Outcomes in Required College Mathematics Courses

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Abstract

The U.S. Department of Education reports that college algebra has the highest failure and withdrawal rate among all postsecondary courses (Bonham & Boylan, 2011), with less than half of students passing this often-required course (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008, Reyes, 2010). The low rate of success in these college mathematics courses presents serious problems for students and colleges because it impacts retention and graduation rates, as well as the opportunities for students to select majors of their choosing.

In an attempt to provide further information on the results of initiatives to improve outcomes in required college mathematics courses, this study examined student outcomes at a small, four-year college that implemented a course redesign initiative. The study used a quantitative, quasi-experimental design. It compared assessment and course evaluation data from a required college algebra course and a redesigned (non-algebra) required college mathematics course, with the goal of determining if a significant difference in course outcomes existed. The study did not find any significant differences between the two groups of students with regards to the scores on departmental assessment tests or course value ratings from the course evaluations.

In spite of this, the findings of this doctoral thesis did yield valuable information regarding outcomes in college mathematics. It includes discussion of the problem of college mathematics, along with several research-based suggestions on improving outcomes in college mathematics. Additionally, several opportunities for future research are discussed, especially in regards to the study’s unintended findings regarding course withdrawal and failure rates.

Keywords: mathematics education, college mathematics, curriculum design, college algebra
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Chapter 1: Introduction

Statement of the Problem

This study sought to evaluate a redesigned, required mathematics course at a small, private college in Massachusetts through assessment and course evaluation data. The study aligns with research on mathematics education, college mathematics, college algebra, curriculum design, and assessment. The findings from this study are of particular value and interest to any educator seeking more knowledge regarding the effectiveness, or ineffectiveness, of both the traditional college algebra course and the less traditional college mathematics course that claims to teach students quantitative and financial literacy skills through real-world problem solving content.

Most colleges and universities in the United States require students to complete at least one course in mathematics (Strasser, 2011; Gordon, 2008; Chen & Zimbler, 2002) in order to graduate. For many institutions, the lowest level mathematics course that a student can take for credit to fulfill this graduation requirement is college algebra (Herriott & Dunbar, 2009). Currently, over a million students take college algebra, or a closely related course (Gordon, 2008).

Many students are not successful in their required college mathematics course (Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008; Halcrow & Hams, 2011), with less than half of students passing required courses (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008, Reyes, 2010). In fact, the U.S. Department of Education reports that college algebra has the highest failure and withdrawal rates among all post-secondary courses (Bonham & Boylan, 2011).
The low rates of success in these college mathematics courses present serious problems for students. Those who are not successful in their required mathematics course are less likely to stay in college (Gordon, 2008; Hall & Ponton, 2005). When students remain in college after failing college algebra they are less likely to graduate (Parker, 2005; Hall & Ponton, 2005; McCormick & Lucas, 2011; Cortés-Suárez & Sandiford, 2008).

Lack of success in college algebra also limits academic opportunities for college students (Reyes, 2010). Mandatory mathematics courses such as college algebra are often a “gateway” course, or prerequisite course, for other classes required for many college majors (Thiel, Peterman, & Brown, 2008; Choke, 2000; Catalano, 2010). Therefore, lack of success in college mathematics creates a barrier for student planning to pursue these majors because they fail to meet the prerequisites.

Students who are not successful in college mathematics are also less likely to possess and/or have difficulty convincing employers that they possess) the mathematical skills needed for 21st century jobs. Most employers seek employees with basic or advanced mathematical skills, who are able to effectively use math to solve problems (Eisner, 2010). In fact, more than 60% of employers specifically cite proficiency in mathematics as an essential workplace skill, and more than 90% of employers state that it is vital for their employees to think critically and problem solve (Eisner, 2010).

Failure to succeed in college mathematics also impacts lifetime earnings. Mathematical skills have been linked to wage determination in the United States in recent years (McIntosh & Vignoles, 2001), with increased performance in mathematics being linked to higher annual earnings (Hanushek & Woessmann, 2008; Tyler, 2004). A study of 200 college career centers found that the highest-earning college degrees all involve math skills (Eisner, 2010).
Colleges need to improve the low success rates in required college mathematics courses (Cortés-Suárez & Sandiford, 2008; Shorter & Young, 2011). With large numbers of college students struggling to pass the college-level math classes required to complete a degree and advance in the workplace, many colleges have initiated a wide range of reform initiatives that make improved outcomes in required undergraduate mathematics courses a major priority (Shorter & Young, 2011). However, no one redesign initiative has yet been universally accepted as best practice (Reyes, 2010), and colleges are trying various instructional and curricular reforms in an attempt to improve student success in required college math courses.

The Mathematical Association of America (MAA) published guidelines for designing undergraduate mathematics curricula to guide mathematics redesign initiatives. These guidelines, published by the organization’s Committee on the Undergraduate Program in Mathematics (CUPM), recommend that current and future college mathematics courses be designed to align with student interests and needs. Specifically, the guidelines state that undergraduate mathematics courses must align to students’ needs by focusing on a conceptual understanding of real-world mathematical models and must motivate student to solve quantitative problems using a variety of problem-solving strategies (Barker, et al., 2004).

The purpose of this quasi-experimental, causal comparative study was to retrospectively compare assessment and course evaluation data from a required college algebra course and a redesigned (non-algebra) required college mathematics course at a small, private college in Massachusetts.

This study provided the curricular decision makers at the college with information on the differences between the two required courses offered by the College in terms of student achievement and perceived value of course content. Specifically, it showed if a significant
difference existed in the achievement, as measured by a standardized math test with empirical data, of students from the two groups; and if a significant difference existed in student ratings of the value of course content, as measured by course evaluation ratings in the two courses.

Finally, analysis of the data showed if a statistically significant relationship occurred between students’ attitudes regarding value of course content in mathematics and students’ achievement in mathematics.

Many colleges across the United States have populations of students with low success rates in their required mathematics course (Gonzalez-Muniz et al., 2012; Reyes, 2010; Mayes, 2004), and the need to improve student achievement in these mathematics courses has been well documented (Bargagliotti, Bothelho, Gleason, Haddock, & Windsor, 2012; Dingman & Madison, 2010; Mayes, 2004). In an attempt to improve outcomes in mathematics courses, many colleges across the United States have implemented recommendations for effective curricula from organizations like the Mathematical Association of America (MAA) (Barker, et al., 2004) when redesigning their required math courses (Bonham & Boylan, 2011; Twigg, 2011).

A small, private college in Massachusetts is one example of a college with low rates of student success in their required college algebra class. For many years, withdrawal and failure rates for the course were too high. In fact, although College Algebra was taken by the largest percentage of students who were enrolled at the College, the course also had the highest withdrawal and failure rates of all of the math courses that the college offered.

In addition, other indicators showed unsatisfactory student outcomes in the college’s required college-level math classes. Scores on departmental assessment tests that were given as common end-of-course measures of student achievement were unacceptable for many students in
the college’s algebra course. Student satisfaction with the course content was also low, with student ratings showing that they did not believe that it would be valuable to them in the future.

The faculty in the mathematics department at this College realized that the combination of low achievement scores and poor value ratings indicated that they needed to make changes to the required College Algebra course. Not only did the students in the College’s College Algebra courses needed to improve their math skills, student perception of the value of the mathematics content also needed to improve. Faculty needed to create a course that would produce better outcomes with regards to student achievement and attitudes towards the value of the course content.

After examining the MAA’s Committee on the Undergraduate Program in Mathematics (CUPM) guidelines for developing successful college math courses, the mathematics faculty decided to completely redesign their college algebra course. After some consideration, they decided that in lieu of maintaining the requirement for a course completely composed of traditional algebraic content, they would implement a redesigned course that would emphasize the application of mathematic skills to solve authentic math problems. This new course would focus on a conceptual understanding of real-world mathematical concepts to facilitate students’ ability to solve quantitative problems using a variety of problem-solving strategies (inductive, deductive, and algorithmic).

The redesigned course, called Foundations of Quantitative Reasoning, provides students with opportunities to learn real-world mathematical concepts that are essential for financial and consumer literacy. For example, using and converting units of measure; solving problems involving two and three dimensional spaces; solving problems using percentages, powers, order of magnitude, rounding with significant digits, and error measurements; applying basic
components in a descriptive statistical study; examining similarities and differences between linear and exponential growth, especially in applications of personal finance; solving problems commonly encountered in consumer mathematics; and analyzing and drawing conclusions from data. Specific topics covered in the redesigned course include, but are not limited to compound interest and its relationship to savings and debt (e.g. credit cards, student loans, mortgages), personal tax basics, insurance concepts, stock/bond concepts, investment plans, and federal budget concepts.

In the Fall Semester of 2013, the College stopped offering College Algebra as their required general education mathematics course and began requiring all entering students who required an entry-level mathematics course to enroll in their redesigned Foundations of Quantitative Reasoning course. Faculty hoped that this new course, dubbed “the math you really need,” would produce better outcomes than their college algebra course because it would better align with students’ interests and needs, allowing their students to recognize and master the mathematical skills needed to succeed in college and beyond.

Anecdotal evidence of the implementation of the redesigned course seemed to indicate positive outcomes. When asked about the success of the redesigned course implementation, the College’s Dean of the School of Liberal Arts and Sciences, along with several of the college’s mathematics faculty, reported that they believe that the course redesign was successful. In their opinion, student satisfaction and student achievement in the redesigned course was the same or greater than it was in their previously required college algebra course. However, when asked for concrete data to substantiate the success of the course, these curricular leaders admitted that no formal study measuring student outcomes has been conducted, and the College did not have any
empirical data showing whether or not their redesigned course improved outcomes relating to student achievement and/or student satisfaction.

Obtaining empirical evidence of student learning and/or satisfaction in these courses was necessary (Parker, 2005; Dingman & Madison, 2010) so that the institution could use quantitative data to determine if their efforts had been successful. These quantifiable outcomes would allow the College’s decision makers to determine the success (or lack thereof) of their redesigned course. After all, when an organization initiates a curricular change to improve their students’ outcomes, they must be sure to validate whether or not the new changes increase student success (Carroll & Gill, 2012; Reyes, 2010). Providing empirical data helps organizations, such as institutions of higher education, decide whether the curriculum should continue to be offered in its current format or undergo another revision (Dingman & Madison, 2010). It also provides quantifiable information to decision makers who are trying to justify their support (or lack thereof) for the continued implementation and funding of the course (Carroll & Gill, 2012; Cole, Bergin, & Whittaker, 2008).

College students who take mandatory courses like college algebra generally report negative attitudes (Catalano, 2010 Sierpinska, Bobos, & Knipping, 2008; Cortés-Suárez & Sandiford, 2008) regarding these courses. Students often perceive their course material in required mathematics as unimportant and irrelevant (Sierpinska et al., 2008; Bonham & Boylan, 2011) to their future personal and professional lives, and give these as reasons for their lack of success.

Student ratings of the value of the course content are significant for several reasons. Student perception of the value of the course content can impact their acquisition of mathematical content material (Ma & Xu, 2004). It can also serve as an indicator of the
students’ overall achievement in the course (Chouinard, Karsenti, & Roy, 2007; Azar, Lavasani, Malahmadi, & Amani, 2010), with students with high perceptions of task value in mathematics tending to have higher achievement scores than those with low task value perceptions (Azar et al., 2010). In addition, value ratings have been linked to rates of retention (Thompson & McCann, 2010) in both the course and college (Chow, 2011), with students who have higher value ratings more likely to persist in the course and college. Value ratings can also predict future enrollment in other mathematics courses (Feather, 1988a; Meece, Wigfield, & Eccles, 1997), potentially impacting a student’s choice of degree or career.

Despite these findings, research regarding attitudes toward course value and math achievement is also incomplete, because “methods to systematically improve students’ attitudes toward mathematics have not been a major focus for researchers, especially in college mathematics courses for non-math majors” (Hodges & Kim, 2013, p. 59). That is, although the relationship between attitudes toward value and math achievement has been documented (Joo, Lim, & Kim, 2013; Singh, Granville, & Dika, 2002; Cole et al., 2008; Chouinard et al., 2007; Azar et al., 2010), more overall research to investigate the strength of the relationship is needed (Carroll & Gill, 2012). Also, more age specific research regarding the links is needed on the relationship between value and performance (Eccles & Wigfield, 2002).

The results of this study help to strengthen the existing research because it examines student achievement and perceived value of course content, and then determines if a significant relationship between these variables exists. In addition, because this study measured outcomes from traditional college-aged students enrolled in the required math courses at the college highlighted in this study, it also helps to strengthen information on full-time college students between the ages of 18 and 25 years old.
Without this study, this College lacked the necessary evidence regarding the effectiveness of their redesigned math course. They did not know if their redesigned course was actually producing the intended student outcomes, because they were deficient in empirical data analysis that indicated if there was a significant difference in the student perception of the value of course content, a significant difference in achievement as measured by the departmental assessment test, and if the research-based relationship between value and achievement was true at their site.

Using data from students in a traditional algebra class and in a redesigned course composed of more real-world content, this study looked at student outcomes through a comparative lens. It compares results of identical assessment tests from students in both courses to determine if there is a significant difference in achievement scores of the groups. Also, because the value that a student places on a course’s content has been shown to be significant (Joo et al., 2013; Singh et al., 2002; Cole et al., 2008; Chouinard et al., 2007; Azar et al., 2010), the study measured the value ratings of students in each group and then determined if a correlation between students’ achievement and ratings of value of course content existed when only curricular changes were implemented. The data also provided empirical evidence that can be used for future curricular development decisions by the mathematics department at the College where the study was conducted. It also adds to the existing research on the topics of content value and college mathematics.

**Significance of Research Problem**

Lack of success in required college mathematics courses has significant impact on students well after the course ends. Students who are not successful in their mathematics courses often later experience issues with persistence (Gordon, 2008; Hall & Ponton, 2005), graduation (Parker, 2005; Hall & Ponton, 2005; McCormick & Lucas, 2011; Cortés-Suárez & Sandiford,
These problems are significant, not only for the students themselves, but also for the colleges that they attend (DeBerard, Spielmans, & Julka, 2004). In the broadest sense, it may also be argued that this issue extends beyond the academic context to the overall United States’ economy (Thiel, Peterman, & Brown, 2008).

The college mathematics course requirement is often said to act as a “gateway,” or prerequisite, for other courses that are required in a number of college majors (Thiel, Peterman, & Brown, 2008; Catalano, 2010). Therefore, students who are unable to experience success in their college math courses are often unable to meet the prerequisites for the other required courses, and are then forced to make the “life altering” decisions involving their choice of college major (Hall & Ponton, 2005). A student’s decision to change their program of study may ultimately impact their future employability and career (Stacey, et al., 2006).

Since success in college mathematics is also related to college retention, students who have difficulty in math are less likely to graduate. Math skills are related to overall success in college, regardless of major (Waits & Demana, 1988), and students who are successful in math are more likely to both stay in college longer and eventually graduate from college (Berenson, Carter, & Norwood, 1992).

Staying in college matters because “the implications of leaving a college without obtaining a degree are many” (DeBerard, Spielmans, & Julka, 2004, p. 66). For instance, students who fail to graduate from college due to problems associated with their required math course may experience significant disadvantages in both their professional and personal lives given that college graduates experience increased lifetime earnings, better health, and increased civic engagement (Brock, 2010; Baum, et al., 2010; Crellin, Kelly, & Prince, 2012; DeBerard,
Spielmans, & Julka, 2004). In addition, colleges themselves lose significant financial resources in terms of tuition, fees, and alumni contributions every time one of their students drops out of their institution.

Failure to succeed in a required mathematics course can also create significant problems for future career success (Ananiadou, Jenkins, & Wolf, 2004; Tyler 2004; Chioke, 2000; Hanushek, Peterson, & Woessmann, 2010) because a large number of jobs require mathematics skills. For instance, by 2018, more than three million jobs created in science, technology, engineering, and mathematics (STEM) fields will be created (Maltese & Tai, 2011). In addition, mathematics skills are also needed in entry level, non-STEM jobs, with about sixty-two percent of entry-level jobs in the next decade requiring proficiency in algebra, geometry, data interpretation, probability and statistics (Hanushek, Peterson, & Woessmann, 2010).

Strong math skills can increase the likelihood of acquiring a job. “Quantitative skills are in such high demand in the labor market” (Mitra, 2002), and employers frequently seek job candidates with good math skills. In fact, resumes showcasing candidates with documented math skills have been shown to sometimes positively affect employer interest (Koedel & Tyhurst, 2012) over resumes from candidates who do not showcase these skills.

Even after finding a job, students with poor math skills are still significantly impacted by their lack of mathematical prowess because they are more likely to earn a lower wages than their counterparts who have superior mathematical skills (Tyler, 2004). Similarly, most of the jobs requiring more math tasks have been shown to pay substantially higher salaries (Handel, 2003; Murnane, Willett, & Levy, 1995) than jobs that do not require math skills.

With student success rates at less than 50% for required courses like college algebra (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008;
Gordon, 2008, Reyes, 2010), the need to improve success rates in required math courses is both significant and well documented (Shorter & Young, 2011; Mayes, 2004; Bargagliotti et al., 2012). When a college math class doesn’t effectively provide students with the mathematical skills necessary for their future personal and professional success, significant problems may be created for both the students and the U.S. economy. For this reason, more research is needed for college mathematics departments that are trying to identify effective and ineffective courses for teaching mathematical skills to college undergraduates.

Positionality Statement

Creswell (2007) said that it is important for researchers to thoroughly comment on any “past experiences, biases, prejudices, and orientations that have likely shaped the interpretation and approach to the study” (p. 208) in order to acknowledge potential bias in the study. For this reason, it is important to address my positionality as the sole researcher of this project.

I conducted this research from the perspective of an Assistant Professor Professor at a small, four-year college in Massachusetts where I teach information technology management and mathematics to students enrolled in non-STEM (science, technology, engineering, mathematics) majors. Prior to my full-time position at this college, I taught mathematics at several other colleges as an adjunct instructor, including the College where the study was conducted. (However, I was never involved with the redesign of the course.)

My personal experiences teaching college mathematics actually created my interest in studying college mathematics courses. Teaching students who were dissatisfied with the course content of traditional college algebra courses, and who struggled to earn satisfactory grades in these courses, created my desire to study alternatives to the most commonly offered college algebra course. I wanted to discover an effective way to raise student achievement and student
satisfaction because several students, who were enrolled in required mathematics courses at the colleges where I have taught, have often failed to succeed in their required mathematics course; they do not meet the course outcomes and objectives and often have negative attitudes toward the content of the course.

I began searching for a solution to help alleviate both the students’ struggles with content, and their negative attitudes toward the course content. I wanted to find a research-based, effective alternative for the students in both the college where I teach and in other colleges across the United States. While I found that some colleges were using the guidelines from organizations like the MAA to redesign courses (Ellington, 2005; Van Perusem et al., 2012; González-Muñiz et al., 2012; Mayes, 2004; Twigg, 2011) for improved student success and/or satisfaction, uniformity in implementation and results did not exist.

As a result, I decided to combine the existing research with the in-depth data analysis on a college’s mathematics redesign initiative and conduct this study because I wanted to determine if the course redesign that replaced traditional college algebra classes with a course that taught real-world mathematics content at a college where I had previously taught was effective.

While I recognize that my experiences teaching at the college level, and at the College where the study was conducted, may have given me perspectives that may differ from others with different backgrounds and experiences, I made every attempt to keep any personal biases out of this research in order to conduct this study as an unbiased external evaluator.

**Research Central Questions/Hypothesis**

1. Is there a significant difference between the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems?
2. Is there a significant difference between student ratings of the value of course content of students who completed a traditional college algebra class and those students who completed a redesigned mathematics course?

3. What is the relationship between student ratings of the value of course content and achievement for students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems?

Statistical testing was performed on the following hypotheses:

1. Hypothesis I: There is a significant difference in the math achievement of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by an assessment test.

2. Hypothesis II: There is a significant difference in the student ratings of the value of course content of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by course evaluation data.

