redesign students with grades of incomplete were removed from the summary. Furthermore, one student in the redesign who performed well on the final exam had all of the demographic data missing, including course grade, and was excluded from this analysis.

Table 28 *Summary of DFW Rates*

	Students in Redesign	Students in Traditional	All Students
N (with incompletes)	85	105	190
N (without incompletes)	78	105	183
Earned A, B, or C (proportion of N)	46 (59.0%)	83 (79.0%)	129 (70.5%)
Earned D, F, or W (proportion of N)	32 (41.0%)	22 (21.0%)	54 (29.5%)

A two-proportion z-test was used to test the second hypothesis that the DFW rate for students initially enrolled in the course redesign for college algebra was less than the DFW rate for students initially enrolled in the traditional approach. Before running the test, the researcher validated the normal approximation assumption by multiplying the sample size by each associated sample proportion and by multiplying the sample size by the sample proportion less than one. In all cases the product was greater than five, indicating the normal approximation was valid. The smallest of these products was 22 and occurred in the traditional group as 22 students earned a D, W, or F. From the z-test it was determined that there was not a significant difference at the 0.05/50 (0.001) level of significance in the DFW rates in college algebra when comparing the redesign and traditional approaches (z = -2.944, p = 0.998). Results of the test are represented in Table 29. Note that the hypothesis was that the DFW rate would be lower for the redesign group than for the traditional group. The opposite happened with a 41% DFW rate in the redesign and a 21% DFW rate in the traditional approach. Therefore, there was clearly evidence that the DFW rate was not lower for the redesign approach when compared to the traditional approach.

Table 29 *Z-Test for Comparing DFW Rates*

Test Statistic	Redesign DFW Proportion	Traditional DFW Proportion	p-value
-2.944	.410	.210	0.998

Results of Final Exam Comparisons Based on Gender and Race/Ethnicity

The results of the third, fourth, fifth, and sixth hypotheses are described in this section. Before proceeding to the details of each of the hypotheses, the researcher provides summary statistics in two different formats. The data for final exam scores within gender, then by instructional method, and within each race/ethnicity are in Table 30; and the data for final exam scores within instructional method, then by gender, and within each race/ethnicity are in Table 31.

Table 30 *Summary Statistics for Final Exam Scores within Gender, Then by Instructional Method, and within Race/Ethnicity*

Redesign (R)		Females			Males			
Traditional (T)		R	T	Total	R	T	Total	Total
All Races Combined	N	44	62	106	28	35	63	170
	Mean	58.4	59.6	59.1	59.6	55.0	57.0	58.45
	S.D.	23.4	20.8	21.8	19.9	21.0	20.5	21.3
African-Americans	N	17	14	31	5	5	10	41
	Mean	44.0	45.7	44.8	42.2	36.4	39.3	43.4
	S.D.	21.9	15.0	18.8	14.5	16.0	14.7	17.9
Caucasians	N	17	27	44	16	17	33	77
	Mean	67.1	65.2	65.9	64.4	57.1	60.6	63.65
	S.D.	20.7	18.9	19.4	14.5	20.0	17.7	18.8
Hispanics	N	4	3	7	0	4	4	11
	Mean	76.25	44.3	62.6	-	47.0	47.0	56.9
	S.D.	7.09	16.0	20.0	-	16.0	16.0	19.5
Non_Residential International	N	2	7	9	3	5	8	17
	Mean	*	*	78.0	*	*	81.9	79.8
	S.D.	*	*	19.6	*	*	10.6	15.7

* Statistic was not provided in order to maintain student privacy.

Since one of the participants did not have demographic information, the sum of the number of females and the number of males was not equal to the total number of final exam scores. Additionally, even though statistical analysis did not occur for some subgroups, the data were included for informational purposes. The mean scores for some subgroups, however, were not included in the information in order to protect student privacy. Overall, as shown in Table 30, females scored higher on the final exam than males (59.1 versus 57.0). Females also scored higher than males for African-Americans (44.8 versus 39.3), for Caucasians (65.9 versus 60.6), and for Hispanics (62.6 versus 47.0); however, females scored lower than males for non-residential international students (78.0 versus 81.9). When comparing mean final exam scores between races, non-residential, international students scored the highest (79.8), Caucasian students the second highest (63.65), Hispanic students next (56.9%), and African-American students last (43.4). Note that the race/ethnicity of the non-residential, international students was not available to the researcher. For females, performance was slightly lower in the course redesign (58.4) than in the traditional sections (59.6); however, males scored slightly higher in the course redesign (59.6) than in the traditional sections (55.0). From the same means, observe that males scored higher than females in the redesign (59.6 versus 58.4) while females scored higher than males with the traditional approach (59.6 versus 55.0). Analysis was not performed by gender within each race/ethnicity, nor was it performed by race/ethnicity within each gender; such analysis is recommended for future studies. Finally, standard deviations were discussed as needed within each hypothesis test.

Table 31 *Summary Statistics for Final Exam Scoresby Instructional Method, Then by Gender, and within Race/Ethnicity*

Females (F) Males (M)		Redesign F	Redesign M	Redesign Total	Traditional F	Traditional M	Traditional Total	Total
All Races Combined	N	44	28	73	62	35	97	170
	Mean	58.4	59.6	59.1	59.6	55.0	57.9	58.45
	S.D.	23.4	19.9	22.0	20.7	21.0	20.9	21.3
African-Americans	N	17	5	22	14	5	19	41
	Mean	44.0	42.2	43.6	45.7	36.4	43.3	43.4
	S.D.	21.9	14.5	20.1	15.0	16.0	15.4	17.9
Caucasians	N	17	16	33	27	17	44	77
	Mean	67.1	64.4	65.8	65.2	57.1	62.1	63.65
	S.D.	20.7	14.5	17.7	18.9	20.0	19.6	18.8
Hispanics	N	4	0	4	3	4	7	11
	Mean	76.25	-	76.25	44.3	47.0	45.9	56.9
	S.D.	7.09	-	7.09	16.0	16.0	14.7	19.5
Non_Residential International	N	2	3	5	7	5	12	17
	Mean	*	*	84.8	*	*	77.8	79.8
	S.D.	*	*	6.14	*	*	18.1	15.7

* Statistic was not provided in order to maintain student privacy.

Table 31 provides data from a different point of view than Table 30 provides. Overall, the mean final exam score was slightly greater in the course redesign (59.1) than in the traditional approach (57.3). As discussed in the results of the first hypothesis, the difference was not statistically significant. For every race/ethnicity provided in Table 31, the mean for students in the redesign was greater than the mean for students in the traditional approach as follows: African-American students (43.6 versus 43.3), Caucasian students (65.8 versus 62.1), Hispanic students (76.25 versus 45.9), and non-residential, international students (84.8 versus 77.8). The largest of the differences was for Hispanic students, but the difference was not tested for significance since the sample sizes were too small. In order to compare Hispanic student preparation for college algebra between the instructional types, the researcher provides Table 32 with means for the college algebra placement exam, ACT Mathematics Sub-score, and high school grade point average. The redesign group had higher means on the placement exam (16.75 versus 15.83), lower means on ACT Mathematics (21.3 versus 21.5), and higher mean grade point average (3.25 versus 3.04).

Table 32 *Summary of Descriptive Statistics for Variables Measuring Preparedness for Success for Hispanics*

Redesign (R)	Placement Exam		ACT Math		High School GPA	
Traditional (T)	R	T	R	T	R	T
N	4	6	3	4	3	4
Mean	16.75	15.83	21.3	21.5	3.25	3.04
Standard Deviation	1.50	0.753	2.08	4.20	0.604	0.498

Analysis within each gender. After analyzing the information from Tables 30, 31, and 32, the researcher proceeded to investigate the third hypothesis. To address the third hypothesis was to determine whether performance on the final exam was better in the course redesign than in the traditional course for females and for males. As stated earlier, the preliminary data analysis indicated there was not significantly different preparedness for college algebra within each gender; therefore no covariates were used.

Before performing the t-test to see if the difference for each gender was significant, the researcher tested the assumptions of normality and equality of variances. First, in testing for normality, skewness and kurtosis were calculated and are shown in Table 33.

Table 33 *Normality Check for Final Exam Grades by Type of Instruction within Gender*

		Redesign		Traditional	
Gender		Skewness	Kurtosis	Skewness	Kurtosis
Female	Statistic	-0.147	-1.024	0.288	-0.919
	Standard Error	0.357	0.702	0.304	0.599
	Critical Ratio	0.412	1.46	0.947	1.53
Male	Statistic	-0.576	-0.852	0.129	-0.795
	Standard Error	0.441	0.858	0.398	0.778
	Critical Ratio	1.31	0.993	0.324	1.02

For the distribution of final exam grades for the female redesign students, the critical ratios for skewness and kurtosis were 0.412 and 1.46, respectively. For the female students in the traditional sections, the critical ratios for skewness and kurtosis were 0.947 and 1.53, respectively. For the distribution of final exam grades for the male redesign students, the critical ratios for skewness and kurtosis were 1.31 and 0.993, respectively; and for the male students in the traditional sections, the critical ratios for skewness and kurtosis were 0.324 and 1.02, respectively. Therefore, the researcher determined that final exam grades were normally distributed for both females and males. Next, in checking for equal variances, the researcher used Levene's test. The test showed that the variances on the final exam between the redesign and traditional groups for both females (F = 1.176, p = 0.281) and males (F = 0.005, p = 0.942) were not unequal. Table 34 displays the results of Levene's Test.

Table 34 *Levene's Test for Equality of Variances between Instruction Groups on Final Exam within Females and Males*

Gender	F	df1	df2	p-value
Female	1.176	1	104	0.281
Male	0.005	1	61	0.942

After showing normality and equality in the variances, the researcher conducted the t-tests to compare overall final exam performance between the two groups within each gender. For females there was clearly not enough evidence that the mean (58.4) in the redesign was higher than the mean (59.6) in the traditional approach since it was in fact lower. The test statistic (t = -0.280) and the p-value (0.610) are shown in Table 35. For males, although the mean for the redesign students was greater than for the traditional approach students, the difference was not significant at a 0.05/50 (0.001) level of significance ($t = 0.890$, $p = 0.189$). Therefore, there was not enough evidence to say the course redesign males performed better on the final exam than the traditional course males. Table 35 contains the test results.

Table 35 *T-Test Results for Comparing Final Exam Scores between Instructional Methods within Gender*

Gender	Mean Difference	Standard Error Difference	t	df	p-value
Female	-1.210	4.319	-0.280	104	0.610
Male	4.636	5.210	0.890	61	0.189

Analysis within each race/ethnicity. To address the fourth hypothesis was to determine whether performance on the final exam was better in the course redesign than in the traditional course for two races/ethnicities. As stated earlier, the only races analyzed were African-American and Caucasian. From the preliminary data analysis, the researcher decided to use the variable, college algebra placement exam, as a covariate when investigating final exam scores for African-Americans. Additionally, the variable, high school GPA, was used as a covariate when investigating final exam scores for Caucasians.

The first analysis within race/ethnicity was performed for African-Americans. Table 31 reported the mean final exam scores for African-Americans in the course redesign (43.6) and in the traditional group (43.3). In the preliminary data analysis, the following means of placement exam scores for African-Americans were provided: 15.7 for the redesign sections and 16.8 for the traditional sections. Therefore, ANCOVA was run to determine if the small difference in final exam means was significant considering the original difference in placement exam scores. Prior to performing ANCOVA, the researcher tested several assumptions. First, the observations were independent. Second, the distribution was tested for normality, and instead of using critical values for skewness and kurtosis, the Kolmogorov-Smirnov test was used. The test indicated that final exam scores were normally distributed for both redesign ($D(22) = 0.113$, p-value ≥ 0.200) and traditional ($D(19) = 0.144$, p-value ≥ 0.200); however, as the skewness and kurtosis critical ratios indicated in the preliminary data analysis, the Kolmogorov-Smirnov test showed a lack of normality for the placement exam scores: redesign ($D(22) = 0.296$, p-value = 0.000) and traditional (($D(19) = 0.236$, p-value = 0.007). The researcher chose to rely on the robustness of ANCOVA to overcome concerns about normality. Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 1.625$, $p = 0.210$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes ($p = 0.497$).

After testing the assumptions, the researcher conducted the ANCOVA test to compare overall final exam performance between the two groups for African-Americans. The results are available in Table 36. The test statistic ($F = 0.256$) and the p-value (0.616) indicated there was not enough evidence to say that in the course redesign African-Americans performed better on the final exam than the traditional approach African-Americans. Furthermore, placement exam scores did not have a significant impact on final exam scores as determined from the parameter estimates created by PASW in the ANCOVA ($B = -3.164$, p = 0.226). Parenthetically, since the value of B is negative, as placement exam scores increased, the final exam scores decreased; however, as stated, the impact was not significant.

