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The impact of an elementary algebra course on student success in a college-level liberal arts math course and persistence in college

Lori Ann Austin
Rowan University

THE IMPACT OF AN ELEMENTARY ALGEBRA COURSE ON SUCCESS IN A COLLEGE-LEVEL LIBERAL ARTS MATH COURSE AND PERSISTENCE IN COLLEGE

by

Lori Ann Austin

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Dedications

This dissertation is dedicated to my husband and three children who always challenge me to fight for what I believe in. It is also dedicated to all developmental students who deserve a fair and appropriate remedial education. And finally to the memory of my mother who enrolled in community college sixteen years after dropping out of high school but was never able to complete remedial math.

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Abstract

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Many students enter community college underprepared for college-level math and are placed into developmental elementary algebra without consideration if the algebra will provide a foundation for their needed college-level math course. Large percentages of those students are unable to succeed in the developmental course and, therefore, are unable to graduate (Bahr, 2008; Bailey, Jeong, & Cho, 2010). This quasi-experimental design focused on students who are not in math-intensive majors, needing only a general liberal arts math course. The purpose was to determine the impact of the elementary algebra course on success in college-level math and persistence in college. Student performance data were aggregated from four community colleges within a state in the northeastern United States. Students' success in a college-level liberal arts math course and total credits earned were examined. An independent *t* test showed students who scored above the cut-off for developmental placement outperforming those who scored below, yet all differences disappeared when a regression discontinuity was implemented, leading to a conclusion that the actual placement in developmental algebra had no impact on students' success in college-level math or total credits earned.

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

List of Figures

List of Tables

Chapter I

Introduction

Community colleges are facing unprecedented issues of higher accountability for student success and lower funding to make the success reality (Bailey, Jaggars, & Jenkins, 2015). Current community college students, forced with limited financial aid, are increasing loan debts at much higher rates than students in the past. More than half of entering students are required to enroll in classes that are meant to help them succeed in college while not actually counting toward their college degree. The low success rates of these courses means more students are depleting financial aid before they enroll in their first college-level course, and colleges are faced with students who never graduate. Placement in developmental math is also shown to have a negative impact on long-term earnings for those who do make it to the work force (Hodara & Xu, 2016). To further exacerbate the situation, research has found that not all the content students learn in a developmental math course is relevant to the college-level courses that students need for their major field of study (Bailey et al., 2015; National Center on Education and the Economy [NCEE], 2013). This study, set within New Jersey community colleges, focused on a specific developmental course, Elementary Algebra, and the impact of the course on students' success in a general college-level liberal arts math courses and persistence in college.

According to a national study of over 250,000 students, 59% of entering community college students are in need of at least one level of developmental mathematics course, and only about 33% complete those courses, giving developmental math students a 20% chance at success the minute they step through the doors of a community college (Bailey et al., 2010). While some of those students may have misguided ambitions of pursuing careers that require an intense study of mathematics, many are realistic about their capabilities. Perhaps they understand their limitations in math and are simply looking to fulfill a standard general education requirement of a liberal arts math course but first must fulfill an algebra-based developmental program, one that they may find irrelevant to their chosen major. Placement into developmental courses prior to enrollment in college-level courses could greatly affect a student's perceived and actual ability to persist.

Students fail to persist in college for many nonskill-related reasons, such as a lack of academic self-efficacy and motivation (Lindley & Borgen, 2002; Sedlacek, 2004). Developmental courses are meant to prepare students for a college-level math course. If time and money are spent on something that is not preparing them properly, then the discouragement that students feel due to their own lack of ability or desire to succeed may lead to failure. This study examined the impact that a developmental elementary algebra course had on student success in a college-level liberal arts math course and persistence in college. Success in college-level liberal arts math was measured by whether a student successfully completed the course achieving a D or higher, and persistence in college was measured by total credits earned after a student's third year in college.

Background of the Problem

The American community college's open door admission policy has given opportunities of postsecondary education to many individuals for most of the last century. Through transfer programs, associate degrees, certificate programs, workforce development, and continuing education, community colleges have provided many Americans with opportunities to improve their standard of living or simply improve themselves. Providing opportunity alone is not enough, and community colleges are being held accountable for the success rates of their programs. Nationally, only 18% of students who enter community colleges leave with a diploma or certificate (McPhail, 2010). For community colleges to be progressively accountable for student success, understanding why students do not persist is paramount.

The lack of preparation, or college readiness, is one of the factors of low student success (Bailey et al., 2010). Community colleges accept students regardless of past academic achievements. The factors that lead to the lack of success early during K-12 education will persist into their college years (Lindley & Borgen, 2002). For community colleges to assist an underprepared student population, they have many programs to help students reach their goals. Often students are placed in intervention programs for deficiencies in language arts and mathematics, such as developmental courses. Developmental education courses are meant to bridge the gap between what students retain in high school with knowledge that is needed to succeed in entry-level college courses; they "are designed to strengthen skills so students can successfully complete college-level courses" (Bailey, 2009, p. 11). Unfortunately with only 33% of students completing the developmental math sequence within 3 years, courses that are designed to help students succeed in college are often seen as a major barrier to student persistence and completion (Bailey et al., 2010).

Two developmental courses offered at most community colleges are arithmetic and basic algebra. After completing basic algebra and sometimes intermediate algebra, students continue toward the required college-level math courses for their major. Students in science, technology, engineering, and mathematics (STEM) majors progress toward College Algebra, Precalculus, and possibly Calculus. Students in non-STEM majors are often required to take College Algebra, Statistics, or a general liberal arts math course. For underprepared students, basic algebra is considered the foundation developmental course that will help these students succeed in college-level math. Nationwide, approximately 50% of students in community colleges place into an elementary algebra course, and over half are unable to pass within 2 years (Nolting, 1997).

For the underprepared non-STEM student needing a liberal arts math course, elementary algebra is the developmental prerequisite that students are required to take to prepare them for success in that liberal arts math course. For successful preparation, the content in the liberal arts math course should build upon what is learned in elementary algebra; however, after careful examination of the content in elementary algebra compared to many first-year math courses, the content seems to build on topics taught prior to an elementary algebra course (NCEE, 2013). In fact, most of the math needed to succeed in many career programs and majors that are not math intensive is middle school mathematics and not algebra (NCEE, 2013). According to the NCEE (2013), the relevant content from middle school mathematics is arithmetic, ratios, proportions, expressions, and simple equations. Therefore, it is not surprising that many college majors only require the general education liberal arts math course that contains a variety of broad concrete topics such as basic descriptive statistics, quantitative reasoning, basic set theory, ancient and modern number systems, and geometry. A developmental elementary algebra course covers more abstract topics such as solving and graphing linear equations, polynomial operations quadratics, radicals, and rational equations. The community colleges for this study require the elementary algebra proficiency (by testing or passing the developmental elementary algebra course) prior to taking the general liberal arts math course.

Situating Developmental Math in New Jersey

New Jersey has 19 independently run community colleges. Seventeen of the state's 21 counties have their own community college, and two colleges are jointly controlled by two different counties. The New Jersey Council of Community Colleges provides a means for the colleges to collaborate on many issues in the state, while giving each college complete autonomy. One issue where the colleges have successfully collaborated was transfer. To facilitate better transfer rates to 4-year institutions across the state, the Lampitt Law was passed in 2008 requiring 2-year and 4-year institutions to devise a general education transfer agreement. As a result of this law, a general education associate's degree from any of the 19 community colleges will fully transfer as the first 2 years of a baccalaureate degree at any New Jersey 4-year public institution.

As a result of the Lampitt Law, the New Jersey community colleges agreed to standardize the college placement procedures. As part of the general education agreement, all students were required to have an elementary algebra proficiency before they could take any college-level math course. All colleges agreed to use the Accuplacer placement test, a computer adaptive test that automatically adjusts to the test taker's skills, as the only means to assess the elementary algebra proficiency. An agreement was made to accept an Accuplacer cut-off off score of 76 in the algebra domain of the test to place students out of Elementary Algebra. To complement this standardized cut-off score,

core standard content for Elementary Algebra was agreed upon by all community colleges. Student progression through math after Elementary Algebra differs dependent upon community college attended and student's major (STEM or non-STEM). Most colleges provide a general liberal arts math course for non-STEM students and a continuation of higher level algebra for STEM students. As part of this study, the content of all liberal arts math courses offered by New Jersey community colleges was examined to ensure that the colleges in the study had similar content in their liberal arts math courses.

The current focus of developmental mathematics in New Jersey is based on key concepts from *Redesigning America's Community Colleges*, specifically the guided pathways approach to college success (Bailey et al., 2015). Community college leaders in New Jersey are attempting to develop statewide recommendations or policies that will limit the money and time students spend in their developmental math courses. Ensuring the content of these courses is relevant and helpful to their overall college success is vital to these current state initiatives.

Statement of the Problem

Considering the dismal pass rates for developmental math courses, understanding whether placement in an Elementary Algebra course truly prepares students for success in college-level math and helps them to persist in college is crucial. For this study, success in college-level math was measured in two areas: by examining student grades in college-level math and by whether or not a student completes (with a D or higher) college-level math. Persistence in college was measured by examining the total college-level credits earned over 3 years. For the first measure, the study focused on whether community college developmental elementary algebra provided an adequate foundation for college-level liberal arts math courses by comparing students who participated in the developmental courses with those who were not required to participate. Provided that elementary algebra does provide an adequate foundation, then an expected result of this study was that the students who recently succeed in elementary algebra would perform equal or better in the liberal arts math course than the students who did not take elementary algebra.

For the second measure of success, the study examined the claim that developmental math courses act as a barrier to student persistence in college (Bahr, 2008; Bailey, Jaggars, & Scott-Clayton, 2013; Goudas & Boylan, 2013). The study specifically examined total credits earned in a set time frame of 3 years. By only looking at students who enter community college with the same skill level on the math placement test, this study would be able to identify if students who placed in the developmental math course earned less credits than those who were able to go directly into the college-level course. This study isolated the elementary algebra course as the one difference between two groups of students with seemingly the same skill level in mathematics.

Nature of the Study

This study reviewed the content of liberal arts math classes in New Jersey community colleges with the intent to determine which of the 19 colleges offer the most similar liberal arts math courses. These colleges identified through the first research question as having the most consistent liberal arts math content were used to determine the role elementary algebra plays in helping non-STEM students pass a general liberal arts math class. Specifically, the study examined if the college-mandated elementary algebra proficiency helps students learn and succeed in a liberal arts math course that requires elementary algebra (or a proficiency deemed through a placement test) as a prerequisite to the course. The research questions that were addressed are the following:

1. To what extent do the liberal arts math courses offered at New Jersey community colleges cover similar content?

2. For non-STEM students, what is the effect of developmental algebra on students' success in a college-level liberal arts math class?

3. For non-STEM students, what is the effect of developmental algebra on number of credits earned over a 3-year period?

Answering these research questions can help inform further discussions on the necessity of algebra for success in college-level math courses for non-STEM students. The first research question examined all liberal arts courses in New Jersey community colleges to ensure that the colleges in the study have similar course content so that the success measure of a D or above is not influenced by the college the student attended. The second research question examined the impact of elementary algebra directly on the success a student has in a college-level liberal arts math class. The third research question will help inform whether taking an elementary algebra course affects the number of credits a student earns as they persist toward completion.

For the purpose of this study, liberal arts math courses are courses that students can enter with only an elementary algebra proficiency. The content in a college-level liberal arts math course varies by college. An examination of the courses listed at select New Jersey community colleges participating in this study included courses in problem-solving skills, quantitative reasoning, and finite math as possible liberal arts math courses a student could take depending on the major. The most popular and heavily enrolled course is often a survey-based math course, which touches upon mathematics topics such as set theory, ancient number systems, symbolic logic, number sense, and geometry. College Algebra and Statistics courses require another level of algebra proficiency beyond elementary algebra and were not considered for this study. New Jersey community colleges have collaborated over the past 5 years to enforce a mandatory common cut-off score for enrollment in elementary algebra and to align the content of the elementary algebra course, allowing a statewide investigation of the research questions. Through Research Question 1, careful examination of each college's course sequence was completed prior to determining which college's liberal arts math courses could potentially be used for the study.

To study the impact of elementary algebra on success in a college-level liberal arts math course, a review of relevant literature examined a historical overview of developmental education, the current theoretical perspectives on the necessity of learning algebra, the current state of developmental education at community colleges, and the impact of developmental courses on persistence in college. A review of research on validity of placement exams and students who score near cut-off points was also examined as this formed a basis for the research design.

Retroactive data were collected from the 2012 cohort of students who enrolled in a liberal arts math course from a selection of community colleges from New Jersey. Initially, the results of Research Question 1 informed the selection of colleges and courses. College and course selection was based on the type of liberal arts math course offered so that the data assessed in Research Questions 2 and 3 were from students who enrolled in courses with similar learning outcomes. To examine similar students who fall near (above and below) a predetermined cut-off score, both a two-population *t* test and a regression discontinuity design was used. The *t* test compared the overall outcomes (grade in liberal arts math and total credits earned in 3 years) of students who needed developmental algebra to those who did not. By definition, this *t* test used two different populations of students (developmental and nondevelopmental students) leading to concerns that other characteristics besides placing in developmental algebra could affect outcomes (Melguizo, Bos, & Prather, 2011). Regression discontinuity (RD) was also used to eliminate bias that could impact the results of the *t* test. The RD design is a quasi-experimental design that examines outcome differences around a cut-off score, often used to mimic random assignment when an experimental design is not possible (Lee & Munk, 2008). The state-mandated Accuplacer cut-off score of 76 for admittance to a liberal arts math course was used as the predetermined cut-off score.