3. Hypothesis III: There is a significant relationship between student attitudes regarding value of course content in mathematics and student achievement in mathematics.
**Theoretical Framework**

**Motivation theory.** One theoretical model sometimes used for mathematical learning is motivation theory. Motivation theory explains “how the motive to achieve and the motive to avoid failure influence behavior in any situation where performance is evaluated against to some standard of excellence” (Atkinson, 1957, p. 371); that is, it attempts to explain people’s choice of tasks, their persistence on those tasks, their vigor in carrying them out, and their performance on the tasks (Wigfield & Eccles, 2000).

In the 1950s, John Atkinson (1957) published seminal work on motivation theory when he researched achievement motivation. In his work, he stated that three factors motivate individuals to achieve: their motivation to succeed, their perception of the likelihood of their success, and their perception of the value of the success (Atkinson, 1957). Additionally, Atkinson found that an individual would be most likely to engage in tasks having a moderate level of difficulty, and less likely to engage in tasks that the individual perceived to be too easy or too difficult.

Atkinson also found that students’ values and ability perceptions were inversely related; students with a high perception of success were less likely to engage in a task that they perceived to be easy because they would not be as motivated to be successful on an easy task (Feather, 1998a, 1998b, 1992). These findings were important to the study on motivation theory because they indicated that an individual’s need for achievement impacted by the likelihood that they would engage in, and succeed at, a given task (Atkinson, 1957). Atkinson’s research was followed up by other researchers (Feather, 1988a; Feather, 1988b; Feather, 1992; Wigfield & Eccles, 1992; Eccles & Wigfield, 2002), who began to study the impact of values on decision making and helped to extend the theory that Atkinson originally developed. For instance, in the
1970s, Ajzen & Fishbein (1973) were instrumental in the emergence of expectancy-value theory, which is a type of motivation theory that states that an individual’s choice, persistence, and performance can be explained by the extent to which they value the activity (Atkinson, 1957; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992).

**Expectancy-value theory.** Later, Norman Feather’s research (1988a, 1988b, 1992) was instrumental in extending the expectancy-value model. Through his study on student value ratings of math and English courses, Feather (1988a) determined that values guide behavior and motivate individuals to achieve; specifically, he showed that people’s values guide their decisions to complete, or not complete, a specific task. Their values cause them “to perceive some potential events and activities as desirable and worth approaching or continuing with, and other aspects as undesirable, to be avoided or terminated” (Feather, 1988a, p. 277).

Feather (1998a, 1998b, 1992) also found that students’ values and ability perceptions were positively related with students who value a task being more likely to successfully complete the task than those students who did not perceive a value in the task. In other words, Feather argued that values motivate individuals to perform acts that they think should be done, and that individuals who value an activity are more likely to perform well on the associated task in the present or the future, while individuals who do not value an activity are not likely to perform well on the associated task.

Jacquelynne Eccles’ (Parsons’) research regarding values and achievement performance (Wigfield & Eccles, 1992; Eccles & Wigfield, 2002) was also instrumental in contributing to expectancy-value theory. She found that the “expectancy-value model has been influential in guiding research on how children’s expectancies and values relate to their achievement performance” (Wigfield & Eccles, 1992, p. 39). Specifically, Eccles’ findings
showed that people’s beliefs regarding the value of a task are directly related to their achievement performance and persistence on the task (Eccles & Wigfield, 2002), which indicated that expectancies and values are positively related to each other (Eccles & Wigfield, 2002), not inversely related to each other as Atkinson proposed.

The research conducted by Eccles et al., (1983) applied expectancy-value theory directly to student achievement. They found that children’s values impact their performance, persistence, and choice of tasks (Wigfield & Eccles, 1992). As a result, students’ behavior regarding achievement on an academic task is related to their expectations regarding the value of the task; that is, if students expect the task to benefit them in their future personal or professional lives, they are more likely to view the task as important. For this reason, students who perceive an academic task as having worth may be more motivated to persist with and succeed in the task (Greene, Miller, Crowson, Duke, & Akey, 2004; Husman & Lens, 1999; Miller & Brickman, 2004; as cited in Tabachnick, Miller, & Relyea, 2008) while individuals who feel that the cost of engaging in a specific activity will encompass all of the negative aspects of completing the task (Wigfield & Eccles, 1992; Eccles & Wigfield, 2002) are less likely to successfully complete the task. That is, individuals who feel that their activity is too “costly,” that it takes too much time or effort to complete, are unlikely to be motivated to succeed in the activity (Meece, Glieneke, & Burg, 2006).
**Theoretical framework used in this study.** Today, expectancy-value theory exists as a theoretical model under the umbrella of motivation theory. It is commonly used to guide many studies on motivation topics (Azar et al., 2010). It is the theory that framed this study on outcomes in required college mathematics courses.

Expectancy-value theory was an appropriate framework to guide this research. Since this study sought to determine if students can raise the achievement scores in their college mathematics course by placing more value on the content a theory like expectancy-value theory, which examines the impact of a person’s perceived value of an activity on their achievement motivation, it is a proper framework for this study.

Expectancy-value theory often examines two factors relating to motivation: students’ expectation for success on a task, and their perception of the value of task (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Azar et al., 2010). Both components are important because expectations determine if individuals believe that they can accomplish a task (Wigfield & Eccles, 2000) while value for the task is the “incentive for engagement in academic activities” (Azar et al., 2010, p. 943).

While both components of expectancy-value theory are significant, this study primarily focused on the students’ perceived value of task, instead of their expectation for success. That is, this study sought to examine the relationship between student ratings of the value of course content and achievement for students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems.
Task value and mathematics. Expectancy-value theory states that an individual’s task value ratings determine their motivation to perform and succeed (Wigfield, 1994). Task value ratings are associated with choice of behaviors, persistence, and effort (Wigfield & Eccles, 2000). They are also directly related to ratings of student satisfaction (Bong, 2001; Joo et al., 2013; Chiu et al, 2007) and academic achievement (Eccles & Wigfield, 2000).

Task value was examined in this case study because it has been shown to have several significant implications on student persistence in mathematics (Eccles & Wigfield, 2002). Specifically, students who have higher ratings of task value associated with their college mathematics course exert more effort than students who have lower ratings of task value (Cole et al., 2008; Joo et al., 2013). They also persist in their mathematics course for a longer period of time, making it less likely that these students will drop out of their required mathematics course (Joo et al, 2013: Wigfield & Eccles, 1992).

Not only do task value ratings significantly impact future student enrollment decisions in mathematics (Eccles et al., 1983; Parsons, Adler, & Meece, 1984; Eccles, 1987), they are even more significant than student expectancy ratings in mathematics. As Wigfield and Eccles (1992) found, “students’ valuing of math predicted their intentions to keep taking math more strongly than their expectancies for success” (p. 17). Task value ratings are more significant because students who have higher ratings of task value for mathematics are more likely to pursue additional mathematical learning in the future (Joo et al., 2013) while students with lower task value ratings are less likely to participate in additional mathematics courses.

Task value ratings also positively correlate with achievement in mathematics (Azar et. al., 2010). For instance, students who have high task value ratings in intrinsic value are generally highly motivated to succeed and become educated in mathematics because they have
an appreciation of the mathematics itself (Miller, DeBacker, & Greene, 2000); they are intrinsically motivated to achieve.

Likewise, students who have high task value ratings of utility value experience success in mathematics because they have extrinsic motivations for succeeding in mathematics; their future goals are well-defined, and these goals require that they are successful in their college mathematics course. These students are motivated to persist and achieve in school mathematics (Eccles et al., 1983; Miller, DeBacker, & Greene, 2000) and more likely to be successful because they believe that their success in school impacts their ability to reach their future goals (Miller, DeBacker, & Greene, 2000). Specifically, students who possess a high utility value often believe that achievement in mathematics will help them obtain career success and often associate mathematics achievement as a qualification to help them get a prestigious job (Eccles & Wigfield, 2002). For instance, a student who values the mathematics that they are taking because they know that they need it for a specific career path that requires the mathematics is more likely to persist and succeed (Miller, DeBacker, & Greene, 2000). Additionally, students with high ratings of utility value often have more than one type of motivation to succeed; they are also likely to experience intrinsic motivation in their classes because of the joy and satisfaction they encounter when moving toward their goals because they know they are improving their competence in a necessary area (Miller, DeBacker, & Greene, 2000).

While high ratings of task value help motivate students to achieve, low ratings of task value can hinder student success in mathematics because they may not be motivated to succeed. Even students who have the cognitive ability to succeed in their college mathematics course have been found to be unsuccessful when they do not value the mathematics they are learning or have not yet fully realized their aspirations (Miller, DeBacker, & Greene, 2000). For instance, Cole et
al. (2008) found that even students who believe that they can succeed at an activity may choose not to participate if they have low task value ratings.

Students with low ratings of task value often believe that the mathematics they are learning will be not useful to them in their future lives or careers (Miller, DeBacker, & Greene, 2000). As a result, these students may not be motivated to succeed or persist in their college mathematics course because they do not feel that mathematics is an essential skill for career attainment and success. For this reason, when “students do not perceive current academic activities as instrumental to attaining personally relevant future goals, we question whether those activities will have sufficient incentive value to foster the level of student cognitive engagement necessary to produce meaningful learning” (Miller, DeBacker, & Greene, 2000, p. 258).

Conclusion

This study examined the impact of a redesigned math course at a small, private college in Massachusetts by analyzing and comparing student outcomes from both the previous and new mathematics course. It analyzed student achievement, as measured by a standardized college mathematics assessment administered in both courses. It also analyzed students’ perceived value of course content as measured by course evaluations administered in both courses. The study also examined the relationship between achievement and value ratings using expectancy-value theory to frame the research and findings. The empirical data that this study from this study provided guidance for curriculum decisions at the College where the study was conducted, and it may also help guide college mathematics departments facing similar challenges with their courses.
Chapter 2: Literature Review

Introduction

This chapter contains a comprehensive review of literature that is pertinent to this study, which assesses outcomes from a redesigned college mathematics course. It contains a summary of research relating to required college mathematics courses. It provides information relevant to the study conducted for this doctoral thesis, as well as important information for anyone interested in required college mathematics courses.

A summary of both historical and recent information pertaining to required college mathematics courses is included. Concerns regarding the current lack of student success in required college mathematics courses are also presented, along with specific information regarding the recent “debate” regarding college algebra as a college mathematics requirement. Additionally, specific research-based suggestions that should be considered by colleges when designing required mathematics courses for their students are summarized.

The impact of student attitudes on mathematics achievement is presented. Background information on motivation theory and expectancy-value theory, which are used as the theoretical framework for this study, is also given. Additionally, research on the impact that the tenets of expectancy-value theory have on student achievement in mathematics is included.

Results from both successful and unsuccessful examples of required college mathematics courses are included, along with research-based explanations for the causes of the successes and failures of the courses. Research-based suggestions for successful college mathematics courses are also given, and information regarding redesign initiatives at several institutions that have attempted to remedy the lack of student success in required college mathematics courses is included.
History and Benefits of Algebra

The earliest algebra was developed about 4000 years ago in Mesopotamia (Katz, 2007). However, despite its longevity, the study of algebra has only become required for the majority of students during the second half of the twentieth century (Usiskin, 2004; Fast Facts, 2015). Today almost all high schools require students to take algebra (Usiskin, 2004; Fast Facts, 2015), and many colleges also require an algebra course for students (Mayes, 2004; Schield, 2008; Ellington, 2005; Gordon, 2013). By 1998, over 90% of high school students were taking at least one year of algebra (Usiskin, 2004). In colleges, algebra is typically a mandated general education requirement for non-STEM (science, technology, engineering, mathematics) majors (Schield, 2008; Herriott & Dunbar, 2009; Gordon, 2008), with 211,000 students taking college algebra each semester in 2000 (Ellington, 2005).

There are many reasons for learning algebra. Through interpretation and comprehension of the symbols and terminology that it uses (Barnard, 2002), it teaches students to understand the relationships among quantities that are becoming more present in everyday language (Usiskin, 2004; Huckstep, 2003). Algebra explains everyday events and those that occur naturally in life, in real-world scenarios (Usiskin, 2004; Huckstep, 2003). It can be used to explain outcomes from flipping coins, playing the lottery, and the impact of natural forces on architectural structures (Usiskin, 2004; Usiskin, 1995). It can also provide explanation of prevalent topics such as growing exponentially, growing logarithmically, varying directly, varying inversely, and lines of best fit (Usiskin, 2004; Gordon, 2004; Gonzalez-Muniz et al., 2012).

Often viewed as a universal language (Stacey et al., 2006; Barnard, 2002), algebra has many uses and benefits for students (Usiskin, 1995; Huckstep, 2003). Algebra teaches students to read and solve formulas (Barnard, 2002; Usiskin, 1995; Gordon, 2004). It also teaches
problem solving (Stacey et al., 2006; Steen, 1992) through the understanding of mathematical relationships; it provides practice working with abstract ideas that are used across fields to solve problems (Barnard, 2002; Stacey et al., 2006). It also teaches problem-solving skills to help learners to think and argue logically (Barnard, 2002; Usiskin, 1995; Steen, 1992; Hagerty, Smith, & Goodwin, 2010).

Understanding algebraic formulas and functions helps learners to solve everyday problems where one quantity is known and another quantity needs to be determined (Usiskin, 1995; Usiskin, 2004; Manly & Ginsburg, 2010). For instance, common calculations such as perimeter, area, income tax, loans, sales tax, discounts, and related money matters are applications of algebra (Manly & Ginsburg, 2010; Usiskin, 2004). And although many people can obtain answers to everyday math problems without using a formula, those people who are able to apply an algebraic formula are generally able to perform the calculation more quickly (Usiskin, 1995; Usiskin, 2004). In addition, people who can apply algebra are also less likely to make unwise decisions based on a calculation or be deceived by someone providing false information regarding the calculation (Usiskin, 1995; Usiskin, 2004).

Individuals possessing algebraic understanding are also able to manipulate algebraic formulas, enabling them to solve a problem with a different context for any unknown quantity without having to learn a separate formula (Usiskin, 1995; Barnard, 2002). For instance, a person with knowledge of algebra is most likely able to manipulate the formula for the area of a rectangle so that they can determine the length or width if they know the area of the rectangle, along with one of the dimensions of the sides (Usiskin, 2004). Or, a person can determine how much food they can eat and still stay within the parameters of a certain diet, how much the
population of a particular region will be if it grows at a given rate, or how to ship oil around the world at the lowest price (Usiskin, 2004).

**Failure of College Algebra**

Over a million students take college algebra, or a closely related course, each year (Gordon, 2008). However, less than half of students who enroll in a required mathematics course such as college algebra successfully complete the course (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008, Reyes, 2010). In fact, the U.S. Department of Education recently reported that college algebra has the highest failure and withdrawal rates for post-secondary courses (Bonham & Boylan, 2011).

While students cite dissatisfaction with the content and poor performance on tasks related to the course content as reasons for withdrawing from or failing their required mathematics course (Gordon & Nicholas, 2013), lack of student success in college algebra is a multi-faceted issue that has many causes. Some students are unsuccessful because they are simply disinterested in mathematics; they feel algebra is boring (Steen, 1992; Gordon & Nicholas, 2013) or irrelevant (Stacey et al., 2006; Steen, 1992). These students feel that algebra is “a dead language with a myriad of rules that seem to come from nowhere, and with applications that are viewed as puzzles, like chess problems (Usiskin, 2004, p. 150). They also feel there is little connection between what they do in math class and what they encounter in other disciplines, their professions, or in their everyday lives (Gordon, 2004; Gordon & Nicholas, 2013; Nicol, 2002; Usiskin, 2004).

Many students also blame the content itself for their lack of success; they complain that the mathematics content is too difficult for them to understand (Sierpinska et al., 2008; Gordon & Nicholas, 2013). They also feel that the difficult content makes completing the course more
difficult and time consuming than completing the work for other courses (Gordon & Nicholas, 2013).

Students also blame their lack of success on the structure of the course (Sierpinska et al., 2008). They feel that the pacing of the course is too quick and that their mathematics instructors do not provide a sufficient structure for adequate academic and moral support (Hourigan & O’Donoghue, 2007; Sierpinska et al., 2008), with some students stating that they drop the course based on the recommendation of their teachers (Gordon & Nicholas, 2013). Other students feel that the quick pace results in their lack of success because it results in rote learning, without time to focus on concepts necessary for adequate understanding (Sierpinska et al., 2008).

The problems relating to lack of student success in college algebra are significant; they often breed frustration in students, causing many to fail or drop the course (Hodges & Kim, 2013; Ma & Willms, 1999). Furthermore, students’ lack of success in the course, combined with their failure to appreciate the value of the mathematics they are learning in the course teaches the students to devalue or disregard all mathematics (Sierpinska et al., 2008; Steen, 1992; Ma & Xu, 2004). As a result, these students may not develop into independent mathematical problem solvers (Sierpinska et al., 2008; Hagerty, Smith, & Goodwin, 2010).

**Underlying Causes of the Lack of Success**

One reason for lack of student success in college algebra is the unpreparedness of the students who enroll in the course; they do not have enough essential math skills needed to be successful in their college math course (Hourigan & O’Donoghue, 2007; Carroll & Gill, 2012; Gordon & Nicholas, 2013; Berenson et al., 1992). They have little competence in algebraic manipulation and are unable to use or apply math beyond one- or two-step problems (Hourigan & O’Donoghue, 2007). They also have difficulty solving and applying problems from other
disciplines (Gordon, 2004). As a result, students entering these classes have difficulties with success and engagement in the content (Gordon & Nicholas, 2013).

Students’ pre-college math experiences do not match the nature of the college level mathematics courses (Hourigan & O’Donoghue, 2007); even though most students have already taken algebra before they enroll in college (Gordon, 2004), students enter college underprepared, with large gaps in their math knowledge, and an inability to reason mathematically (Hourigan & O’Donoghue, 2007). As a result, most colleges require these students to repeat the same algebra material that they were given in high school because many of the students failed to master algebra when it was first presented (Usiskin, 2004; Gordon, 2004).

Many theories exist as to why so many students are entering college with poor math skills. For instance, students may have failed to master the algebra content during high school because of a decreasing focus on mathematics during their middle and high schooling, because students in grades 7 to 12 often experience a documented decrease in interest in mathematics (Köller, Baumert, and Schnabel, 2001). Or, researchers like Hourigan and O’Donoghue (2007) believe that the emphasis on passing the mathematics portion of state competency exams may explain why many students entering college have weak math skills. They feel that the “obsession” with preparing students to be successful on the state test may have inadvertently caused secondary school teachers to limit practice with independent mathematical learning with unfamiliar problems because they feel obligated to “teach to the test” (Hourigan & O’Donoghue, 2007). As a result, high school graduates are unprepared for the college mathematics curriculum because they have limited problem-solving experiences with unseen/different mathematical problems (Hourigan & O’Donoghue, 2007) and are unable to solve college level or real-world math problems.
In addition, students’ attitudes also contribute to their lack of success in college algebra; Gordon and Nicholas (2013) found students’ poor feelings regarding self-efficacy and mathematics cause students to lose confidence in their ability to be successful in mathematics. In fact, self-efficacy was a stronger predictor of mathematics achievement than general mental ability (Stevens, Olivárez, & Hamman, 2006); similarly, Reyes (2010) found that some students will fail to succeed in college mathematics because they fear the subject of math, or simply because they believe that they do not possess the ability to be successful.

**Concerns and Implications**

Colleges are in a difficult position; they know that the students enrolling in their colleges need broader preparation in mathematics (Gordon, 2004), and they try to educate their students accordingly (Hourigan & O’Donoghue, 2007). However, colleges are faced with several obstacles in providing the students with adequate preparation in mathematics. First, students enrolling in college often enter with inadequate skills in mathematics (Hourigan & O’Donoghue, 2007), making them immediately less likely to succeed in their required mathematics course because students who weren’t successful in high school math are unlikely to succeed in their college math (Hastings, 2006). Students have also established poor attitudes toward mathematics by the time they enroll in the required college course (Catalano, 2010; Sierpinska et al., 2008; Cortés-Suárez & Sandiford, 2008), making them less likely to succeed.