Table 36 *ANCOVA Results for Comparing Final Exam Scores between Instructional Method within African-Americans and with Placement Exam Score as a Covariate*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Placement Exam	489.288	1	489.288	1.514	0.226	0.038
Instructional Type	82.861	1	82.861	0.256	0.616	0.007
Error	12283.7	38	323.256			

The second analysis within race/ethnicity was performed for Caucasians. Table 31 reported the mean final exam scores for Caucasians in the course redesign (65.8) and in the traditional group (62.1). In the preliminary data analysis, the following means of high school GPA for Caucasians were found: 2.93 for the redesign sections and 3.28 for the traditional sections. Therefore, ANCOVA was run to determine if the small difference in final exam means was significant considering the original difference in high school GPAs. The data only provided high school GPAs for 43 Caucasians, and the aforementioned means on the final exam were for 77 Caucasians. Hence, the means in the ANCOVA were somewhat different, 66.2 for the redesign and 61.2 for the traditional.

Before performing ANCOVA, the assumptions were tested. Firstly, the observations were independent, and the distribution of final exam scores were normally distributed for both redesign ($D(17) = 0.157$, p-value ≥ 0.200) and traditional ($D(26) = 0.155$, p-value = 0.111) as tested by the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test also showed the distribution of high school GPAs to be normally distributed for both redesign ($D(17) = 0.145$, p-value ≥ 0.200) and traditional ($D(26) = 0.145$, p-value = 0.169). Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 1.103$, $p = 0.300$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes ($p = 0.466$).

After testing the assumptions, the researcher conducted the ANCOVA test to compare overall final exam performance between the two groups for Caucasians. The results are available in Table 37. The test statistic ($F = 0.998$) and the p-value (0.324) indicate there was not enough evidence to say the course redesign Caucasians performed better on the final exam than the traditional approach Caucasians. Furthermore, high school GPAs did not have a significant impact on final exam scores as determined from the parameter estimates created by PASW in the ANCOVA ($B = 4.131$, $p = 0.485$). Parenthetically, since the value of B was positive, as high School GPAs increased, the final exam scores also increased; however, as stated, the impact was not statistically significant.

Table 37 *ANCOVA Results for Comparing Final Exam Scores between Instructional Method within Caucasians and with High School GPA as a Covariate*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
High School GPA	190.255	1	190.255	0.496	0.485	0.012
Instructional Type	382.635	1	382.635	0.998	0.324	0.024
Error	15334.3	40	383.356			

Since only 43 of 77 Caucasians were used in the previous analysis, the researcher chose to remove the covariate and run a t-test to determine whether performance on the final exam was better in the course redesign than in the traditional course. Results of the test are reported in Table 38 with assumptions assumed to be true. The test statistic ($t = 0.852$) and the p-value (0.199) did not provide enough evidence to reject the null hypothesis; therefore, performance on the final exam for Caucasians in the redesign sections was not significantly better than performance in the traditional sections.

Table 38 *T-Test Results for Comparing Final Exam Scores between Instructional Methods within Caucasians*

Mean Difference	Standard Error Difference	t	df	p-value
3.689	4.328	0.852	75	0.199

Analysis between genders. Upon completion of investigating final exam comparisons within population subgroups, the researcher proceeded to investigate the fifth hypothesis. To analyze the fifth hypothesis was to determine whether performance on the final exam was different by gender within each instructional approach, redesign and traditional. From the preliminary data analysis, the researcher decided to use the variables, ACT Mathematics Sub-score and high school GPA, as covariates when comparing genders in the course redesign. The variable, high school GPA, was used as a covariate when comparing genders in the traditional sections.

The researcher began with the analysis for the course redesign sections. Table 31 reported the mean final exam scores in the redesign sections for females (58.4) and for males (59.6). In the preliminary data analysis, the following means for ACT Mathematics in the redesign were provided: females (19.73) and males (22.50); and the high school GPA for redesign were given: females (3.16) and males (2.63). Therefore, ANCOVA was run to determine if the difference in final exam means was significant considering the original differences in ACT Mathematics Scores and in high school GPAs. Unfortunately, only 33 students in the redesign sections had data for both ACT Mathematics and high school GPA, and the aforementioned means on the final exam were for 72 students in the redesign. Hence, the means in the ANCOVA were dissimilar to the means for the 72 students, 55.7 for the females and 56.9 for the males.

Before performing ANCOVA, the assumptions were tested. Firstly, the observations were independent, and the distribution of final exam scores were normally distributed for both females ($D(21) = 0.120$, p-value ≥ 0.200) and males ($D(12) = 0.204$, p-value $= 0.182$) as tested by the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test also showed the distribution of ACT Mathematics Scores to be normally distributed for both females ($D(21) = 0.132$, p-value ≥ 0.200) and males ($D(12) = 0.190$, p-value ≥ 0.200); however, there was evidence that high school GPA may not be normally distributed for both females ($D(21) = 0.190$, p-value = 0.047) and males ($D(12) = 0.236$, p-value = 0.063). Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 0.301$, $p = 0.587$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes for the interaction with gender and ACT ($p = 0.466$); however, there was not homogeneity at a 0.05 level of significance in the regression slopes for the interaction with gender and high school GPA ($p = 0.028$).

After testing the assumptions and with disregard to the lack of normality and non-homogeneity of regression slopes in high school GPA, the researcher conducted the ANCOVA test to compare final exam performance between females and males in the redesign sections. The results are available in Table 39. The test statistic ($F = 0.598$) and the p-value (0.446) indicated there was not enough evidence to say there was a difference in final exam scores in the redesign sections between genders. ACT Mathematics Sub-scores, however, had a significant impact on final exam scores as determined from the parameter estimates ($B = 3.178$, $p = 0.001$). As ACT scores increased, the final exam scores also increased. On the other hand, High School GPAs did not have a significant impact on final exam scores ($B = -2.262$, $p = 0.868$). The insignificant impact was negative, meaning, as High School GPA increased, the final exam scores decreased.

Table 39 *ANCOVA Results for Comparing Final Exam Scores between Genders within the Redesign Sections and with ACT Mathematics and High School GPA as Covariates*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
ACT Math	4828.37	1	4828.37	14.859	0.001	0.339
High School GPA	9.188	1	9.188	0.028	0.868	0.001
Gender	194.344	1	194.344	0.598	0.446	0.020
Error	9423.26	29	324.940			

Since only 33 of 72 students in the redesign were used in the previous analysis, the researcher removed the covariates and ran a t-test with all 72 students to determine whether performance on the final exam was different between females and males. Results of the test are reported in Table 40 with assumptions assumed to be true. The test statistic (t = -0.228) and the p-value (0.820) did not provide evidence to reject the null hypothesis; therefore, performance on the final exam in the redesign sections was not significantly different by gender.

Table 40 *T-Test Results for Comparing Final Exam Scores between Genders within the Course Redesign*

Mean Difference	Standard Error Difference	t	df	p-value
-1.221	5.351	-0.228	70	0.820

The second analysis between genders was performed with the traditional sections. Table 31 reported the mean final exam scores in the traditional sections for females (59.6) and for males (55.0). In the preliminary data analysis, the following means for high school GPA for traditional sections were given: females (3.22) and males (2.84). Therefore, ANCOVA was run to determine if the difference in final exam means was significant considering the original difference in high school GPAs. Unfortunately, only 61 students in the traditional group had data for high school GPA, and the aforementioned means on the final exam were for 97 students in traditional. Hence, the means for the 61 students in the ANCOVA were different than the means for the 97 students, namely, 54.5 for the females and 47.9 for the males. After noticing the dramatic change in means, the researcher investigated the traditional sections, this time noticing that a greater percentage of students who were missing GPA information had high final exam scores than students with low final exam scores. The researcher decided to continue with ANCOVA but also decided to run a t-test with all 97 traditional-enrolled students.

Before performing ANCOVA, the assumptions were tested. Firstly, the observations were independent, and the distribution of final exam scores were normally distributed for both females ($D(41) = 0.100$, p-value ≥ 0.200) and males ($D(20) = 0.135$, p-value ≥ 0.200) as tested by the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test also showed the distribution of high school GPAs to be normally distributed for both females ($D(41) = 0.097$, p-value ≥ 0.200) and males ($D(20) = 0.130$, p-value ≥ 0.200). Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 0.941$, $p = 0.336$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes for the interaction with gender and high school GPA (p = 0.299).

After testing the assumptions, the researcher conducted the ANCOVA test to compare final exam performance between females and males in the traditional sections. The results are available in Table 41. The test statistic (F = 0.059) and the p-value (0.809) indicated there was not enough evidence to say there was a difference in final exam scores in the traditional sections between genders. High school grade point averages, however, had a significant impact on final exam scores as determined from the parameter estimates (B = 14.105, p = 0.007). As high school GPAs increased, the final exam scores also increased.

Table 41 *ANCOVA Results for Comparing Final Exam Scores between Genders within the Traditional Sections and with High School GPA as a Covariate*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
High School GPA	2766.65	1	2766.65	7.834	0.008	0.119
Gender	20.868	1	20.868	0.059	0.809	0.001
Error	20483.3	58	353.161			

Since only 61 of 97 students in the traditional approach were used in the previous analysis, the researcher removed the covariates and ran a t-test with all 97 students to determine whether performance on the final exam was different between females and males. Results of the test are reported in Table 42. Equality of variances was verified with Levene's test (F = 0.000, p = 0.999), while the test statistic (t = 1.048) and the p-value (0.297) did not provide evidence to reject the null hypothesis; therefore, performance on the final exam in the traditional sections was not significantly different by gender.

Table 42 *T-Test Results for Comparing Final Exam Scores between Genders within the Traditional Sections*

Mean Difference	Standard Error Difference	t	df	p-value
4.625	4.413	1.048	95	0.297

Analysis between races/ethnicities. Following the completion of final exam comparisons between genders, the researcher proceeded to test the sixth hypothesis. To analyze the sixth hypothesis was to determine whether performance on the final exam was different by race/ethnicity within each instructional approach, redesign and traditional. The only two races/ethnicities compared were African-Americans and Caucasians. From the preliminary data analysis, the researcher decided to use the variables, college algebra placement exam and ACT Mathematics Sub-score, as covariates when comparing races/ethnicities in the course redesign. The variables, ACT Mathematics and high school GPA, were used as covariates when comparing races/ethnicities in the traditional sections.

As was done with gender, the researcher began with the analysis for the course redesign sections. Table 31 reported the mean final exam scores in the redesign sections for African-Americans (43.6, N =22) and for Caucasians (65.8, N =33). The following means were calculated in the preliminary data analysis and were recorded in Table 18 for ACT

Mathematics in the redesign: African-Americans (17.7, N = 18) and Caucasians (23.4, N = 19). The placement exam means were also provided for the course redesign: African-Americans (15.7, N = 22) and Caucasians (16.6, N = 33). Therefore, ANCOVA was run to determine if the difference in final exam means was significant considering the original differences in ACT Mathematics Scores and in placement exam scores. Only 37 students in the redesign sections had data for both ACT Mathematics and the placement exam, and the data from Table 31 were for 55 students in the redesign. Hence, the means in the ANCOVA were not equal to the means for all students, 43.4 for African-Americans and 67.6 for Caucasians.

Before performing ANCOVA, the assumptions were tested. Firstly, the observations were independent, and the distribution of final exam scores were normally distributed for both African-Americans ($D(18) = 0.159$, p-value ≥ 0.200) and Caucasians ($D(19) = 0.172$, p-value $= 0.143$) as tested by the Kolmogorov-Smirnov test. In contrast, the test showed the distribution of placement scores to not be normally distributed for African-Americans ($D(18) = 0.276$, p-value $= 0.001$), and the test nearly provided enough evidence at a 0.05 level for non-normality for Caucasians ($D(19) = 0.194$, p-value $= 0.057$). Similarly, there was evidence that ACT Mathematics Scores may not be normally distributed for African-Americans in the redesign ($D(18) = 0.249$, p-value $= 0.004$), but there was not sufficient evidence to dispute normality for Caucasians ($D(19) = 0.174$, p-value $= 0.131$). Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 0.017$, $p = 0.898$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes for the interaction with race/ethnicity and placement exam scores (p = 0.480) and for the interaction with race/ethnicity and ACT Mathematics (p = 0.086).

After testing the assumptions and with disregard to the lack of normality, the researcher proceeded to conduct ANCOVA to compare final exam performance between African-Americans and Caucasians in the redesign sections. The results are available in Table 43. The test statistic (F = 1.766) and the p-value (0.193) indicated there was not enough evidence with the two covariates to say there was a difference in final exam scores in the redesign sections between races/ethnicities. ACT Mathematics Sub-scores, however, had a significant impact on final exam scores as determined from the parameter estimates (B = 2.646, p = 0.004). As ACT scores increased, the final exam scores also increased. Conversely, placement exams did not have a statistically significant impact on final exam scores (B = -2.086, p = 0.420). The insignificant impact was negative, meaning, as placement exam scores increased, the final exam scores decreased.