A regression discontinuity design will not only be presented as a logical approach to the research questions but will also be tied to a review of current research in developmental education. This design allows the researcher to examine the research questions using two similar group of students, closely mimicking random assignment. The initial expectation of the two groups of students is that students who took the elementary algebra course, considering cost and time, should outperform those in the liberal arts math course and in the long run complete the similar amount of credits in the same time period as those who did not need the developmental course. Previous RD studies that focused on all students entering college-level math courses (algebra based and non-algebra based) did not find this to be true (Bettinger & Long, 2005; Calcagno &

Long, 2008; Martorel & McFarlin, 2007). The developmental students scoring just below the cut-off score achieved grades in the college-level courses that were equal to or lower than those scoring just above who did not take developmental math.

The advantage of the RD design, the capability to examine two groups of similar students, also leads to a major disadvantage in that the effects can only be associated with the small group of students around the cut-off score (Goudas & Boylan, 2012, 2013). While this has been refuted by Bailey et al. (2013) with the argument that previous RD designs used multiple cut-off scores with similar results at each cut-off point, this RD design was paired with a comparison of means *t* test that utilized all students in both groups. The limitations of each test is discussed along with how pairing the two can provide some compensation for the distinct limitations.

Significance of the Study

This study can provide valuable information for curriculum changes in New Jersey community colleges. Prior research on the impact of developmental math on student success did not examine the non-STEM student population separately from all other students. A refocused initiative to provide students in developmental education with the appropriate amount of remediation for their individual field of study demands that the impact of the current developmental requirements be examined more closely. As institutions across the state are attempting to limit time students spend in developmental math, the information gained in this study can help determine the effect that the current elementary course has specifically on non-STEM students.

Understanding this effect is informative to decisions focused on developmental pathways to college-level math. These new pathways would take into consideration the content a student needs to be proficient in to be successful in the college-level math course that is relevant to the major, as opposed to all students taking the same elementary algebra course. Programs that have implemented relevant pathways to college-level math with promising initial results include the New Math Pathway's project in Texas, modularized curriculum reforms in North Carolina and Virginia, and Carnegie's Quantway and Statway in California (Burdman, 2013). The New Math Pathways project in Texas had preliminary showed that 30% of developmental students who enrolled in Pathways were able to complete their college-level math with 1 year, compared to only 8.3% who enrolled in a traditional developmental sequence (Rutschow, Diamond, & Serna-Wallender, 2015). As New Jersey educators investigate pathways programs for their own community colleges, understanding the impact that the current developmental elementary algebra course has on student success in a college-level liberal arts math course could provide beneficial information to any redesign efforts.

While the independent *t* test showed students who took elementary algebra succeeding and persisting at a lower rate than those who did not take elementary algebra, the RD showed no difference in college-level math success or total credits earned for both groups. This should raise questions for any college that demands all students have an elementary algebra proficiency. While the study will not provide information on what is appropriate, it can, at the very least, cause colleges to question their current offerings and further research what is most appropriate for underprepared incoming students. If students who are considered college ready by a small margin on a placement test can succeed in a college-level liberal arts math class at a higher rate than those who are considered not college ready by the same small margin, then perhaps community colleges can reexamine what it means for a non-STEM student to be college ready.

Limitations

This study is limited to the impact an elementary algebra class has on a specific subset of New Jersey students. Due to insufficient sample of New Jersey community colleges, the results of the study are limited to the colleges that participated. The subset is also limited to students who place in elementary algebra and are in need of a general education math class that contains a broad base of topics such as set theory, mathematical logic, basic geometry, base systems, ancient number systems, and operations on real numbers. Limited information can be gained on the impact of elementary algebra on a general liberal arts math class with different topics or at different colleges.

The regression discontinuity design limits any observed impact on students who fall very near the cut-off point (Jacob, Zhu, Somers, & Bloom, 2012). This local impact may be very different for students who place lower on the Accuplacer. The two-sample *t* test addressed this limitation by comparing the college-level math grades of all students who place in elementary algebra with all students who place directly into the college-level math course. The concern with this comparison is the presumed untested behavior difference of the two populations, leading to biased results (Bettinger & Long, 2005).

Definitions

For the purpose of this study, the following terms are defined.

Accuplacer: This term refers to college placement tests distributed by the College Board to assess incoming college students' abilities in mathematics, grammar, and reading.

College-level liberal arts math courses: This term refers to courses designed for students in nonmath-intensive majors needing to fulfill a general education math requirement.

Developmental mathematics: This term refers to college programs designed to prepare students who test not college ready in mathematics.

Elementary algebra: This term refers to a first-level developmental algebra course.

Gateway math course: This term refers to the first nondevelopmental math course a student takes.

Non-STEM students: This term refers to students who are not in science, technology, engineering, or math majors.

STEM students: This term refers to students who are in science, technology, engineering, or math majors in college.

Conclusions

This study can provide valuable insight into how the elementary algebra course, that so many community college students are required to take, impacts success in a liberal arts college-level math course and credits earned in college. The literature review in Chapter 2 will describe how algebra became an integral part of education for all students, influential factors of student success in learning algebra, the effects that it has had on college placement and progression, and relevant efforts to improve student success in college math. To gain a better understanding of students in nonmath-intensive majors who enroll in a general liberal arts math class, Chapter 3 will explain how a regression discontinuity design paired with a two-population *t* test is the most appropriate research design to examine the impact the developmental course has on student success in a liberal arts math course and credits earned in college.

Chapter II

Literature Review

Developmental mathematics is perceived by many as the single greatest barrier to college success for students enrolled in community colleges. Students entering college need to demonstrate a proficiency in basic math and algebra before proceeding to a college-level math course, even if that college-level math course is not algebra based. Students entering college with limited math skills may be overwhelmed by additional courses meant to prepare them for college-level math but offer no credit toward completion. This literature review will examine the historical origin, purpose, and significance of developmental algebra in college while examining the effect this course has on a student's college aspirations. Entwined in the discussion will be the ethical and philosophical foundations that align with and against current trends. The review will focus on the debate regarding the necessity of algebra while examining whether algebra actually provides a foundation for students to be successful in subsequent college-level courses.

Historical Overview

Remedial course work has been a necessity in higher education for as long as higher education has existed in the United States (Boylan, 1987a, 1987b, 1988). At a time when colleges relied solely on tuition for sustainability, any student with the ability to pay was accepted, regardless of prior academic experience. College preparatory programs became integral to a college's ability to survive. In 1849, University of Wisconsin was the first to establish an entire department dedicated to college preparatory courses. By the late 1800s, many colleges across the United States had begun college preparatory departments to bridge the gap in knowledge between secondary schools and universities. By 1889, 80% of colleges and universities had preparatory programs, leading to the establishment of the College Entrance Examination Board designed to standardize college entrance requirements with the purpose of normalizing the admission process, raising academic requirements of incoming students and eventually eliminating college prep programs (Boylan, 1988).

Prior to the standardization of a secondary curriculum, algebra itself was not a stand-alone subject. Algebra was taught throughout a student's schooling as he or she progressed through learning arithmetic. In an effort to standardize the American precollege education system in 1892, the National Education Association established the Committee of Ten chaired by the President of Harvard University. This committee recommended 8 years of primary school followed by 4 years of high school, with standard curricula for college-bound students and another for noncollege-bound students. By the end of the 1920s, the high school curriculum was organized in tracks consisting of college bound, business (for accounting and secretarial), vocational (for skilled laborers), and general (for those seeking no further education or career training). During this time, algebra became a subject taught in high school for those in the college track; as high school itself was not yet a requirement, the study of algebra was mainly reserved for wealthier Americans intending to go to college.

Over the first half of the 20th century, states started mandating high school attendance until age 16. The number of high school graduates grew from 30% in 1924 to 75% in 1960, while college admission grew from 10% to 45% during the same time period (Cohen & Brawer, 2008). Access to college significantly expanded with the advent of 2-year junior colleges. These colleges were primarily thought of as a way for the underprepared to fulfill their first 2 years of college before completing upper-level courses at a 4-year college or university. The advent of 2-year junior colleges presented an opportunity for all college preparatory courses to be offered at the junior colleges, so the junior colleges began offering a wide range of developmental education for underprepared college students (Cohen & Brawer, 2008). This allowed students who graduated high school in one of the noncollege-bound tracks access to college through participation in these newly expanded remedial programs. These developmental options became more prominent as the handful of junior colleges of the 1940s expanded into hundreds of community colleges by the 1970s. Enrollments grew as the federal government provided financial incentives for veterans and underprivileged Americans to attend college in order to improve their place in society (Boylan, 1988). The open access admission policies of a rapidly increasing number of community colleges across the country meant that students with any academic background could pursue their dream of a college education in the local community college.

College preparation became known as developmental or remedial studies and started to become recognized as a field with a curriculum of its own. These programs moved beyond basic skills instruction to holistic college student development. In 1976, what would later be known as the National Association of Developmental Education was established, making developmental education a recognized field of study (Boylan, 1988). The first research report by the National Center for Education Statistics on developmental education in 1984 showed that approximately 30% of students entering 2-year colleges were enrolled in remedial education. The report cited that 68% of students successfully completed remedial math, but it did not define what content was contained within a remedial math course, such as arithmetic, pre-algebra, or algebra.

A later report of the National Center for Education Statistics, analyzing remedial education at postsecondary institutions, noted that the content, availability, and delivery of remedial education varied greatly and was reflective of institutional mission. At some institutions, remedial education was integrated into academic departments while other institutions used separate departments where students had to complete basic skills training before moving into any college-level work. There was no common standard as to what knowledge a college-ready student possessed. There is also no discussion in these reports as to how college ready could be defined differently for different individuals. As developmental programs continue to prepare students for college-level work, it is important to understand what exactly a college-ready student needs to know to be successful in college and then in the academic pursuits.

College Readiness

The current state of college readiness has been a national policy issue since *A Nation at Risk* was published in the 1980s, but the gaps we see today in high school graduation and college readiness stem from the evolution of current K-12 and higher education systems. As summarized by Bailey et al. (2013), the misalignment of K-12 and college preparation grew out of the differentiated purposes of both sectors and the overall acceptance that college was considered acceptable for a select few. Though a few intentional policy movements were enacted to align K-12 education with college, these movements often died down quickly without reaching the end goal of curricular alignment. The report in 1983, *A Nation at Risk*, created the national attention that placed college readiness on the public policy agenda, a necessary step in the process of creating a public policy of alignment (Bailey, 2009).

A Nation at Risk critiqued the existing comprehensive high school model that varied by and across states, for a more uniform national model that raised standards for graduation emphasizing college preparation. In response to American students performing poorly on national math assessments, the document "recommended 3 years of mathematics in high school and a decrease in the 'general track'" (Bailey, 2009, p. 22). In response to this document, national professional educational organizations started developing curriculum standards to meet these goals. Following the breakthrough work of the National Council of Teachers of Mathematics, other professional organizations such as National Council of Teachers of English and National Science Teachers Association developed guidelines specific to what students should know and be able to do at various grade levels (Ball, 2003). The National Council of Teachers of Mathematics specifically outlined principles and standards for where, when, and how algebra should occur in the high school curriculum, making it a subject that all students would learn.

These standards were quickly followed by state policies that recognized and implemented professional standards for all major subject areas. The data from one study by Hacker (2016) showed that standards alone did not appear to address the challenges that schools and teachers, confronted with students of varying academic skills and engagement, too often face and cannot overcome by curriculum alone. Variable teacher expectations coupled with an uneven implementation of standards magnified unresolved pressures regarding how teachers should manage academic differences and maintain common educational goals (Hacker, 2016).

While state policies focused on adopting standards, national policies at the time focused on ways to assess the standards. The national policy agenda with the largest significant impact on college readiness policies was the No Child Left Behind Act (NCLB). Signed into law in 2002 by George W. Bush, NCLB provided a means for the federal government to make states accountable for standards implementation. The policy called for high-stakes testing tied to ranking and performance measures. Schools were required to make Adequate Yearly Progress or risk getting sanctions with regard to funding. With the federal government adopting accountability policies, states were left with the issue of how to implement changes to meet the requirements of the NCLB. Although well intentioned, the impact of the adoption and implementation of high-stakes tests has not shown any gains in college readiness or closing the achievement gap to date (Lesik, 2007; Quarles & Davis, 2016; Quinton, 2014).

The various organizations and policy agendas of the past 30 years have culminated in the Algebra for All movement (Eddy et al., 2015). There are four main factors that have been used by policy makers to justify this need to have all students proficient in algebra: global competitiveness, equity for all students, algebraic thinking, and high-stakes assessments. The need for global competitiveness and high-stakes assessment were a direct result of *A Nation at Risk* and NCLB policy agendas. Equity for all students and the need for algebra thinking will be discussed further in this literature review by differentiating the value that algebra has and the impact that taking algebra has on students who plan to pursue mathematics-related fields compared to those students who do not.