Under preparedness in college mathematics is a concern because it has implications for students’ future success in college, and much work still needs to be done before college level instructors can be confident that their incoming students are adequately prepared (Hourigan & O’Donoghue, 2007). Berenson et al. (1992) linked the math skills and math placement of students entering college to the likelihood that they will complete college, finding that students
entering college with poor math skills are least likely to complete college. Likewise, Waits and Demara (1988) found that the mathematical skills of students entering college are directly related to the likelihood that they will complete their bachelor’s degree program. As an example, a study at one of the largest community colleges in the country supports the significance of success in required college mathematics courses such as college algebra as an important factor in degree completion; Miami Dade Community College used data from their college algebra students to determine that college algebra was the course most responsible for the college’s attrition rate in their 2003-2004 report (Gordon, 2013).

Lack of success in college algebra also impacts choice of college major. As the prerequisite to most other college level mathematics classes, college algebra is the gateway to students’ future study (Reyes, 2010; Stacey et al., 2006) because students who are not successful in college algebra will be unable to enroll in some courses required in certain majors. Furthermore, because algebra is the foundation of calculus, students who do not have a strong understanding of algebraic processes and concepts are unlikely to meet the requirements to enroll and succeed in calculus (Hagerty, Smith, & Goodwin, 2010; Usiskin, 2004), which is a requirement for many college majors.

Lack of success in a required college mathematics course, such as college algebra, is also important to students’ success beyond the classroom; students must now have an adequate level of quantitative understanding in order to make informed decisions in their personal, academic, and professional lives (Agustin, Agustin, Brunkow, & Thomas, 2012). Success in math is often linked directly to students’ future career success, or lack of success, while failing to be successful in a college math course has been linked to graduates’ ability to meet the criteria in job descriptions (Hourigan & O’Donoghue, 2007; Barnard, 2002) and obtain positions in many
fields of employment (Stacey et al., 2006). For example, after studying documents from San Antonio’s colleges, the Economic Development Council in San Antonio identified college algebra as the “principal impediment to most college students’ achieving the sufficiently high level of quantitative skills needed to function in the increasingly technological workplace that the city expects to develop” (Gordon, 2013, p. 129). These findings caused the mayor of San Antonio, Texas to appoint a special task force to work with colleges to redesign college algebra (Gordon, 2013) in a way that would improve student success rates.

Many corporations want college graduates who are proficient using quantitative methods to solve real-life business scenarios and complex business problems (Agustin et al., 2012; Champion et al, 2011; Eisner, 2010); a national study found that 72% of college alumni and 61% of employers cite quantitative reasoning, or the ability to use mathematics or statistics, as very important or important for the workplace (Holtzman & Kraft, 2011). Problem solving and critical thinking skills, often applied when solving problems presented in college mathematics courses, are also cited as important; 84% of all employers cite critical thinking as an important workplace skill (Eisner, 2010), and 91% of employers cite the ability to think creatively to solve problems as very important or important (Holtzman & Kraft, 2011).

In today’s world, students need numeracy skills for personal finance, citizenship, and personal health (Gainsburg, 2005). However, students also need proficiency in mathematics beyond their own personal needs and goals; math proficiency has been shown to have far-reaching societal effects (Hilton, 1992) that extend beyond the students themselves. For instance, mathematics proficiency is increasingly cited as a major factor in a country’s economic success and competitiveness (Hourigan & O’Donoghue, 2007; Carroll & Gill, 2012; Mayes, 2004) because, in order to remain competitive in a global economy, companies need highly
skilled workers (Gordon & Nicholas, 2013) with quantitative skills; industries including, but not limited to, sociology, psychology, and biochemistry are using more advanced mathematical ideas and techniques (Hilton, 1992). Furthermore, advances in technology, which often help to impact the future of the country’s economy, are dependent on mathematical literacy of its citizenry (Stacey et al., 2006; Gainsburg, 2005) who will help to research and develop the advancing technologies.

**Algebra as a College Mathematics Requirement**

Many colleges require students to complete an algebra course to fulfill their college mathematics requirement (Schield, 2008). However, the less than satisfactory student outcomes in college algebra (Cortés-Suárez & Sandiford, 2008; Shorter & Young, 2011) have sparked a debate on the appropriateness of college algebra as a requirement for most college students. Some researchers (Gordon, 2013; Usiskin, 2004; Gordon, 2004) feel that a universal college algebra requirement is good, if not vital, for all students. Others (Gordon, 2013; Usiskin, 2004; Agustin et al., 2012) believe that college algebra, in its current format, is problematic because it is not highly relevant for all students, and has high rates of student failure and withdrawal.

The study of algebra teaches concepts such as solving equations, statistical analysis procedures, and logarithmic and exponential functions (Hagerty, Smith, & Goodwin, 2010); it helps students acquire processes such as modeling, problem solving, communication, and analysis (Hagerty, Smith, & Goodwin, 2010). In addition, algebra is a necessary prerequisite for any student wishing to study calculus (Ellington, 2005) because students with a strong foundation in algebra are much more likely to be successful in calculus (Ellington, 2005).

However, the argument that a “mismatch between the original rationale for a college algebra requirement and the actual needs of the student who take the course” (Mathematical
Association of America, 2004) exists because the scope of what students learn in college algebra may not be the most relevant mathematical content for students’ future schooling or profession (Sierpinska et al, 2008) because the mathematics taught in school and the mathematics used and needed outside of school don’t match (Gainsburg, 2005; Hoyles, Noss, & Pozzi, 2001). The abstract rules taught in mathematics courses like algebra have been found to be very different from everyday problem solving (Gainsburg, 2005), and most of the specific content taught in algebra is not often used at work (Gainsburg, 2005). Most people rarely use many algebra skills, such as factoring expressions and reducing rational expressions, after completing their algebra course (Gordon, 2004).

Even positions requiring quantitative reasoning skills do not always use the specific algebra content. For instance, an analysis on architects and structural engineers’ mathematical behaviors found that most of the mathematical knowledge that they needed involved strong quantitative reasoning and only relatively simple computational skills (Gainsburg, 2005). Likewise, Hoyles, Noss, and Pozzi, (2001) found that experienced nurses did not always use their school-taught algorithm to calculate drug doses for their patients. Furthermore, even many scientific publications require little to no knowledge of algebra to understand of the content (Usiskin, 2004).

While students intending to study calculus need strong algebra skills, students without the intention of entering a profession that needs calculus do not need a primary focus on abstract algebra skills (Gordon, 2004). Currently, many of today’s college students do not plan to pursue careers that require knowledge of calculus; in fact, only about 10% of students who take college algebra actually eventually enroll in calculus (Gordon, 2004; Gordon, 2008).
Most people realize that they need to be quantitatively literate; they need to know mathematical concepts such as whole numbers, fractions, decimals, and percents (Usiskin, 2004), along with other daily living tasks involving the comprehension of the content from daily newspapers and store sale flyers (Usiskin, 2004). However, college algebra may not be the most appropriate math course for most students (Ellington, 2005) because most people don’t use specific algebraic algorithms like factoring polynomials, manipulating symbolic algebraic expressions, taking derivatives, etc. beyond the college algebra course (Agustin et al., 2012; Gordon, 2004). In fact, even some faculty in non-mathematical disciplines believe that the mathematics from required college algebra classes is too abstract to easily relate to their discipline (Gordon, 2004). In addition, in one national study (Eisner, 2010), only 23% of employers cited advanced mathematical skills as important for their employees.

The mathematical skills commonly valued in the workplace, such as mental calculations, measurement, and estimation (Gainsburg, 2005) are not often taught in algebra, and many workers who enter the workforce after college “are not sufficiently competent even with these basic math skills” (Gainsburg, 2005, p. 6). For instance, Schield (2008) found that many college students lacked basic mathematical skills; nearly one-fifth of students misread a table of rates and percentages (Schield, 2008), and about one-third had difficulty interpreting ratios presented in tables and graphs. Similarly, 20% of college students were unable to read pie charts similar to those featured daily in the USA Today snapshots (Schield, 2008).

Current algebra courses may not be ideally designed to assist students with developing quantitatively literacy (Mayes, 2004) because taking one or more traditional math courses such as college algebra did not necessarily develop quantitative reasoning skills in students (Agustin et al., 2012). Traditional courses such as college algebra tend to focus on manipulative skills and
algorithms in limited contexts (Agustin et al., 2012), and students who do not fully understand the mathematical concepts behind the skills and algorithms may not be able to transfer the mathematics to new situations (Gordon, 2004). As a result, students are less likely to recognize the mathematics that they need to use when it needs to be applied in other courses or fields (Gordon, 2004). In fact, on national measures of quantitative literacy, less than one in ten adults score in the highest category, which itself is only comparable to the expectations of first year algebra (Steen, 1997).

**Recommendations for College Math**

The problems with success in college mathematics have prompted a call for change (Barker, et al., 2004) in required college mathematics courses, and possible solutions have been proposed for improving the poor performance in required college mathematics courses. Organizations such as the Mathematical Association of America (MAA), the Adult Numeracy Network (ANN), and the International Commission on Mathematical Instruction (ICMI) have published recommendations; the MAA suggests that required mathematics courses be designed to focus on practical applications of math (Agustin et al., 2012), the MAA’s Committee on the Undergraduate Program in Mathematics (CUPM) suggests that mathematics courses expose students to mathematical concepts that are important to other academic disciplines (Mathematical Association of America, 2004), and the ICMI suggests making required college mathematics courses more accessible to students from a success standpoint (Stacey et al., 2006).

In an effort to synthesize the numerous recommendations for college mathematics courses, the MAA created a committee composed of leading educators from twenty-two disciplines to develop specific recommendations for college mathematics content. This committee attempted to identify the mathematics that is needed to be successful in each of their
disciplines (Mathematical Association of America, 2004). Collectively, they decided that required college mathematics courses must do the following:

- Emphasize conceptual understanding over rote memorization
- Emphasize realistic problem solving with mathematical modeling
- Use data, particularly statistics, that is important across most disciplines
- Regularly use technology such as Excel (Gordon, 2013)

Similarly, the Adult Numeracy Network, an adult education affiliate of the National Council of Teacher of Mathematics (NCTM), also developed recommendations regarding mathematics content for adult learners that are very similar to the MAAs. They recommend

- Including concepts of number, data, geometry, and algebra in all courses so that students can connect and develop mathematical ideas
- Integrating mathematical processes with problem solving, conceptual understandings, and positive attitudes
- Including course activities that relate to real life experiences
- Developing student confidence in successfully performing mathematical computation

(Adult Numeracy Network, 2005)

Outside researchers echo the MAA’s and Adult Numeracy Network’s recommendations for improving success in required college mathematics courses and reaffirm these recommendations regarding the importance of having relevant content in all required mathematics courses (Hourigan & O’Donoghue, 2007). For instance, researchers (Berenson, et al., 1992; Nicol, 2002; Gainsburg, 2005) showed that students are often more successful in their college mathematics course when they are able to connect the course content to problems from the real world and make connections with what they already know; courses that contain relevant,
relatable content allow students to relate and apply the course concepts to their future personal and professional lives (Gordon, 2004; Stacey et al., 2006; Usiskin, 2004), while also providing students from diverse backgrounds and educational experiences with the opportunity to participate and engage in the mathematics that they are learning (Gordon & Nicholas, 2013). In addition, all required mathematics courses should utilize tools and activities that help students interpret mathematical results (Gordon, 2013), so that they can develop their ability to communicate quantitatively both orally and in writing (Mathematical Association of America, 2004).

Providing opportunities for students to develop their confidence in mathematical computation has also been proven to be an important factor in student success in mathematics (Gordon, 2013) because students who are predisposed to confront a mathematics problem with the assurance that they will be able to progress and come up with a solution (Hourigan & O’Donoghue, 2007) are likely to be better prepared for, and more successful in, their college mathematics course. For these reasons, students must be confident in their ability, along with their ability to select the appropriate tool to help them solve their problem (Gordon, 2013).

In addition to the MAA recommendations regarding the importance of integrating technology into required mathematics courses, organizations such as the ICMI have also documented the importance of using computers and related technologies as learning tools in college mathematics courses (Stacey et al., 2006). With the growing availability of computers and related technologies continuing to change how mathematics is done, much of the mathematics previously done by hand is now being completed using spreadsheets, calculators, or other computer programs (Gainsburg, 2005). For instance, commonly used formulas that previously had to be committed to memory or referenced in a mathematics textbook can now be
embedded in commonly used computer programs (Gainsburg, 2005). However, technology is only a tool, and students still need the quantitative reasoning skills necessary to solve these problems (Usiskin, 2004); they also need to be able to recognize when they should utilize paper and pencil to solve a problem and when to use technology to find their solution.

Furthermore, technology simply provides students with another tool to be successful in their required college mathematics course because current technology tools provide students with different ways of learning content and solving problems (Stacey et al., 2006). For instance, many people do not realize that they are using components of algebra when they utilize spreadsheet programs such as Excel (Usiskin, 2004; Barnard, 2002). However, the names of the cells incorporate variables and calculations and are examples of algebraic formulas (Usiskin, 2004), and algebraic symbols such as the summation symbol (Σ), are also used to represent algebraic formulas within the spreadsheet (Usiskin, 2004).

College students have responded positively to using technology to analyze data and communicate mathematics (Champion et al, 2011), and technology tools are now being utilized by many college mathematics courses (Gordon, 2004). For instance, Internet enabled devices allow users to easily access real data (Stacey et al., 2006), making real-world problems more logical (Gordon, 2004). Subscription websites such as WebAssign (www.webassign.net) and MyMathLab (www.mymathlab.com) also provide students with another tool to help them achieve success through video tutorials and step-by-step instructions.

Along with the specific recommendations above, it is also recommended that any revisions to the college mathematics curriculum ensure that college mathematics courses maintain rigor (Hagerty, Smith, & Goodwin, 2010; Asera, 2011). Students must learn that “sustained effort is necessary to overcome the difficulties they encounter” (Hagerty, Smith, &
Goodwin, 2010, p. 421) because success after encountering some degree of struggle may build a student’s self-efficacy in mathematics, allowing them to believe that they have the ability to succeed in additional mathematics courses needed for many majors (Hagerty, Smith, & Goodwin, 2010) and professions. This way, students are not closed off from any future opportunities.

**General Examples of Change**

Hoping to increase student success rates in their required college mathematics courses, colleges are implementing the suggestions for effective courses through curricular and curriculum-related changes. Some colleges have changed course lengths (Reyes, 2010), or decreased the class sizes in (Gonzalez-Muniz et al., 2012) their required courses. Others have provided interventions, such as tutoring services (Hourigan & O’Donoghue, 2007; Reyes, 2010), for enrolled students.

Yet, curriculum-related interventions like these have produced little change in rates of student success. The course length did not appear to have a significant impact on course outcomes (Reyes, 2010), and smaller class sizes also showed little impact on student performance (Gonzalez-Muniz et al., 2012). Likewise, while mathematics support centers have been shown to improve the mathematical achievement of many students, not all students who utilized the support benefited (Bhaird, Morgan, & O’Shea, 2009).

Some colleges have elected to make minor curricular revisions to the traditional college algebra class. For instance, many required algebra courses have maintained the same curriculum, only electing to showcase more examples of the “what” and “why” of algebra (Usiskin, 2004). Similarly, some colleges hope to change attitudes toward algebra (Usiskin, 2004) by showcasing connections within their existing curriculum to other mathematical
disciplines by using a problem-centered approach, rather than solely assigning practice skills (Usiskin, 2004)

Other institutions have opted to use the MAA recommendations to modify their existing course curriculum to include more conceptual understanding of fundamental math ideas, along with more realistic applications of the math (Gordon, 2004). These classes, sometimes referred to as functional mathematics courses, aim to teach mathematics that will be directly useful to the students in their life and profession, rather than just show students the “beauty of mathematics” (Nicol, 2002, p. 290). That is, these classes attempt to bridge the disconnection that currently exists between the traditional rule-based mathematics sometimes taught in school and the mathematics that people use in the real world (Gainsburg, 2005).

Some examples of redesigns of required mathematics course include alternatives that focus on:

- The use of real-world data
- Applications of probability
- The use of spreadsheets
- The integration of modern technologies
- Applications of matrix algebra (Gordon, 2004)

**Student Attitudes**

Many factors impact student success in their required mathematics courses (Thiel, Peterman, & Brown, 2008) and their identification, along with the size of the effect of these factors, is important when making recommendations for improving student achievement in mathematics (Azar et al., 2010). Examination of the impact of these factors can help provide educators with insight into causes of the problems, along with potential solutions.
Student attitudes toward mathematics have been shown to be an important factor in learning the coursework (Royster, Harris, & Schoeps, 1999; Ma & Xu, 2004) because these beliefs can impact student achievement in mathematics (Eccles & Wigfield, 2002). Students with negative attitudes often have poor outcomes in mathematics; these students are often poorly engaged (Gordon & Nicholas, 2013; Nicol, 2002), and they are more likely to fail or drop the course (Mayes, Chase, & Walker, 2008; Ma & Willms, 1999). On the other hand, students with positive attitudes toward mathematics often have good outcomes; these students are often engaged (Gordon & Nicholas, 2013; Nicol, 2002), and they are more likely to achieve and succeed in the course (Evans, 2007; House, 1995).

Student attitudes toward mathematics have significance in and out of the classroom. In college mathematics, positive student mindsets have been shown to be a significant factor in motivating students to succeed, while negative attitudes have been linked to lack of success (Köller, Baumert, & Schnabel, 2001; Chouinard et al., 2007). Beyond the classroom, attitudes toward mathematics have been viewed as important factors in career choices (Bleyer, Pedersen, & Elmore, 1981; Dogbey, 2010; Lent, Lopez, & Bieschke 1991); students with poor attitudes toward mathematics often avoid mathematics courses and limit their future career choices (Dogbey, 2010) while students with higher opinions of mathematics are more likely to consider a mathematically intensive career (Dogbey, 2010). This is significant, because as stated in American Mathematical Association of Two-Year Colleges (2006) “active participation of all students in mathematics and the pursuit of mathematics-intensive careers by many are critical goals of our society” (p. 10).

Examination of student attitudes shows that many students acquire a poor attitude toward the required mathematics course because they often question the value of the mathematics
(Gainsburg, 2005). They are unable to connect the mathematics curriculum from their college course with the mathematics that is used in daily life (Gainsburg, 2005; Köller, Baumert, and Schabel, 2001; Mathematical Association of America, 2004; Hoyles, Noss, & Pozzi, 2001) because they frequently feel that the mathematics that they are learning is not valuable to their future personal or professional life (Sierpinska, et al., 2008; Bonham & Boylan, 2011; Gordon & Nicholas, 2013).

All in all, “mathematics is often seen as a very difficult subject in which motivational factors are particularly important for the enhancement of learning” (Köller, Baumert, & Schnabel, 2001, p. 452). Recognizing this, organizations such as NCTM have cited the importance of student attitudes toward mathematics; they specifically identified “learning to value mathematics” as a goal for students in their *Curriculum and Evaluation Standards for School Mathematics* (1989) and state that the impact of attitude on student achievement in mathematics justifies the consideration of student attitudes when designing or evaluating curriculum.

**Attempts to Solve the Problem**

Colleges need to improve the low success rates in their mathematics courses (Cortés-Suárez & Sandiford, 2008; Shorter & Young, 2011). To do this, colleges must consider the needs of the students who enroll in the courses and attempt to meet those needs (Joo, Lim, & Kim, 2013). To meet the needs of their students, colleges need to consider factors such as student engagement in the mathematics course and student perception of the mathematics course.

Student engagement in mathematics is often impacted by their attitudes toward mathematics. While students who have positive attitudes toward mathematics are more likely to succeed (Köller, Baumert, & Schnabel, 2001; Chouinard et al., 2007), students who have poor
attitudes toward their required mathematics courses often experience “poor engagement with the course, which inevitably leads to failure” (Mayes, Chase, & Walker, 2008, pp. 28-29).

Student perception of a positive mathematics experience is thought to be significant (Hourigan & O’Donoghue, 2007) because students who perceive the courses they are taking are valuable are more likely to succeed. Specifically, the value that a student places on a course’s content has been shown to be significant in determining students rates of success in their college mathematics course (Joo et al, 2013; Singh et al., 2002; Cole et al., 2008; Chouinard et al., 2007; Azar et al., 2010).

Several organizations have published suggestions to assist colleges in designing and implementing courses that consider student attitudes and perceptions. For instance, the Adult Numeracy Network has suggested that the mathematics curriculum focus on worthwhile tasks that foster a positive attitude about learning mathematics (Adult Numeracy Network, 2005). Similarly, the Mathematical Association of America has suggested that all college mathematics departments design their mathematics courses around the strengths, weaknesses, career plans, fields of study, and aspirations of their students (Mathematical Association of America, 2004).