Table 43 *ANCOVA Results for Comparing Final Exam Scores between Races/Ethnicities within the Redesign Sections and with Placement Exam and ACT Mathematics as Covariates*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
Placement Exam	213.387	1	213.387	0.668	0.420	0.020
ACT Math	3008.35	1	3008.35	9.411	0.004	0.222
Race/Ethnicity	564.572	1	564.572	1.766	0.193	0.051
Error	10548.4	33	319.648			

Because only 37 of 55 students in the redesign were used in the immediately previous analysis, the researcher removed the covariates and ran a t-test with all 55 students to determine whether performance on the final exam was different between African-Americans and Caucasians. Results of the test are reported in Table 44 with assumptions assumed to be true. The test statistic (t = -4.304) and the p-value (0.000) provided strong evidence to reject the null hypothesis; therefore, performance on the final exam in the redesign sections was significantly different by race/ethnicity with Caucasians scoring higher than African-Americans. By combining the preceding ANCOVA results with this t-test, it was evident that there was a large gap between the two races/ethnicities; however, a large gap existed before the course based on ACT differences. Therefore, there was not evidence that the technology-heavy redesign course impacted learning differently for African-Americans than for Caucasians.

Table 44 *T-Test Results for Comparing Final Exam Scores between Races/Ethnicities within the Course Redesign*

Mean Difference	Standard Error Difference	t	df	p-value
-22.167	5.151	-4.304	53	0.000

The second analysis between races/ethnicities was conducted with the traditional sections. Table 31 reported the mean final exam scores in the traditional sections for African-Americans (43.3, N =19) and for Caucasians (62.1, N =44). The following means were calculated in the preliminary data analysis and were recorded in Table 18 for ACT

Mathematics in the traditional sections: African-Americans (17.7, N = 18) and Caucasians (22.4, N = 33). High school GPAs were also provided for the traditional sections: African-Americans (2.90, N = 18) and Caucasians (3.28, N = 26). Therefore, ANCOVA was run to determine if the difference in final exam means was significant considering the original differences in ACT Mathematics Scores and in high school GPAs. Only 43 students in the traditional sections had data for both ACT Mathematics and high school GPA, and the data from Table 31 were for 63 students in the traditional approach. Hence, the means in the ANCOVA were not equal to the means for all students; instead they were 43.1 for African-Americans and 61.2 for Caucasians.

Before performing ANCOVA, the assumptions were tested. Firstly, the observations were independent, and the distribution of final exam scores were normally distributed for both African-Americans ($D(17) = 0.124$, p-value ≥ 0.200) and Caucasians ($D(26) = 0.155$, p-value $= 0.111$) as tested by the Kolmogorov-Smirnov test. Likewise, the test showed that the distribution of high school GPAs were not significantly different from normal for African-Americans ($D(17) = 0.192$, p-value $= 0.97$) and for Caucasians ($D(26) = 0.145$, p-value $= 0.169$). In contrast, the test showed the distribution of ACT Mathematics Scores to not be normally distributed for African-Americans ($D(17) = 0.237$, p-value $= 0.012$), but there was not sufficient evidence to dispute normality for Caucasians ($D(26) = 0.112$, p-value ≥ 0.200). Next, in checking for equality of error variances across groups, the researcher used Levene's test. The test showed that the error variances ($F = 0.589$, $p = 0.447$) were not unequal. Finally, homogeneity of the regression slopes was tested, and the researcher found homogeneity in the regression slopes for the interaction of race/ethnicity with high school GPA (p = 0.208) and for the interaction of race/ethnicity with ACT Mathematics (p = 0.109).

After testing the assumptions, the researcher proceeded to conduct ANCOVA to compare final exam performance between African-Americans and Caucasians in the traditional sections. The results are available in Table 45. The test statistic (F = 0.001) and the p-value (0.976) indicated there was not enough evidence with the two covariates to say there was a difference in final exam scores in the redesign sections between races/ethnicities. ACT Mathematics Sub-scores, however, had a significant impact on final exam scores as determined from the parameter estimates (B = 3.724, p = 0.000). As ACT scores increased, the final exam scores also increased. High school GPAs, however, did not have a statistically significant impact on final exam scores (B = 3.631, p = 0.450). The insignificant impact was positive, indicating, as high school GPA increased, the final exam scores modestly increased.

Table 45 *ANCOVA Results for Comparing Final Exam Scores between Races/Ethnicities within the Traditional Sections and with ACT Mathematics and High School GPA as Covariates*

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Sqrd
ACT Math	6198.08	1	6198.08	29.207	0.000	0.428
High School GPA	123.804	1	123.804	0.583	0.450	0.015
Race/Ethnicity	0.198	1	0.198	0.001	0.976	0.000
Error	8276.23	39	212.211			

Because only 43 of 63 students in the traditional group were used in the immediately previous analysis, the researcher removed the covariates and ran a t-test with all 63 students to determine whether performance on the final exam was different between African-Americans and Caucasians. Results of the test are reported in Table 46 with assumptions assumed to be true. The test statistic (t = -3.718) and the p-value (0.000) provide strong evidence to reject the null hypothesis; therefore, performance on the final exam in the traditional sections was significantly different by race/ethnicity with Caucasians scoring higher than African-Americans. A large gap was evident between the two races/ethnicities; however, a large gap existed before the course based on ACT differences. Therefore, there was not evidence that the traditional lecture course impacts learning differently for African-Americans than for Caucasians.

Table 46 *T-Test Results for Comparing Final Exam Scores between Races/Ethnicities within the Traditional Approach*

Mean Difference	Standard Error Difference	t	df	p-value
-18.805	5.058	-3.718	61	0.000

Results of Procedural and Conceptual Questions

After meeting with two other mathematics educators individually, the researcher classified the final exam questions as either conceptual, procedural, or neither. The questions classified as conceptual were questions 1, 2, and 4 from the short answer section and questions 2, 3, 5, 6, 8, 10, 16, 17, and 19 from the multiple choice section; the questions determined to be procedural were questions 1, 4, 7, 9, 12, 13, 14, 15, 18, and 20 from the multiple choice section. The third and fifth short-answer questions and the eleventh multiple-choice question were not classified as there was not agreement among the three mathematics educators on those questions. Additionally, the scores were calculated as percentages based on their weights on the tests. Each multiple-choice question was worth 3 points, and the value of the individual short-answer questions is shown on the final exam. The Appendix contains a copy of the final exam questions.

Two t-tests, one for conceptual questions and one for procedural questions, were used to test the hypotheses that performance for students enrolled in the course redesign were greater than in the traditional approach. These tests were used to test the seventh and eighth hypotheses. The seventh hypothesis was designed to test whether the mean score on the conceptual questions of the final exam for students enrolled in the course redesign was greater than for students enrolled in the traditional approach. The eighth hypothesis was the same but for procedural questions instead of conceptual questions. Before performing the tests, the researcher calculated descriptive statistics and validated the normality and equal variance assumptions. See Table 47 for the descriptive statistics for both the conceptual and procedural questions; the two paragraphs following Table 47 contain a descriptive summary of the contents of the table. Notice that the sample size (N = 169) was one less than the sample size for the overall final exam scores (N = 170). The answer sheet for the multiple choice questions was misplaced for one student in one of the traditional sections.

Table 47 *Summary Statistics for Conceptual/Procedural Questions* (N = 169)

	Conceptual		Procedural	
	Redesign	Traditional	Redesign	Traditional
N	73	96	73	96
Mean	54.1	55.2	70.6	66.9
Standard Deviation	22.0	23.1	24.8	21.6
Skewness	-0.063	0.245	-0.606	-0.210
Standard Error	0.281	0.246	0.281	0.246
Critical Ratio	0.224	0.996	2.16	0.854
Kurtosis	-0.934	-0.770	-0.762	-0.767
Standard Error	0.555	0.488	0.555	0.488
Critical Ratio	1.68	1.58	1.37	1.57

For the conceptual questions the mean for the students in the redesign (54.1) was slightly less than in the traditional sections (55.2). The standard deviations were 22 for the redesign and 23 for the traditional students, and the Levene test (Table 48) indicated that the difference in variances was not significant ($F = 0.082$, $p = 0.775$, $p > 0.05$). For the redesign students, the critical ratio for skewness was 0.224 and for kurtosis was 1.68, and the critical ratio for skewness for students in the traditional approach was 0.996 and for kurtosis was 1.58. Therefore, the researcher determined that the distributions for both groups on the conceptual questions were approximately normal.

For the procedural questions the mean for the students in the redesign (70.6) was greater than in the traditional sections (66.9). The standard deviations were approximately 25 for the redesign and 22 for the traditional students, and the Levene test (Table 48) indicated that the difference in variances was not significant ($F = 2.103$, $p = 0.149$, $p > 0.05$). For the redesign students, the critical ratio for skewness was 2.16 and for kurtosis was 1.37, and the critical ratio for skewness for students in the traditional approach was 0.854 and for kurtosis was 1.57. Though the critical ratio for skewness of the redesign group was greater than 2, the researcher determined that the robustness of the t-distribution made the use of t-tests acceptable.

Table 48 *Levene's Test for Equality of Variances between Instruction Groups on Conceptual Questions and Procedural Questions*

Question Type	F	df1	df2	p-value
Conceptual	0.082	1	167	0.775
Procedural	2.103	1	167	0.149

Since the mean on the conceptual questions was higher for the traditional group than for the redesign group, it is clear that the data did not provide evidence that the redesign group performed better ($t = -0.317$, $p = 0.624$, $p > 0.05/50$); and though the performance for the redesign students was higher on the procedural questions, the difference was not significant at 0.05/50 (0.001) level of significance ($t = 1.027$, $p = 0.153$, $p > 0.05/50$). Table 49 contains the results of the tests.

Table 49 *T-test for Comparing Conceptual/Procedural Questions between Groups*

Question Type	Mean Difference	Standard Error of Difference	t	df	p-value
Conceptual	-1.11	3.51	-0.317	167	0.624
Procedural	3.67	3.58	1.027	167	0.153

Results on Question-Type Based on Gender and Race/Ethnicity

After comparing students in the redesign sections to students in the traditional sections on conceptual questions and procedural questions, the researcher addressed the ninth, tenth, eleventh, and twelfth research hypotheses, by considering performance on the conceptual and procedural questions based on gender and race/ethnicity. T-tests were used for all four hypotheses.

Analysis within genders on conceptual questions. The ninth hypothesis sought to determine within each gender whether the mean score on the conceptual questions of the final exam for students enrolled in the course redesign was greater than for students enrolled in the traditional approach. As indicated in the preliminary data analysis section, there was not significantly different preparedness for college algebra within each gender; therefore, no covariates were used. Before performing the t-tests to see if the difference for each gender was significant, the researcher calculated the means and standard deviations for exploratory data analysis. The sample sizes, means, and standard deviations are provided in Table 50.

Table 50 *Summary Statistics for Final Exam Conceptual Questions within Gender by Instructional Method*

Redesign (R)		Females			Males			
Traditional (T)		R	T	Total	R	T	Total	Total
All Races Combined	N	44	61	105	28	35	63	169
	Mean	53.8	57.6	56.0	53.8	51.2	52.3	54.8
	S.D.	24.4	22.4	23.3	18.0	23.9	21.3	22.6

The means for all of the subgroups were in the fifties. For females, the redesign sections scored lower than the traditional sections (53.8 versus 57.6); however, for the males, the redesign sections scored higher than the traditional sections (53.8 versus 51.2). The standard deviations for the four subgroups ranged from 18.0 to 24.4. In addition to investigating the means and standard deviations, the researcher checked assumptions. First, the data arise from independent samples. Second, normality was checked. The distribution of conceptual question scores for females were normally distributed in both the redesign sections ($D(44) = 0.099$, p-value ≥ 0.200) and traditional sections ($D(61) = 0.096$, p-value ≥ 0.200) as tested by the Kolmogorov-Smirnov test. Likewise, the test showed a normal distribution for males in both the redesign sections ($D(28) = 0.151$, p-value $= 0.100$) and the traditional sections ($D(35) = 0.074$, p-value ≥ 0.200). Next, in checking for equal variances, the researcher used Levene's test. The test showed that the variances on the conceptual questions between the redesign and traditional groups for both females ($F = 0.500$, $p = 0.481$) and males ($F = 1.787$, $p = 0.186$) were not unequal. Table 51 displays the results of Levene's Test.