Placement and Success in Developmental Math

For the small percentage of students who can successfully complete the developmental requirement and its related sequence, successful developmental education can lead to college persistence. Bahr (2008) found, through a study of developmental students across 107 community colleges in the state of California, that once students successfully remediate they have an equal, if not higher, chance of being successful in college-level math. The downside to Bahr's research was that three of four students did not remediate successfully, so 75% of students become stopouts or noncompleters. As students try to retake a failed developmental math course, their chance of success diminishes with each attempt. Nolting (1997), when studying developmental math students at a large Florida community college, found that 50% of students pass the first time. Of those who retake the course, 30% pass on the second attempt, and 25% pass on the third attempt. Developmental mathematics is a real barrier to students' success in college. These rates of completion also suggest that the current system is failing its intended purpose.

Considering the low pass rates of developmental math courses, proper placement into these courses is vital. Students are often placed into developmental courses based on a single score on a placement test. The accuracy and validity of these placement tests have been questioned by researchers. Bailey et al. (2010) found that students who ignored remedial placement had only a slightly lower success rate than students who placed directly into college-level courses but had a substantially higher persistence rate in college than those who enrolled in their remedial placement. The most common college placement tests, Accuplacer and Compass, assess cognitive abilities in reading, writing, and mathematics (Hughes & Scott-Clayton, 2010). Research on the validity of these placement tests in placing community college students suggests considerable test error demonstrating that test scores alone should not be used to place students; colleges should be considering other criteria (Belfield & Crosta, 2012; Scott-Clayton, 2012). The validity of placement tests such as Accuplacer has caused some states to consider alternative criteria for students who place in what they refer to as the decision zone, or placements 13 points below the cut-off score (Abel & Hayes, 2012).

Placement policies vary across and sometimes even within states giving researchers multiple opportunities to examine the impact that developmental education has on student success in college-level courses. As noted earlier, Bailey et al. (2010) found that in states where placement is only a recommendation, students who chose to ignore their remedial placement had only slightly less success in a college-level course when compared to those who place directly into it. In Ohio, Bettinger and Long (2005) utilized differences in placement scores across the state to assess the success of development math and English courses. By examining schools with different placement cut-off scores, Bettinger and Long were able to examine students with similar scores at different colleges: one where the score placed them in developmental courses and one where the same score placed them in a college-level course. While this study found positive results for the developmental student’s overall likelihood to transfer to a 4-year institution, it did not find that remedial students had a higher likelihood to complete their 2-year degree; nor did it examine success in college-level math courses.

States with mandated consistent cut-off scores have allowed researchers to examine students who place right below and above the cut-off point to determine the effect of remediation. A comprehensive study completed in Texas capitalized on the state's mandated consistent cut-off score for all higher education placement and used the RD design to examine students who fell just below and just above a that cut-off score (Martorel & McFarlin, 2007). The argument for this comparison suggests that the students are essentially the same and the difference in their score can be attributed solely to testing error. The research showed weak evidence that students who placed and succeeded in developmental course work had a slight improvement over those who did not, and the researchers found little evidence that remediation helped students make progress toward a degree or transfer to a 4-year institution. A similar study in Florida, also utilizing the RD design, found mixed results for the benefits of remediation. Students who placed in developmental math had a slightly greater persistence into the second year, but there was no significant increase in college-level math scores from those who completed developmental math to those who did not (Calcagno & Long, 2008).

Using a similar RD design, Lesik (2006), on the other hand, found a significant increase in college-level math grades from students who successfully completed developmental math. The students who completed developmental math were 3.3 times more likely to succeed in the college-level math course than those who fell right above the cut-off score and did not take it (Lesik, 2006). It is important to note, however, that the students she studied were from a competitive 4-year institution and the college-level course the students entered was algebra based. One of the limitations of these research studies is the inability to control for curriculum sequence design, teacher preparation, and teaching ability.

Considering the research on placement into developmental math courses as it stands, there needs to be a real benefit to making a developmental elementary algebra course a prerequisite to a liberal arts math course. There can be a significant ethical impact to policy if elementary algebra is not beneficial to students in college-level liberal arts math courses. The standard elementary algebra proficiency should be questioned as a requisite requirement for a college degree. One study that tested college algebra as a prerequisite for a psychology statistics course found that when grade point average was controlled for, the college algebra grade was not a predictor for success in statistics, providing greater support for the argument to remove the algebra prerequisite (Sibulkin & Butler, 2008). This study led to adjustment in policy regarding the college algebra prerequisite. Further research needs to be conducted, specifically looking at the elementary algebra impact on college-level liberal arts math courses and its necessity as a requirement of knowledge for a college degree.

Algebra as a Foundation

The studies described above question placement into developmental courses or algebra prerequisites, but they do not differentiate STEM students from non-STEM students. While the study by Bailey et al. (2010) reported that students can skip developmental math and fare better than those who enroll in it, it does not specifically examine students who are in need of a single liberal arts math course, or one that does not continue with algebra content as a college algebra or precalculus class does. An argument can be made for Lesik's (2006) study that students were tested in a college algebra course, where the content logically follows the developmental algebra math course. The developmental math students in her study needed the review algebra concepts to do better in the next class that was required for success in their degree program and career field.

The STEM students preparing for fields requiring higher level of mathematics such as calculus need to have a proficiency in algebra to succeed in these courses. The traditional developmental sequence of basic arithmetic, elementary algebra, and then intermediate algebra intends to prepare students for college-level course work in college algebra or statistics. Bahr's (2008) research showed that students who successfully completed their developmental sequence had as much if not more probability of success in college-level math. The college-level math course for his study was college algebra, a course with content that logically continues after developmental math. He did not examine if the remedial courses in elementary algebra helped prepare students for work in a general liberal arts math course that is not algebra based.

Algebra content prepares students for future courses in precalculus and calculus, but is mastering the content in a developmental elementary algebra course pertinent for success in a traditional liberal arts math course? To examine this question, it is important to understand why algebra is considered the basis for learning all math. A 2003 research report commissioned by the Office of Educational Research and Improvement (currently the Institute of Education Sciences) argued that algebra is more than just a standalone topic in mathematics; it "provides linguistic and representative tools for work throughout mathematics" (Ball, 2003, p. 48). The report further indicated that the skills stated above are required in a variety of professions and are essential skills for knowledgeable citizens to in professional careers (Ball, 2003). The urgency of learning algebra was further proclaimed in the 2008 position statement by the National Council of Teachers of

Mathematics, summarizing why algebra has evolved as a course in mathematics essential for all students to learn.

Algebra is a way of thinking and a set of concepts and skills that enable students to generalize, model, and analyze mathematical situations. Algebra provides a systemic way to investigate relationships, helping to describe, organize, and understand the world. Knowing algebra opens doors and expands opportunities, instilling a broad range of mathematical ideas that are useful in many professions and careers. All students should have access to algebra and support for learning it. The theoretical argument that algebra provides a foundation for learning all types of math needs to be examined more closely as initial research suggests a fallacy in that argument. At a time when the National Council of Teachers of Mathematics was crafting stricter standards in K-12 mathematics learning in response to the need for more students proficient in math and science, some educators spoke out against the trend of algebra for all as a way to promote equity for all students (Noddings, 1992; Smith, 1994).

Smith (1994) agreed with the notion that algebra does promote reasoning and problem solving but also argued that algebra is not the only field that does so and that students who struggle with the formal style of algebra learning can better be served in gaining a stronger background in basic math. Educational philosopher Nell Noddings (1992) warned against such strict national standards, which require all students to learn one single mathematics discipline such as algebra. In response to the national report on the state of math education, *Everybody Counts*, Noddings argued that the mathematics that one learns can and should be dependent upon the path a student chooses for life. Through an ethical and caring education, students should learn the life skills that make them productive and worthwhile members of society and not be forced into courses where learning occurs through a regurgitation of concepts leading to no long lasting understanding of lasting knowledge of algebra (Noddings, 1992). Considering the fact that 70% of recent high school graduates, who all passed an algebra course, are not proficient in elementary algebra, many students are not retaining what they learned and therefore ending up in college developmental algebra courses (Bahr, 2008). By teaching algebra as an isolated course, students are unable to retain the concepts and make connections to relevant situations and therefore the purpose of making all student learn algebra is negated in the very way that it is taught (Smith, 1994).

The argument made by those who are questioning the fact that algebra provides a foundation for students in all math courses is embedded in the idea that students are able to transfer the knowledge and critical thinking skills learned in an algebra course to any other math course. Knowledge of elementary algebra is unquestionably essential for learning in classes that require higher level algebra as students advance toward a calculus. The question is whether or not the same elementary algebra knowledge is necessary to learning other math content such as set theory, mathematical logic, geometry, modular arithmetic, descriptive statistics, which is content often found in a survey style liberal arts math course, or one that non-STEM students often take.

The process of a student's ability to transfer knowledge from one domain to another has been a topic studied extensively in psychology. Barnett and Ceci (2002) reviewed decades of research on transfer of knowledge to develop a framework on what, how, and when students are able to transfer knowledge. According to their framework, there was no evidence to support the idea that algebra students could transfer the reasoning skills learned in algebra to other disciplines. When looking at problem-solving transfer, Mayer and Wittrock (2006) found that students responded better when problem-solving skills are taught specific to a topical domain, rather than generalized, and once learned, the range of applicability past that domain is greatly restricted. This goes against the recommendations that algebra provides students with a foundation of skills that is relevant across mathematical disciplines.

The foundation skills students learn in algebra is implied by proponents to extend beyond math courses into further areas of study and professional careers. Essential course work for various careers is examined to determine the extent algebra skills are necessary. The National Center on Education and the Economy (NCEE) would argue that algebra content does not provide an appropriate foundation for students in some college-level courses (NCEE, 2013), specifically those that are not part of the statistics or calculus sequence. On examining seven community college course listings across seven states, NCEE found that the majority of entry-level math courses in most majors require little to no algebra skills to succeed, and most of the math needed to be successful in college is learned in middle school (i.e., arithmetic, ratio, proportions, expressions, and simple equations). The organization warned that community colleges cannot continue to place students in developmental courses with low success rates, learning material that is not relevant to the math needed for their particular area of study. Developmental mathematics is meant to prepare underprepared students for the math they need in college-level courses. The NCEE found that the math preparation required for many majors is middle school math, not college algebra. By having students try to pass classes with higher level of math than what is expected in their major field of study, NCEE warns that we are losing qualified individuals from the workforce because they are never able to move beyond the developmental sequence.

Research has shown that about 25% of students who do place in developmental math in community colleges are able to complete their remedial sequence and progress to college-level courses (Bahr, 2008). Research does not address how some students can complete an algebra sequence in college and go on to higher level of mathematics when others cannot. Clearly, these students were unable to retain the algebra they learned in secondary school. Yet, some of them are able to gain the knowledge again the second time around; whether they retain it or not is unknown. This may be due to teacher-led pedagogical practices that were not present in high school or the student’s own self-efficacy, motivation, desire to learn, or socioeconomic factors (Lindley & Borgen, 2002; Markus & Kitayama, 1991).

Noncognitive Influences

Noncognitive factors may play an important role in determining who retains previously learned algebra concepts when entering college and who is finally able to master algebra. When examining factors that can be used to level the playing field of college entrance exams among diverse student populations, researchers found that noncognitive variables, when used in conjunction with the Scholastic Achievement Test scores, are better indicators for student success than standardized test scores alone (Sedlacek, 2004). Sedlacek (2004) defined noncognitive variables as those that relate to “adjustment, motivation, and student perception” (p. 36). After extensive research in the field, Sedlacek identified eight areas that should be used to add to the range of attributes that colleges use to judge whether or not a student will be successful: positive selfconcept, realistic self-appraisal, successfully handling the system, preference for long-term goals, availability of strong support systems, leadership experience, community involvement, and knowledge acquired in the field. Many 4-year colleges and universities have successfully employed these eight noncognitive variables in predicting student success during admission selections (Sedlacek, 2004). As open door institutions, community colleges do not need to predict student success for admission purposes, but noncognitive predictors could be used to identify student who are at risk of failing their developmental math sequence and help develop alternative paths (Lotkowski, Robbins, & Neoth, 2004).

One noncognitive factor that has shown to have a great influence on student persistence in college is academic self-efficacy (Lindley & Borgen, 2002). Academic self-efficacy, different from general self-efficacy, refers to a student's belief in the ability to successfully perform academic tasks, such as preparing for and taking tests (Zajacova, Lynch, & Espenshade, 2005). Students' self-efficacy determines the amount of stress they place on themselves when presented with a given task. It can also determine the amount of effort that a student will exert to complete an assignment. A student with poor self-efficacy is demonstrated to have low confidence in completing a task, and to extend a low amount of effort, resulting in poor academic performance. This cycle reconfirms the fear that students have that they are not college material, contributing to their lack of persistence (Cox, 2009). Recently graduated high school students who are placed into an elementary algebra course, one they presumably passed during their high school tenure, may start their college education seriously questioning their ability to succeed, as the efficacy of placement to the students appears questionable.