In general, most of the suggestions relate to creating courses that are valuable to the students who enroll. To do this, most recommendations suggest that the most effective college mathematics courses utilize projects that are valued by math instructors and employers, and demonstrate the value of the content to the students (Champion et al, 2011). Additionally, effective courses also generally provide an environment in which students solve relevant problems with many right answers (Hourigan & O’Donoghue, 2007). For instance, a course that teaches basic concepts such as percentages, ratio, multiplying decimals, estimation, interpreting tables and graphs, etc. (Agustin et al., 2012), can easily showcase examples from everyday, real-
world scenarios. It is also important that the course focus on operations with properties of exponents and logarithms because these types of problems are becoming more commonly emphasized (Gordon, 2004; Gordon, 2013) across many fields and disciplines.

Admittedly, simple solutions to solve the problems associated with lack of success in required college mathematics courses do not yet exist (Sierpinska et al., 2008; Gainsburg, 2005), and colleges have not yet widely adopted alternative courses (Gordon, 2013). However, in an attempt to improve student success in their required college mathematics course, many colleges have used both the national recommendations for college mathematics curriculum and the findings from the research on expectancy-value theory to redesign their required college mathematics course. Some noteworthy examples are chronicled below.

**West Virginia University’s initiative.** Before their required college mathematics course redesign, the majority of students at West Virginia University were not successful in their required college mathematics course. With a withdrawal and failure rate as high as 61% (Mayes, 2004), the lack of success was impacting the enrollment and graduation rates. The inability to succeed in the course also limited career choices for many students graduating from West Virginia University (Mayes, 2004).

In response to the low success rates in their required mathematics course at West Virginia University, the college established the Institute for Mathematics Learning (IML) within their department of mathematics (Mayes, 2004). Once established, the IML immediately began working to improve outcomes for mathematics courses under the calculus level (Mayes, 2004). With an intention of improving student attitudes regarding the course content, the IML decided to implement a new Applied College Algebra course that focused on modeling real-world data through conceptual understandings and problem solving (Mayes, 2004). They felt that this
initiative would align with the national recommendations for change, fitting the needs of students across social science, business, and liberal arts programs (Mayes, 2004).

The IML was trying to improve student task value ratings by demonstrating that the course content in mathematics could be useful to the students in their future lives and careers. They hoped that their integration of real-world data, derived from a variety of contexts, would make the math content more interesting and relatable to the students in the course. They also hoped that the revised content would help students to discover the value of the mathematics course, and later be motivated to take more mathematics courses in the future (Mayes, 2004).

After six years of implementation, West Virginia University’s initiative had mixed results; while the rates of drops and withdrawals in the required mathematics courses went from a high of 61% of students to a low of 18% (Mayes, 2004), the rates of drops and withdrawals increased in the subsequent mathematics course at the University because the redesigned course implemented by the IML did not adequately prepare students to be successful with the mathematics content in the next course (Mayes, 2004). Changes in student attitudes, which the applied mathematics course was meant to improve so they would engage more fully in learning mathematics (Mayes, 2004), showed no significant improvement in student attitudes; the only exception was a small positive increase in value ratings of intrinsic versus extrinsic motivation (Mayes, 2004).

**Virginia Commonwealth University’s initiative.** Prior to 2004, Virginia Commonwealth University had the same problem that many other colleges were having; only 36% of their students who took college algebra at their college received an A, B, or C in the course (Ellington, 2005). Furthermore, 25% of students who enrolled in the course failed to
complete it (Ellington, 2005). The poor rates of success were a concern to VCU (Ellington, 2005).

To attempt to solve the problem, VCU obtained a grant to improve student outcomes in math courses that serve as a “gateway” to the traditional college experience (Ellington, 2005). They used the grant money to research the problem and decided on a model-based approach to college algebra that would cover similar topics to traditional college algebra, but would cover the topics in the context of real-world problems. This redesigned course was a major shift from their traditional college algebra course because the traditional course did not focus on mathematics in a real-world context.

The purposes of the new math course were to focus on mathematics topics that are important in other disciplines, help students to communicate quantitatively, and increase the percentage of students who are successful in their college algebra courses (Ellington, 2005). That is, VCU hoped that the newly designed course would raise student value ratings of their required mathematics course, and also raise student achievement in these mathematics courses (Ellington, 2005), all without decreasing the students’ ability to successfully solve traditional problems from a traditional college algebra textbook (Ellington, 2005).

A study of the pilot project comparing outcomes of students who enrolled in the traditional college algebra course and the new course showed that students in the model-based course had a lower withdrawal rate than the students in the traditional course (Ellington, 2005). In addition, the students in the modeling course scored similarly or better on the course final exam than students in the traditional course (Ellington, 2005). Also, almost 75% of the students in the modeling sections at VCU reported that the modeling approach to algebra was more applicable to solving real-world problems (Ellington, 2005). Students in the modeling course
also reported higher ratings regarding the usefulness of the mathematics, stating that they recognized the value of the mathematics for their potential careers (Ellington, 2005). However, some of them also reported frustration due to higher cognitive demands of critical thinking in mathematics (Ellington, 2005).

**Florida Atlantic University’s initiative.** Prior to 2008, Florida Atlantic University (FAU) also had poor success rates in their college algebra course, with as much as 48% of students failing to pass the course in 2007-2008. To deal with the problem, the college formed a committee of the full-time mathematics professors at the college who were tasked with changing the course to increase student rates of success.

Unlike some of the restructuring initiatives taken by other colleges, FAU decided not to redesign the content in their college algebra. Instead, FAU decided to address the problems with the course and attempt to raise success rates by changing some non-content aspects of the course. The changes included a required placement test for all students who placed into the college algebra course, a day-by-day syllabus with clear objectives, more streamlined communication, a common departmental exam, and teacher assistants (TAs) to provide assistance to students in need of extra help.

The FAU committee hoped that their changes would provide more means for student success. For instance, FAU believed that administering the placement test would identify students who needed remedial help before enrolling in the course; they believed that establishing a day-by-day syllabus with clear objectives in all courses would help provide clear expectations to students; they believed that a slightly slower pace would help students who struggle with a fast pace to experience less frustration and more success; they also believed that the online course content system MyMathLab, combined with training faculty to collaborate and streamline
student communication, assignments, and grades, would help avoid communication problems. Also, they believed that providing departmental exams to all teachers well in advance so that they would know what would be assessed would help teachers create a more effective course; and they believed that implementing extra help from teacher’s assistants (TAs) would give students another path to success (Gonzalez-Muniz et al., 2012).

After they implemented the above changes, the rates for dropping the course, failing the course, and withdrawing the course did improve. Further investigation of the results showed that the implementation of technology, the formative feedback provided by the students, the collaboration of the instructors teaching the course, the ongoing assessment initiative, and extra assistance available to the students attributed to the increase rates of success (Gonzalez-Muniz et al., 2012).

**Black Hills State University’s initiative.** After data showed that only 54% of their students were passing college algebra (Hagerty, Smith, & Goodwin, 2010), Black Hills State University (BHSU) in South Dakota decided that they needed to implement a change to their required college mathematics course. Using recommendations from the MAA and NCTM, along with feedback from students regarding their career goals and their selection of math courses, BHSU changed the curriculum of their college algebra course. The university’s changes included integration of technology through a computer-based learning program, implementation of fewer classroom lectures, inclusion of more application problems, explanation of the historical developments of the problems, and inclusion of cooperative activities (Hagerty, Smith, & Goodwin, 2010).

The curriculum revisions at BHSU seemed to work. After the changes were enacted, BHSU experienced a 21% improvement in student success rates, with 75% of students passing
college algebra (Hagerty, Smith, & Goodwin, 2010). In addition, the school also reported other positive outcomes, reporting 25% better attendance in algebra classes and 10% increase in nationally normed test scores after the changes were enacted (Hagerty, Smith, & Goodwin, 2010). Furthermore, students reported better attitudes toward their ability to be successful in future math courses, and some other professors reported increases in students’ technology skills and reasoning skills (Hagerty, Smith, & Goodwin, 2010).

**University of South Dakota’s initiative.** After experiencing some difficulties with their required mathematics course, the University of South Dakota (USD) implemented a Quantitative Literacy course that could fulfill their student’s required college mathematics course. USD modeled the course after one developed by Dr. Bernie Madison at the University of Arkansas (Van Peursem, Keller, Pietrzak, Wagner, & Bennett, 2005). The course was different than their traditional algebra course; it included the incorporation of data from current newspaper articles, mathematical issues related to voting, and interest rates in personal finance decisions. The college hoped that the course, dubbed “The math that makes sense” (Van Peursem et al., 2005), would help students to gain an appreciation of math and see the application of mathematics in real-life situations.

When the University of South Dakota implemented the redesigned course, the college faculty wanted to ensure that the students in the redesigned course were learning at least an equivalent amount of mathematics as those students who took the traditional college algebra course. In addition, the college needed to ensure that the redesigned course would prepare the students to be successful on the administration of the Collegiate Assessment of Academic Proficiency (CAAP), which is a required assessment of postsecondary mathematical problem
solving ability, for students wishing to obtain a college degree in South Dakota (Van Peursem et al., 2005).

To address the University of South Dakota concerns regarding student attitudes and the amount of student learning that occurred in the quantitative literacy course, USD administered two assessments to students at the end of the semester. First, they included a self-assessment pertaining to achievement and attitudes. Second, they administered a mock assessment of the Collegiate Assessment of Academic Proficiency (CAAP) to students at the end of the semester. The college felt that it was important to administer the CAAP as a mock assessment because at the time, the CAAP contained more questions that would likely be encountered in a college algebra course, instead of questions that would likely occur in their general course of quantitative literacy (Van Peursem et al., 2005). Therefore, USD thought that information regarding student performance on a mock CAAP could be applied to results on the actual CAAP.

After the administration of the mock CAAP, the University of South Dakota compared the outcomes of the students who enrolled in the CAAP course with students in their college algebra course, which was still being offered. The study used data from 2009 and 2010. Results showed that while the students who selected the Quantitative Literacy course had statistically significant weakness in their mathematics backgrounds as compared to the students who selected the college algebra class, they did not perform statistically different on the mock CAAP test; in fact, assessment results from the mock CAAP tests showed that showed no statistical difference in the mean scores between the students who enrolled in the algebra course and the students who enrolled in the quantitative literacy course (Van Peursem et al., 2005). Likewise, no statistical difference in the students’ perception of their ability to solve problems resulted (Van Peursem et al., 2005).
However, a statistically significant difference in attitudes occurred between the students in the Quantitative Literacy course and the student in the traditional College Algebra course; the students in the Quantitative Literacy course showed more gains in positive attitudes toward the mathematics in their required mathematics course than the students in the traditional College Algebra course (Van Peursem et al., 2005). In other words, students from the Quantitative Literacy course not only had higher ratings of appreciation of mathematics but also had higher ratings of the utility value of the mathematics from their course, meaning that they ranked the mathematics in their course as useful (Van Peursem et al., 2005).

**Texas’ Community Colleges initiative.** In order to expand its educated population and workforce, the state of Texas launched an educational initiative titled Closing the Gaps (Reyes, 2010). The intention of the initiative was to increase the state’s college enrollment and graduation rates. However, Texas officials knew that the overall initiative would only be successful if they could help students overcome their obstacles to graduation.

State officials knew that passing their required college mathematics course is an obstacle for many students because students who are unsuccessful in their required college mathematics class are unlikely to graduate from college (Parker, 2005; Hall & Ponton, 2005; McCormick & Lucas, 2011; Cortés-Suárez & Sandiford, 2008). In addition, student success in college algebra is important to a successful initiative because entrance into many programs currently in demand in the workforce requires successful completion of college algebra (Reyes, 2010). For this reason, the state committed to attempting to increase the success rates in required college mathematics class.

The Charles A. Dana Center at the University of Texas at Austin and the American Mathematical Association of Two-Year Colleges (AMATYC) were tasked with creating a
solution that would attempt to improve student outcomes in their required mathematics course. As a result, the two organizations created and implemented a new alternative mathematical pathway for all of Texas’ community college students to increase access and success (Asera, 2011). The resulting program, Mathway, is customized to provide student with mathematics courses based on their specific career goals (Asera, 2011). That is, instead of the traditional college mathematics requirement, the community colleges began offering a course in statistical reasoning for students who are pursuing degrees that utilize statistics, such as business (Asera, 2011). Students not pursuing a field dependent on statistics enroll in a course in quantitative reasoning (Asera).

Early findings of the Texas initiative are positive; outcomes showed that approximately 51% of students successfully completed their remedial pathway course during the first year and their Statway course during the second year (Yamada, 2014). These findings are significant because the success rates in the redesigned courses indicate students succeeded at three times the rate that they did in their previous mathematics course (Yamada, 2014).

**Bemidji State University’s initiative.** In an attempt to address lack of interest and lack of success in their required mathematics course, Bemidji State University in Minnesota redesigned their required college mathematics course. They implemented an “Introduction to the Mathematical Sciences” course composed of one-third algebra, one-third statistics, and one-third computer science (Webb, Richgels, Wolf, Frauenholtz, & Hougen, , 2009). The course is different than traditional college algebra courses in that algebra only comprises one-third of the course’s content. However, empirical data on course outcomes has been positive because results have shown that the students who complete the course learn more algebra than students in a traditional college algebra course (Webb et al., 2009)
Conclusion

Although much can be learned from the previous course redesigns, the results do not provide a “one size fits all” answer to increasing student success in their required college mathematics course. As a result, colleges implementing redesign initiatives should monitor outcomes and continue to implement changes until all students are successful in their college mathematics class. Research findings, such as those that are published in this study, are still needed for many reasons that include potential bias of some published studies, including quantitative studies regarding students’ attitudes toward the value of math (Champion et al, 2011) incomplete research regarding attitudes toward course value and math achievement (Hodges & Kim, 2013); deficient research investigating the strength of the relationship between value ratings and mathematics achievement (Carroll & Gill, 2012); and deficient age specific research regarding the links between value ratings and performance in mathematics (Eccles & Wigfield, 2002).
Chapter 3: Methods

The study took place at a small, private college in New England with an approximate enrollment of 1,500 students. Previously a junior college, the institution granted only associate’s degrees from 1942–1993. Since 1994, the college has offered both two- and four-year degrees. In 2012, the college’s most popular majors included visual and performing arts, liberal arts and sciences, and business (“ASC College,” n.d.).

Regardless of their major or degree, all of the college’s students have been required to pass at least one college level math course. Prior to the Fall of 2013, most students enrolled in College Algebra as their required course. Since the Fall of 2013, the College has instead required all students to enroll in their newly redesigned mathematics course, named Introduction to Quantitative Reasoning and dubbed “The Math You Really Need.”

The college faculty and administration decided to implement the newly redesigned mathematics course because they believed that a required course emphasizing content that relates to everyday mathematical tasks offering financial and consumer literacy would not only provide course content that students would perceive as more valuable, but also create increased rates of student success in their college mathematics course. However, the faculty and administration did not have any quantitative data on outcomes from the new course before this study was conducted; that is, the College’s assessment of outcomes from their redesigned course was anecdotal and lacked the empirical data needed to determine if course outcomes were being met. Thus, in order to determine if their intended course outcomes were being met, the College needed to learn how the outcomes in the redesigned class compared to the outcomes in the original course.

Study Design
The overall goal of this study was to determine if a significant difference in student outcomes existed between the two required mathematics courses offered at the College highlighted in this study. These two groups included students who completed the redesigned course, Introduction to Quantitative Reasoning, and students who completed the original course requirement, College Algebra. To do this, the study used a quasi-experimental, causal comparative methodology to examine outcomes in both the previous and redesigned required mathematics courses at the College highlighted in this study.

The study design leveraged existing data (Butin, 2010) from students enrolled in both courses. It retrospectively compared data from existing assessment tests and course value in order to determine if there was a significant difference in either the achievement or perceived ratings of course value between the two groups of students. It also determined if there was a relationship between the perceived value ratings of the course and the achievement in the course, by collecting and analyzing data from students in both groups. In essence, the study sought to determine if there existed statistically significant differences between students who completed two different mathematics courses.

Using data from instruments with preset questions and responses (Creswell, 2011), this study used a quantitative approach to obtain measurable and observable results (Creswell, 2011) to the research questions. First, data from departmental assessment tests from both groups of students were analyzed to determine if there was a significant difference between the scores of the two groups. Then, course evaluation data with Likert-scale ratings that measured perceived value from the two groups of students was analyzed to determine if there was a significant difference between the two groups. Finally, the data from the achievement tests and the course
evaluations were examined in order to determine if a significant relationship existed between the two variables.

**Quasi-experimental vs. Experimental**

In a true experimental design, researchers have to follow a specific protocol to create a controlled environment for their study; they must determine the treatment, select the sample, assign individuals to groups, decide what group will get the treatment, try to create circumstances that control extraneous factors that may impact the study, and measure the effect of the treatment (Fraenkel & Wallen, 2009). In this study, the circumstances of the context did not allow for the protocol of a true experimental design (Creswell, 2011) because pre-existing groups were used for this study, and it was not possible to control all extraneous variables within the groups. For instance, as with most colleges, students at the college in this study are allowed to select their own sections and instructors, making it logistically impossible to establish a true control and experimental group in an educational study like this one (Butin, 2010). As a result, the study used a retrospective analysis to examine data from pre-existing course value ratings and achievement scores on a departmental mathematics assessment from the two groups of students.

Ideal study designs also utilize the entire population for the study because outcomes from studies that use large populations are more easily generalized and usually considered more applicable to other situations (Fraenkel & Wallen, 2009). However, it is not always reasonable to study the entire population. For instance, using the entire population of the College was not practical because it would have resulted in an extremely large sample that would have made this study tremendously time consuming, difficult to manage, and unlikely to complete.
Research Design

Researchers can use either descriptive or inferential statistics to report the findings from their study. Descriptive statistics generally include measures of central tendency (mean, median, and mode) and measures of dispersion (variance, standard deviation, etc.), and inferential statistics generally involve more advanced statistical analysis (ANOVA, regression, etc.). Generally, descriptive statistics help researchers present information on overall data trends as well as the distribution of the data (Creswell, 2011) while inferential statistics measure similar characteristics between groups in order to justify group comparisons (Butin, 2010). Answering the research questions in this quantitative study required the use of both descriptive and inferential statistics.

In this study, the researcher used descriptive statistics on several occasions; for instance, descriptive statistics were used to report mean scores from the mathematics achievement tests and course value ratings for both groups of students. In addition, the researcher also used descriptive statistics to determine if the two sample populations in this study were comparable.

Using statistical measures to establish similarity between the two populations of students in this study was essential because the researcher needed the data to determine whether or not comparing the outcomes of the two different groups made sense (Creswell, 2011). In other words, a causal comparative study of the outcomes of different groups is only appropriate if the descriptive statistics establish comparable compositions of the different groups.

In this study, the researcher needed to use descriptive statistics to establish similarity between the two populations of students, both the population of students who completed the redesigned course *Introduction to Quantitative Reasoning* and the population of students who completed the original *College Algebra* course requirement. To do this, the researcher first
calculated the mean SAT score for each of the two sample populations in this study. Then, the researcher used the calculation from the College Board’s (College Board, n.d.) website to determine if the difference between the two groups’ mean scores was statistically significant. The resulting calculation, derived from the College Board’s formula, allowed the researcher to both determine if there was a statistically significant difference between the two groups of students and provide information regarding the strength of the conclusions that were derived from the data provided by this study (Creswell, 2011). That is, the College Board’s formula established if a statistically significant difference in scores existed between the two populations and if it provided information on the strength of the relationship between the groups.

Inferential statistics, which are most often used to examine the relationship between groups (Fraenkel & Wallen, 2009) or the relationship between two or more variables (Creswell, 2011), were also used to answer all of the research questions in this study. Specifically, research question one, which asked if there a significant difference between the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems, used a two-tailed t-test to determine if the means of the two groups were significantly different. This way, the researcher could calculate a “P value” using a statistical software program such as G*Power (Buchner, Erdfelder, Faul, & Lang, n.d.) or Excel, which was matched to values in a statistical table to determine statistical significance (Fraenkel & Wallen, 2009), to provide validation regarding the strength of the conclusions derived from the differences between the mean scores of the two groups of students.