Table 51 *Levene's Test for Equality of Variances between Instruction Groups on Conceptual Questions within Females and Males*

Gender	F	df1	df2	p-value
Female	0.500	1	103	0.481
Male	1.787	1	61	0.186

After showing normality and equality in the variances, the researcher conducted the t-tests to compare performance on the conceptual questions between the two groups within each gender. For females, there was clearly not enough evidence that the mean (53.8) in the redesign was higher than the mean (57.6) in the traditional approach since it was in fact lower. The test statistic (t = -0.814) and the p-value (0.791) are shown in Table 52. For males, although the mean for the redesign students was greater than for the traditional approach students, the difference was not significant at a 0.05/50 (0.001) level of significance (t = 0.482, p = 0.316). Therefore, there was not enough evidence to say the course redesign males performed better on the conceptual questions than the traditional course males.

Table 52 *T-Test Results for Comparing Conceptual Question Scores between Instructional Methods within Gender*

Gender	Mean Difference	Standard Error Difference	t	df	p-value
Female	-3.752	4.608	-0.814	103	0.791
Male	2.624	5.273	0.482	61	0.316

Analysis within genders on procedural questions. The tenth hypothesis was to determine within each gender whether the mean score on the procedural questions of the final exam for students enrolled in the course redesign was greater than for students enrolled in the traditional approach. Again, there was not significantly different preparedness for college algebra within each gender; therefore, no covariates were used. Before performing the t-tests to see if the difference for each gender was significant, the researcher calculated the means and standard deviations. The sample sizes, means, and standard deviations are provided in Table 53.

Table 53 *Summary Statistics for Final Exam Procedural Questions within Gender by Instructional Method*

Redesign (R)		Females			Males			
Traditional (T)		R	T	Total	R	T	Total	Total
All Races Combined	N	44	61	105	28	35	63	169
	Mean	70.7	68.0	69.1	70.0	64.9	67.1	68.5
	S.D.	25.4	21.7	23.3	24.6	21.6	23.0	23.0

The means for all of the subgroups were between 64 and 71. For females, the redesign sections scored higher than the traditional sections (70.7 versus 68.0); similarly, for the males, the redesign sections scored higher than the traditional sections (70.0 versus 64.9). The standard deviations for the four subgroups ranged from 21.6 to 25.4. In addition to investigating the means and standard deviations, the researcher checked assumptions. First, the data arise from independent samples. Second, normality was checked. The distribution of procedural question scores for females were not normally distributed in both the redesign sections (D(44) = 0.189, p-value = 0.000) and traditional sections (D(61) = 0.123, p-value = 0.023) as tested by the Kolmogorov-Smirnov test. For males, however, there was not enough evidence at a 0.05-level to say the distributions were not normal in both the redesign sections (D(28) = 0.158, p-value = 0.073) and the traditional sections (D(35) = 0.137, p-value = 0.095). Third, in checking for equal variances, the researcher used Levene's test. The test showed that the variances on the procedural questions between the redesign and traditional groups for both females (F = 1.894, p = 0.172) and males (F = 0.540, p = 0.465) were not unequal. Table 54 displays the results of Levene's Test.

Table 54 *Levene's Test for Equality of Variances between Instruction Groups on Procedural Questions within Females and Males*

Gender	F	df1	df2	p-value
Female	1.894	1	103	0.172
Male	0.540	1	61	0.465

Even though normality was lacking in the distribution of scores for females, the researcher again relied on the robustness of the t-test and conducted t-tests to compare performance on the procedural questions between the two groups within each gender. For both females and males, though the mean for the redesign students was greater than for the traditional approach students, the difference was not significant at 0.05/50 (0.001) level of significance with the following values: females (t = 0.574, p = 0.284) and males (t = 0.882, p

= 0.191). Therefore, there was not enough evidence to say students in the course redesign performed better on the procedural questions of the final exam than students in the traditional course for both females and males.

Table 55 *T-Test Results for Comparing Procedural Question Scores between Instructional Methods within Gender*

Gender	Mean Difference	Standard Error Difference	t	df	p-value
Female	2.649	4.614	0.574	103	0.284
Male	5.143	5.919	0.882	61	0.191

Analysis within races/ethnicities on conceptual questions. The eleventh hypothesis was to determine within each race/ethnicity whether the mean score on the conceptual questions of the final exam for students enrolled in the course redesign was greater than for students enrolled in the traditional approach. As was done with race/ethnicity on the final exam analysis, only African-Americans and Caucasians were used in the investigation. From the preliminary data analysis, the researcher determined the need to use the placement exam as a covariate when analyzing African-Americans and to use high school GPA as a covariate when analyzing Caucasians; however, no covariates were used for the examination on conceptual questions. This decision was made because the covariates had little impact on the final exam analysis within the races/ethnicities and because the conceptual questions were a subset of the final exam. Before performing the t-tests to see if the difference for each race/ethnicity was significant, the researcher calculated the means and standard deviations as part of the exploratory data analysis. The sample sizes, means, and standard deviations are provided in Table 56.

Table 56 *Summary Statistics for Final Exam Conceptual Questions within Race/Ethnicity by Instructional Method*

Redesign (R)		African-Americans			Caucasians		
Traditional (T)		R	T	Total	R	T	Total
All Races Combined	N	22	19	41	33	44	77
	Mean	37.5	38.3	37.9	60.7	59.2	59.8
	S.D.	18.7	17.5	17.9	18.5	21.3	20.0

The means were quite different between African-Americans and Caucasians. For African-Americans, the redesign sections scored lower than the traditional sections (37.5 versus 38.3); however, for Caucasians, students in the redesign sections scored higher than in the traditional sections (60.7 versus 59.2). The standard deviations for the four subgroups ranged from 17.5 to 21.3. In addition to investigating the means and standard deviations, the researcher checked assumptions. First, the data arose from independent samples. Second, normality was checked. The distribution of conceptual question scores for African-Americans were normally distributed in both the redesign sections ($D(22) = 0.152$, p-value $\geq$ 0.200) and traditional sections ($D(19) = 0.171$, p-value = 0.147) as tested by the Kolmogorov-Smirnov test. Likewise, the test showed a normal distribution for Caucasians in both the redesign sections ($D(33) = 0.080$, p-value $\geq$ 0.200) and the traditional sections

(D(44) = 0.065, p-value ≥ 0.200). Next, in checking for equal variances, the researcher used Levene's test. The test showed that the variances on the conceptual questions between the redesign and traditional groups for both African-Americans (F = 0.183, p = 0.671) and Caucasians (F = 0.836, p = 0.363) were not unequal. Table 57 displays the results of Levene's Test.

Table 57 *Levene's Test for Equality of Variances between Instruction Groups on Conceptual Questions within African-Americans and Caucasians*

Race/Ethnicity	F	df1	df2	p-value
African-American	0.183	1	39	0.671
Caucasian	0.836	1	75	0.363

After showing normality and equality in the variances, the researcher conducted the t-tests to compare performance on the conceptual questions between the two groups within each race/ethnicity. For African-Americans, there was clearly not enough evidence that the mean (37.5) in the redesign was higher than the mean (38.3) in the traditional approach since it was in fact lower. The test statistic (t = -0.133) and the p-value (0.552) are shown in Table 58. For Caucasians, although the mean for the redesign students (60.7) was greater than for the traditional approach students (59.2), the difference was not significant at a 0.05/50 (0.001) level of significance (t = 0.333, p = 0.370). Therefore, there was not enough evidence to say the course redesign Caucasians performed better on the conceptual questions of the final exam than the traditional course Caucasians.

Table 58 *T-Test Results for Comparing Conceptual Question Scores between Instructional Methods within Race/Ethnicity*

Race/Ethnicity	Mean Difference	Standard Error Difference	t	df	p-value
African-American	-0.759	5.692	-0.133	39	0.552
Caucasian	1.544	4.642	0.333	75	0.370

Analysis within races/ethnicities on procedural questions. The twelfth hypothesis was to determine within each race/ethnicity whether the mean score on the procedural questions of the final exam for students enrolled in the course redesign was greater than for students enrolled in the traditional approach. As with the previous analysis, only African-Americans and Caucasians were used in the investigation, and no covariates were used. Once again, the decision to not use covariates was made because the covariates had little impact on the final exam analysis within the races/ethnicities and because the procedural questions are a subset of the final exam. Before performing the t-tests to see if the difference for each race/ethnicity was significant, the researcher calculated the means and standard deviations as part of the exploratory data analysis. The sample sizes, means, and standard deviations are provided in Table 59.

Table 59 *Summary Statistics for Final Exam Procedural Questions within Race/Ethnicity by Instructional Method*

Redesign (R) Traditional (T)		African-Americans R	T	Total	Caucasians R	T	Total
All Races Combined	N	22	19	41	33	44	77
	Mean	57.7	54.7	56.3	77.0	70.5	73.3
	S.D.	27.2	18.0	23.2	19.4	22.0	21.1

Again, the means were quite different between African-Americans and Caucasians. For African-Americans, the redesign sections scored higher than the traditional sections (57.7 versus 54.7). Similarly, for Caucasians, the redesign sections scored higher than the traditional sections (77.0 versus 70.5). The standard deviations for the four subgroups ranged from 18.0 to 27.2 with both extremes occurring within African-Americans. In addition to investigating the means and standard deviations, the researcher checked assumptions. First, the data arose from independent samples. Second, normality was checked. The distribution of procedural question scores for African-Americans were normally distributed in both the redesign sections ($D(22) = 0.157$, p-value = 0.170) and traditional sections ($D(19) = 0.146$, p-value ≥ 0.200) as tested by the Kolmogorov-Smirnov test. In contrast, the test did not show a normal distribution for Caucasians in both the redesign sections ($D(33) = 0.173$, p-value = 0.014) and the traditional sections ($D(44) = 0.145$, p-value = 0.021). The critical ratios for skewness and kurtosis, however, were 1.34 and 0.985, respectively, for the redesign sections and 1.25 and 1.03, respectively, for the traditional sections. Next, in checking for equal variances, the researcher used Levene's test. There was evidence from Levene's test that variances on the procedural questions were unequal between the redesign and traditional sections for African-Americans (F = 6.175, p = 0.017), but the test showed the variances to be equal for Caucasians (F = 0.579, p = 0.449). Table 60 displays the results of Levene's Test.

Table 60 *Levene's Test for Equality of Variances between Instruction Groups on Procedural Questions within African-Americans and Caucasians*

Race/Ethnicity	F	df1	df2	p-value
African-American	6.175	1	39	0.017
Caucasian	0.579	1	75	0.449

The researcher conducted t-tests to compare performance on the procedural questions between the two groups within each race/ethnicity. The t-test for African-Americans was performed not assuming equal variances, and the t-test for Caucasians was utilized even though normality was potentially a concern. For African-Americans, there was not enough evidence that the mean (57.7) in the redesign was higher than the mean (54.7) in the traditional approach. The test statistic (t = 0.419) and the p-value (0.339) are shown in Table 61. For Caucasians, the mean for the redesign students (77.0) was greater than for the traditional approach students (70.5), and the difference was not significant at 0.05/50 (0.001) level of significance (t = 1.351, p = 0.091). Therefore, there was not enough evidence to say the course redesign Caucasians performed better on the procedural questions of the final exam than the traditional course Caucasians.

Table 61 *T-Test Results for Comparing Procedural Question Scores between Instructional Methods within Race/Ethnicity*

Race/Ethnicity	Mean Difference	Standard Error Difference	t	df	p-value
African-American	2.990	7.135	0.419	39	0.339
Caucasian	6.515	4.822	1.351	75	0.091

Results of Multiple-Choice Question Analysis

The researcher used the normal approximation to the binomial distribution, a two-proportion z-test, to test the thirteenth hypothesis that the proportion of students correctly answering each multiple-choice question was greater for students enrolled in the course redesign than it was for students enrolled in the traditional approach. Before running the tests, the researcher validated the normal approximation assumption by multiplying the sample size by each associated sample proportion and by multiplying the sample size by the sample proportion less than one. In all cases the product was greater than five, indicating the normal approximation was valid. The smallest of these products was 10 and occurred on question 8 in the redesign group as 10 students missed the question. The results of the 20 tests for the multiple-choice questions are in Table 62. For each question, Table 62 provides the proportion of each group with a correct answer, the difference in proportions, the test statistic, and the p-value for testing whether the proportion in the redesign group was greater than the proportion in the traditional group.