A noncognitive factor often expressed among faculty as the driving force behind student failure is lack of motivation. Motivation to attend college can be based on individual intrinsic factors, such as personal interest, desire for a fulfilling career, or simple intellectual curiosity, or it can be based on external factors such as the demands and expectations of family members (Markus & Kitayama, 1991). Cohen and Brawer (2008) found that students with internal motivation for attending college had greater success than those with external factors. The *Opening Doors Project*, a multi-community college effort to enhance student services, found that many students under the age of 20 showed little personal motivation for attending college, and many reported they attended college mainly to please their parents (Cohen & Brawer, 2008). Students with internal motivation are more likely to set clear goals and stay on a planned path to fulfill those goals.

Nonacademic support mechanisms such as creating social relationships, setting and committing to goals, developing college know-how, and making college life feasible have all shown to increase student persistence and success (Karp, Hughes, & O'Gara, 2010). Cohen and Brawer (2008) suggested that the best way to educate people is to integrate all their objectives and all their ways of functioning: cognitive, affective, and psychomotor. The challenge is that counselors at community colleges often have hundreds, some up to a thousand, students at any given time, making it almost impossible to ensure that all students' objectives are understood and being integrated (Cohen & Brawer, 2008). Providing students with the relevant remedial education prior to taking a college-level math course could alleviate some of the noncognitive issues surrounding student lack of success.

Relevant Pathways to College-Level Math

Many of the reforms currently gaining ground in developmental education allow for relevant preparation of course work, often known as pathways programs. Pathways programs, such as Carnegie's Quantway and Statway, move away from a single developmental path for STEM and non-STEM students and prepare students specifically for the programs they are entering (Bailey et al., 2013). Pathways provide quicker routes to a college-level course, with focused remediation, placing students who are preparing for STEM course work on a different developmental path (be it a statistic path or calculus path) than those preparing for a general liberal arts math course.

Carnegie's Quantway and Statway programs track students from the beginning of their developmental placement. The Quantway path starts with a developmental course focused on quantitative reasoning, using foundations of algebra to help students gain a better understanding of general mathematical reasoning. When completed, students progress into a college-level Quantitative Reasoning course, thus fulfilling their math requirement. Statway is a two-semester Statistics course that integrates basic developmental math (including algebra concepts) into a collaborative, focused class. The New Mathways Program developed by the Dana Center at the University of Texas provides three pathways for students: statistics, quantitative reasoning, and STEM. All students start with a Foundations of Mathematics course meant to teach them the critical thinking skill needed to succeed in any math pathway (Quinton, 2014). Preliminary results for the New Math Pathways program show that 30% of students who progressed through the new pathway were able to successfully complete the college-level math class, compared to only 8.3% from the traditional developmental sequence (Rutschow et al., 2015). Bailey et al.'s (2010) initial research of developmental education students showed that it took 3 years for 33% of developmental students to complete college-level math. Essentially, the New Math Pathways program has the same number of students completing developmental math in a third of the time.

Both Carnegies' and Dana Center's programs align with current research focusing on relevant pathways for community college success. A critique of some of traditional research on developmental education is the absence of examining how well the actual content of developmental courses align with the content in the gateway math course (Goudas & Boylan, 2012). As noted in the development of the programs above, this alignment varies dependent on whether a student is in a STEM track. This study can provide information specifically to how well the traditional elementary algebra course contributes to student success in non-STEM math courses.

Conclusions

This study can inform the debate surrounding the necessity of learning algebra. Most of the literature is based on predicting student success in developmental courses, proper placement into such courses, and factors that influence student success in developmental courses. There is research that studies the long term effect of students who choose to ignore their placement (Bailey et al., 2010). There are studies that examine the impact that a developmental course has on grades, retention, credits earned, and successful transfer of students; but they do not differentiate the type of student in the studies, specifically STEM and non-STEM (Calcagno & Long, 2008; Lesik, 2007; Martorel & McFarlin, 2007). At this time, there is little research that specifically studies whether success in a developmental algebra course will have significant impact on the completion of a liberal arts college-level math course for non-STEM students.

Chapter III

Research Methods

The purpose of this study was to determine if an elementary algebra requirement for non-STEM, developmental students affected their success in college. The research methods examined the impact the elementary algebra course had on student success in a liberal arts math course and total credit completion in college. Nondevelopmental student success in a liberal arts math course was compared to developmental student success in the same course to determine if there is a significant difference and/or causal relationship between the college-level math grades and total credits earned between those two populations.

The possible relationship was examined using a quasi-experimental design because random assignment to developmental mathematics is not practical in this situation. The initial comparison was conducted using a two-sample independent *t* test to determine if there if there was a significant difference in the outcomes of remedial and nonremedial students. To further analyze the outcome of the *t*-test results and examine if the developmental elementary algebra course is a cause of those differences, the RD design provided a means to test similar students who fall above and below a set cut-off point (Shadish, Cook, & Campbell, 2002).

Research Questions

Data were collected from multiple community colleges in New Jersey. Prior to collecting student data, the content from New Jersey liberal arts math courses was compared so that the courses with the most similar content were chosen for data collection. By using both the *t* test and RD design, this study examined students at and around the state-prescribed placement test cut-off score for enrolling in the developmental elementary algebra course. The research questions addressed in this study are as follows:

1. To what extent do the liberal arts math courses offered at New Jersey community colleges cover similar content?

2. For non-STEM students, what is the effect of developmental algebra on students' success in a college-level liberal arts math class?

3. For non-STEM students, what is the effect of developmental algebra on number of credits earned over a 3-year period?

This chapter will clarify why both the *t* test and RD design were the most appropriate to answer the research questions and detail how they were executed.

Research Design

Students entering community college are more likely to need courses in developmental math than not (Bailey et al., 2010). For this reason, numerous quantitative, qualitative, and mixed-methods studies have been conducted to evaluate the impact of remedial math courses on the educational outcomes and persistence of community college students. A thorough review of the literature identifies three groupings of summative quantitative designs: descriptive studies, quasi-experimental designs, and experimental designs (Melguizo et al., 2011). For this study, descriptive analysis was completed along with a more rigorous quasi-experimental design to address the limitations found when conducting descriptive comparisons alone.

Ideally, an experimental design with random assignment would provide the optimal results (Shadish et al., 2002). In the context of this study, students who place into the developmental elementary algebra course would be randomly separated into two equal groups. One group would complete an elementary algebra course prior to taking the college-level math, and the other group would take college-level math without the elementary algebra. In random assignment, the only difference between the two groups would be the treatment (taking elementary algebra); therefore, any resulting differences in the outcomes could be contributed to remediation. Randomly assigning students to remedial education not only goes against the state's general education requirements and placement policies, it is unfair and unethical to the students due to the high cost of remediation.

To comply with state policy, the ethical treatment of students, and individual institution policies, descriptive statistics can be used to compare students who were in need of and completed remedial math courses to those who placed directly in a college-level general education math course. This type of comparison has been utilized often in research with major limitations (Bettinger & Long, 2005). By comparing these two groups using basic statistical analysis, such as a *t* test, analysis of variance, chi-square analysis, or regression, the results are designed to determine if those who needed remediation have the same educational outcomes after completing remediation compared to those who did not need it. The purpose of remedial education is to get developmental students to the same outcomes as nondevelopmental students (Bailey et al., 2015), which may provide a valid comparison but may not truly provide information on the statistical significance on the influence of the elementary algebra course. An important limitation of this type of evaluation is the difference among the two groups of students being compared. The preexisting conditions that are common within each group will likely make any results biased and no causal inferences can be made (Melguizo et al., 2011).

The RD design mimics random assignment so that the differences between the developmental and nondevelopmental group is minimized while not violating the integrity of the placement policies at New Jersey community colleges. The RD design uses a predetermined cut-off score to place students into two different groups, allowing the researcher to isolate similar students who fall directly above and below the cut-off point (Shadish et al., 2002). Because random assignment is not possible, a regression discontinuity design can be used to determine the causal relationship between participation in elementary algebra and future success in a college-level math course and college credits earned. The RD design has been shown to test causal relationships while eliminating selection bias using an exogenous determined cut-off score (Shadish et al., 2002). The New Jersey statewide prescribed cut-off score for placement into college-level math makes an RD design more appropriate and robust for this study. Melguizo et al. (2011), in a critical review of research on developmental education, argued that the RD design "most closely resembles true random assignment because many of the students who score below the cut-off score might have tested above on a different day or different test form and vice versa" (p. 176). Research presented earlier on placement test validity supports this assumption (Belfield & Crosta, 2012; Scott-Clayton, 2012).

The RD design has been used to understand the effectiveness of remedial education in 4-year and 2-year institutions (Calcagno & Long, 2008; Lesik, 2007; Martorel & McFarlin, 2007). This method has been considered by researchers to be the closest to randomized assignment that one can get when a predetermined cut-off point for treatment is required. The rationale behind the design is that the participants who fall right above and right below the cut-off point are considered identical (Shadish et al., 2002). This design can be considered random for the students falling in the neighborhood of the cut-off score, leaving any difference in success in the college-level course based on the treatment administered, in the case of this study: the Elementary Algebra course (Melguizo et al., 2011).

In regression discontinuity, the normal regression line is split in two: One group represents the students who participated in the developmental course, and the other group is selected to represent those who did not (see Figure 1). The extent of the discontinuity (jump) at the cut-off represents the treatment effect. For this study, the discontinuity will represent the effect that an elementary algebra course has on student achievement in college-level math and total credits earned in college toward graduation (i.e., if students receiving the treatment effect of elementary algebra proceed in the math sequence at a different rate of achievement than those who do not take elementary algebra and the impact on eventual graduation). To ensure that any differences in outcomes of this design were contributed to the elementary algebra course, threats to internal validity were addressed. If students are not placed properly or are allowed to skip their remedial assignment, then the design is no longer a sharp RD design and is considered a fuzzy RD design (Lee & Munk, 2008). A different statistical analysis needs to be applied in a fuzzy design to ensure internal validity. In this study, all placements in the state at the time of the study were uniform and mandatory, allowing for a sharp design. To assure proper assignment, placement scores were checked against actual placement as part of the data cleaning process.

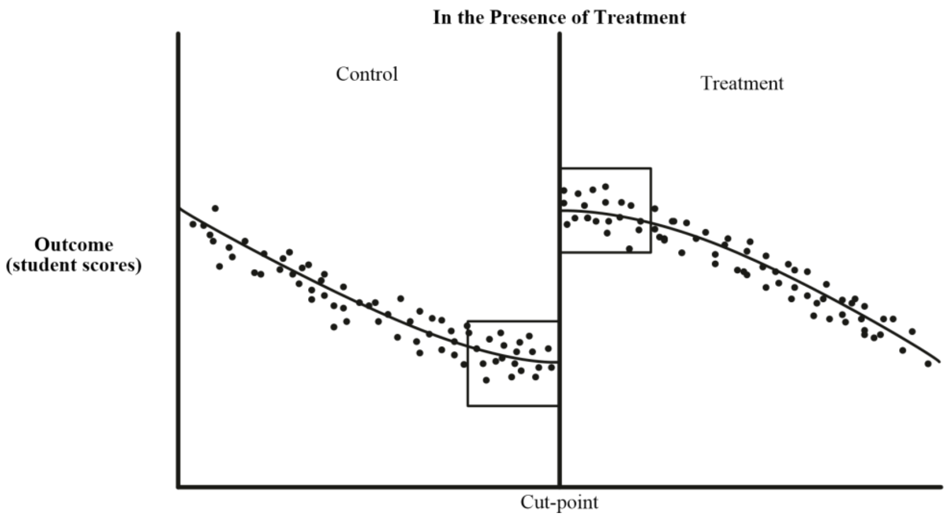

Figure 1. Sample regression-discontinuity graph showing a discontinuity at the cut-off.

Another threat to validity occurs when students retake the placement tests multiple times. Retaking the test can allow more motivated students initial access to the college-level course, changing the assignment process (Melguizo et al., 2011). This threatens the entire premise of the RD design, where the students just above and just below the cut-off point are essentially equivalent, leading to selection bias (Urquiola & Verhoogen, 2007). Retest policies will vary by institution and can change year to year. Calcagno and Long (2008) addressed the retest issue by identifying colleges throughout the state of Florida that did not allow retests. When data were collected, retest polices at all participating institutions were examined and all attempts at the placement test were recorded and examined.

The statistical analysis used to determine if a significant number of students repeated the placement tests until they achieved a score above 76 involved density tests. Density tests can determine if a significant number of students are scoring directly above the cut-off point, causing a bunching effect. If this occurs and further examination of the data confirms that a large number of students retook the test until they got the required score of 76, then a fuzzy design should be implemented. The fuzzy discontinuity weights those scores above the cut-off point so they do not disproportionality give false results to the researcher (Jacob et al., 2012). For this study, the density and evaluation of placements along with the density tests validated the use of a sharp design.

Sampling and Participant Selection

Site selection. This study used retrospective data from select New Jersey community colleges. Sampling students from across the state was possible for this study because in 2008 all community colleges in the state of New Jersey agreed to use common placement tests and cut-off scores to determine readiness for college-level mathematics courses. The colleges for this study were carefully selected to ensure only colleges with consistent content of the liberal arts math class were asked to participate. Selection was also based on placement practices. While all community colleges in New Jersey have agreed to a statewide cut-off score on the Accuplacer and a set of topics for Elementary Algebra, only colleges that have adhered to this agreement were considered.