Research question two, which asked if there was significant difference between student ratings of value of course content of students in a traditional college algebra class and students in
a redesigned course emphasizing the application of mathematic skills to solve realistic problems, also used inferential statistics; this question used a chi-square test because chi-square tests measure how close non-numeric data, such as the Likert scale data from the student ratings of course content, conforms to the null hypothesis by measuring the difference between the observed and expected results (Siegel, 2012).

The third research question, which examined the relationship between two different variables, also used inferential statistics. Specifically, research question three used regression analysis because regression analysis can determine the impact more than one variable has on the outcome and determine if a statistically significant relationship between the two variables existed (Creswell, 2011). Specifically, for question three, regression analysis determined if a statistically significant relationship existed between the value ratings of course content and the student’s end of course achievement scores.

Furthermore, regression analysis not only establishes if a statistically significant relationship between more than one variable exists, it also provides a more detailed classification of any existing relationships by categorizing them as positive or negative. For instance, positive relationships indicate that when one variable rises, the other variable is likely to rise; on the other hand, negative relationships indicate that when one variable falls, the other variable is likely to rise. In terms of this study, a positive relationship would have indicated that when course content ratings rise, achievement test scores also rise (or vice versa), and a negative relationship would have indicated that when course content ratings fall, achievement test scores also fall (or vice versa).
Population and Sampling

A study’s sample size is an important consideration in the design of a study (Fraenkel & Wallen, 2009) because the size of the sample determines if a statistically significant (or not due to chance) relationship exists. However, when circumstances such as the ones encountered for this study indicate that studying the entire population isn’t feasible, Fraenkel and Wallen (2009) suggest using a representative sample population to effectively reflect the outcomes of the larger group. As long as a smaller sample size is shown to be statistically significant, the results are generally a representative sample of the target population.

For this study, data from all courses taught during the Fall 2010 through Spring 2015 semesters were not used for several reasons. First, the sample of data would have been too large and time consuming to analyze for the scope of this study. In addition, some data from some courses could not be utilized in this study because of problems with the data; for instance, assessment test data for some algebra courses had been inadvertently discarded while a different course assessment was inadvertently administered to some of the Introduction to Quantitative Reasoning sections.

Ideally, the sample population of students included in the study would have been chosen by random sample. However, because the sources of data have been collected in advance, students used in this study were not selected by random sample. Instead, the researcher simply used data from sections that had available data and was representative of the entire population of students, without attempting to change or influence the data (Fraenkel & Wallen, 2009). Specifically, a sample of data from various course sections offered during the last five academic years (Fall 2010 through Spring 2015) was utilized.
Although most textbooks suggest using a minimum sample size of 40 participants (Fraenkel & Wallen, 2009) from each population, the researcher decided to utilize a larger representation from each of the two subsets of the population from the small, private college in New England over the course of five academic years (Fall 2010 through Spring 2015) because *a Priori Power Analysis* (Buchner et al., n.d.) indicated that a sample size of at least 90 be used to yield statistically significant results. Therefore, this study collected data from more than 100 students from each of the two subsets of the population of this study, one group with students who completed College Algebra and one group with students who completed the Introduction to Quantitative Reasoning course.

**Data Analysis: Establishing Comparison Groups**

As previously noted, the researcher needed to establish that the sample populations from each of these groups were indeed comparable because the research questions posed in this quasi-experimental study compare outcomes from students who completed two different mathematics courses. Therefore, the researcher needed to show that the students in the two different groups had comparable academic skills. After all, if the differences between the groups had been found to be statistically significant, comparisons of outcomes of the two groups may not have been valid.

To establish comparable sample populations, the researcher used scores from the mathematics section of the SAT and student high school grade point averages (GPAs) to calculate the magnitude of the different scores for the two populations. Then, the researcher conducted statistical calculations on the data in order to provide specific information for these results.
First, in order to determine if the difference in mean scores for the mathematics section of the SAT for each of the two populations was statistically significant, the researcher followed instructions written by the administrators of the SAT test, the College Board (College Board, n.d.). On their website, the College Board instructs researchers who wish to determine if the difference in mean SAT scores is statistically significant to first calculate the difference between the means of each group, along with the average size of the two groups. After doing this, the researcher plotted a coordinate point on a graph provided by the College Board, using the average size of the two groups as an x-coordinate, and the difference between the mean SAT scores for the two groups as a y-coordinate. After the point was plotted, visual inspection of where the point rests on the colored regions surrounding the graph’s curve indicated whether the differences in the means were most likely just chance or statistically significant.

Then, in order to determine if the difference in mean scores for the student GPAs of the two populations was statistically significant, the researcher conducted a t-test for independent means. The t-test was selected because, by definition, t-tests use the means, standard deviations, and sample sizes of each group to indicate if the mean scores of the two different populations of students are statistically significant (Fraenkel & Wallen, 2009).

**Recruitment and Access**

After receiving permission from Northeastern University’s Internal Review Board (IRB) to conduct the study, the researcher made a formal request to conduct this study at the College highlighted in this study; specifically, the researcher made a request to conduct this study, at the school being studied, to the College’s Vice President of Academic Affairs and Planning, along with the Dean of the School of Liberal Arts and Sciences.
Data used in this study was collected from records of students who completed their required college mathematics course at the College highlighted in this study. Since archival data were used for this study, no special requests were made for participants to partake in any activities. Once formal permission from the college was obtained, the researcher was able to collect the data needed for this study with assistance from the College’s Dean of the School of Liberal Arts and Sciences, along with two members of the mathematics faculty (see appendix A). Sources of data used in the study include student scores on departmental assessment tests, scores from mathematics portion of the SAT, ratings from course evaluation, and high school GPAs. When the data were sent it to the researcher, GPAs and SAT scores were sent electronically while hard copies of departmental assessment test results were provided. Since the approval from the College required the researcher to maintain confidentiality of the data used in the study, none of the data contained individually identifiable information.

**Description of the Data**

Data used in research studies can be classified as primary or secondary. Primary data sources are used in true experimental research and collected specifically for the research study (Hox & Boeije, 2005). Secondary data are sources of data that were originally administered for another purpose (Hox & Boeije, 2005). The data collected and analyzed in this quasi-experimental study was secondary, or existing, data.

**Advantages of secondary data.** Research using secondary data has several advantages and is often a necessity (Fraenkel & Wallen, 2009) when conducting research. First, secondary data is generally easier to acquire (Fraenkel & Wallen, 2009) because it already exists. In addition, because using secondary data is much less costly and time consuming for a researcher to gather and use (Hox & Boeije, 2005), additional time and money to collect data from
participants doesn’t have to be allotted. As a result, researchers don’t have to worry about the time or costs required to obtain additional participants and are able to utilize a wider sample base (Hox & Boeije, 2005) for their study. Finally, researchers using secondary data also generally benefit from less demanding Internal Review Board (IRB) requirements of research institutions granting research approval because the data already exists.

**Disadvantages of secondary data.** Of course, secondary data also has drawbacks because it was not specifically designed for the study in which it is being used. While primary data can be customized to the theoretical constructs, “the research design, and the data collection strategy can be tailored to the research question, which ensures that the study is coherent and that the information collected indeed helps to resolve the problem” (Hox & Boeije, 2005, p. 594), secondary data may not be as customized as the researcher would like it to be (Hox & Boeije, 2005), because the researcher has to rely on the existing, available data.

Another disadvantage of secondary data is that the researcher is “one step removed” from the data because they were not present when it was collected (Fraenkel & Wallen, 2009, p. 537), making the accuracy of the data reported more difficult to check (Fraenkel & Wallen, 2009). In addition, using secondary data also requires that the researcher base the accuracy of the data on the person who collected the data (Fraenkel & Wallen, 2009), meaning that they must always rely on someone else to ensure the validity and credibility of the data.

**Use of secondary data.** All of the data used in this study was secondary data, because all of the data sources used in this study had an original purpose different than its use in this study. For instance, the students’ GPAs and math SAT scores, which were used here to establish comparable populations for this study, were already being collected by college admissions staff and administrators for the purpose of accepting or denying a student admission to the college.
Similarly, the departmental mathematics assessments were already administered by college faculty as both a course pre-test and post-test to any student taking an introductory mathematics course at the college; the college’s academic dean and mathematics faculty used the results of the assessment test for mathematics placement and to measure the “value added” by the course content. Finally, course evaluation data were also already collected for purposes of course and faculty evaluations.

**Implications of secondary data for this study.** In this study, the researcher relied on the faculty and administrators at the college being highlighted in this study to provide the researcher with accurate data for this study. Therefore, the researcher must trust that the math SAT scores, student GPAs, and course evaluation data provided by the college was accurate, and that the data accurately represents student performance.

Both the researcher and stakeholders involved in this study benefitted from the existing data used in this study because, if secondary data weren’t available, conducting this study would have been virtually impossible; collecting comparable primary data would have taken several years, making it too time consuming for the researcher to collect. In addition, even if the researcher had the time to collect the data, the time that it would have taken to collect data relevant to the problem would have greatly delayed feedback to the interested parties in this study, making the information less valuable to students and faculty at the college highlighted in this study.

**Data Collection Protocol**

Good data collection plans should explain where the data will be collected, when the data will be collected, how often the data will be collected, and who will collect the data (Fraenkel & Wallen, 2009). Without reliable data collection and analysis, the results of a study cannot be
considered valid or reliable. Since several sources of data were used in this study, it was important to have a detailed plan for data collection and analysis for this quantitative study before actual data collection began, because “you have to understand why you are gathering data and what you will do with it in order to understand which data to collect and how to analyze them” (Butin, 2010, p. 111).

**Instruments.** Proper data collection plans must include an explanation of important components of the study. Instruments are important elements of any study because they are the tools used for measuring, observing, or documenting quantitative data (Creswell, 2011) in the study. In quantitative research, instruments for data collection are chosen before the study begins because the research questions and hypotheses do not change during the course of the study (Creswell, 2011).

When deciding on the sources of data for this study, the researcher had to consider the questions asked by the study, the data that could realistically be collected, and the advantages and disadvantages of the selected data sources. Inevitably, the decisions were based on methods that were likely to provide sources of data that effectively answered the questions from this study while experiencing minimal disruptions, bias, and mistakes related to the organization and the students who were studied. This way, once all of the data for this study was collected, organized, and cleaned, it was ready for analysis. The sources of the data that were inevitably selected are detailed in the following sections.
**Student assessment data.** Student assessment tests used by the College highlighted in this study were used to evaluate student end-of-course performance. They were specifically chosen as an appropriate measure of the mathematical knowledge and skills of students who completed their required mathematics course. The assessment was deemed to be both reliable and valid because it was found to be an effective evaluation in a prior study conducted by Foley-Peres and Poirier (2008), comparing the departmental assessment scores with SAT (Scholastic Aptitude Test) scores; therefore, data from this test were collected and analyzed in order to answer this study’s first and third questions.

**Course evaluations.** In this study, course evaluation data were used to measure student viewpoints on the usefulness of course content. Specifically, answers to a five point “Likert Scale” question that appears on the course evaluation tool were collected and analyzed for this study. Data from course evaluations were used to answer questions two and three in this study.

The question regarding the usefulness of the course content was specifically selected over other questions on the course evaluation tool because prior research has shown that measures of the usefulness of course content have indicated that motivational factors in mathematics are significant for successful learning processes (Köller, Baumert, & Schnabel, 2001). That is, because “there is a general consensus that university students’ academic motivation is driven by extrinsic reasons such as getting a job in a field they like” (Wood, 2010, p. 189), measures of students’ perceptions of the usefulness of the course content for their personal and professional lives can be a valid indicator of overall course effectiveness. Furthermore, researchers like Miller and Brickman (2004) argue that an individual’s perception of how the activity will help them achieve future goals influences the value that they place on the task.
Math SAT scores and high school grade point averages. This study used two instruments to establish valid comparison groups: student scores on the mathematics portion of the Scholastic Achievement Test and high school grade point averages (GPAs). MSAT scores were specifically chosen to establish similarity in mathematical knowledge between the groups because they are a standardized measure of student achievement in mathematics. GPAs were selected because, when used in conjunction with the departmental mathematics assessment scores and the mathematics scores from the SAT, they can be used to triangulate the data. Data triangulation occurs when multiple data sources are cross-referenced in order to establish more validity in the conclusions of a study (Butin, 2010).

Procedures. Data collection for this study began in the Spring of 2015, after Northeastern University’s IRB (Internal Review Board) and the administration from the college highlighted in the study granted approval for the study to be conducted. At that point, the primary researcher for this study went to the College’s campus to collect the data necessary to complete this study. During the visits, she interacted with the members of the college’s mathematics faculty, the Dean for Liberal Arts and Sciences, and other college personnel who oversaw the administration and storage of the information. It took several visits to the College to complete the data collection.

Throughout the duration of the data collection, the researcher followed ethical practices (Creswell, 2011), ensuring that the utmost respect was always given to the students and organization used in this study. Actual data collection was done without bias or prejudice. All interactions with anyone from the institution used in this study were professional.

Data collection decisions and the exact purpose of the study were clearly communicated to all stakeholders involved in the study. Informed consent from the College was secured. Best
attempts to minimize disruption to the site while collecting research was also made so that the research did not distract faculty or students (Creswell, 2011).

**Software.** As it was being collected, data for the study were placed in a spreadsheet in Microsoft Excel in an organized and uniform format on the researcher’s password protected computer. Once the researcher received the data, the electronic data were stored on the researcher’s password protected computer. All data were then organized in a Microsoft Excel workbook by course section and data type.

Microsoft Excel was selected to assist in data collection and analysis because it is a robust spreadsheet program that is capable of organizing and analyzing large amounts of data. It provides the ability for statistical computation and creation of graphs needed for the analysis conducted for this study. In addition, because the program is widely used in both business and education, assistance using the program would have been easily available to the researcher because training and support for the program is widely available online. (However, the researcher conducting this study was already very familiar with the capabilities of Microsoft Excel; she teaches advanced Microsoft Excel classes at the college level and, as a result, is very proficient with using the capabilities of the program.) For these reasons, the program was used to create all of the graphs and calculate all of the mathematical and statistical calculations that were used in this study.

Once the data from the instruments were actually entered into columns and rows in Microsoft Excel, they needed to be “cleaned” of anything that would allow a student or faculty member to be identified (Fraenkel & Wallen, 2009) in order to ensure confidentiality and anonymity. The first column contained ID numbers associated with the students in the study, and other columns contained scores for each variable that was collected. Since the research
questions in this study deals with academic outcomes, all of the columns in this spreadsheet were independent variables (Butin, 2010).

The data entered in Microsoft Excel was also checked for errors and missing data. To find these scores, data were sorted in multiple ways for all variables that were used. When missing or erroneous data were found, the researcher determined the better choice based on the Creswell’s (2011) recommendations to determine if it could be fixed, if it should be included, or if it should be omitted. For ethical reasons, the final study included information on how the missing data were handled so that readers of the study can accurately interpret the results (George & Mallery, 2001, as cited in Creswell, 2011). After this is done, the data were also “cleaned” for scores that were outside the acceptable range of scores.

This spreadsheet of information then became “a complex yet analyzable data set” (Butin, 2010, location 1323) that easily allowed the researcher to perform the necessary calculations, relating to the mathematical and statistical functions in Excel, that were necessary for this study. In addition, having the data available in a spreadsheet also decreased the chance of researcher bias and increased the validity and reliability of data collection and analysis; it is now easier for another researcher to redo the statistical analysis to validate the results if they feel that the data analysis “reveals some unexpected findings and correlations across variables” (Butin, 2010, p. 90).

Data Storage and Protection of the Data

All types of data used in this research needs to be protected against loss, corruption, or unauthorized access. To ensure protection of data used in this study, the following precautions were utilized:
• Only the institution that collected the data used in this research and the researcher has access to the data used in this study.

• To preserve students’ confidentiality, individual student data will not be reported. All results are aggregated in order to report results of the groups.

• Paper documentation is kept in a locked drawer.

• All electronic files are securely stored on the researcher’s password protected personal computer, which is only used by the researcher.

• The researcher is very cognizant of keeping all paper and electronic files clearly labeled to ensure that data properly managed, ensuring that a possible data comprise will not occur at a later date.

• The college providing the data for the research ensured that it was stripped of anything that would allow identification of a specific student.

• The researcher used a pseudonym for the College where the data were obtained when publishing results of the study.

• Once the study was completed, all data were returned to the institution that provided the data to the researcher.

Furthermore, because most of the data were stored in an electronic format, additional steps to keep all electronic data safe and secure were also implemented to ensure that confidential student information was not compromised. Specifically, all computers used to access, compile, or analyze data relating to this study were password protected and backed up regularly using a secure online backup system. In addition, all electronic files stored on these computers were clearly labeled and stored in a separate folder so that a possible data comprise will not occur at a later date.
To ensure the security of the research data, the researchers employed Carbonite’s secure, online backup (Carbonite.). Carbonite meets security requirements for research studies because their service encrypts files with 128-bit encryption before they are transferred to their service, and then transmits them over a secure socket layer (SSL) connection. It is the same data security technology used to protect online banking and e-commerce transactions. Once stored at the Carbonite. data center, security and protective measures at the data include:

- Temperature control uninterruptible power supplies (UPS)
- On-site emergency backup generators with guaranteed fuel contracts
- Tightly restricted personnel access using biometric scanners
- Server access controlled with electronic key cards and PIN codes
- Guards on duty 24 hours a day, 365 days a year

**Data Analysis**

It is important for the researcher to explain the procedures used to analyze the data necessary to answer the research questions in this study. In this study, existing data were used to retrospectively compare assessment and course evaluation data from two different college mathematics courses. When conducting the data analysis for the study, the researcher followed Butin’s (2010) guidelines for analysis of existing data for this study because working with existing data requires a different protocol than working with data that does not yet exist.

Butin’s model supported the practice that this study used actual raw data, not the summary or aggregate data, because using summary data would not have allowed the researcher to link back to the individual answers (Butin, 2010), as was necessary for the later item analysis. In addition, Butin’s (2010) model also considered the importance of confidentiality and anonymity when using a spreadsheet for data entry and analysis; for this reason, the spreadsheet
with all of the data did not include any individual identifiers, and data were not shared with anyone who was not authorized to view it.

As previously mentioned, the researcher first needed to establish that the two sample populations used in this study were comparable before she could compare the outcomes of the two populations. For this reason, the researcher first established that the two groups of students had similar mathematical ability by showing that they had similar scores on the mathematics portion of the SAT, along with similar high school grade point averages (GPAs). Specifically, the researcher collected and recorded scores from the mathematics section of the SAT from students in the both the experimental (students in the redesigned math course) and the comparison (students who took the original math course) groups. After these data were collected and entered into the Excel spreadsheet, the researcher then calculated the means and standard deviations of the scores for students in each group. Finally, the researcher used the step-by-step procedure, explained on the College Board’s website (College Board, n.d.), to determine if the difference between two group mean scores was statistically significant.

The researcher then collected and recorded all student GPAs in an Excel spreadsheet. To show that the GPAs of the students in both groups were comparable, the researcher then used the StatPlus add-on for Excel to conduct a double-tailed t-test in order to determine whether two samples were significantly different.

Once similarity between the groups was established, the remaining data were collected and recorded, and they were ready to be analyzed. However, before the actual analysis began, the researcher needed to ensure that the quantitative data from this study were collected and analyzed according to professional standards of practice. For this study, Creswell’s (2011) recommended steps for data analysis were followed. Specifically, Creswell’s (2011) multi-step
process that consists of “drawing conclusions about it; representing it in tables, figures, and pictures to summarize it; and explaining the conclusions in words to provide answers” (Creswell, 2011, location 1056) was utilized.

All data used in this quantitative study were analyzed using descriptive and inferential statistics. Using Microsoft Excel, along with the StatPlus add-on for Excel, the researcher used existing data to answer the study’s three research questions. For questions one and three, the researcher used data from twelve questions on the departmental assessment test. For question two and three, the researcher used data from the student course evaluations. Additionally, in order to draw conclusions about the data, the researcher used both graphical and numerical analysis to help to visualize if significant differences between the students of both courses existed.