Table 62 *Summary of Multiple-Choice Question Analysis*

Redesign (N=73) Traditional (N=96)	Redesign Proportion	Traditional Proportion	Proportion Difference	Test Statistic	p-value
Question 1	0.808	0.885	-0.077	-1.400	0.919
Question 2	0.753	0.781	-0.028	-0.425	0.665
Question 3	0.781	0.771	0.010	0.154	0.439
Question 4	0.616	0.542	0.075	0.974	0.165
Question 5	0.644	0.667	-0.023	-0.310	0.622
Question 6	0.630	0.583	0.047	0.616	0.269
Question 7	0.767	0.781	-0.014	-0.218	0.586
Question 8	0.863	0.854	0.009	0.163	0.435
Question 9	0.534	0.604	-0.070	-0.911	0.819
Question 10	0.616	0.729	-0.113	-1.557	0.940
Question 11	0.671	0.677	-0.006	-0.080	0.532
Question 12	0.575	0.531	0.044	0.571	0.284
Question 13	0.836	0.750	0.086	1.347	0.089
Question 14	0.630	0.677	-0.047	-0.637	0.738
Question 15	0.740	0.635	0.104	1.441	0.075
Question 16	0.507	0.510	-0.004	-0.046	0.518
Question 17	0.342	0.333	0.009	0.124	0.451
Question 18	0.726	0.656	0.070	0.968	0.166
Question 19	0.630	0.583	0.047	0.616	0.269
Question 20	0.822	0.625	0.197	2.795	0.0026

The biggest difference (19.7%) in proportions occurred on Question 20 of which 82.2% of the redesign group and 62.5% of the traditional group answered correctly. Question 20 asked the students to find the x-coordinate of the solution of a system of two linear equations with two unknowns. Although the p-value of 0.0026 was small, it was not less than the level of significance of 0.05/50 (0.001). Strictly speaking, therefore, there was not enough evidence to say the students in the redesign course scored statistically significantly higher than the students in the traditional course.

Two additional questions differed by more than 10%, one in favor of the traditional approach and the other in favor of the redesign group. The second biggest overall difference (-11.3%) occurred on Question 10 and was in favor of the traditional group. Question 10 requested the students to find the domain of a function with a rational expression. The p-value was large (0.940) since the test was one-tailed in the direction of the redesign. The third largest overall difference happened on Question 15 from which percentages differed by 10.4% in favor of the course redesign. Question 15 requested the students to find the solution set of a quadratic equation with non-real roots. The p-value associated with the Question 15 hypothesis was 0.075 meaning there was not enough evidence at a 0.05/50 (0.001) level of significance to say that the redesign classes scored better than the traditional classes. Furthermore, the p-values for all of the remaining questions were larger than 0.075, so none of the remaining differences in proportions were statistically significant.

Questions 1, 4, 9, 13, and 18 differed between 7% and 9%. Students in the traditional approach scored better on Question 1 and Question 9, and students in the redesign course scored better on the other three questions. They were asked to simplify an algebraic expression involving exponents on Question 1, to solve a combined inequality on Question 4, to find the y-intercept of a rational function on Question 9, to solve an equation with rational expressions on Question 13, and to solve an exponential equation on Question 18.

Finally, the differences between groups were less than 5% for the twelve questions not discussed, and the difference was at most 1% on five of the questions. On these twelve questions, students in the redesign sections scored better on six, and students in the traditional sections scored better on six. The statistical results are in the abovementioned table, Table 62, and the individual questions can be viewed in the Appendix.

Results of Short-Answer Question Analysis

The final exam consisted of five short-answer questions; the first three questions were worth 10 points each, and the fourth and fifth questions were worth 5 points each. The total of 40 points on the short-answer questions was also 40 percent of the final exam. The hypothesis for examining these questions, the fourteenth hypothesis, states that the mean score on each short-answer question for students enrolled in the course redesign was greater than the mean score on each short-answer question for students enrolled in the traditional approach. Five t-tests were used to examine the hypothesis, one for each short-answer question. Once again, before running the tests, the researcher calculated some descriptive statistics, validated the normality assumption by calculating the critical ratios of skewness and kurtosis, and validated the equal variances assumption using Levene's test. Table 63 contains descriptive statistics for both types of instruction for each question; and Table 64 contains the results of Levene's test for each question.

The means were lower for the redesign sections than for the traditional sections on Question 1 (5.04 versus 5.21), Question 2 (4.11 versus 4.32), and Question 4 (1.70 versus 1.74); while the students in the redesign sections performed better than students in the traditional sections on Question 3 (5.03 versus 4.77) and Question 5 (2.78 versus 2.42). On Question 1, students were provided a graph of a function with both a vertical and horizontal asymptote, and they were asked to interpret the graph in several ways. For Question 2, students were given a situation with a constant rate of change and were asked to determine average rate of change and to model the situation with a linear function. On Question 3, students were given a quadratic function to graph and to use the graph to determine range. Question 4 was an investment problem, and Question 5 had a rational cost function to interpret. The Appendix provides a copy of the questions. Parenthetically, the three questions for which traditional sections performed better were on the conceptual questions, and the two questions for which redesign sections performed better were not given a designation of procedural or conceptual.

Table 63 *Summary Statistics for Short-Answer (SA) Questions*

Redesign ((N=73) Traditional (N=97)	SA#1 (10 points)	SA#2 (10 points)	SA#3 (10 points)	SA#4 (5 points)	SA#5 (5 points)
<u>Redesign</u>					
Mean	5.04	4.11	5.03	1.70	2.78
Standard Deviation	2.536	3.729	3.416	2.119	1.446
Skewness	-0.105	0.384	-0.020	0.823	-0.398
Standard Error	0.281	0.281	0.281	0.281	0.281
Critical Ratio	0.374	1.37	0.071	2.93	1.42
Kurtosis	-0.338	-1.320	-1.412	-1.137	-0.515
Standard Error	0.555	0.555	0.555	0.555	0.555
Critical Ratio	0.609	2.38	2.54	2.05	0.928
<u>Traditional</u>					
Mean	5.21	4.32	4.77	1.74	2.42
Standard Deviation	2.787	3.891	3.525	2.103	1.587
Skewness	-0.023	0.311	0.102	0.760	-0.247
Standard Error	0.245	0.245	0.245	0.245	0.245
Critical Ratio	0.094	1.27	0.416	3.10	1.01
Kurtosis	-0.831	-1.455	-1.391	-1.226	-1.021
Standard Error	0.485	0.485	0.485	0.485	0.485
Critical Ratio	1.72	3.00	2.87	2.53	2.11

The evaluation of the assumptions mostly indicated the independent sample t-tests could be used. The standard deviations were approximately the same for the two groups on each of the questions, and Levene's test provided evidence that the variances were not enough different statistically to say that they were unequal. The smallest p-value from the five tests was 0.177. Questions 1 and 5 had the biggest proportional difference in standard deviations. Once again, Table 64 provides the results of Levene's test. The critical ratio for skewness was high for both groups on Question 4, near or above 3.00; and the critical ratio for kurtosis was high on some of the questions. The researcher, however, decided to run a t-test for each question since the sample size was large enough to have a normal approximation to the distribution of sample means.

Table 64 *Levene's Test for Equality of Variances between Instruction Groups on Short-Answer Questions*

Question	F	df1	df2	p-value
SA#1	1.630	1	168	0.204
SA#2	0.624	1	168	0.431
SA#3	0.011	1	168	0.917
SA#4	0.011	1	168	0.917
SA#5	1.837	1	168	0.177

Each of the five t-tests resulted in failure to reject the null hypothesis and failure to accept the research hypothesis that the mean score on each short-answer question for students enrolled in the course redesign would be greater than the mean score on each short-answer question for students enrolled in the traditional approach. The largest difference in means, both absolutely (0.358) and statistically ($t = 1.513$, $p = 0.066$), occurred on Question 5 in favor of the course redesign. The second largest difference, also in favor of the course redesign, was on Question 3 with an absolute difference of 0.254 and test statistics, $t = 0.472$ and $p = 0.319$. The remaining differences were in favor of the traditional approach with the largest of those, statistically speaking ($t = -0.397$, $p = 0.654$), occurring on Question 1; and the largest absolute difference (-0.210) in favor of the traditional approach occurring on Question 2. Finally, although the mean was higher for the traditional approach on Question 4, the difference between means was only -0.044. Table 65 contains results of the five tests for the short-answer questions, and the abovementioned summary statistics table, Table 63, contains the sample means.

Table 65 *T-test for Comparing Short-Answer (SA) Questions between Groups*

Question	Mean Difference	Standard Error of Difference	t	df	p-value
SA#1	-0.165	0.416	-0.397	168	0.654
SA#2	-0.210	0.592	-0.355	168	0.639
SA#3	0.254	0.539	0.472	168	0.319
SA#4	-0.044	0.327	-0.133	168	0.553
SA#5	0.358	0.237	1.513	168	0.066

Summary of Results

Fourteen research hypotheses were tested after the preliminary data analysis. Because so many tests were run and Bonferroni's correction was used for the level of significance (0.05/50 = 0.001), very few statistically significant differences were present in all of the hypothesis tests; however, a few more results would have been significant if 0.05 would have been used as the level of significance. The only hypothesis test with a p-value less than 0.001 was the sixth hypothesis that the mean final exam score for students enrolled in the course redesign and the mean final exam score for students enrolled in the traditional approach would differ by race/ethnicity. The p-value, correct to 3 decimal places, when comparing African-Americans to Caucasians, was 0.000 for both the redesign and traditional sections; Caucasians scored much higher than African-Americans. The preliminary data analysis, however, showed that a significant difference existed in ACT Mathematics Scores between the two groups. Furthermore, ANCOVA demonstrated that the ACT Mathematics Scores were highly correlated to final exam scores. Therefore, African-Americans and Caucasians had a large gap at the beginning of the semester and at the end of the semester, and the test does not provide any information about the effectiveness of the technology-intensive or traditional lecture approach.

Two other tests had interesting results. First, the test of the second hypothesis that the DFW rate was lower for the course redesign than for the traditional sections was clearly not evident as the DFW rate for the redesign was 41% , and the DFW rate for the traditional approach was 21%. The test had a p-value of 0.998 indicating the DFW rate for the redesign was not lower than the traditional approach. The other test with interesting results came from one question on the multiple choice section of the final exam. The question, Question 20, asked the students to solve a system of equations. Of the students in the course redesign, 82.2% answered the question correctly, and of the students in the traditional approach, 62.5% answered correctly. In testing whether the students in the redesign scored significantly higher, the p-value was found to be 0.0026. Once again the result was not statistically significant at a 0.05/50 (0.001) level; however, it is worth further investigation. Another interesting result came from a comparison that was not tested. When comparing instructional approaches within Hispanics, a large difference in the final exam scores existed (76% for Hispanics in redesign, 46% for Hispanics in traditional); however, the sample size was not large enough to draw any strong conclusions.

The remaining tests resulted in no significant differences, and the remaining p-values were greater than 0.05. These include the tests that compared final exam scores between the redesign and traditional sections with the following groups: all students, within genders, and within races/ethnicities. The tests also included comparisons between the two instructional methods for the conceptual questions as a group, the procedural questions as a group, and all individual questions with the exception of the aforementioned question, Question 20. The conceptual and procedural questions were also compared within genders and within races/ethnicities. Finally, no significant difference was found between genders in both the redesign and traditional sections.

CHAPTER 5

DISCUSSION

Summary of the Study

The purpose of the study was to determine the effectiveness of a technology-intensive course redesign of college algebra as compared to the traditional lecture approach. The researcher assessed the effectiveness of a modified emporium model course redesign on student learning by comparing overall scores on the final exams for the two groups using a quantitative, observational study or quasi-experimental study. Overall effectiveness was also measured and contrasted between the two groups by means of DFW rates. In addition to evaluating overall performance on the final exam, item-by-item analysis and a comparison of performance on conceptual questions and procedural questions were executed. Finally, attention was given to final exam performance based on gender and race/ethnicity.

The participants in the study were students enrolled in college algebra during the spring semester of 2012 at the University of Missouri-Kansas City, a mid-sized, diverse, urban university. The students were not randomly assigned the method of instruction as they were allowed to choose the section in which they enrolled. Of the 191 students enrolled in college algebra, 86 students enrolled in a technology-heavy redesign course, and 105 students enrolled in a traditional lecture section. Final exams were taken by 97 students in the traditional sections and by 73 students in the redesign. In the course redesign, there were 28 males, 44 females, 22 African-Americans, 33 Caucasians, 4 Hispanics, 5 Non-Residential International Students, and 8 other. In the traditional sections, there were 35 males, 62 females, 19 African-Americans, 44 Caucasians, 7 Hispanics, and 15 other. One person's demographic information was not available.