Participants. The population for this study was the 2012 cohort of New Jersey community college students whose major field of study requires a liberal arts math course; students who are not on a path toward courses in statistics or calculus (non-STEM students). All non-STEM students from the selected community colleges who placed directly into and took Elementary Algebra (scoring under 76 on algebra module of the Accuplacer) and placed directly into and took the liberal-arts math course (scoring 76 or above on the Accuplacer) were used for this study. Unlike other similar studies who used all developmental math students, the population is limited to the impact of a specific developmental course (elementary algebra) on students who are not in math-intensive programs where statistics or calculus is required (Bettinger & Long, 2005; Calcagno & Long, 2008; Lesik, 2007; Martorel & McFarlin, 2007). This study was conducted retrospectively using existing data. All data from the two populations (developmental and nondevelopmental students in college-level math) collected from participating colleges were used, eliminating the need for sampling.

Data Collection

College testing procedures. To ensure that all colleges selected adhered to the statewide testing recommendations, college cut-off scores were collected and analyzed for conformity. Individual college testing procedures were collected and analyzed to determine if a possible overestimation of students scoring above the cut-off could bias the results. A robust retesting policy can lead to an overestimation of motivated individuals scoring above the cut-off score (Lee & Munk, 2008). If this was the case, then a fuzzy RD design would have been appropriate.

Mathematics course content. Elementary algebra and liberal arts math syllabi from all New Jersey state community colleges were analyzed for course content. Colleges with liberal arts math courses that contain topics such as set theory, logic, ancient number systems, base operations, geometry, rational numbers, and modular arithmetic were asked to participate in the study.

Data. In this study, all data were taken from the 2012 cohort of students from the selected colleges. The RD design requires an exogenous cut-off point (Shadish et al., 2002). This cohort is appropriate for the study because the student experience occurs after the adoption of the statewide prescribed cut-off score of 76 on the Accuplacer placement test and before several community colleges within the state started varying their placement policies for students scoring near the cut-off. The 76 cut-off score determines who is placed into elementary algebra and who can enroll in a liberal arts college-level math course. The 2012 student cohort can also provide 3 years of ex post facto performance data. Once the appropriate liberal arts math courses for analysis were determined, performance data from full-time students from the 2012 cohort who enrolled in those courses between Fall 2012 and Spring 2015 were collected. While initially 11 colleges were asked to participate in the study, only four were able to provide data. The data include Accuplacer math placement scores (all attempts), enrollment and grade in elementary algebra (if taken), enrollment and grade in liberal arts math course (if taken), school attended, major field of study, gender, race, and total college-level credits earned each year from 2012 to 2015.

Variables

The independent variable for Research Questions 2 and 3 is the student's Accuplacer score (SAS). The SAS determines whether the student is in the remedial group or nonremedial group for the *t* test and is the assignment variable for the RD design. The cut-off is a 76; a SAS of 76 and above is nonremedial and below 76 is remedial. For Research Question 2, student success is evaluated by the grade the student receives in college-level math and whether or not they completed college-level math with a grade of D or higher. The dependent variables for Research Question 2 are the student's grade in the college-level math course (GCL) and completion of college-level math (CCL). Due to variations of grading across colleges, grade values with + and - letter grades were grouped together, as shown in Table 1, for the variable GCL. The variable

CCL is a dichotomous variable with an outcome of 0 if the student did not complete college-level math with a D or better, and an outcome of 1 if the student did complete college-level math with an outcome of D or better. For Research Question 3, the dependent variable was total number credits earned (TCE). Only college-level credits were included.

Table 1

Grade Distribution Assignment

Letter grade	Completion level
A-, A, A+	4
B-, B, B+	3
C-, C, C+	2
D-, D, D+	1
F, W	0

Covariates would normally be used to validate the RD design and to help determine that any effect found is indeed caused by the elementary algebra course and no other variables. One means to test the validity of the RD design and ensure that local randomization is present is to check if covariates are balanced on either side of the cut-off score (Lee & Lemieux, 2010). For this study, the covariates that could be tested are participating college (COL), gender (GEN), and race (RAC). No treatment effects were found for any of the variables, so no validation of treatment effects was necessary in this study.

Data Analysis Methods

The methodology combined some descriptive statistics with a quasi-experimental design. Using multiple approaches strengthens the overall statistical analysis, as each approach can balance the limitations associated with the other approaches. Descriptive statistics were obtained from the developmental group and the nondevelopmental group to describe the total populations in terms of relevant characteristics. A two population independent *t*-test was used to determine if an overall difference exists between students who placed in developmental math and those who did not. The RD design further informed any potential difference by analyzing if placement in the developmental math course has an effect on the college math grades and overall credits earned of students. All statistical analyses were completed through STATA, specifically STATA modules known as RD robust, RD density, and RD locrand developed for the RD design (Calonico, Cattaneo, & Titiunik, 2014; Cattaneo, Jansson, & Ma, 2016; Cattaneo, Titiunik, & Vazquez-Bare, 2016).

Comparison of means. To determine if there was a significant difference in success (liberal arts math course and total credits earned) of remedial and nonremedial students, a two-population *t* test compared the overall performance of the students who participated in the developmental algebra course with those who enrolled directly into the college math course. For Research Question 2, two hypothesis tests were conducted to compare non-STEM student success in college-level math between developmental and nondevelopmental students. For Part 1, the mean grade point average in the college-level math course for each group was compared using a two-population *t* test to determine if there is any significant difference with the following hypothesis test:

RQ2 H_o: There is no difference in the mean college-level math course grades for remedial and nonremedial students.

RQ2 H_a: There is a difference in the mean college-level math course for remedial and nonremedial students.

For Part 2 of Research Question 2, the completion rate of college-level math was compared using a two-population *t* test to determine if there is any significant difference with the following hypothesis test:

RQ2 H_o: There is no difference in the college-level math completion rate for remedial and nonremedial students.

RQ2 H_a: There is a difference in the college-level math completion rate for remedial and nonremedial students.

For the third research question, the mean total credits earned for each group was compared using a two-population *t* test to determine if there is any significant difference with the following hypothesis test:

RQ3 H_o: There is no difference in the mean total credits earned for remedial and nonremedial students.

RQ3 H_a: There is a difference in the mean total credits earned for remedial and nonremedial students.

The total population size and variance of both the remedial and nonremedial students was evaluated to determine if a pooled or non-pooled two-population *t* test should be used. This design compared the two populations and determined if there is sufficient evidence to claim a difference in remedial and nonremedial student success in college-level math. Due to the lack of random assignment, this design cannot provide evidence that any proposed difference would exist if the remedial students did not take the remedial course (Melguizo et al., 2011).

Regression discontinuity. The basic RD design for this research examined what if any discontinuity is occurring at the cut-off score to determine treatment effect (ability to pass college-level math). All data below the cut-off score had treatment (Elementary Algebra) and those above did not. A graphical representation of the data was used initially to determine if a discontinuity exists. The outcome variable (GCL and TCE) was plotted on the vertical axis and the assignment variable (SAS) on the horizontal for each research question. This provided a visual representation of any discontinuity. Further statistical analysis provided a clearer representation of the significance and magnitude of the discontinuity.

Getting the most accurate as possible representation of the true functional form around that cut-off score is imperative to implement a design with limited bias. Three overall strategies exist to achieve this goal: a parametric approach, a nonparametric approach, and local randomization (Cattaneo, Jansson, et al., 2016; Jacob et al., 2012). In the first two approaches, the treatment effects are calculated by the difference in the discontinuity on the regression line from the left and right hand sides (see Figure 1). Local randomization compares the mean of a small sets of values that fall directly above and directly below the cut-off point (Cattaneo, Jansson, et al., 2016).

The parametric approach uses all data points, allowing those closer to the cut-off to be influenced by those further away in order to gain a more precise discontinuity at the cut-off. Using all data points will make finding an accurate functional form more difficult leading to greater bias. The nonparametric approach uses local linear (or polynomial) regression only on those data points that fall directly above and directly below the cut-off score. The nonparametric approach has a greater chance of fitting a linear form, leading to less bias, but due to smaller sample size, the statistical power is much less than a parametric approach (Jacob et al., 2012). To increase reliability of the overall design, both specifications were used. Due to the relatively small data set in this study, the regression lines from these approaches may be overly sensitive to each data value, leading to questions of validity. The local randomization method does not rely on regression and is more appropriate for small data sets (Cattaneo, Jansson, et al., 2016). Consistent results across all approaches (parametric, nonparametric, and local randomization) are more reliable than results that are sensitive to design specification (Lee & Lemieux, 2010).

Parametric approach. Identifying the closest functional form possible can lead to the least bias in the parametric approach. An adaption of Jacob et al. (2012) shows general equation accounts for the varying possible functional forms:

$$Y_i = \alpha + \beta_0 T_i + f(X_i) + \varepsilon_i$$

where:

Y_i = outcome variable

RQ2: GCL and CCL

RQ3: TCE;

α = the average treatment value of the outcome for those in the treatment group after controlling for Accuplacer score;

T_i = 1 if observation *i* was placed in developmental algebra and 0 otherwise*;*

X_i = SAS – CUT-OFF, assignment variable (SAS) centered at cut-off (CUT-OFF);

ε_i = random error term for observation i.

The function, $f(X_i)$, will be determined by the best fitting functional form and may be linear, quadratic, cubic, or higher. The coefficient $\hat{\beta}_0$ represents the effect of the treatment. The coefficient $\hat{\beta}_0$ represents the difference between a student's score right at the cut-off would be with and without treatment (Thistlewaite & Campbell, 1960). In practice, two separate regression lines will be implemented: the regression line to the left ($X < 0$) representing students who were assigned to and participated in developmental algebra and the regression line to the right ($X > 0$) representing students who placed directly in college-level math. Lee and Lemieux (2010) suggested allowing the functional form for the right-hand side to differ from the left-hand side so that variables form one side are not used to influence the other. Allowing the treatment from each side of the regression to influence the slope as well as the intercept can be important when non-linearity is expected as would be expected here, but it can also lead to less statistical power in the research model. Some possible models with interaction between assigning variable and outcome variable for $f(X_i)$ are as follows:

linear: $f(X_i) = \beta_1 X_i + \beta_2 X_i T_i$

quadratic: $f(X_i) = \beta_1 X_i + \beta_2 {X_i}^2 T_i + \beta_3 X_i T_i + \beta_4 {X_i}^2 T_i$

To ensure that the best fit is made with the highest power of analysis, all possible models (with and without interaction) were tested using an *F* statistic in STATA. Starting with the linear regression model, the results of the functional model were compared to a model that included a set of dummy variables that relate to the bins used to graphically depict the data. If the resulting *F* statistic is not statistically significant, then the data from the bins are not adding any additional information and the selected functional form is not overshooting the data (Lee & Lemieux, 2010). Once the functional form is found, the treatment effect at the discontinuity can be evaluated.

Nonparametric approach. The nonparametric approach uses values that fall near the cut-off, making an easier estimation for the functional form, resulting in less bias from data values far from the cut-off (Jacob et al., 2012; Lee & Lemieux, 2010). Theoretically, one nonparametric approach would be to simply find the difference of means within the selected neighborhood on each side of the cut-off point to determine the expected value of the treatment. This is not robust as that difference may change dramatically with the size of the neighborhood selected. Hahn, Todd, and van der Klaaw (2001) suggested a local linear regression that allows different slopes and intercepts on either side of the cut-off, similar to the parametric design above that allowed interaction. The general regression model with the linear interaction function using the same variables is as follows:

$$Y_i = \hat{\beta}_0 + \hat{\beta}_1 T_i + \beta_1 X_i + \beta_2 X_i T_i + \varepsilon_i$$

The challenge with the nonparametric approach is choosing the appropriate size neighborhood, or bandwidth (h). A larger bandwidth will produce better estimates due to more data, but a bandwidth that is too large can lead to a less accurate linear model, creating more bias when estimating the treatment effect, leading to an inaccurate discontinuity (Jacob et al., 2012). The optimal bandwidth, proper balance of bias and precision, will be determined using the IK “plug-in” formula in STATA. This formula was originally developed by Fan and Gijbels (1996) for local linear regression, then modified by Imbens and Kalyanaraman (2009) for RD designs. Once optimal bandwidth is found, the treatment effect can be determined at the discontinuity.

Local randomization approach. The local randomization approach does not rely on regression to find treatment effect, making it more suitable alternative RD approach for this study's small data set (Cattaneo, Jansson, et al., 2016). The first step was to find the largest window surrounding the cut-off score where the values on either side are considered random. The idea is that any covariates that are not related to a student's placement in elementary algebra will be balanced on either side of the Accuplacer cut-off of 76. The covariates used for this study were college attended (COL), race (RAC), and gender (GEN). Initially, a very small window is selected and a hypothesis tests are conducted on each covariate using increasingly larger windows until one shows significant effects on the covariate tested. Of the three covariates tested, the smallest window is selected for the local randomization approach.

Once the appropriate window was selected, a null hypothesis that the treatment effect is zero was tested for all impacted variables (GCL, CCL, and TCE). Unlike the parametric and nonparametric approaches, which test how the average treatment effect varies across data values, the hypothesis tests for local randomization use point estimates for the average treatment effect. This approach was used to check the validity of the parametric and nonparametric approach due to the relatively small data set. All three approaches yielded similar results.