When analyzing the first question, data from departmental assessment tests from both groups of students were analyzed to determine if a significant difference between the two groups existed. For the analysis, the researcher conducted two-tailed t-tests from mathematics achievement tests of students in both populations in order to determine if the mean score between the two populations was statistically significant. The t-test indicates if the means of the two groups, one group consisting of students in the college algebra course and one group consisting of students in the redesigned course, were significantly different. In fact, the “p value” derived from the t-test revealed whether or not the null hypothesis related to the research question should be rejected or accepted. In addition to the two-tailed t-test analysis, graphs of math assessment data for students from both groups of students were constructed so that the relationships in the data could be visualized.
For question two, Likert-scale ratings of perceived value from course evaluation data from the two groups of students was analyzed to determine if a significant difference between the two groups existed. Since research question two also examined the significance of the difference between a variable measured in each of the two groups, a procedure similar to the one explained in the previous paragraph was used to analyze research question two; that is, the researcher used a combination of graphs and statistics to determine whether or not to accept or reject the null hypothesis for question two. However, because the data from the course evaluations are measured using a categorical Likert scale (strongly agree, agree, disagree, and strongly disagree), a chi-square test was used instead of a t-test, because a t-test is used with numerical data. The chi-square test was used to determine if a significant difference existed in the ratings of the groups because a chi-square test is used when the data yields non-numeric categories that cannot be ordered or calculated (Siegel, 2012). In addition, a chi-square test measures how close the data conform to the null hypothesis by measuring the difference between the observed and expected results (Siegel, 2012).

Research question three examined the data from the achievement tests and the course evaluations in order to determine if a significant relationship between the two variables existed. To answer this question, the researcher utilized regression analysis to determine the extent of the relationship between the two variables in this study because regression is used to quantify the relationship between two different variables. Regression analysis was selected in lieu of the statistical tests used to answer research questions one and two because neither a t-test nor chi-square test was an appropriate analysis technique for question three because it relates to both groups of students and the relationship between the two variables being examined in the study (the value ratings of course content and the students’ end-of-course achievement scores).
The researcher used Kleinbaum, Kupper, Nizam, & Rosenberg’s, (2014) strategy for regression analysis, which emphasizes the importance of a visual display of the data. First, in order to show how the scores regress or differ from the mean and/or identifying outliers in data (Butin, 2010), the researcher created a scatterplot. Then, in order to express the data as a linear relationship, a best-fit (straight) line through the data was constructed. Finally, a “goodness of fit” (Mayr, Erdfelder, Buchner, & Faul, 2007) test was conducted on the newly created best-fit line to determine if the straight-line model works correctly with the data because more complex models would have needed to be employed if the straight-line method had been shown to be inaccurate.

Figure 1: Regression Analysis Flow Diagram (Kleinbaum et al., 2014, p. 49)

Validity, Reliability, and Generalizability

When conducting quasi-experimental research, researchers need to identify potential threats to the internal validity of their experiments and design them so that these threats are controlled or minimized (Creswell, 2011; Fraenkel & Wallen, 2009). In this study, which examined outcomes in both a traditional college algebra course requirement and a redesigned
mathematics course that teaches “the math you really need to know,” issues of validity and reliability needed to be addressed to help ensure the trustworthiness of this study.

This study used convenience-sampling techniques, which means the data were collected from individuals who were readily accessible (Fraenkel & Wallen, 2009). While these techniques are common, they are not always ideal because they can be biased (Fraenkel & Wallen, 2009). For this reason, the researcher needed to be cautious with regards to the generalizability of the study’s findings. That is, while the results of this study are considered valid and reliable for the college highlighted in this study, broader generalizations should be avoided, as the findings may be limited by characteristics specific to students at this exact college, or specific to the required math courses offered by this college. This study of the students’ outcomes at this college only examined a relatively small target population that was selected due to its convenience and, for this reason, additional similar research would need to be conducted before it can be determined if there is any greater “generalizability” of the findings (Creswell, 2011).

The most valid and reliable findings typically come from studies that employ random assignment to groups. In this study, random assignment was not possible for two reasons. First, data have been previously collected; and second, students self-select into classes. However, the lack of random assignment does not mean that the results of this study are not reliable or valid. It simply means that the threats associated with using the existing groups needed to be addressed (Creswell, 2011)

Since pre-existing groups were used to examine the differences in and relationships between the two groups in a study, the researcher needed to show that the groups are comparable on certain variables (Fraenkel & Wallen, 2009). After all, conclusions from the data collected
for a study can only be reliable if the groups compared in the study are comparable on some variables. For this study, the researcher used a “matching-only” design (Fraenkel & Wallen, 2009) to show that the groups were comparable based on past achievement and ability. That is, the researcher used the high school grade point average and score on the mathematics section of the SAT for the students in the two groups to show the groups were comparable with regards to these variables.

Using the “matching-only” design addresses some concerns related to validity and reliability as it attempts to equalize the groups to some degree (Fraenkel & Wallen, 2009). However, it is important to mention that there may be other differences between the groups that were be measured. As a result, the findings may not be generalizable to other students and contexts (Creswell, 2011).

Addressing the validity and reliability of the main instruments used in this study is also significant to the overall study’s validity and reliability. The mathematics portion of the SAT is a standardized test that has been assessed for both reliability and validity by the College Board (Ewing, Huff, King, & Andrews, 2005). Similarly, the college’s departmental mathematics assessment test was found to be a valid instrument to measure student achievement because when a study of its appropriateness for assessing proper college math level was conducted, it was found that the college math assessment was an effective evaluation measure for student placement in math courses (Foley-Peres & Poirier, 2008). In addition, to address any concerns of instrumentation, the college’s math test has established consistent scoring criteria that is used by all instructors who administer the test.

However, despite the most carefully planned and well-executed research, the researcher needed to avoid generalizing the results. Instead, the researcher must use caution when reporting
the results of the relationship between the two variables being studied; that is, although the data analysis from this study provides information about the significance of the differences in scores between the two different groups, educational researchers exercise caution when drawing conclusions from the results of the analysis. Even when two variables are related, it does not necessarily mean that one causes the other. “There may be a host of intervening variables (technically called “mediating variables”) that impact the actual variables studied” (Butin, 2010, p. 87).

Limitations

It is possible that the results of this study did not accurately evaluate student mathematical achievement or student perceptions of course value. While the study was carefully conducted using effective research techniques, errors may still have inadvertently occurred because the data and the resulting analysis and conclusions from a study are always subject to “ordinary variability in human behavior” (Boruch, 1997, p. 4). For instance, sometimes student behaviors, such as mood or environment, can be impacted by factors that cannot be easily measured by the study.

Since “ordinary chance variability in human and institutional behavior can be substantial” (Boruch, 1997, p. 4), extraneous factors may have impacted the results in a statistically significant way. The students in the sample used for this study could have inadvertently impacted the outcomes for the assessment or course evaluation data if they had a change in mood or attitude when completing the evaluation tools. Additionally, actions of the instructors administering the assessments to the data could have impacted the results.

The somewhat small sample size used for this study may limit generalizability of results. Likewise, the fact that the entire sample of students attended the same college may limit
generalizability. Additionally, the conclusions from the study should not be interpreted as misleading because the detailed description of the population found in this study will give interested individuals enough detail to “determine the applicability of the findings to their own situations” (Fraenkel & Wallen, 2009, p. 91)

**Protection of Human Subjects**

All necessary precautions to protect human subjects involved in the research study were taken when research was conducted. The researcher, who successfully completed the National Institutes of Health (NIH) Office of Extramural Research web-based training course on protecting human research participants, is knowledgeable in the protection of human subjects. Furthermore, the researcher followed the Belmont Ethical Principles, which emphasize respect for persons, beneficence, and justice when gathering and reporting data for this study.

All involved parties were informed of the parameters of the study. In addition, everyone who agreed to participate in the research study were told that all of their responses would be kept confidential, and that all student data were kept in a secure location that was only accessible by the researcher.

To further ensure the protection of human subjects, Northeastern University’s Internal Review Board (IRB) approved the parameters of the study. In addition, because the college highlighted in this study does not have a formal IRB of their own, the researcher had to obtain written approval detailing the parameters of the study from the College’s lawyer, Vice President of Academic Affairs, and Dean of the School of Liberal Arts and Sciences.
Chapter 4: Summary of Findings

Purpose of Study

The purpose of this quasi-experimental, causal comparative study was to retrospectively compare assessment and course evaluation data from a required college algebra course and a redesigned (non-algebra) required college mathematics course at a small, private college in Massachusetts. This study was intended to provide the curricular decision makers from the college where data collected with information on the differences between the two required courses offered by the College in terms of student achievement and perceived value of course content. The study also provides benefits by adding to the research relating to expectancy-value theory, as this study examined the relationship between achievement and value ratings using expectancy-value theory to frame the research and findings.

The findings in chapter 4 give the findings of the study’s research questions. Specifically, chapter 4 uses empirical data to show if there was a significant difference between students from the two groups in math achievement as measured by a standardized math test, and if there was a significant difference between the two courses in terms of student ratings of the value of course content as measured by course evaluations. Finally, it provides data to show if there was a significant relationship between students’ attitudes regarding value of course content in mathematics and students’ achievement in mathematics.

Design of the Study

This quasi-experimental, quantitative study utilized a causal-comparative design to compare outcomes from two groups of students; data from students in a traditional algebra class were compared with data from students in a redesigned course (Introduction to Quantitative
Reasoning) composed of more real-world content. The study examined both assessment data and course evaluation data to answer the research question below.

**Research Questions**

The research questions that guided this investigation are:

1. Is there a significant difference between the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems?
2. Is there a significant difference between student ratings of the value of course content of students who completed a traditional college algebra class and those students who completed a redesigned mathematics course?
3. What is the relationship between student ratings of the value of course content and achievement for students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems?

Statistical testing was performed on to test the following hypotheses:

1. **Hypothesis I:** There is a significant difference in the math achievement of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by an assessment test.
2. **Hypothesis II:** There is a significant difference in the student ratings of the value of course content of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by course evaluation data.
3. Hypothesis III: There is significant relationship between student attitudes regarding value of course content in mathematics and student achievement in mathematics.

Statistics on College Algebra Course

Data from eight sections of College Algebra, with an initial enrollment of 149 students, were analyzed. The average GPA of all students enrolling in these eight sections of college algebra was 2.11, with a maximum student GPA of 4 and a minimum student GPA of 1.1. The standard deviation of the GPAs was 0.61. The average SAT score in mathematics of all students enrolling in these eight sections was 421, with a maximum SAT score in mathematics of 620 and a minimum score of 230. The standard deviation of the SAT scores was 75.2.

Twenty-one, or 14.1%, of the originally enrolled 149 students withdrew from the algebra course and received a grade of a W (Withdrawn), WP (Withdrawn-Passing), or WF (Withdrawn-Failing). Twenty-two, or 14.8%, of the originally enrolled 149 students received a failing grade in the course. In other words, 30% of students who originally enrolled in College Algebra withdrew from or failed the course.
Statistics on the Introduction to Quantitative Reasoning Course

Data from seven sections of Introduction to Quantitative Reasoning, with an initial enrollment of 166 students, were analyzed. The average GPA of all students enrolling in these seven sections of Introduction to Quantitative Reasoning was 2.3, with a maximum student GPA of 4 and a minimum student GPA of 1.3. The standard deviation of the GPAs was 0.54. The average SAT score in mathematics of all students enrolling in these seven sections was 430, with a maximum SAT score in mathematics of 660 and a minimum score of 270. The standard deviation of the SAT scores was 79.3.

13, or 7.8%, of the originally enrolled 166 students withdrew from the Introduction to Quantitative Reasoning course and received a grade of a W (Withdrawn), WP (Withdrawn-Passing), or WF (Withdrawn-Failing). 16, or 9.6%, of the originally enrolled 193 students received a failing grade in the course. In other words, 18% of students who originally enrolled in College Algebra withdrew from or failed the course.
Comparing groups using SAT scores in mathematics.

To determine if the difference between mean scores of the two comparison groups of mathematics SAT scores was statistically significant, the researcher used methods described in the College Board’s guide to comparing group scores on the SAT (College Board, n.d.). Specifically, the researcher calculated the difference between the group means by subtracting the mean of the sample population so that this difference could be graphed versus the sample population size in each group.

Subtracting the mean of the sample population of College Algebra students (421) from the sample population of Quantitative Reasoning students (430) resulted in a difference of 9 points. The number of people in each group was calculated by averaging the two sample populations. The sample population of the Introduction to Quantitative Reasoning group (n=135) was averaged with the sample population of the College Algebra group (n=129) to yield an average sample population of 132.
Then, plotting the point in the standard \((x, y)\) format used for coordinate planes, the researcher plotted the point using 132 (the average number of people in each group) as the \(x\) coordinate and 9 (the difference between the two group means) as the \(y\) coordinate. As shown in Figure 4, the plotted point showed that the difference between the two groups mean scores was not statistically significant.

**Figure 4:** Graph, Comparing Groups on the SAT

**Comparing groups using high school GPAs**

To establish that the differences in high school GPAs between the two sample populations were not statistically significant, the researcher conducted a t-test for independent means. The t-test for independent means was selected because it is used to compare the mean scores of two different groups (Fraenkel & Wallen, 2009). In this study, the two groups being compared were the sample population of students who took College Algebra and the sample population of students who took Introduction to Quantitative Reasoning.
Running a 2-tailed t-test of independent means using the statistics listed in Table 1 yielded a “T” of 1.5893, with a confidence level of 88.69%, confirming that the means of the two groups used in this study are not significantly different at the 95% confidence level ($\alpha=0.05$). In other words, the difference between the mean GPA scores of the two groups was not statistically significant.

Table 1: Statistics from two independent groups

<table>
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<th>Sample Size</th>
<th>Mean</th>
<th>Standard Deviation</th>
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</thead>
<tbody>
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<td>142</td>
<td>2.15</td>
<td>0.63</td>
</tr>
<tr>
<td>Introduction to Quantitative Reasoning</td>
<td>145</td>
<td>2.26</td>
<td>0.54</td>
</tr>
</tbody>
</table>

**Summary: Comparing Groups**

At the onset of this study, before students completed their first required college mathematics course, the two groups of students compared in this study did not have statistically significant scores on the mathematics portion of the SAT or grades on their GPAs. While lack of statistical significance does not necessarily mean that the comparison groups in a quasi-experimental study are equivalent, for the purposes of this study, the researcher will suggest that the two groups are similar in order to compare outcomes from students who completed College Algebra with students who completed Introduction to Quantitative Reasoning to see if they are statistically significant.

**Data Analysis: Research Question One**

Question one from this research study asked if there was a significant difference in the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems. The researcher’s hypothesis was that there was a significant difference in the math achievement
of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by an assessment test.

To answer question one, the researcher collected data from the college’s departmental mathematics assessment from eight sections of College Algebra and seven sections of Introduction to Quantitative Reasoning with the intention of using the data to determine if a significant difference in outcomes exists. Specifically, the researcher studied twelve questions that were included in the college’s departmental mathematics assessment, given to students at the end of both mathematics courses examined in this study. The departmental assessment was specifically chosen as an appropriate instrument because of its reliability and validity; in a prior study conducted by Foley-Peres and Poirier (2008), the assessment was found to be an effective evaluation when the college compared their departmental assessment scores with SAT scores.

Student answers to the twelve questions from the departmental assessment were examined. These twelve questions included basic algebraic questions, percentages, fractions, and basic mathematical word problems. The analysis included an aggregate count of the scores for students in each course. The results of this analysis are displayed in Table 2.

Table 2: Mathematics Assessment Test Results

<table>
<thead>
<tr>
<th>Total Questions Correct (out of 12)</th>
<th>% of College Algebra students</th>
<th>% of QR students</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 questions correct</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1 question correct</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2 questions correct</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>3 questions correct</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>4 questions correct</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>5 questions correct</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>6 questions correct</td>
<td>2%</td>
<td>6%</td>
</tr>
<tr>
<td>7 questions correct</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>8 questions correct</td>
<td>6%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Overall, 106 students in eight College Algebra sections completed the departmental assessment. On average, the students in this group answered 9.6 out of the twelve questions correctly. The standard deviation was 1.83. Seventeen out of the 106 students (16%) answered all of the 12 questions correctly. One student (0.9%), who only answered three questions correctly, received the lowest score.

In Introduction to Quantitative Reasoning, 132 students in seven sections completed the departmental assessment. On average, the students in this group answered 9.6 out of the twelve questions correctly. The standard deviation was 1.81. Fourteen out of the 132 students (10.6%) answered all of the 12 questions correctly. One student (0.8%), who only answered four questions correctly, received the lowest score.

**Statistical analysis: Research Question One.** A two-tailed t-test, which is used to compare means of two groups, was used to determine if the means of the two groups were statistically different. Results of the analysis, summarized in Table 3, showed that the means of the two groups in this study were not significantly different in several instances. First, because the absolute value of the test statistic (0.01508) was not greater than the critical value (1.97007), the test indicated that the means were not statistically different.

Furthermore, the two-tailed t-test indicated that it is very likely that the null hypothesis of the research question is actually true. Since the results revealed a p-level of 0.98798, it is 98% likely that the data in the study would occur when the null hypothesis, which states that the math achievement of students in a traditional college algebra class is equal to the achievement of
students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems, as measured by the departmental assessment. Obviously, if the means are shown to be equal, they are not statistically different.

Table 3: Two-tailed t-test for Question 1

| Comparing Means [ t-test assuming equal variances (homoscedastic) ] |
|---|---|---|---|
| **Descriptive Statistics** | | | |
| **VAR** | **Sample size** | **Mean** | **Variance** |
| College Algebra | 106 | 9.5566 | 3.33486 |
| Introduction to QR | 132 | 9.55303 | 3.27198 |

**Summary**

| Degrees Of Freedom | 236 | Hypothesized Mean Difference | 0.E+0 |
| Test Statistics | 0.01508 | Pooled Variance | 3.29995 |

**Two-tailed distribution**

| **p-level** | 0.98798 | **t Critical Value (5%)** | 1.97007 |

**One-tailed distribution**

| **p-level** | 0.49399 | **t Critical Value (5%)** | 1.65134 |

**G-criterion**

| **Test Statistics** | #N/A | **p-level** | #N/A |
| Critical Value (5%) | #N/A |

**Pagurova criterion**

| **Test Statistics** | 0.01507 | **p-level** | 0.01201 |
| Ratio of variances parameter | 0.55932 | Critical Value (5%) | 0.06278 |

**Item analysis of mathematics assessment.** Since the aggregate mean assessment scores of the two groups did not yield a significant difference in outcomes, an item analysis of each question on the departmental mathematics assessment was conducted. Scores from common questions from assessment tests for students in both courses were examined to determine if a significant difference in the scores of each common question existed for the students in each of these two groups. The rationale for this in-depth analysis was so that the faculty and
administration at the college where the study was conducted could determine if any significant
differences existed for specific assessment questions.

A scatterplot showing the percentage of students in each group who answered each
question on the mathematics assessment correctly is shown in Figure 5.