A variety of tests were used to test the research questions. T-tests were used to test a majority of the hypotheses. Additionally, two-proportion z-tests and Analysis of Covariance were also utilized. Prior to running the tests that addressed the research hypotheses, Multivariate Analysis of Variance (MANOVA), Analysis of Variance (ANOVA), and t-tests were used to evaluate student performance at the beginning of the course in order to determine whether the two groups were equal in student preparedness for college algebra. Preparedness was measured by a department placement exam, ACT Mathematics Sub-scores, and high school cumulative grade point average. The results of the preliminary data analysis were provided in Chapter 4 and are only discussed in this chapter as relevant to the research questions.

Discussion and Implications of Findings

Conclusions are discussed based on the six research questions, and results of the fourteen research hypotheses are discussed within the associated research questions. Overall, fifty hypotheses were tested, so the researcher used a level of 0.05/50 (0.001) to determine statistical significance. Also, within each research question, the results are summarized and are followed by a discussion of their implications.

Research Question 1

Is there a difference in student scores on the comprehensive college algebra final exam for the course redesign versus the traditional approach?

The research hypothesis associated with this research question is in the direction of a higher mean for the redesign approach. Since the preliminary data analysis described in Chapter 4 indicated equality of preparedness for college algebra between the two groups, the samples for each group were independent, and the normality and equal variance assumptions were satisfied; a t-test was run to answer this question. Although the mean final exam score for the course redesign, 59.1, was higher than the mean final exam score for the traditional approach, 57.3, the difference was not significant (p-value = 0.358). The results are consistent with previous NCAT-supported course redesigns as mentioned in Chapter 2. Learning outcomes in previous NCAT redesigns have either improved or stayed the same (The National Center for Academic Transformation, 2012i).

The slightly better performance on the final exam in the course redesign sections at UMKC could be considered quite promising for future implementation of the modified emporium model used in the course redesign, especially considering that the implementation in the spring semester of 2012 was the first implementation. The traditional lecture approach, to which the course redesign was compared, had been used for many years, so there had been opportunity for many improvements. Usually, many lessons are learned the first time an approach to learning is undertaken, and the lessons learned often lead to considerable improvement in future attempts. The lessons learned by the mathematics department at UMKC have been placed into a faculty course manual for the redesigned college algebra (UMKC Department of Mathematics and Statistics, 2012).

Slightly lower preparedness for college algebra for the redesign sections as compared to the traditional sections is another encouraging result for proponents of the technology-intensive redesign approach. The result is encouraging in the sense that the students in the redesign started at a lower level of preparedness but still scored slightly higher. The differences in the three measures of preparedness for success were not significant, but the students in the redesign had lower preparedness scores nonetheless.

Improvement to activities and training for graduate teaching assistants (GTAs) is one area in which lessons were learned by the mathematics department at UMKC. The problem as stated in the faculty course manual for the redesigned college algebra was that "ill-defined GTA duties and roles were probably the greatest source of problems in the pilot course, leading to low morale among GTAs, frustration among course designers, and confusion and complaints from students" (UMKC Department of Mathematics and Statistics, 2012, p. 14). The following actions are recommended by the mathematics department: (1) the faculty lead should provide extensive training for the GTAs in regard to philosophy, technology platform, lab conduct expectations, and student progress monitoring responsibilities; (2) the faculty lead should formally introduce the students to the GTAs during the first class session; (3) the students should have contact information for the GTAs; (4) the GTAs should take a genuine interest in the students; and (5) the GTAs should meet with the faculty lead consistently to discuss any concerns.

An additional area from which lessons were learned is delivery of coursework. First, in regard to the implementation of the redesign in the spring of 2012, "students were not forced to step out of their own personalized, self-paced online learning environment" (UMKC Department of Mathematics and Statistics, 2012, p. 16). Because of this, the expected collaboration among students did not occur. The mathematics department at

UMKC recommended that the instructor place greater emphasis on building community. Another delivery-related issue occurred because some problems had so many parts that student fatigue became an obstacle. The course manual recommends more careful review of homework assignments in order to achieve proper emphasis and balance of the material. Insufficient time on task was another problem to be addressed. "Students needing assistance would raise their hands, but many students got tired of holding their hand in the air and got little work done in that state" (UMKC Department of Mathematics and Statistics, 2012, p. 16). One idea was to equip each workstation with an object, such as a flag, that could be used as a signal.

Suggestions for video usage in future implementations of the course redesign were also provided in the course manual. It was proposed to use orientation videos to provide the course philosophy of the redesign, instructions for swiping attendance cards, descriptions of lecture and lab structure, instructions for clicker registration and usage, and instructions for software access and usage. Using the university's video supplemental instruction (VSI) was also recommended for future offerings of the redesign course. The VSI consists of recorded lectures by a professor from the mathematics department that were not utilized in the pilot of the redesign. The proposal suggests embedding the videos as links in the course content of MyMathLab® (UMKC Department of Mathematics and Statistics, 2012).

Finally, had the abovementioned suggestions been implemented in the pilot semester, the mean of the final exams for the course redesign sections might have been statistically significantly greater than the mean of the final exams in the traditional sections.

Research Question 2

Is there a difference in DFW rate in college algebra for the course redesign versus the traditional approach?

The research hypothesis associated with this research question was that there would be a lower DFW rate for the redesign group than for the traditional group. The result, however, indicated the opposite. The DFW rate for the redesign sections was 41%, and DFW rate for the traditional sections was 21%. The large difference is in contrast to the results of other college algebra redesigns supported by NCAT. Only two out of twenty other NCAT-supported redesigns had significantly higher DFW rates after changing from the traditional lecture approach to a technology-intensive approach (The National Center for Academic Transformation, 2012i), but the difference in DFW rates for this study was larger both proportionally and absolutely. One variation of the aforementioned other studies as compared to this study is concerned with the extent of implementation of the redesign. This study is only a pilot study while the other studies reported results beyond the pilot phase.

The drastic difference in the DFW rates could be related to the lack of experience that the university had with implementation of the course redesign. As mentioned in the discussion of Research Question 1, many lessons were learned by the UMKC Department of Mathematics and Statistics. As recommendations from the department are set in motion, the DFW rate may decrease. Another result of the newness of the approach is that students are often resistant to different or uncomfortable approaches to learning. Often when people encounter uncomfortable situations, they choose to abandon those situations. An additional potential contribution to the large difference in DFW rates is that performances on all three measures of preparedness for success were lower for the redesign group than for the traditional group. Though the differences were not significant statistically, the differences in preparedness may have contributed to some of the disparity.

Course completion rates may also have influenced the differences between groups in the mean final exam scores. Twenty-one students who enrolled in college algebra either withdrew from the course or did not take the final exam. Thirteen of the students were enrolled in the redesign sections, and the other eight students were enrolled in the traditional sections. So, if the 21 students had taken the final exam and had completed the course, the results may have been different. For example, the difference in final exam scores might have been in favor of the traditional group instead of the redesign group. Since these 21 students could be considered high risk for failure and since more of them had been in the redesign group, the resulting mean final exam score for the redesign sections could have been lower than the traditional sections.

Research Question 3

Is there a difference in student scores on the college algebra final exam for the course redesign versus the traditional approach within each gender, within each race/ethnicity, between genders, and between races/ethnicities?

The third research question was formulated to assess the effectiveness of the course redesign versus the traditional approach based on two additional factors. The tests within genders, between genders, and within races/ethnicities did not result in any statistically significant differences. In contrast, the test for both the redesign and traditional sections resulted in statistically significant ($p = 0.000$) differences between races/ethnicities, specifically between African-Americans and Caucasians with Caucasians scoring much higher than African-Americans. The large difference in performance between African-Americans and Caucasians is consistent with the ongoing achievement gap nationwide and within NCAT-supported redesigns (Reardon et al. 2012; Twigg, 2005). Twigg (2005)reports that as a whole, the NCAT redesigns have improved student learning, but the gap has remained.

The results of the large gap between African-Americans and Caucasians did not provide information on the effectiveness of either the technology-intensive redesign approach or the traditional lecture approach. The ability to evaluate the effectiveness was hindered by two factors. First, the difference was significant for both groups. Therefore, the instructional method that caused the gap could not be determined. Second, the large gap between African-Americans was present before the spring semester of 2012 as measured by ACT Mathematics Scores. An ANCOVA test to compare final exam performance between the two races/ethnicities with ACT Mathematics as a covariate, indicated that no difference existed. This was true for both the redesign and traditional sections.

Though no statistical testing was done within Hispanics due to small sample sizes, some interesting results arose from exploratory data analysis. A comparison of instructional approaches within Hispanics revealed a large difference in the final exam scores. Four Hispanics in the redesign averaged 76%, and seven Hispanics in the traditional averaged 46%. Additionally, ACT Mathematics Scores were slightly lower for the students in the redesign (21.3) than for the students in traditional approach (21.5). Two other measures of preparedness for success favored the four students in the redesign (placement exam: 16.75 versus 15.83, high school GPA: 3.25 versus 3.04).

Research Question 4

Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach?

Since the assumptions were satisfied for the t-test for independent samples, a t-test was performed for evaluating the effectiveness of the course redesign for both conceptual and procedural questions. The students in the traditional approach scored slightly better on conceptual questions (55.2%) than the students in the course redesign (54.1%), but on procedural questions the students in the redesign course scored better (70.6%) than the students in the traditional sections (66.9%). Neither difference was statistically significant. The results cannot be compared to current research because the other NCAT-supported redesigns did not consider effects of the redesign implementation on question types. Hence, this study paves the way for further analysis on the effectiveness of technology-intensive instruction by question type. Additionally, as implied by the researcher in Chapter 2, consideration of the effects of instructional technology on different types of questions provides additional insight into the manner in which technology helps or hinders student learning.

Better performance on the procedural questions of the final exam in the course redesign sections is promising for upcoming implementation of the modified emporium model. Giving consideration to the spring of 2012 being the pilot study, even the slightly poorer, but almost equal performance by the course redesign sections on the conceptual questions is also cause for optimism about the effectiveness of the technology-heavy approach. Again, as lessons are learned by the mathematics department, implementation of the course redesign should improve.

The researcher finds it interesting, though not necessarily surprising, that the differences for the conceptual and procedural questions were in the direction they were, higher for the redesign sections on procedural questions yet lower for the redesign sections on conceptual questions. It is possible that MyMathLab® software is most effective in helping students with their procedural understanding. As the software acts as an independent tutor, students are helped to correct their individual mistakes and become more procedurally proficient. The question for educators then becomes: Is procedural understanding the type of understanding that is most desirous for developing productive citizens? This question is addressed briefly below in suggestions for future research. For conceptual understanding, student performance in the technology-heavy redesign approach may become better than student performance in the traditional lecture approach as changes are made as recommended by the UMKC mathematics department in their faculty course manual for the redesign college algebra. One such change is greater emphasis on student collaboration when focusing on understanding of concepts (UMKC Department of Mathematics and Statistics, 2012).

Research Question 5

Is there a difference in student scores on procedural questions and conceptual questions on the comprehensive final exam for the course redesign versus the traditional approach within each gender and within each race/ethnicity?

Current research on NCAT-supported redesign does not address question type within gender or within race/ethnicity. Therefore, analyses within the fifth research question add to the current literature. Tests were performed within females, within males, within African-Americans, and within Caucasians, and no significant differences were found for any of the groups.

The differences between genders and between races/ethnicities on the procedural and conceptual questions were not tested. The means that would have been compared had the tests been performed are reported in Table 66. The females and males were almost identical on the two types of questions in the redesign sections, and the females scored a little better on both types of questions with the traditional approach. The race/ethnicity comparisons show the same results as the overall final exam questions did, namely, Caucasians scored much higher than African-Americans.

Table 66 *Mean Percentages Correct for Females, Males, African-Americans, and Caucasians on Conceptual and Procedural Questions from the Final Exam*

Question Type/ Instructional Type	Females	Males	African-Americans	Caucasians
Conceptual/Redesign	53.8	53.8	37.5	60.7
Conceptual/Traditional	57.6	51.2	38.3	59.2
Procedural/Redesign	70.7	70.0	57.7	77.0
Procedural/Traditional	68.0	64.9	54.7	70.5

Research Question 6

Is there a difference in student scores on each individual question on the comprehensive final exam for the course redesign versus the traditional approach?

The sixth research question was designed to go beyond evaluating the effectiveness of the course redesign on conceptual and procedural questions to evaluating the redesign on the final exam item by item. The differences between groups on the 20 multiple choice questions were investigated using a normal approximation to the binomial distribution—multiple choice questions were recorded as either right or wrong. Independent sample t-tests were utilized for the analysis of the short-answer questions. Once again, fifty tests were performed and Bonferroni's correction was used to adjust the level of significance (0.05/50 = 0.001); none of the group differences were statistically significant when p-values were compared to a 0.001 level of significance. In the same way that the investigation of the fourth and fifth research questions adds to the literature, the investigation of the sixth research question adds to the literature; previous research of NCAT-supported, technology-heavy course redesigns did not consider student performance question-by-question.