Threats to Validity

Multiple threats to validity were addressed during data analysis. The overall validity of any discontinuity at the cut off could be examined using covariates. This approach to testing for validity examines how well balanced other variables (e.g., race, gender, major) are in relation to the cut-off score to ensure that any discontinuities can be contributed to the variables being tested and not covariates (Lee & Lemieux, 2010). Considering that this study would have limited covariates, the original RD design can be run by replacing the dependent variable with each covariant. The results of the study showed no discontinuities at the cut-off so this test was not needed.

Other anticipated threats to validity for this design center on when and if students take their college-level math course. Many students who take a developmental algebra course never proceed to the college-level math either because they never pass the developmental course, never enroll in the college-level course, or drop out of school. This could have serious implications on the treatment effect if the developmental algebra group is comprised of students who have already demonstrated college success (in passing elementary algebra) when they take the college-level math course. Many factors, cognitive and noncognitive, influence a student's ability to succeed in college (Cox, 2009; Lindley & Borgen, 2002). The factors that caused the developmental algebra students to fail may also cause the college-level math students to fail when faced with their first college math course. The problem is that these students are present in one group of the study (college-level math) and not in the other (developmental math), because they have been weeded out of the developmental population prior to taking the college-level course. To address this threat, the RD was conducted first examining only the student grades of those who took the liberal arts math class. Then the RD was conducted on all students by examining whether or not they successfully completed a liberal arts math class in three years with a D or better.

Limitations

The generalizability of this design was limited. The design tested the impact of the elementary algebra course near the cut-off score. Arguments can be made that those students were not in need of the treatment in the first place and that the initial prescribed cut-off scores are invalid. As the study is limited to students who fall right below the cut-off, any valid local impact can only be applied to those students and the impact could be very different or nonexistent to the students who place much further away from the cut-off (Jacob et al., 2012). Considerations will be made to how the impact at and around the cut-off score can be applied to students who fall further away from the score. Arguments also can be made that the students who fall further from the cut-off would benefit from the treatment (elementary algebra course) more so than those who fall closer to the cut-off (Shadish et al., 2002). Pairing the results of the regression discontinuity with those of the *t* test can provide a larger picture of the effects of elementary algebra on college success of non-STEM students.

The RD design has had some controversies in its use on developmental education students. Leaders of the National Association of Developmental Education have expressed concerns over using developmental math courses as treatments in RD designs. Goudas and Boylan (2013) argued that scientific treatments must be universal and controllable by the researcher, citing such institutional variations as course content, teaching style, and curricula. While this limitation is certainly a concern, the careful selection of statewide institutions that have made effort to align curricula would strengthen the validity of this study. Goudas and Boylan further warned that the results of an RD design should be limited to the specific set of students, around a specific cut-off score in specific institutions. This limitation will be addressed in the discussion write-up of the study.

Chapter IV

Findings

The purpose of this study was to determine the impact of developmental algebra on non-STEM student success in college-level math and persistence in community college. Many students who place in developmental math are unable to succeed in college-level math (Bahr, 2008; Bailey et al., 2010). Recent initiatives in developmental education have questioned the need for an indepth understanding of algebra for non-STEM students whose course of study require a general liberal arts math class (Bailey et al., 2015; NCEE, 2013). This study can help inform whether the placement in a developmental algebra course has an impact on eventual success in college-level math and persistence in college by examining the students who place above and below a predetermined placement score using a two-population independent *t* test and the RD design. The research questions addressed in this study are as follows:

1. To what extent do the liberal arts math courses offered at New Jersey community colleges cover similar content?

2. For non-STEM students, what is the effect of developmental algebra on students' success in a college-level liberal arts math class?

3. For non-STEM students, what is the effect of developmental algebra on number of credits earned over a 3-year period?

Course catalogs of all 19 community colleges in the state of New Jersey were collected and analyzed to answer Research Question 1. The results of this analysis ensured that colleges chosen for the study had similar liberal arts math course prerequisites and content. For Research Questions 2 and 3, two statistical analysis were performed on the data resulting from Research Question 1's completion. A two-population independent *t* test examined if any differences existed in student college-level math grades and total credits earned between those who were required to take developmental algebra with those who were not. The RD analysis examined similar students who placed around the cut-off to determine if placement in developmental algebra could account for any differences. The RD design was chosen for this study to ensure that the two groups of students compared were as similar as they could be without random assignment. Arguments against *t*-test comparisons highlight the fact that students who place into developmental courses are much different than those who place out of them, concluding that any difference found between the two groups may not be due to actual placement but undetermined factors that could have initially contributed to that placement (Meguizo et al., 2011). Random assignment cannot be used to eliminate those differences because it is not possible to randomly assign students to developmental courses considering the extra cost and time associated with taking them. The RD design uses the margin of error associated with the state mandated cut-off score on the Accuplacer to simulate random assignment for those students who fall directly above and below the cut-off, allowing any differences to be contributed to the treatment, which for this study is the elementary algebra course (Shadish et al., 2002).

Selection of Colleges

One of the initial prerequisites of conducting an RD analysis is the requirement of a consistent, predetermined cut-off for placement (Jacob et al., 2012). In 2008, the 19 community colleges in the state of New Jersey agreed to have statewide consistency in placement of community college students. A 76 on the Algebra Domain of the

Accuplacer placement test was the agreed cut-off for placement into college-level math. The colleges also agreed on the content that must be included in the basic developmental algebra course that students who placed below the 76 were required to pass. Colleges did not agree on the course content for the general liberal arts math course that non-STEM students who placed out of developmental algebra could enroll in. Some schools required all students to continue course work in algebra, while others allowed non-STEM students to enroll in a survey style math courses with various topics.

Prior to requesting data, all 19 New Jersey community college catalogs and placement procedures were reviewed to determine which colleges had similar liberal arts math content and consistent compliance with the state college math placement cut-off score. The mathematics topics covered in each college's liberal arts math course was retrieved from course catalogs for the 2012-2013 academic year. Most catalogs were found archived on college websites, some had to be requested. Testing procedures were obtained from the same catalogs to ensure compliance with state mandated placement test use and cut-off score. Most colleges used the Accuplacer test with a cut-off score of 76 as the only method of placement. Once the list of possible colleges was finalized, test retake policies were examined to determine if student manipulation of placement was possible through excessive retesting. While at least one college did allow a retest for an additional cost to the student, density tests completed during this study did not find significant evidence of student manipulation of test scores.

Eight community colleges were eliminated from any data request for the following reasons. One was immediately dismissed due to noncompliance with statewide testing procedure by allowing an additional elementary algebra exit test for students to place out of developmental algebra. Five colleges were eliminated due to requirements for advanced algebra-based courses for their non-STEM students, even though for three of them, the content in the liberal arts math course did not build upon the algebra content. One college revamped the delivery of the developmental program to self-paced modular approach during the study time frame. Another college was not included because of a standard two-semester liberal arts math course where all others colleges had a one-semester course.

Initially, 11 colleges were asked to participate and provide data for this study. While few colleges' course content matched exactly, 11 colleges had similar content that was not a continuation of content found in a development algebra course. This content included set theory, mathematical logic, basic geometry, ancient number and modern numeration systems, consumer mathematics, problem solving, modular arithmetic, descriptive statistics, and some probability. All colleges selected had courses that covered at least six of the above mentioned topics.

All 11 colleges were sent a detailed email requesting data along with any Internal Review Board applications required by the colleges. Four of the 11 colleges did not respond to initial or follow-up requests. Three colleges chose not to participate citing overworked and understaffed offices. Of the 11 colleges selected, data could only be obtained from four of the colleges. Once the data were initially examined, one of the four colleges was found to have a shortened, one-credit elementary algebra course for those who placed just below the 76. The course was originally listed in the college catalogue for only students who failed developmental algebra, giving them an opportunity to take a one-credit course instead of retaking the four-credit full algebra course. Once the data were examined, it was found that students who initially placed within 13 points of the cut-off could take this course in place of the four-credit elementary algebra course. The course covered the same topics and the data were used in this study but were clearly disaggregated in the *t* test and RD analysis, as the processes described in Table 2 illustrate.

Table 2

College and Student Characteristics

Characteristic	College 1 (*n* = 315)	College 2 (*n* = 270)	College 3 (*n* = 22)	College 4 (*n* = 190)
College type	Suburban	Suburban	Rural	Suburban
College size	Large	Large	Small	Large
Student gender, *n* (%)				
Male	161 (51.1)	148 (54.8)	7 (31.8)	107 (56.3)
Female	154 (48.9)	122 (45.2)	15 (68.2)	83 (43.7)
Student race, *n* (%)				
White	187 (59.4)	17 (6.3)	19 (86.4)	132 (69.5)
Black	31 (9.8)	6 (2.2)	0	29 (15.3)
Hispanic	54 (17.1)	200 (74.1)	2 (9.1)	12 (6.3)
Asian	11 (3.5)	0	0	11 (5.8)
Other	32 (10.2)	47 (17.4)	1 (4.5)	6 (3.2)

Descriptive Statistics

First-time, full-time student-level data were collected from the four participating community colleges. Only data from students enrolled in non-STEM majors were collected. Colleges 1 through 3 required students who scored under the 76 placement test cut-off score to take a traditional full-semester elementary algebra course and their data were grouped together for all analysis; College 4 remained separate. Table 2 gives a general description of college and student data. College size classification follows the Carnegie Classification of Institutions of Higher Education. The total sample size was 797 with Table 2 showing the breakdown by college, gender, and race.

To answer Research Questions 2 and 3, five processes are identified in Table 3. For Research Question 2, success is defined two ways: student grades in college-level math for all students who attempted college-level math and by successful completion of college-level math over a 3-year period. Research Question 2 would be answered through Processes A, B, and C.

Processes A and B represent the three schools in this study with traditional developmental algebra courses. Process A addresses the impact elementary algebra has on grades in college-level math and Process B addresses the impact elementary algebra has on completing college-level math. Process C addresses the impact a short elementary algebra review course has on grades in a college-level math course using data from College 4.

Research Question 3 examines the impact of developmental algebra on total college credits earned over a 3-year period and would be answered through Processes D and E. Process D looks at this impact in schools with a traditional developmental algebra course and Process E looks at this impact in the school with the modified algebra course. These impacts are examined through a comparison of means using two-population independent *t* tests and RD design using global and local polynomial regression as well as local randomization methods.

Table 3

Description of Processes

Process	Description
A	Impact elementary algebra has on grades in college-level math of non-STEM students who attempted college-level math in schools with traditional developmental algebra course.
B	Impact elementary algebra has on successful completion of college-level math for all non-STEM students in schools with traditional developmental algebra course.
C	Impact elementary algebra has on grades in college-level math of non-STEM students who attempted college-level math in schools with a modified shortened one credit review elementary algebra course.
D	Impact elementary algebra has on total credits earned of non-STEM students enrolled in full traditional developmental algebra course.
E	Impact elementary algebra has on total credits earned of non-STEM students enrolled in modified (shortened) developmental algebra course.

The number of participants varied for each process. For example, students who never attempt a college-level math are not included in Process A but are included as a non-success in Process B. Table 4 provides summary statistics for each variable as it relates to the process. The SAS (student Accuplacer score) is the independent variable in all processes. This raw score represents the score the student received on the Algebra Domain of the Accuplacer placement test. Students scoring 76 and above are placed in a college-level math course with no remediation, and students scoring below 76 are placed in a developmental algebra course. In Colleges 1, 2, and 3, this course is a three- to four-credit full-semester algebra course. College 4 students who score 63 to 75 are placed in a one-credit algebra review course. The difference in number of observations for the SAS depends on the process.

Table 4

Summary Statistics of Each Process

Process	Variable	Observations	Mean	*SD*	Minimum	Maximum
A	GCL	329	2.28	1.25	0	4
A	SAS	329	67.41	20.34	28	116
B	CCL	607	0.47	0.50	0	1
B	SAS	607	60.07	19.39	22	116
C	GCL	153	2.96	1.09	0	4
C	SAS	153	82.83	14.41	58	120
D	TCE	607	36.69	25.25	0	87
D	SAS	607	60.07	19.39	22	116
E	TCE	190	47.07	23.98	0	94
E	SAS	190	80.17	14.21	62	120

Process A, with 329 observations, examines grade in college-level math (GCL); therefore, only those students who took a college-level math course are included in the observations. Process B, 607 observations, examines whether or not a student completes college-level math (CCL) in 3 years and includes all non-STEM students who initially placed in either developmental algebra or college-level math. The difference between those numbers represents the number of students who never took a college-level math class either because they never passed development algebra or they did pass but never enrolled in the college-level math course. Process C examines the impact of the review course on students' grades in college-level math (GCL) for all students in College 4 who placed in the one credit review developmental algebra course and went on to a college-level math course as well as those who placed in college-level math. Process D and E examine the total credits earned (TCE) of all students who placed directly in developmental math and college-level math.