![Item Analysis of Math Assessment: Percentage of Students Answering Correctly](image)

**Figure 5**: Item Analysis Scatterplot

Then, in order to determine if the percentages of students in each group who answered the questions correctly showed a statistically significant difference, a two-tailed t-test between proportions was performed for each of the twelve questions. The results of these tests, summarized in the results in Table 4, showed that three out of the twelve questions had a statistically significant difference in percentage of students answering correctly.
Table 4: Item Analysis T-test

<table>
<thead>
<tr>
<th>Item</th>
<th>t-statistic</th>
<th>Degrees of Freedom</th>
<th>2-tailed Probability</th>
<th>Statistically Significant Difference?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>2.18</td>
<td>236</td>
<td>0.03</td>
<td>Yes</td>
</tr>
<tr>
<td>Question 2</td>
<td>0.62</td>
<td>236</td>
<td>0.536</td>
<td>No</td>
</tr>
<tr>
<td>Question 3</td>
<td>1.978</td>
<td>236</td>
<td>0.049</td>
<td>Yes</td>
</tr>
<tr>
<td>Question 4</td>
<td>0.775</td>
<td>236</td>
<td>0.439</td>
<td>No</td>
</tr>
<tr>
<td>Question 5</td>
<td>0.706</td>
<td>236</td>
<td>0.481</td>
<td>No</td>
</tr>
<tr>
<td>Question 6</td>
<td>0.224</td>
<td>236</td>
<td>0.823</td>
<td>No</td>
</tr>
<tr>
<td>Question 7</td>
<td>0.799</td>
<td>236</td>
<td>0.437</td>
<td>No</td>
</tr>
<tr>
<td>Question 8</td>
<td>0</td>
<td>236</td>
<td>0.999</td>
<td>No</td>
</tr>
<tr>
<td>Question 9</td>
<td>1.26</td>
<td>236</td>
<td>0.209</td>
<td>No</td>
</tr>
<tr>
<td>Question 10</td>
<td>0.89</td>
<td>236</td>
<td>0.375</td>
<td>No</td>
</tr>
<tr>
<td>Question 11</td>
<td>0.854</td>
<td>236</td>
<td>0.394</td>
<td>No</td>
</tr>
<tr>
<td>Question 12</td>
<td>3.193</td>
<td>236</td>
<td>0.002</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Two of the three questions that had a statistically significant difference, questions one and three were word problems. For both of these questions, the students completing Introduction to Quantitative Reasoning scored significantly higher than the students completing College Algebra. The other question that had statistically significant outcomes pertained to basic algebra. For this question, item 12, the student who completed College Algebra outperformed the students completing Introduction to Quantitative Reasoning.

**Data Analysis: Research Question Two**

In order to determine if there was a significant difference between student ratings of the value of course content of students who completed a traditional college algebra class and students who completed a redesigned, non-college algebra mathematics course, the researcher analyzed the results of a course evaluation question that asked students to strongly agree, agree, disagree, or strongly disagree with the statement stating that “The course content was valuable.”
Ninety-one ratings from students enrolled in the eight sections of College Algebra used in this study were combined and averaged across sections. Likewise, 127 ratings from the students who enrolled in the seven sections of Introduction to Quantitative Reasoning course were also combined and averaged across sections. The results of the evaluation question are displayed in Figure 6.

![Student Ratings of Value of Course Content](image_url)

**Figure 6**: Graph of Student Ratings of Value of Course Content

In order to determine if the difference in ratings of the value of the course content was statistically significance for students in each of the two groups, a chi-square test was conducted. The chi-square test was selected because it measures how close the data conforms to the null hypothesis by measuring the difference between the observed and expected results (Siegel, 2012). The chi-square test is used when the data yields non-numeric categories that cannot be ordered or calculated (Siegel, 2012).

The observed values of the ratings from each course are displayed in Table 5, while the expected values of the ratings from each course are displayed in Table 6. The results of the chi-squared test are summarized in Table 6.
Table 5: Observed Ratings of Value of Course Content

<table>
<thead>
<tr>
<th>Observed Value</th>
<th>College Algebra</th>
<th>Intro to QR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>47</td>
<td>60</td>
<td>107</td>
</tr>
<tr>
<td>Agree</td>
<td>13</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Disagree</td>
<td>29</td>
<td>52</td>
<td>81</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total (n)</td>
<td>91</td>
<td>127</td>
<td>218</td>
</tr>
</tbody>
</table>

Table 6: Expected Ratings of Value of Course Content

<table>
<thead>
<tr>
<th>Expected Value</th>
<th>College Algebra</th>
<th>Intro to QR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>44.66513761</td>
<td>62.33486239</td>
<td>107</td>
</tr>
<tr>
<td>Agree</td>
<td>10.43577982</td>
<td>14.56422018</td>
<td>25</td>
</tr>
<tr>
<td>Disagree</td>
<td>33.81192661</td>
<td>47.18807339</td>
<td>81</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>2.087155963</td>
<td>2.912844037</td>
<td>5</td>
</tr>
<tr>
<td>Total (n)</td>
<td>91</td>
<td>127</td>
<td>218</td>
</tr>
</tbody>
</table>

Table 7: Results of Chi-square Test on Course Evaluation Data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square statistic</td>
<td>2.473</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>3</td>
</tr>
<tr>
<td>Two-tailed probability</td>
<td>0.480</td>
</tr>
<tr>
<td>p-value</td>
<td>0.480</td>
</tr>
<tr>
<td>Conclusion at the .05</td>
<td>The difference is not significant.</td>
</tr>
</tbody>
</table>

Since the p-value that resulted from the chi-square analysis (0.480) was greater than the significance level of 0.05, there was not a statistically significant difference in the ratings of value of course content between the two courses.
**Data Analysis: Research Question Three**

For question three, the resulting outcomes from the assessment tests and the course evaluation data were used to determine if a correlation exists between students’ achievement and ratings of value of course content. Since research question three related to both groups of students, and the relationship between two variables being examined in the study (the value ratings of course content and the student’s end of course achievement scores), research question three utilized regression analysis to determine the extent of the relationship between the two variables. Regression analysis was selected because regression is used to quantify the relationship between two different variables (Fraenkel & Wallen, 2009).

The regression analysis used in this study followed Kleinbaum et al.’s (2014) strategy for regression analysis, which requires construction of a scatterplot, along with the insertion of a best-fit (straight) line through the data in the scatterplot. This approach was selected because it could allow the researcher to use the correlation coefficient (r-value) to determine if a relationship exists between the two variables represented in the scatterplot (Fraenkel & Wallen, 2009). In addition, the r-value will indicate the type and strength of the relationship between the variables, if one exists.

While all correlation coefficients (r-values) will fall between positive one and negative one, the positioning of the r-value on that range will indicate the relationship between the variables. For instance, if an r-value is positive one, it means that the predicted scores correlated perfectly with the actual scores on the criterion variable (Fraenkel & Wallen, 2009) while r-values of 0.70 or 0.80 are considered to be reliable predictors of relationship between the variables (Fraenkel & Wallen, 2009). On the other hand, r-values of zero indicate that no relationship between the two variables exists while r-values at or close to negative one indicate
that a high score on one of the variables is generally accompanied by a low score on the other variable.

After the r-values are calculated through regression analysis for each of the two populations in this study, a t-test for the correlation coefficient can be used to test significant differences of the values. In other words, this t-test will indicate if there is a significant difference in the outcomes from the two different courses.

By definition, scatterplots are used to show the relationship between two quantitative variables (Fraenkel & Wallen, 2009). However, because the two variables being examined in this question were the (already) quantitative average assessment score and the non-quantitative Likert-based question results from the question regarding the value of the course content, the researcher needed to transfer the Likert question results into a quantitative measure before being able to begin the regression analysis.

In order to transfer the results of the Likert-based question into a quantitative measure, the researcher calculated the percentage of students in each section of both courses being examined in this study. Then, the percentage of students who strongly agreed that the course content was valuable was added to the percentage of students who simply agreed that the course content was valuable; the sum of these two categories created a quantitative score that measured the percentage of students who agreed that the course content to which they were exposed was valuable.

Once the data were collected and recorded, scatterplots of the data were created. Best-fit lines, along with the equation of the lines and the r-squared values are also displayed in Figures 7 and 8.
Using the data from the graphs above, the researcher calculated the r-value of the College Algebra sections to be -0.391 and the r-value of Introduction to Quantitative Reasoning sections to be -0.8097x + 152.98 with $R^2 = 0.07469$.
to be -0.273. Since both of these r-values are relatively close to zero, the regression analysis of both courses indicates that the relationship between outcomes on a course assessment and ratings of value of course content is random and nonlinear; therefore, the test for correlation was not conducted because the relationship between the courses didn’t need to be measured. A significant relationship within each course did not exist.

**Summary**

The data analysis in this chapter utilized statistical measures to test the hypothesis of each of the three research questions presented in this study. The t-tests conducted for research question one revealed that there was not a significant difference between the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems. Therefore, the hypothesis for question number one was rejected. The chi-square test conducted for research question two indicated that there was not a significant difference between student ratings of the value of course content of students who completed a traditional college algebra class and students who completed a redesigned mathematics course, and the hypothesis for this question was also rejected. The regression analysis conducted for question three revealed that a significant relationship between student ratings of the value of course content and scores on the mathematics achievement test for students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems did not exist. For this reason, the hypothesis for question three was also rejected. Discussion of findings from the study, along with limitations of the study and implications for future research will be discussed in the next chapter.
Chapter 5: Findings

Introduction

The goal of this study was to compare assessment and course evaluation data from a required college algebra course and a redesigned (non-algebra) required college mathematics course, with the goal of determining if a significant difference in course outcomes for students in each course existed. It used existing data from students enrolled in both courses to retrospectively compare data from existing assessment tests and course value in order to determine if there was a significant difference in either the achievement or perceived ratings of course value between the two groups of students. It also determined if there was a relationship between the perceived value ratings of the course and the achievement in the course, by collecting and analyzing data from students in both groups.

A summary of the key findings of this research, along with a discussion on the implications of the findings on educational research, is given in Chapter 5. In addition, suggestions for future research on the topics of this study are also discussed.

Findings from Comparisons of the Two Populations Used in the Study

Analysis of student demographic and academic data gathered prior to analyzing the course data for this study showed that the two populations of students used in this study were not significantly different. Not only were the two groups not significantly different in size and gender composition, but a comparison of their scores from the mathematics portion of the SAT, along with a separate comparison of the high school grade point averages (GPAs) showed that the students in both populations also showed no significant difference in prior academic performance. In fact, when the mean scores from each measure were calculated and plotted on the College Board’s graph designed specifically to determine if two populations were statistically
significant, the mean scores of the two populations of students in this study showed no significant difference in their scores on the mathematics portion of the SAT. Additionally, an independent t-test of the GPAs of the students in the two different groups showed that differences in the mean scores of high school GPAs of each group were not significant.

**Findings from Research Question One**

Research question one from this study asked if there was a significant difference between the math assessment test scores of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems. The researcher’s hypothesis was that there was a significant difference in the math achievement of students in a traditional college algebra class and students in a redesigned course emphasizing the application of mathematic skills to solve realistic problems as measured by an assessment test.

For this question, the researcher used the information from the literature collected for this study to make a decision regarding the outcomes for the question. That is, to create the hypothesis, the researcher used the information in the literature review regarding the recommendations relating to college mathematics curriculum designed to improve student achievement in mathematics.

The independent research cited in the literature review for this study revealed that students are often more successful in their college mathematics course when they are able to connect the course content to problems from the real world and make connections with what they already know (Berenson et al., 1992; Nicol, 2002; Gainsburg, 2005); and that courses that contain relevant, relatable content allow students to relate and apply the course concepts to their future personal and professional lives (Gordon, 2004; Stacey et al., 2006; Usiskin, 2004) are best
practice in college mathematics. Furthermore, the research indicated that organizations like the Mathematical Association of America (MAA), the Adult Numeracy Network (ANN), and the International Commission on Mathematical Instruction (ICMI) consistently recommend that college mathematics courses include realistic problem solving with mathematical modeling (Gordon, 2013), the use of statistics, (Gordon, 2013), and the inclusion of course activities that relate to real-life experiences (Adult Numeracy Network, 2005).

Based on this information from the literature review, the researcher hypothesized that there would be a significant difference between the achievement scores and the assessment scores for the two populations of students. That is, the Introduction to Quantitative Reasoning Course (dubbed “The Math You Really Need”) contained more real-world applications and statistics, the researcher believed that students in that course would experience significantly better outcomes because the Introduction to Quantitative Reasoning Course (dubbed “The Math You Really Need”) contained more real-world applications and statistics, and the curriculum for the course incorporated the recommendations from the research cited in the literature, the researcher believed that students in that course would experience significantly better outcomes.

However, a two-tailed t-test indicated that the mean scores of the two populations were not statistically different. In fact, the test statistic from the t-test (p=0.988) revealed that the math achievement of the students in the college algebra class was essentially equal to the achievement of students in the Introduction to Quantitative Reasoning class.

While the curricular decision makers at the College highlighted in this study had hoped that the students completing the newly implemented Introduction to Quantitative Reasoning course would have significantly higher assessment results, the virtually equal performance of the students in the two different populations on the departmental mathematics test do not suggest
that implementing the Introduction to Quantitative Reasoning course was a poor decision. The results of this study simply showed that students who took the Introduction to Quantitative Reasoning course did not perform statistically differently on the questions selected for analysis in this study than those who took the College Algebra course. In other words, with regards to assessment scores, while the decision to revise the course did not produce significantly improved student assessment scores, neither did it produce significantly lower assessment scores.

**Findings for Research Question Two**

Research question two sought to determine if there was a significant difference between student ratings of the value of course content of students who completed a traditional college algebra class and those students who completed a redesigned, non-college algebra mathematics course. To do this, the researcher analyzed the results of a course evaluation question that asked students to strongly agree, agree, disagree, or strongly disagree to the statement stating that “The course content was valuable.”

Using a method similar to the first question, the researcher used the information from the literature collected for this study to make a decision regarding the outcomes for the question. That is, to create the hypothesis, the researcher used the information in the literature review regarding the recommendations relating to the impact of student value rating on achievement in mathematics.

The research highlighted in the literature review showed that many students believed that college algebra is boring (Gordon & Nicholas, 2013) and irrelevant (Stacey et al., 2006). In addition, students did not believe algebra to be highly relevant to their future lives or professions (Gordon, 2004; Gordon & Nicholas, 2013; Nicol, 2002; Usiskin, 2004).
Using the information from the literature review, the researcher hypothesized that the data analysis for research question two would show that a significant difference between the ratings of the two populations would produce low ratings of the value of course content in the College Algebra courses. That is, if College Algebra was shown to not be highly valued by many students in the above research, the researcher hypothesized that the course dubbed, “The Math You Really Need” would receive significantly higher ratings pertaining to the value in course content because the content of the Introduction to Quantitative Reasoning Course was specifically designed to include mathematics that was valuable to students in their future personal and professional lives.

However, even though the researcher’s hypothesis stated that there would be a significant difference between the ratings of the two populations, a chi-square analysis yielded results (p=0.480) that were well over the significance level of 0.05, showing that there was not a statistically significant difference in the ratings of value of course content between the two courses.

While the faculty and administrators at the College highlighted in this study hoped that the students in the Introduction to Quantitative Reasoning class, which focused on real-world mathematical concepts essential for financial and consumer literacy, would rate the content as more valuable, the results of the analysis do not suggest that implementing the Introduction to Quantitative Reasoning course was a poor decision. The results simply showed that the students who took the Introduction to Quantitative Reasoning course did not find the content to be statistically more, or less, valuable than the content from the College Algebra course. For this reason, the decision to revise the course did not produce significantly improved ratings of the value of course content, nor did it produce significantly lower ratings of course content.
Findings for Research Question Three

Research question three studied the resulting outcomes from the assessment tests and the course evaluation data to determine if a correlation between students’ achievement and ratings of value of course content existed. To do this analysis, the researcher conducted a regression analysis on the assessment test scores from research question one and the course value ratings from research question two.

Using a method similar to questions one and two, the researcher used the information from the literature collected for this study to make a decision regarding the outcomes for the question. That is, to create the hypothesis, the researcher used the information in the literature review regarding the recommendations relating to the relationship between student value ratings and achievement in mathematics.

In this research, Eccles’ (Parsons’) work on expectancy-value theory (Eccles & Wigfield, 2002) as a form of motivation theory was highlighted because it showed that people’s beliefs regarding the value of a task are directly related to their achievement performance and persistence on the task (Eccles & Wigfield, 2002). Specifically, the research showed that students who have higher ratings of task value associated with their college mathematics course exert more effort than students who have lower ratings of task value (Cole et al., 2008; Joo et al., 2013); they also persist in their mathematics course for a longer period of time, making it less likely that these students will drop out of their required mathematics course (Joo et al., 2013: Wigfield & Eccles, 1992).

For these reasons, the researcher hypothesized that ratings of the value of course content and achievement scores would be positively related to each other. However, a regression analysis of the variables yielded statistics (r values of 0.391 for the College Algebra students and
-0.273 for the Introduction to Quantitative Reasoning students) indicated that the relationship between outcomes on a course assessment and ratings of value of course content was random and nonlinear; that is, the analysis showed that there was no correlation between the students’ achievement and ratings of course content value.

Although the faculty and administrators at the College highlighted in this study hoped that the assessment scores and rating of course content would both increase, and maybe even show positive correlation between those two variables, the fact that the analysis showed that no relationship did not mean that the decision to revise the course was a poor decision. The results simply showed that no correlation between course value ratings and assessment scores existed for the populations examined in this study.

**Additional Research Findings and Future Research**

As detailed above, the data findings from this study showed that a significant difference does not exist in either the overall math assessment scores or ratings of value of course content of students from the two populations in this study. Additionally, the findings showed that a statistically significant relationship between students’ attitudes regarding value of course content in mathematics and students’ achievement on a valid and reliable mathematics assessment did not exist. However, even though the findings for the three research questions posed by this study fail to show any statistical significance or correlation, the findings from the study are still valid and still yield potentially valuable information.

For instance, one potentially valuable finding was discovered through an item analysis of student performance on each common question from the mathematics assessment that was administered to students who took both courses studied in this research study. This item analysis measured the number of students who correctly answered each of the questions, thus allowing
the outcomes of each question to be analyzed individually. For each question on the assessment, the total number of students from the College Algebra course with a correct answer was compared to the total number of students from the Introduction to Quantitative Reasoning course with a correct answer.

The two-tailed t-test between proportions that was performed for each of the twelve questions showed that three out of twelve questions had statistically different results. Two of the three questions that had a statistically significant difference (questions one and three) were word problems that simply required basic math skills (see appendix B). For both of these questions, the students completing Introduction to Quantitative Reasoning scored significantly higher than the students completing College Algebra. The third question (question 12) that produced statistically different results between the two populations required students to be able to read a symbol predominately used in pre-algebra and algebra courses. For this question, students taking the College Algebra course scored significantly higher than the students in the Introduction to Quantitative Reasoning course.

While the limitations of this study did not allow for meaningful analysis of the reasons for the significant differences in outcomes of the questions mentioned above, future researchers could use the results from the item analysis of differences between the two populations of students to determine if students who completed one course are better able to answer certain questions than students who completed the other course because insight into the course content could yield valuable information. For instance, a future study could provide insight into the best content to help students to correctly answer certain types of math problems. Or a future researcher could modify the questions that were selected to include questions other than multiple
choice to see if students from one of the groups are better equipped to answer open-ended questions.

**Unintended Research Findings and Future Research**

The results of the data analysis for this study did not show a significant difference in assessments scores or value ratings of course content for one population of students at a specific college who completed a required college algebra course and one population of students who completed a redesigned (non-algebra) required college mathematics course. However, this research still yielded valuable information that allows several opportunities for future research because the study did yield some valuable unintentional findings that resulted from the analysis of the data used to answer the study’s research questions. Details of these unintended findings, which relate to the significance of the research problem that justified this research study, are detailed below. Areas for potential future research are also given.

The first unintentional finding from this research study has to do with student withdrawal rates. That is, when conducting the analysis used to ensure that the composition of the two populations of students used in this study were not statistically different, the researcher noticed that the student withdrawal rates for the two populations exhibited what appeared to be a statistically significant difference. In fact, out of the population of 149 students enrolled in the College Algebra classes, 21 students withdrew from the course; this represents 14% of students who originally enrolled, but withdrew after the add/drop period for the course ended. On the other hand, out of the 166 students who initially enrolled in the Introduction to Quantitative Reasoning course, only 13 students withdrew from the course; this represents 8% of students who originally enrolled, but withdrew after the add/drop period for the course ended.
While the design of this study did not allow the researcher to determine if the 6% lower rate of student withdrawal in the Introduction to Quantitative Reasoning course was statistically significant, a future possible study could be designed to specifically examine course retention. That is, because this study design only provided the researcher with data relating to how many students from the sample populations withdrew, the researcher was not able to calculate a mean and use a statistical measure (such as a t-test) to determine if there was a significant difference in those means. However, given an alternate study design, the researcher would then be able to calculate significant, or insignificant, outcomes with respect to course withdrawal.

Likewise, analysis of data from the two populations of students also showed that there appeared to be a potentially significant difference in student failure rates from students in the two populations. In this study, 22 students (15%) of the 149 students who initially enrolled in the College Algebra course at the College highlighted in this study ended the course with a failing grade. By comparison, 16 students (10%) of the 166 students who initially enrolled in the Introduction to Quantitative Reasoning course at the College highlighted in this study ended the course with a failing grade.