Even though none of the differences between the groups on the 25 questions were statistically significant, a few of the differences are worthy of note. The final exam questions are available in the Appendix. The biggest difference (19.7%) in percentages occurred on Question 20 of which 82.2% of the redesign group and 62.5% of the traditional group answered correctly, and the p-value (0.0026) was small. To answer Question 20 correctly, students would have to had known how to solve a system of two linear equations with two unknowns. The rest of the multiple choice questions had p-values greater than 0.05, but two differed by more than 10%. Question 10, which requested the students to find the domain of a function with a rational expression, favored the traditional group with a difference of 11.3%; and Question 15, which requested the students to find the solution set of a quadratic equation with non-real roots, favored the course redesign with a difference of 10.4%. Of the short-answer questions, only Question 5 had a p-value less than 0.3. The question had a rational cost function to interpret, and the absolute difference on the five-point question was 0.36 (2.78 versus 2.42). The students in the redesign performed better, but the difference was not statistically significant ($p = 0.066$).

Limitations of the Study

This study has a few limitations including some that affect the ability of educators to generalize the results. One threat to external validity was that the study occurred at an urban, diverse, four-year public university in the Midwest. The results might have been different, for instance, at a private, rural, two-year institution in the Southeast. Another threat to the power to generalize was that the study considered the results from one pilot semester as opposed to following the effectiveness of the college algebra redesign over time as improvements are made.

This study was also not immune to threats to internal validity. One threat to internal validity occurred as students were allowed to select a section in which they enrolled. Therefore, the assignment to groups was not random, meaning the study was not experimental; rather, it was observational and quasi-experimental. Student choice could lead to non-equivalent ability levels for the groups at the start of the semester. The UMKC department of mathematics and statistics informally observed that students who enrolled early tended to choose a traditional section; however, students who enrolled late could not choose a traditional section because the traditional sections were full. Therefore, the late-enrolling students enrolled in the redesign sections disproportionately more often than in the traditional sections. The researcher believes, though not backed by research, that students who enroll late are more likely to withdraw or perform poorly. Consequently, the drastic difference in DFW rate should be considered carefully.

A second threat to internal validity was the absence of a pre-test for comparison purposes. This threat was lessened by comparing the ability levels of the groups at the start of the semester according to college algebra placement exam scores, ACT Mathematics Sub-scores, and high school grade point averages. Variables with significant differences were then used as covariates.

A third potential threat to internal validity was potential confounding of the instructor variable. The instructor variable could have been a problem if the instructor effectiveness had had an impact on student learning outcomes when the instructional method was the variable being evaluated. This threat was lessened because two of the three graduate teaching assistants who taught the traditional sections also led the laboratory sessions of the course redesign, and the third graduate teaching assistant provided help in the computer lab.

Another possible threat to internal validity was the increased instructor-contact time for students in the course redesign. In the traditional approach students received 150 minutes (3 sessions of 50 minutes each) of instruction time; however, in the course redesign students received 200 minutes (2 sessions of 75 minutes each and 1 session of 50 minutes) of instructor contact time. Hence, performance may have been lower in the course redesign had the students been in class fifty minutes less than they were. While this was cause for concern, the course redesign used at UMKC, with the extra instruction time, was what the researcher desired to compare to the traditional approach. The analysis of the effectiveness of the course redesign at UMKC adds to the literature because a modification of the emporium model, rather than the strict emporium model that has been analyzed in several institutions. Moreover, although the course redesign has additional meeting time, it is still less expensive to administer than the traditional approach as outlined in the final plan submitted to NCAT by UMKC's department of mathematics and statistics (2011).

Additionally, the main measure of student learning outcomes, the final exam, could have added a threat to internal validity since the researcher made no attempt to investigate the validity or reliability of the final exam. The exam creator, however, has had much experience with teaching and evaluating college algebra. Therefore, the researcher believes it is likely that the final exam had validity, measuring the desired learning outcomes for a college algebra student, and reliability, measuring the learning outcomes consistently.

The awareness of other limitations arose during the analysis process. For example, in the preliminary data analysis, MANOVA was run with the three variables for measuring preparedness for college algebra, and the data set only had the measures of all three variables for 90 of the 170 students who took the final exam. Related to this, none of the non-residential, international students had ACT or GPA data. Because of the missing information, a few extra tests were run when evaluating final exam data. For example, when comparing final exam scores between races/ethnicities in the traditional sections with two covariates, ANCOVA was used; however, because the values of the covariates were missing for many students, a t-test, which doesn't use covariates, was performed with all of the final exam scores in the traditional sections.

Another limitation was that some of the race/ethnicities had very small samples, and some of the students did not have race/ethnicity specified. Because of the small samples, tests were only run for African-Americans and Caucasians

Yet another limitation that arose during the analysis process was related to sample distributions. Some of the sample distributions were shown to be lacking normality. The researcher relied on two things to lessen the impact of the problem: (1) the tests used were robust, and (2) the distribution of sample means was normal because of the large sample sizes.

Finally, a major limitation occurred because so many tests were performed. There were 24 hypothesis tests in the preliminary data analysis and 50 hypothesis tests in the final data analysis. By chance alone, a few small p-values were likely. Therefore, the researcher chose to use Bonferroni's correction when determining level of significance, namely 0.05/24 for the preliminary data analysis and 0.05/50 for the final data analysis.

Suggestions for Future Research

Even though this study had limitations, it provides promising results for the use of technology in the college algebra classroom. Additionally, it has implication for future research including analyses of the ongoing course redesign at UMKC; extended examinations of the relationship among type of instruction, type of understanding, and gender; possible changes of foci in race/ethnicity studies; possible changes of curriculum in college algebra; and investigations of instruction type with students of varied ability levels. Each of these is discussed below.

Considering all of the recommendations made by the UMKC mathematics department after the initial offering of the course redesign, the most logical suggestion for additional research is to evaluate the effectiveness of the implementation of the department's advice. Because the redesign has only been piloted one semester, the researcher recommends analyzing the effects in the next few years of the redesign with the suggestions from the mathematics department (2012): more intentional cooperative learning, more time on task, use of orientation videos, use of video supplemental instruction, and better-trained graduate teaching assistants. Ye and Herron (2010), after a comparison study of computer-based college algebra and traditional college algebra, proposed changes similar to the improvements advocated by the UMKC mathematics department (2012) related to training the GTAs. Ye and Herron (2010), recommended more effective tutoring and more student time in the lab, which might lead to significantly better results for computer-based instruction.

> It is expected that significance could be possible in the future if something is done such as adding more lab hours or hiring more effective tutors, etc. As a result, students have to adjust their roles, duties and responsibilities and so do the instructors who are no longer "the sage on the stage" but "the coach on the team" (p. 48).

Additionally, they suggested that future studies be focused on faculty attitudes and the pedagogy of computer-assisted instruction.

This study included analysis of performance between the two types of instruction by question type, conceptual and procedural, and by individual test items. Future research might consider gender differences within instruction types on both conceptual and procedural questions and the relationship between gender and type of instruction on algebraic and geometric questions.

The researcher also suggests an analysis between genders on the procedural and conceptual questions. Furthermore, since this study did not look at gender differences on individual items, analysis could be done to consider, item-by-item, whether the computer-intensive approach or traditional lecture approach is more effective within each gender for all questions separately. Also, related to procedural and conceptual questions, upcoming research should consider a continuum for determining whether a question is procedural or conceptual. While discussing conceptual and procedural question categories with instructors, one of the instructors noticed that conceptual questions often had a procedural component. Potentially, a scale could be developed to place questions on a continuum from one question type to the other.

More studies could also be done to assess the effectiveness of computer-assisted instruction based on race/ethnicity. Firstly, as mentioned in the suggestions for future gender-related studies, the researcher recommends more studies to assess the effectiveness of a modified emporium model on procedural learning and conceptual learning. Studies with larger sample sizes of the subgroups could prove to be especially beneficial. Secondly, studies should be conducted to investigate the effectiveness of technology-intensive instruction within and between all combinations of gender and race/ethnicity. Only a few of these analyses were done in this study. Thirdly, the focus of research related to race/ethnicity could, and maybe should, be shifted. Currently, much of the research, including this research, on race/ethnicity only reports differences in performance between groups in order to disaggregate data. This type of research doesn't address the underlying issues. In a study to critically examine the conceptualization of race constructs in mathematics education research and practice, Danny Martin (2009) concluded future studies should consider the socially constructed nature of race in order to analyze racial inequalities.

The focus of this study was to assess the effectiveness of a technology-intensive approach to college algebra as compared to a traditional lecture approach; however, in both approaches the content was the same. This researcher believes the content of college algebra at most institutions is not the most beneficial for students, especially for students who take college algebra as a terminal mathematics course. Therefore, a suggestion for future research is to compare a data-driven, modeling-based approach to college algebra to courses with traditional content. Presently, at many universities, college algebra consists of algebraic manipulation with contrived application problems. Chris Arney stated: "Traditional College Algebra is a boring, archaic, torturous course that does not help students solve problems or become better citizens. It turns off students and discourages them from seeking more mathematics learning" (as cited in Small, n.d.). Parenthetically, the article by Small (n.d.) used the term *traditional* to reference the content of the course and not the method of instruction. In addition to considering curriculum reform, the researcher recommends that future research related to college algebra content reform should include analysis of the effectiveness of different modes of instruction within and between the different contents.

As stated in Chapter 2, Brewer and Becker (2010) assessed the effectiveness of online homework. One of their findings was that final exam scores were significantly higher for low level of preparation students when using online homework as opposed to traditional, textbook homework. There was not a significant difference for the high level of preparation students. This researcher's study did not assess the effectiveness of online homework generally or the effectiveness of online homework among low or high level of preparation of students specifically. He does, however, recommend investigation of the effectiveness of technology-heavy college algebra instruction for various levels of student preparation.

Finally, several other opportunities for further investigation within the assessment of a technology-heavy approach to teaching college algebra present themselves for researchers. The following list of comparative analyses provides possibilities: student progress in future mathematics courses, grade distributions, a true item analysis of responses on multiple choice questions including incorrect responses, performance by age, types of responses on open-ended questions, and DFW rates by gender and race/ethnicity.

Conclusions

This research presents important results that give mathematics education researchers insight into the effectiveness of using technology in the teaching of college algebra. First, as demonstrated by many of the tests, the technology-intensive course redesign piloted at UMKC, proved to be as effective as the traditional lecture approach. This conclusion was based on using final exam data as the main measure of student learning outcomes. The significance of the result is that the redesign approach has been, and is expected to be, less expensive than the traditional approach. Furthermore, proponents of the redesign believe that performance will improve with appropriate instructional technology as experience is gained by the instructors and program implementers. A second significant result is a negative for proponents of the course redesign. In this study of the pilot implementation at UMKC, the

DFW rate was much worse for the redesign approach (41%) than for the traditional approach (21%). Fortunately, the rates could improve as experience is gained, improvements are made, and students acclimate to course expectations.

Finally, this study is important in providing several recommendations for future research. For example, as improvements are made as recommended by the UMKC Department of Mathematics and Statistics, researchers can evaluate the technology-intensive approach further. This can especially be accomplished through replication with larger sample sizes, randomization, and well-designed pretests. Additional analysis within and between genders and races/ethnicities on the final exam and on individual questions and question types provides another example of opportunity for ongoing studies. Again, this would prove to be even more effective with larger sample sizes, randomization, and well-designed pretests. A supplementary analysis to the race/ethnicity studies is for researchers to investigate the relationship between type of instruction and student learning for Hispanics, as suggested in this study by interesting results from exploratory data analysis.

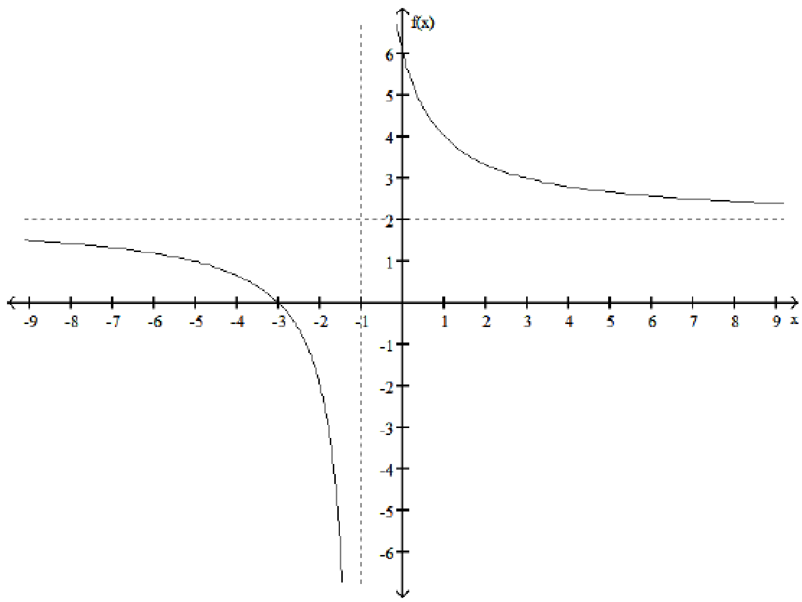
APPENDIX

COLLEGE ALGEBRA FINAL EXAM

College Algebra Final - Part 1
Spring Semester 2012

SHORT ANSWER.