Comparison of Means

Independent two-population *t* tests were used to determine if a difference existed in the grade in college-level math, completion of college-level math, and total credits earned for those who took developmental algebra and those who did not. The assumption for equality of variances, using Levine's test, was met for Processes A, B, C, and E. For Process D, the *t* test was adjusted to accommodate for unequal variances. Table 5 shows that there is a significant difference in Processes B, C, and D. For Process B, there is sufficient evidence to support that students who did not need an Elementary Algebra course (M = 0.77, SD = 0.04) completed college-level math at a different rate than those who took elementary algebra (M = 0.40, SD = 0.02), $t(605) = 7.78$, $p < .01$. These results suggest that the students who are placing out of elementary algebra are completing their college-level math course at a higher rate than those who are placing in elementary algebra. There was not statistically sufficient evidence, at the 95% confidence level, to determine a difference in grades of the students who took a traditional elementary algebra

Table 5

Comparison of Elementary Algebra Students With College-Level Math Students

		Elementary algebra*			College-level math				
Process	Variable	*n*	*M*	*SD*	*n*	*M*	*SD*	*t*	*p*
A	GCL	216	2.19	0.08	113	2.45	0.12	1.84	.07
B	CCL	479	0.40	0.02	128	0.77	0.04	7.78	<.01
C	GCL	54	2.46	1.13	99	3.23	0.97	4.43	<.01
D	TCE	479	33.22	25.29	128	49.68	20.50	7.66	<.01
E	TCE	54	50.94	19.50	99	56.13	19.90	1.55	.12

Note. H_o: There is no difference in grade in college-level math (GCL), completion of college-level math (CCL), and total credits earned in 3 years (TCE) between students who place in elementary algebra and those who place directly in college-level math.
*For Process A, B, and D, Elementary Algebra represents a traditional full 3-4 credit course, for Process C and E, Elementary Algebra represents a 1 credit review course.

(M = 2.19, SD = .08) course with those who did not (M = 2.45, SD = 0.12), $t(327) = 1.84$, $p = .07$. These results suggest that students who are able to pass the traditional elementary algebra course are getting near the same grades in college-level math as those who did not need the course. The results for the modified elementary algebra review course reflect a different interpretation. In Process C, there was sufficient evidence to determine the grades of students who took the elementary algebra review course (M = 2.46, SD = 1.13) were different from those who did not take the review course (M = 3.23, SD = 0.97), $t(151) = 4.43$, $p < .01$.

The only populations that tested significant for a variance ratio greater than one is the comparison of total credits earned by students who placed in elementary algebra and those who did not, as shown by Process D. This was the only t test that needed to be adjusted to account for unequal variances. There is sufficient evidence to support a difference in total credits earned between students who took a traditional elementary algebra course (M = 33.22, SD = 25.29) and those who did not need the algebra course (M = 49.68, SD = 20.50), $t(240.72) = 7.66$. There is not sufficient evidence to support a difference in total credit earned between students who took an algebra review course (M = 50.94, SD = 19.50) and those who did not need one (M = 56.13, SD = 19.90), $t(151) = 1.55$, $p = .12$.

Regression Discontinuity

The RD design assesses whether any treatment effect is significant at the cut-off, implying that the actual treatment (taking elementary algebra) had an effect on the outcome. This possible treatment effect was evaluated using multiple approaches. The graphical representation shows the overall data before and after the cut-off. The parametric approach used all data points to graph a best fit polynomial function for the points before and after the cut-off and used the polynomial to estimate treatment effect. The local polynomial approach creates an optimal bandwidth around the cut-off and uses local linear regression to estimate treatment effect. The local randomization approach creates an optimal window using covariates to mimic randomization around the cut-off to compare difference between control and treatment group. The validity of assuming a sharp RD design was checked using density functions.

Validity of a sharp RD design. One of the major assumptions that must hold for an RD design to be valid is that there is no influence on the assignment variable that could affect whether treatment is received. Student Accuplacer scores could be influenced by administrative overrides or constant retesting until desirable scores are achieved. Students who received an administrative override would have Accuplacer scores that are not compatible with their actual placement. Figure 2 shows the probability that all students who achieved a score of lower than 76 on the Accuplacer took the elementary algebra course is 1 and those who scored 76 and above is 0. This implies that there was 100% compliance with placement scores and no administrative overrides were given.

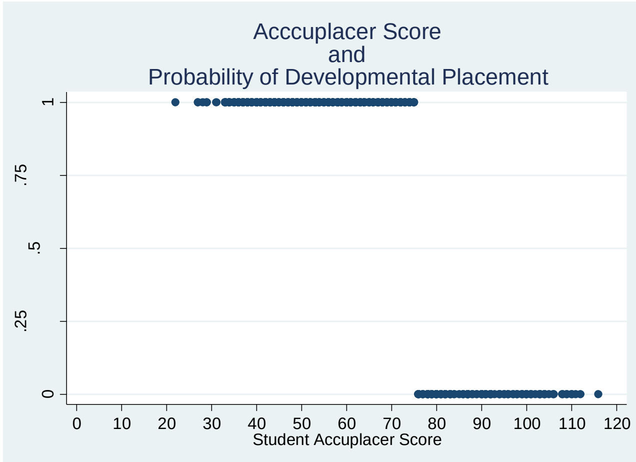

Figure 2. Accuplacer score and probability of developmental placement

Multiple retesting could lead to an abundance of scores right above the cutoff, making random assignment around the cutoff less feasible. A comparison of testing policies showed that at least one school did allow students to retest for a small fee. Students who retest multiple times until they get a score above 76 could significantly impact RD results. A density test can ensure that all assigning variable values are balanced right above and right below the cut-off. This is necessary to implement a sharp RD design. If data values are not balanced, suggesting that students manipulated their placement through excessive retesting or administrative overrides, a fuzzy design can be implemented to adjust for the imbalance. The assigning variable for the RD tests is the student's centered Accuplacer score, CAS, which is found by subtracting the student's raw Accuplacer score (SAS) from 76 (the cut-off for college-level placement). This was completed using the RD density command in the RD density STATA package. In density tests, a null hypothesis is set up to test the continuity of the density of data values directly above and below the cut-off. Density tests were conducted on the CAS for each of the five processes and displayed in Table 6. In all cases, there was not sufficient evidence to conclude that densities were not equal. There is no statistical evidence of manipulating of the assignment variable at the cut-off, suggesting that a significant amount of students did not manipulate their original placement score by retesting (Cattaneo et al., 2016).

Table 6

Comparison of the Density of the Centered Accuplacer Scores (CAS) Directly Below and Above the Placement Cut-off

	Below Cut-off		Above Cut-off			
Process	*n*	*BW*	*n*	*BW*	*t*	*p*
A	47	7.2	35	5.6	-1.31	.19
B	118	13.8	70	13.1	-0.17	.86
C	16	5.5	29	6.1	0.70	.48
D	118	13.8	70	13.1	-0.17	.86
E	16	5.5	29	6.1	0.70	.48

Graphical representation. Figures 3 through 7 present the graphical representation of each process around the cut-off score of 76. The dependent variable for all graphs is the student's Accuplacer score, and a dotted line is drawn at 76 to easily visualize the cut-off score. Those who fall below the line took Elementary Algebra (full course for Processes A, B and D; one credit modified course for Processes C and E), and those who fell above the cut-off took a college-level liberal arts math course. The dependent variable for Process A and C was grade in college-level math (GCL), for Process B it was completion of college-level math (CCL), and for Process D and E it was total college credit earned (TCE). Each graph is shown with a line of best fit for all scores below the cut-off and all scores above the cut-off. Each graph is a scatter plot with 20 equal-sized bins to distribute the data and allow a less cluttered visual to determine if a discontinuity is present. The appendix displays each graph with discrete style binning to show that the binning choice is not influencing any possible visual discontinuity. While a noticeable discontinuity cannot be seen by the data points alone, the line of best fit on each side of the cut-off score (dotted line) on each graph shows enough of a difference to further test the magnitude and significance of any differences occurring at the cut-off.

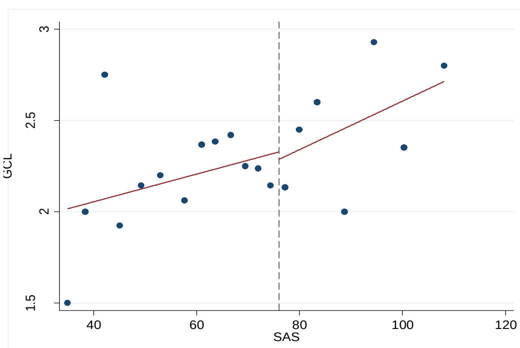

Figure 3. Binned scatter plot of grades in college-level math and placement score for Process A. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.

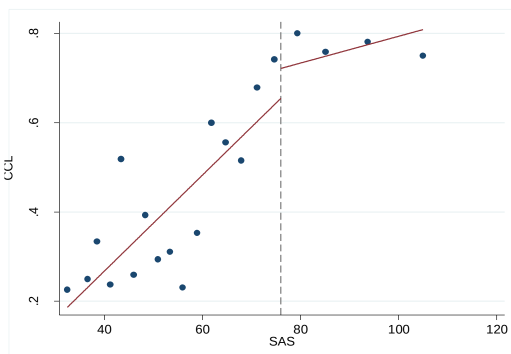

Figure 4. Binned scatter plot of completing college-level math and placement score for Process B. Relationship between probability of completing college-level math and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.

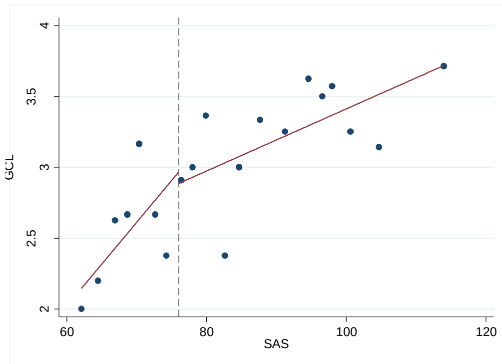

Figure 5. Binned scatter plot of grades in college-level math and placement score for Process C. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with 1 credit review Algebra course.

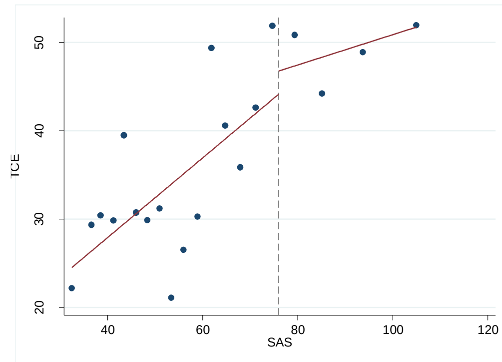

Figure 6. Binned scatter plot of total college-level credits earned and placement score for Process D. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with traditional 4 credit Algebra course.

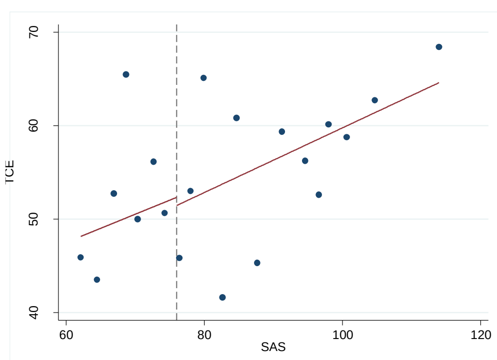

Figure 7. Binned scatter plot of total college-level credits earned and placement score for Process E. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with 1 credit review Algebra course.

The graphical representation of Process A and Process C (see Figures 3 and 5) suggests that students who place right above the cut-off may have lower grades in college-level math than those who score just below the cut-off. Process B (see Figure 4) suggests that students who score below the cut-off are less likely to complete college-level math than those who score right above. Students who took a traditional elementary algebra course appear to earn less credits that those who placed in college-level math (see Figure 6).

Parametric global polynomial approach. The parametric approach was used to determine if any discontinuity shown in Figures 3 to 7 is significant by applying a global polynomial that best fits each process using all data points from the cut-off. As outlined in the previous chapter, the order of the polynomial (P) is determined by testing various ordered polynomials starting with linear until an *F* test shows no significant difference after the addition of dummy variables. This analysis was completed with the RD plot command in the RD robust STATA package. For each process, as shown in Figures 8 through 12, a fourth-degree polynomial is found to be the best fit each set of data. Fourth- and fifth-degree polynomials are commonly used to get the most flexible fit for the entire set of data in the global approach (Calonico et al., 2014).

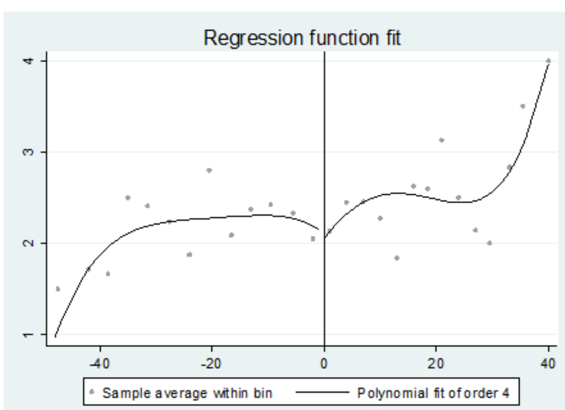

Figure 8. Best fit polynomial function of grade in college-level math and placement score for Process A. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.