Although grades are sometimes considered unacceptable methods of statistical analysis because they are based on a teacher’s subjective value judgments (Chiekem, 2015; Allen, 2005), the researcher felt that differences in the final grades for the two populations in this study were significant enough to warrant mention. After all, because failure rates in college mathematics courses are directly related to the significance of the research problem that justified this research study, a 5% lower rate of student failure in the Introduction to Quantitative Reasoning course warrants mention and further investigation in future research.
That is, while the study design for this research did not allow the researcher to determine if the differences in course failure rates in the two populations were statistically significant because the mean failure rates of the sample populations could not be calculated using the data gathered for this study, future research can determine whether the differences were simply a random occurrence of the populations included in this study, or if the results are significant and indicative of the entire population.

Further examination of course outcomes with regard to rates of student failure and withdrawal would provide value to the problem of practice examined in this study. As previously noted, withdrawal and failure rates in required college mathematics courses are a serious problem; college algebra has the highest failure and withdrawal rate among all post-secondary courses (Bonham & Boylan, 2011). With less than half of students passing required courses such as college algebra (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008, Reyes, 2010), solutions to the problem of lack of success in college mathematics need to be found. The current lack of success is negatively impacting college retention rates, college graduation rates, and ability to pursue a major that requires successful completion of a required mathematics course (Gordon, 2008; Hall & Ponton, 2005; Parker, 2005; McCormick & Lucas, 2011; Cortés-Suárez & Sandiford, 2008; Thiel, Peterman, & Brown, 2008; Choike, 2000; Catalano, 2010).

However, before initiating a future research study into course withdrawal and failure rates, the desired outcomes from the study should be carefully considered, because different study designs will most assuredly offer different results. That is, while a properly designed quantitative study specifically analyzing withdrawal and failure rates could yield important
information, a qualitative or mixed methods study design also has the potential to deliver significant information through a different lens.

For instance, a qualitative or mixed methods study might better examine the lower rates of withdrawal and failure in the Introduction to Quantitative Reasoning course through the theoretical framework of expectancy-value theory; it could examine if students may have had lower withdrawal or failure rates in the Introduction to Quantitative Reasoning course because they found some more value in the course content. Or another study design could determine if the possibly meaningful differences in student persistence and performance, in regards to withdrawal and failure rates, can be explained by the extent to which they value the activity (Atkinson, 1957; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992).

**Additional Areas for Future Research**

While the additional and unintended findings from this research study are significant and deserve consideration for future research studies, there are also other areas for potential future research. The limitations of the design of this study did not allow for further investigation into some of the unintentional, potentially significant results that did occur in this research study. However, future research will provide additional information into a serious problem. Furthermore, additional research will help to determine if the results of this study are indicative of the entire population, or simply a random occurrence of the populations included in this study.

A correctly designed study could potentially provide information on several important concerns with the success of students taking their required college level mathematics course. Since lack of success in required college mathematics classes impacts college retention rates, college graduation rates, and ability to pursue a major that requires successful completion of a required mathematics course (Gordon, 2008; Hall & Ponton, 2005; Parker, 2005; McCormick &
Lucas, 2011; Cortés-Suárez & Sandiford, 2008; Thiel, Peterman, & Brown, 2008; Choike, 2000; Catalano, 2010), any information that will lead to a solution to the problem warrants appropriate investigation.

Improving success in required college mathematics courses is an important issue for all colleges; with required college mathematics courses like college algebra having the highest failure and withdrawal rates for post-secondary courses (Bonham & Boylan, 2011), and with less than of half of students currently enrolled in a required mathematics course such as college algebra successfully completing the course (Gonzalez-Muniz et al., 2012; Thompson & McCann, 2010; Thiel, Peterman, & Brown, 2008; Gordon, 2008, Reyes, 2010), outcomes in college mathematics are a concern. For this reason, any further research into the previously mentioned topics will benefit curricular decision makers, like the faculty and administrators at the College highlighted in this study, by providing them with more information on the benefits and drawbacks of different options in course content of required college mathematics courses.

**Discussion of Findings in Relationship to the Theoretical Framework**

While the restrictions of this study did not allow the results of the data analysis to contribute to the study of expectancy-value in the way that the researcher intended because the results of the study did not show that student ratings of the value of the course content were statistically different between the two courses, future research examining mathematical learning through the lens of expectancy-value theory is still warranted. After all, there is documented need for more research in this area; as Eccles & Wigfield (2002) state, “more work is needed on how the links of expectancies and values to performance and choice change across ages and on the links between expectancies and values” (p. 122).
Expectancy-value theory plays a significant role in research examining mathematical learning and can produce important findings in providing information regarding outcomes in college mathematics. After all, the literature shows that student attitudes toward mathematics have been shown to be a significant factor in learning mathematics (Royster, Harris, & Schoeps, 1999; Ma & Xu, 2004), and that students’ attitudes toward mathematics have been identified as a factor that can impact student achievement in mathematics (Eccles & Wigfield, 2002). Furthermore, research shows that the value that student’s place on a course’s content helps to determine students’ rates of success in their college mathematics course (Joo et al.; Singh et al., 2002; Cole et al., 2008; Chouinard et al., 2007; Azar et al., 2010).

A differently designed future research study of the expectancy-value theory could produce meaningful findings. For instance, a future quantitative study could examine the content of each course with the purpose of determining which course contained content that was more beneficial to students, either in other courses or outside of the classroom because the value of course content can impact student persistence and achievement (Eccles & Wigfield, 2002; Azar et. al., 2010). Or, since most recommendations suggest that the most effective college mathematics courses utilize projects that are both valued by math instructors and employers, and demonstrate the value of the content to the students (Champion et al, 2011), a future study could analyze the student value ratings of each topic for each course to determine if some topics were considered more valuable than others.

**Discussion of Design and Implementation Findings**

Almost all types of research studies have strengths and limitations (Fraenkel & Wallen, 2009). For this reason, further research is always beneficial to validate the findings of a study.
because all studies. Doing so can help to strengthen the results and reduce the validity or trustworthiness concerns from a previous research study.

Causal comparative studies like this one have identified strengths. For instance, these studies examine existing data and can use the results from the data analysis to identify possible causes of outcomes. Furthermore, the relationships that are established from quasi-experimental, causal-comparative studies often create a basis for future experimental study (Fraenkel & Wallen, 2009) by providing identification of, along with information regarding, these relationships. In other words, any properly designed quasi-experimental study such as this one can be replicated to validate the findings of the study (Fraenkel & Wallen, 2009).

Yet, causal-comparative studies also have limitations. Although they can show significance or lack of significance in the relationships between the variables of the study, they generally have weak conclusions; they are unable to show causality, and their interpretations of the research are somewhat limited because their findings do not necessarily determine if one outcome is caused by the other outcome (Fraenkel & Wallen, 2009).

Other limitations, including threats to the internal validity of the study, also need to be mentioned because threats to validity have the potential to limit the findings from a causal-comparative study such as this one. A study that demonstrates high internal validity is generally considered to be reliable and trustworthy while a study that has low internal validity is generally considered unreliable and untrustworthy. In general terms, internal validity seeks to ensure that differences in variables are due to factors of the variables themselves and not due to some other unintended variable; this was a limitation of this study (Fraenkel & Wallen, 2009).

For instance, non-comparison groups, which were used in this study, were an identified threat to validity. It is common for a researcher to be unable to make accurate comparisons
between the two populations because the groups lack equivalency (Fraenkel & Wallen, 2009). Therefore, internal validity for this study was threatened because the researcher did not have full control over the variables used in the study and as a result was unable to manipulate the groups to be exactly equivalent; non-equivalent comparison groups were an unavoidable necessity in this study. However, non-equivalent groups are not an uncommon limitation of causal-comparative studies like this one, and the identical populations were addressed using statistics. Using a double-tailed t-test, the researcher is able to show that the two groups of students were comparable and did not have any significant differences in scores on the mathematics section of the SAT or in their high school GPAs.

Yet, despite the statistics used to demonstrate statistical equivalency between the two populations, with regards to their mathematics SAT scores and high school GPAs, there were still differences between the comparison groups that were not controlled. For instance, subject characteristics, such as variations in socioeconomic level of the family, gender, ethnicity, etc., could not be controlled for this study because the students taking the courses self-selected their own sections.

The internal validity of this study was also susceptible to an implementation threat because numerous instructors, who most likely had various teaching styles, taught the courses. Therefore, student-learning styles, along with general student biases toward the instructors, could have impacted outcomes on the assessment tests and the ratings of the value of course content. In order to reduce this concern, this researcher opted to include seven sections of Introduction to Quantitative Reasoning and eight sections of College Algebra in the study. This way, a larger sample, that included several different teachers for each of the sections, was used to help minimize the threat (Fraenkel & Wallen, 2009).
Instrumentation decay may have been a threat to internal validity of this study because the departmental assessment test has had minor modifications to some questions over the past couple of years. However, this threat to internal validity was greatly reduced when the researcher opted to design the study to only use twelve questions from the assessment test that were consistently identical on all administrations of the assessment for this study.

The study also faced a small amount of an experimental mortality threat because each group in this study lost students who dropped their mathematics course. Therefore, although the initial comparison groups had an equal population, the final groups varied slightly in number. However, this threat was reduced because the final number of students who completed the assessment, and were included in the results of this study, did not have substantial variations. Since the completion of the course evaluation is optional for students at the college being studied, some students failed to complete the question pertaining to the ratings of course content. As a result, the study’s validity could be threatened if the sample size of the groups became significantly smaller and may or may not necessarily have been representative of the entire population being studied. However, this threat was insignificant in this study because the majority of students did actually complete the survey.

The particular locations in which these courses were taught did not pose a location threat to internal validity because all of the sections had access to a similar classroom and classroom resources.

As stated above, the researcher conducting this study worked to minimize the threats to internal validity; however, several threats to internal validity still existed. For this reason, recommendations for future studies on this topic include repeating this study with a different population of students to see if similar findings result. Alternately, the findings of this study
could be used to conduct another type of research study investigating topics similar to those examined through the research questions from this study.

**Plans for Dissemination**

The researcher intends to disseminate the findings for this study in several ways. First, the results of this study will be presented to the Dean for Liberal Arts & Sciences at the College where this study was conducted. In addition, the researcher has presented the findings of this study to faculty at the college where she is currently employed. Last, the researcher intends to submit the findings of this research to several journals, with the hopes that publication will bring more attention to the issue and spark interest in future study.

**Conclusion**

The goal of this study was to compare assessment and course evaluation data from a required college algebra course and a redesigned (non-algebra), more “real world” required college mathematics course, with the goal of determining if a significant difference in course outcomes for students in each course existed. The results of this research study did not produce quantitative data to show statistically different outcomes in either class. In fact, the analysis from this study showed that both the assessment scores and student ratings of value of course content between the two populations were mostly very similar.

However, the absence of evidence of a statistically significant difference for the three research questions explored in this study does not imply that the study was not informative (Altman & Bland, 1995). The data results from this study contribute valuable information on a college-wide initiative pertaining to college mathematics requirements that can be added to the collection of existing studies on this important topic, similar to some of those that were discussed
in the literature review in this study. Additionally, the expectancy-value theoretical framework described in this study can be informative for future research studies.

Furthermore, it is important to consider that “absence of evidence is not evidence of absence” (Sedgwick, 2014); that is, because the sample populations used in this study were only one example from the entire population of non-STEM college students completing their required college mathematics course, the results from this study may or may not be indicative of the outcomes of the entire population (Sedgwick, 2011). In other words, just because statistical testing fails to find a difference between the two groups, it does not necessarily mean that a difference does not exist in the populations (Sedgwick, 2014); further research with another sample may give different results (Sedgwick, 2011).

Finally, other useful information was also obtained from this study; it provided the curricular decision makers at the College where the study was conducted with information on the differences between the two required courses offered by the college in terms of student achievement and perceived value of course content through quantifiable results that, based on the sample populations used in this study, the College’s change in course requirements did not produce negative outcomes. As a result, the College’s decision makers can use the results to justify either continuing the revised course in its present format, or trying to implement changes that will potentially cause significant improvements. Either way, results of future initiatives can be viewed through the lens of the information provided by this study.
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doi:10.1136/bmj.d3126


APPENDICES
Appendix A (Agreement)
1. The parties to this Agreement are [Redacted] College and Jennifer Fleury-Lawson.

2. The College will provide Ms. Fleury-Lawson with the following information: (a) student responses to specific questions on the Final Common Exam for the College courses MTH 150 and MTH 121 for the academic terms MTH 121: FA2009-SP2012; MTH 150: FA2013-SP2015; (b) student responses on course evaluations for the MTH 121: FA2009-SP2012; MTH 150: FA2013-SP2015 terms as to whether they found MTH 150/MTH 121 content useful; and (c) MSAT data and HS GPA data to show that the two groups are comparable. The information will not include any student names or other information from which individual students could be identified.

3. Ms. Fleury-Lawson may use the information in connection with her doctoral research project and any scholarly presentations or publications derived from that research project. She may not use the information for any other purpose without the express, advance permission of the College. Ms. Fleury-Lawson will not identify the College as the source of the information to any person other than her doctoral dissertation advisor without the express, advance permission of the College.

4. Ms. Fleury-Lawson will provide the College with an analysis and observations of the data described above, which the College will use solely for its internal purposes. The College will not disclose Ms. Fleury-Lawson’s analysis or observations to any third party or use her analysis or observations for any other purpose without her express, advance permission.

5. This Agreement sets forth the entire agreement between the parties with respect to the matters addressed herein. It supersedes any prior or contemporaneous agreements, representations, or understandings with respect to the matters addressed herein.

JENNIFER FLEURY-LAWSON

Date: 3/18/15

Date: 3/18/15
Appendix B (Assessment)
Directions:
Solve each problem. The questions may get more difficult as you proceed.
Indicate the best answer on your Answer Sheet.

1) Jane spent $293 on airfare, $174 for lodging and $108 for food while on a business trip. If her company gave her $375, how much will she have to pay herself?

(A) $575  (B) $200  (C) $375  (D) $467  (E) none of the above

2) George is purchasing a stereo for $612. He agrees to pay the amount in twelve equal monthly payments. Find the amount of each monthly payment.

(A) $51  (B) $11.77  (C) $102  (D) $1.96  (E) none of the above

3) In the past, Mr. Harry Honstabee earned $300 a week. This week he will receive a 4% raise. What will his new weekly wage be?

(A) $12.00  (B) $120.00  (C) $320.00  (D) $312.00  (E) $1200.00

4) Fifteen years ago, the student population of Dean College was 800. Now there are 1,000 students. What is the percent increase in the Dean student population?

(A) 25%  (B) 20%  (C) 80%  (D) 120%  (E) none of the above

5) Evaluate the expression: \(7 + 3(4-8) = \) ___

(A) -40  (B) 11  (C) -5  (D) 6  (E) none of the above

6) \(\frac{7 - 1}{8} = \) ___

(A) 4/5  (B) 1  (C) 3/8  (D) 5/8  (E) none of the above

7) \(-5+(-6)+12=\) ___

(A) 22  (B) 1  (C) -22  (D) 13  (E) none of the above
8) \((-4)(6)(2) =\)

(A) -48  (B) -16  (C) 16  (D) 48  (E) none of the above

9) \(2 + (-3) \div (12 \div (-11) + 2) =\)

(A) -2  (B) 1  (C) 6  (D) 3  (E) none of the above

10) If \(m = -5\) and \(n = -14\), then \(3m - n =\)

(A) -29  (B) -1  (C) -9  (D) 19  (E) none of the above

11) Solve for \(x\): \(9 + x = -5\)

(A) -14  (B) 14  (C) -4  (D) 4  (E) none of the above

12) Which of these is a correct graph of \(X \leq 4\)

(A)  
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(B)  
\[\begin{array}{c}
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\text{4}
\end{array}\]

13) What is the value of a 15% tip on a $200 meal?

(A) $15  (B) $20  (C) $30  (D) $40  (E) none of the above

14) Last year you bought a new car for $29,500. After 1 year the car’s value has depreciated by 19%. What is the value of the car after 1 year?

(A) $5,605  (B) $23,895  (C) $27,600  (D) $28,939.50  (E) none of the above

15) A $100 CD (certificate of deposit) earns 6% each year for 2 years compounded annually. How much is its exact worth when it matures in 2 years?

(A) $106  (B) $112  (C) $160  (D) $256  (E) none of the above
16) Express 12% as a fraction

(A) $\frac{3}{50}$  (B) $\frac{12}{25}$  (C) $\frac{3}{25}$  (D) $\frac{1}{12}$  (E) none of the above

17) Express $\frac{2}{5}$ of a fraction.

(A) 10%  (B) 20%  (C) 25%  (D) 40%  (E) none of the above

18) Express 27% as a number.

(A) 0.027  (B) 0.27  (C) 2.7  (D) 2.7  (E) none of the above

19) Express the number 0.75 as a fraction.

(A) $\frac{1}{75}$  (B) $\frac{3}{40}$  (C) $\frac{2}{15}$  (D) $\frac{3}{4}$  (E) none of the above

20) Add the following and simplify: $\frac{2}{5} + \frac{3}{7} = ?$

(A) $1\frac{1}{35}$  (B) $\frac{6}{35}$  (C) $\frac{3}{4}$  (D) $\frac{1}{2}$  (E) none of the above

21) Multiply the following and simplify: $\frac{5}{5} + \frac{3}{7} = ?$

(A) $\frac{16}{35}$  (B) $\frac{9}{35}$  (C) $\frac{3}{4}$  (D) $1\frac{1}{2}$  (E) none of the above

22) Add the following and simplify: $6\frac{1}{3} + 3\frac{3}{4} = ?$

(A) $9\frac{1}{3}$  (B) $9\frac{4}{7}$  (C) $5x^{2} - \frac{2}{x} + 7$  (D)  (E)

23) You are putting in new flooring across a room which is 15 feet wide. Each row of flooring is 4¼ inches wide. What is the minimum number of rows of flooring needed to complete the room’s entire floor? (Remember that 1 foot = 12 inches)

(A) 40 rows  (B) 41 rows  (C) 42 rows  (D) 43 rows  (E) 44 rows
24) You are seated at a circular table which measures 30 inches across. What is the area of the table to the nearest square inch?

(A) 47 in\(^2\)  (B) 94 in\(^2\)  (C) 707 in\(^2\)  (D) 900 in\(^2\)  (E) 44 rows

25) You own a swimming pool in the shape of a right triangle with a 9 foot leg, a 12 foot leg, and a 15 foot hypotenuse. If the swimming pool is 3 feet deep, what is its volume?

(A) 36 ft\(^3\)  (B) 108 ft\(^3\)  (C) 162 ft\(^3\)  (D) 270 ft\(^3\)  (E) none of the above

26) What is the MEDIAN of the following data set: \{6, 36, 12, 41, 19, 21, 12\}?

(A) 12  (B) 19  (C) 21  (D) 36  (E) 41

27) What is the MEAN of the following data set: \{6, 36, 12, 41, 19, 21, 12\}?

(A) \{-7, 5\}  (B) \{-7, -5\}  (C) \{-7, -5\}  (D) \{-7, 5\}  (E) none of the above

28) What is the MODE of the following data set: \{6, 36, 12, 41, 19, 21, 12\}?

(A) 12  (B) 19  (C) 21  (D) 36  (E) 41

Math Assessment  Page 4 of 5  As of April 2014
29) $3.5 \times 10^4$ is what number?

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<td>(A)</td>
<td>140</td>
<td>(B)</td>
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30) Express SIX MILLION in scientific notation.

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<td>(A)</td>
<td>$0.6 \times 10^6$</td>
<td>(B)</td>
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31) 1 meter contains 100 centimeters. There are 1,000 meters in a kilometer. How long is a 5 kilometer race when measured in centimeters (cm)?

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<td>(A)</td>
<td>5,500 cm</td>
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32) One U.S. dollar converts to 0.75 Euros. Therefore, 36 Euros is equivalent to having how many U.S. dollars?

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<td>$27$</td>
<td>(B)</td>
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This completes the math exam.

Please return both the Exam and Answer Sheet.