1. **(10 points) Use the graph of the function f(x) to answer the following questions:**



a) What is the domain of f?

b) What are the zero(s)?

c) What is f(1)?

d) For what value of x is f(x) = 1?

e) For what values of x is $f(x) < 0$?

f) What does f(x) approach as x approaches infinity?

g) As $x \to -1^-$, $f(x) \to$?

2. (10 points) A deep sea diving bell is being lowered at a constant rate. After 12 minutes, the bell is at a depth of 400 ft. After 40 minutes the bell is at a depth of 1800 ft.

a) What is the average rate of lowering per minute?

b) Use the points (12,400) and (40,1800) to find a linear function that models the depth, y, in terms of the number of minutes, x.

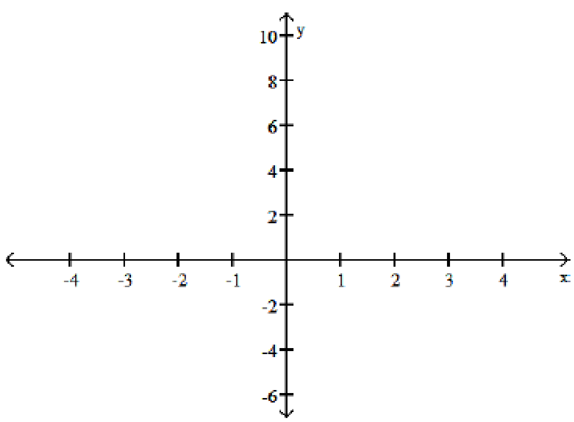
c) Use the function that you found in part b to find the depth after one hour.

3. (10 points) Consider the function $f(x) = -x^2 + 2x + 8$

a) Find the x-intercepts of the graph.

b) Find the vertex.

c) Sketch the graph of the function.



d) What is the range of the function?

4 & 5 Solve these problems. Please show your work.

4. (5 points) You inherit \$10,000 with the stipulation that for the first year the money must be invested in two stocks paying 6% and 11% annual interest, respectively. How much should be invested at each rate if the total interest earned for the year is to be \$900?

5. (5 points) The rational function $C(x) = \dfrac{135x}{100 - x}, \quad 0 \le x < 100$

describes the cost, C, in millions of dollars, to inoculate x% of the population against a particular strain of the flu.

Determine the cost of inoculating 40% of the population. (Round to the nearest tenth, if necessary.)

What happens to the cost as x approaches 100?

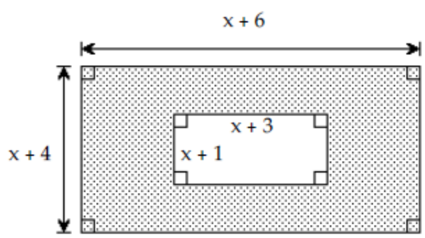
College Algebra Final - Part 2
Spring Semester 2012

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) **Simplify using properties of exponents.** $(100x^{10}y^8)^{1/2}$

A) $10x^5y^4$ B) $10{,}000x^{20}y^8$ C) $100x^5y^4$ D) $5x^5y^4$

2) **Write a polynomial in standard form that represents the area of the shaded region.**



A) $-6x - 21$ B) $6x + 21$ C) $x^2 + 20x + 21$ D) $14x + 27$

3) **Write an equation for the line passing through (5, 3) and parallel to the line whose equation is** $6x + y - 7 = 0$

A) $y = 6x - 33$ B) $y = -6x - 33$ C) $y = -\frac{1}{6}x - \frac{11}{2}$ D) $y = -6x + 33$

4) **Solve the inequality.** -4 ≤ -4x - 12 < 4

A) (-4, -2]

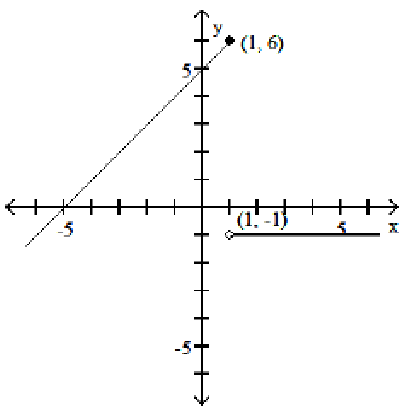
B) (-∞, -4) or [-2, ∞)

C) (-∞, -4]

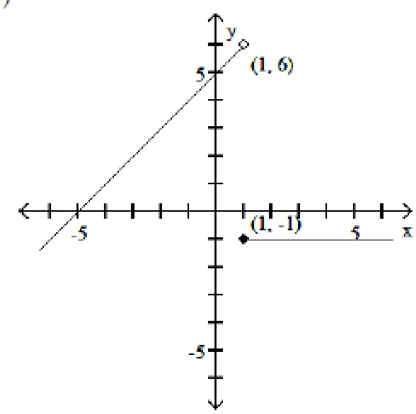
D) [-4, -2)

5) **Graph the function.** $f(x) = \begin{cases} x + 5 & \text{if } x < 1 \\ -1 & \text{if } x \geq 1 \end{cases}$

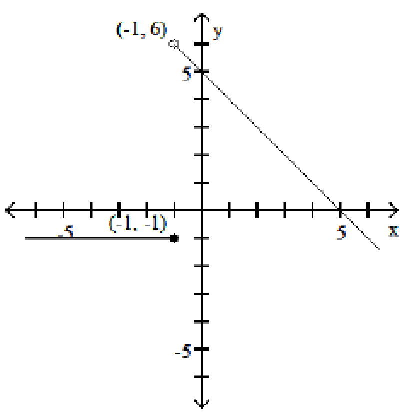
A)



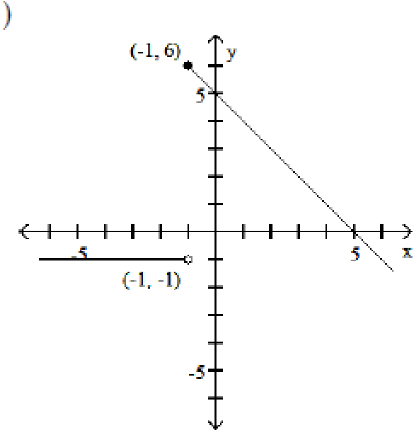
B)



C)



D)



6) **How many solutions does this equation have?** $2(4x - 7) = 8x - 14$

A) Infinitely many solutions
B) No solutions
C) One solution
D) Two solutions

7) **Find the distance between the pair of points.** (3, -5) and (5, -1)

A) $2\sqrt{5}$ B) $12\sqrt{3}$ C) 12 D) 2

8) **Solve the absolute value equation or indicate that the equation has no solution.**

$$|5x + 7| + 5 = 9$$

A) $\{-\frac{11}{7}, -\frac{3}{7}\}$ B) $\left\{-\frac{11}{5}, -\frac{3}{5}\right\}$ C) $\left\{\frac{3}{5}, \frac{11}{5}\right\}$ D) $\varnothing$

9) **Find the y-intercept of the graph of the function.** $f(x) = \dfrac{x - 13}{x^2 + 15x - 9}$

A) (0, 13) B) $\left(0, -\frac{9}{13}\right)$ C) $\left(0, \frac{13}{9}\right)$ D) none

10) **Find the domain of the function.** $f(x) = x - \frac{3}{x - 2}$

A) $(-\infty, 3) \cup (3, \infty)$
B) $(-\infty, 2) \cup (2, 3) \cup (3, \infty)$
C) $(-\infty, 2) \cup (2, \infty)$
D) $(-\infty, \infty)$

11) **For the given functions f and g , find the composition $(f \circ g)(x)$.**

$f(x) = \frac{8}{x + 7}$, $g(x) = \frac{5}{8x}$

A) $\frac{5x + 35}{64x}$
B) $\frac{64x}{5 - 56x}$
C) $\frac{8x}{5 + 56x}$
D) $\frac{64x}{5 + 56x}$

12) **Find the inverse of the one-to-one function.** $f(x) = \frac{7x - 3}{5}$

A) $f^{-1}(x) = \frac{5x - 3}{7}$
B) $f^{-1}(x) = \frac{5x + 3}{7}$
C) $f^{-1}(x) = \frac{5}{7x - 3}$
D) $f^{-1}(x) = \frac{5}{7x + 3}$

13) **Solve the equation.** $\frac{9}{x + 3} - \frac{7}{x - 3} = \frac{2}{x^2 - 9}$

A) {-25}
B) {25}
C) {50}
D) $\{\sqrt{70}\}$

14) **Solve the equation.** $(x + 11)^{3/2} = 27$

A) $\left\{\sqrt[3]{3} - 11\right\}$ B) {-2} C) {-8} D) {20}

15) **Find the solution set for the equation** $x^2 + 12x + 45 = 0$

A) {-9, -3}
B) {-6 - 3i, -6 + 3i}
C) {-6 - 9i, -6 + 9i}
D) {-6 + 3i}

16) **Solve the polynomial inequality.** $x^2 - 2x - 3 < 0$

A) $(-\infty, -1) \cup (3, \infty)$
B) (-1, 3)
C) $(-\infty, -1)$
D) $(3, \infty)$

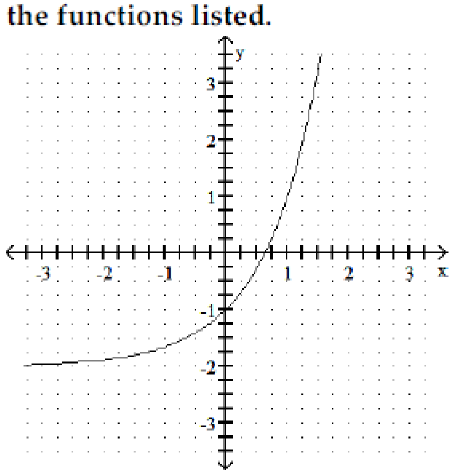
17) **Solve the logarithmic equation. Give the exact answer.** $\log_9 (x + 2) - \log_9 x = 2$

A) $\{\frac{1}{40}\}$ B) {9} C) {40} D) $\{\frac{2}{81}\}$

18) **Solve the exponential equation.** $e^{5x} = 3$

A) $\left\{\frac{\ln 5}{3}\right\}$ B) $\left\{\frac{\ln 3}{5}\right\}$ C) $\{5 \ln 3\}$ D) $\left\{\frac{3}{5}e\right\}$

19) **The graph of an exponential function is given. Select the function for the graph from the functions listed.**



A) $f(x) = 3^x + 2$ B) $f(x) = 3^{x - 2}$ C) $f(x) = 3^x - 2$ D) $f(x) = 3^x$

20) **Solve the system. What is the x-coordinate of the system?**

$-3x + 7y = -8$

$5x - 3y = 22$

A) 5 B) 1 C) -5 D) -1

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VITA

Mark Andrew Brown was born on March 12, 1969, in Rockford, Illinois. He received his K-12 education in the Grinnell-Newburg Community School District in Grinnell, Iowa, where he graduated with honors in 1987. Mark received an academic and athletic (track and cross country) scholarship to Mid-America Nazarene College, now MidAmerica Nazarene University (MNU), in Olathe, Kansas. He graduated summa cum laude in 1991 with a Bachelor of Arts degree in Mathematics and Mathematics Education.

After completing his bachelor's degree, Mr. Brown attended Wichita State University as a graduate teaching assistant in the department of mathematics and statistics. He was awarded the Master of Science degree in Mathematics in July, 1993.

In 1993, Mr. Brown received a position teaching mathematics at Haven High School in Haven, Kansas. He taught at Haven High School for seven years before assuming a position as a mathematics instructor at Hutchinson Community College (HCC). From 2000 to 2002, he taught at HCC, and in 2002, Mr. Brown began teaching at MNU. He began work toward his Interdisciplinary Ph.D. in Curriculum & Instruction and Mathematics at the University of Missouri-Kansas City in 2004. Upon completing his degree requirements, Mr. Brown plans to continue teaching mathematics and preparing future teachers of mathematics.

Mr. Brown is a member of the Association of Christians in the Mathematical Sciences, the Association of Mathematics Teacher Educators, Christian Educators Association International, the Mathematical Association of America, and the National Council of Teachers of Mathematics.