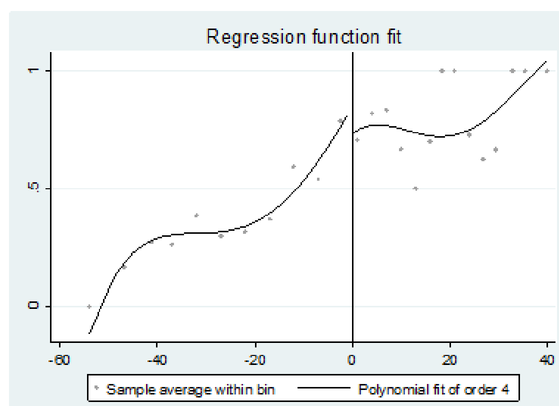

Figure 9. Best fit polynomial function of completing college-level math and placement score for Process B. Relationship between probability of completing college-level math and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.

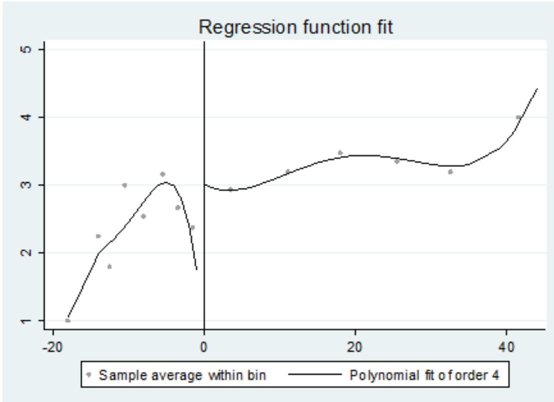

Figure 10. Best fit polynomial function of grade in college-level math and placement score for process C. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with 1 credit review Algebra course.

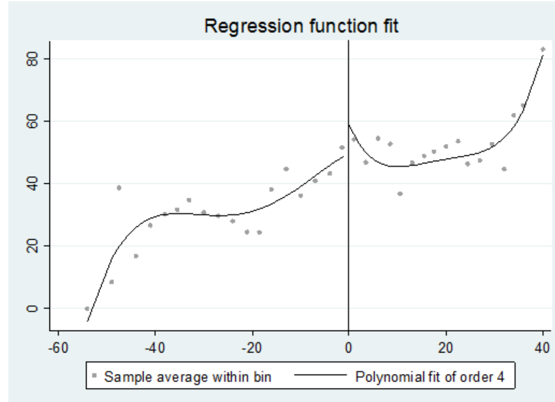

Figure 11. Best fit polynomial function of total college-level credits earned and placement score for Process D. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with traditional 4 credit Algebra course.

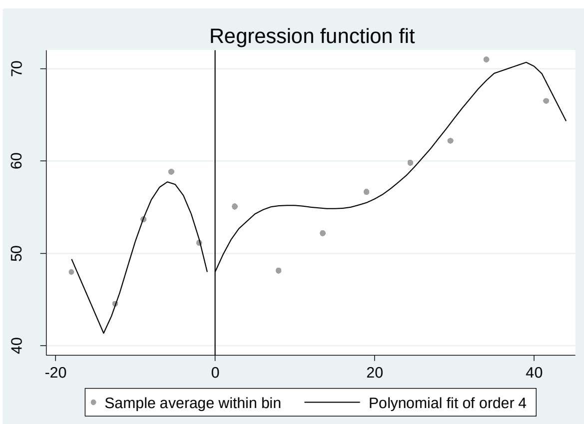

Figure 12. Best fit polynomial function of total college-level credits earned and placement score for Process E. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with 1 credit review Algebra course.

Since all processes are represented with a fourth-order polynomial, the general equation is as follows:

$$Y_i = \alpha + \beta_0 T_i + f(X_i) + \varepsilon_i$$

where:

Y_i = the outcome measure for observation I;

Process A and C: grade college-level math class (GCL)

Process B: completed college-level math class (CCL)

Process D and E: total college credits earned in 3 years (TCE);

α = the average treatment value of the outcome for those in the treatment group after controlling for Accuplacer score;

β_0 = marginal impact of the taking an elementary algebra course at the cut-off point, treatment effect;

T_i = 1 if student took an elementary algebra course, 0 if not

$f(X_i) = \beta_1 X_i + \beta_2 X_i^2 + \beta_3 X_i^3 + \beta_4 X_i^4 + \beta_4 X_i T_i + \beta_5 X_i^2 T_i + \beta_6 X_i^3 T_i +$ $\beta_i X_i^4 T_i$ represents the 4th degree polynomial showing the relationship between rating variable (X) and outcomes (GCE, CCL, TCE);

ε_i = random error for observation i.

The estimated treatment effect, represented in Table 7 as TE, is calculated as the discontinuity at the cut-off point. This treatment effect is the difference of the each polynomial function at the cut-off point, as seen in Figures 8 through 12. Table 7 also displays the variable tested in each process and the size of the polynomial of best fit (P), which in all cases is a fourth-order polynomial. The treatment effects listed in Table 6 are consistent with the visual representations in Figures 8 through 12 with Processes A, B, and E showing a negative effect at the cut-off point. While differences of magnitudes in

TE ranging from .12 (Process B) to 9.59 (Process D) do exist, the differences are considered insignificant (see *p* values in Table 5) in all processes.

Table 7

Global Polynomial Estimates of Treatment Effect of Students Taking an Elementary Algebra Course

Process	Variable	P	TE	Std. err.	*z*	*p*
A	GCL	4	-0.35	0.61	-0.52	.60
B	CCL	4	-0.12	0.21	-0.58	.56
C	GCL	4	2.29	1.68	1.36	.17
D	TCE	4	9.59	9.06	1.06	.29
E	TCE	4	-3.26	18.36	-.177	.86

Nonparametric local polynomial approach. The local polynomial approach identifies an optimal bandwidth around the cut-off where a local linear regression equation best fits the data points. Separate equations are identified on each side of the cut-off with the difference at the cut-off being the treatment effect (TE). The optimal bandwidth reported as BW in Table 8 is calculated using Imbens and Kalyanaraman (2009) “plug-in” method, which balances bias with precision. These bandwidths were calculated using the MSE-optimal bandwidth selector using the command rdbwselect in the rdrobust STATA package. The regressions were run with the optimal bandwidth for a linear regression with the results of the difference at the cut-off appearing under TE in Table 8.

Table 8

Local Polynomial Estimates of Treatment Effect of Students Taking an Elementary Algebra Course

Process	Var	BW	TE	Std. err.	*z*	*p*
A	GCL	10.41	-0.19	0.52	-0.37	.71
B	CCL	9.42	-0.19	0.18	-1.04	.30
C	GCL	4.55	1.62	1.05	1.53	.12
D	TCE	15.16	5.61	6.51	0.86	.39
E	TCE	5.32	-1.21	11.81	-.102	.92

According to Table 8, the -0.16 treatment effect for Process A suggests that students who score above the cut-off on the placement exam are getting lower grades (by a magnitude of 0.16) in college-level math than those who took elementary algebra, but the *p* value of .71 implies that there is no sufficient evidence that this treatment effect is statistically different from zero. For all processes, there is not sufficient evidence that a significant treatment effect occurs at the cut-off (see *p* values in Table 8).

Local randomization. Local randomization calculates the difference in means around a specific window centered at the cut-off. The preintervention covariates of race, gender, and college attended were used to select the appropriate window to run the local randomization tests. Starting with the smallest possible window around the covariate that contains sufficient data points, covariates are tested for effect of treatment on the covariates. For each window, the smallest covariate *p* value was compared to a predetermined *p* value of .15. Tests continued until one covariate showed a *p* value that was smaller than .15. The data were analyzed using the rdwinselect option in the rdlocrand STATA package. Optimal windows sizes are presented under Win in Table 9.

Table 9

Local Randomization Estimates of Treatment Effect of Students Taking an Elementary Algebra Course

			Elementary algebra			No elementary algebra				
Process	Variable	Win	*n*	*M*	*SD*	*n*	*M*	*SD*	*t*	*p*
A	GCL	8	29	2.21	1.26	30	2.17	1.23	-1.04	.92
B	CCL	8	33	0.78	0.42	34	0.74	0.44	-0.05	.62
C	GCL	14	24	2.67	1.13	34	2.94	1.18	0.28	.41
D	TCE	8	33	49.06	22.72	34	50.47	20.57	1.41	.80
E	TCE	18	33	54.30	18.88	40	53.25	21.40	-1.05	.81

Summary of Findings

The RD design found no significant difference in college-level course grade, completion of college-level course, or total credits earned between non-STEM students who took elementary algebra and those who did not. All three RD approaches (parametric, nonparametric, local randomization) to find treatment effects around the cut-off led to the same results. This implies that any significant differences in student grades, completion rates, and total credits earned over 3 years between non-STEM students who took algebra and those who did not found in the independent *t* tests seem to disappear around the cut-off score. The findings in this study do not provide sufficient evidence to conclude that taking an elementary algebra course has an effect on grades in college-level math, completion of college-level math, or total credits earned for non-STEM students who place near the Accuplacer placement cut-off score of 76.

Chapter V

Findings and Implications

Rising higher education costs coupled with lower financial aid availability make community colleges a worthy option for a student's first 2 years of education. Unfortunately, many students are unable to complete or even persist through these years of community college. With over 70% of community college students deemed not college ready and placing into developmental courses with less than 50% pass rates, it is no wonder that developmental courses have been seen as a the leading reason for lack of student success (Bahr, 2008; Bailey et al., 2010; Nolting, 1997). In developmental mathematics, the emphasis over the last decade has been to accelerate students through relevant remedial courses so students are enrolled in college-level courses as soon as possible while also acquiring all the skills needed to be successful. While many reform efforts have taken place, few have shown anything more than marginal success (Bailey et al., 2015).

Current reform efforts have looked to focus directly on the developmental needs of students dependent on their major field of study (Bailey et al., 2015). Students in non-STEM majors take different college-level math courses than those in STEM majors. Traditionally, non-STEM students enroll in a general varied topic liberal arts math course, while those in STEM majors take more rigorous math courses, such as College Algebra, that prepare students for Calculus. Because STEM and non-STEM students enroll in different college-level math courses, they should have different preparation if they enter college underprepared. Yet, elementary algebra has traditionally been the course that all college students are required to master, regardless of where they are headed. The purpose of this study was to examine the impact that a developmental elementary algebra course has on non-STEM student success in college-level math as well as total college credits earned.

Discussion of Research Design

Students who placed in and took a developmental algebra course were compared with those who placed in and took the general liberal arts math class. A two-part research design was used to make this comparison. To determine if there was an overall difference in grades in college-level math, completion of college-level math, and total college-level credits earned of all non-STEM students who took developmental algebra and those who did not, a two-population *t* test was used to compare the above mentioned three outcomes. An RD design was then performed to determine if the placement in developmental algebra had a causal effect on non-STEM students' grades in college-level math, whether or not they completed college-level math, and total college-level credits earned.

The initial comparison was made using a two-population independent *t* test. This comparison initially highlighted the generalization that non-STEM students who place in college-level math tend to perform better in college-level math and earn more college level credits over 3 years. While the *t* test was useful in looking at the overall differences in the two groups of students, the *t* test did not provide causal inference, and no conclusions could be made that the elementary algebra course impacted those outcomes. Additionally, considering the preexisting conditions that may have led to a student's placement, the *t*-test results are considered greatly biased due to the difference between the two groups (Melguizo et al., 2011). The best method to eliminate the bias of preexisting factors is to use a random trial (Shadish et al., 2002). The random trial would consist of randomly assigning all students who place in developmental algebra to either take the algebra course or bypass it and go directly to the college-level course. This completely defeats the entire idea of placement and could cause students to spend unnecessary time and money. To lessen selection bias and be able to provide a causal effect of the elementary algebra course, an RD design was applied to complement the *t* test.

The RD design mimics a random assignment, hence diminishing any bias based on preexisting characteristics, allowing the comparison of two similar groups (Lee & Lemieux, 2010). An RD design was acceptable in this situation because all New Jersey colleges used the same cut-off score of 76 for placement out of elementary algebra. Considering the margin of error associated with placement testing, a student's score above and below the cut-off is arbitrary within a certain window (Shadish et al., 2002), meaning the same student taking the same test could score a 74 one day and then score a 78 on a different day. By examining students who fell directly above and directly below the cut-off score, two groups were created where essentially the only difference was that one group took elementary algebra and one did not. The RD design for this study used three approaches: parametric, nonparametric, and local randomization. The fact that all three approaches yielded similar results increases the reliability of those results, especially the local randomization, which was most appropriate for small data sets (Cattaneo, Jansson, et al., 2016; Lee & Lemieux, 2010).

One factor that could have caused bias in the outcomes was if students who scored right above the cut-off score did so after repeated retesting or if students ignored their placement referral all together. Calcagno and Long (2008) had to adjust their RD design when examining the impact of developmental education across the state of Florida due to student noncompliance with placement referral and weak retest policies found at some institutions that allowed students to take placement tests multiple times until they passed it. Further statistical analysis by Calcagno and Long found that, when given the opportunity, students only retested in reading placement tests and not math. Fortunately in New Jersey, strict placement policies are adhered to and all placement scores are aligned with the appropriate course. While New Jersey colleges do allow limited retesting, there was no statistical evidence of students manipulating their placement by retaking the math test. These findings validated the use of the use of a sharp RD design.

Discussion of Findings

The research questions addressed in this study were as follows:

1. To what extent do the liberal arts math courses offered at New Jersey community colleges cover similar content?

2. For non-STEM students, what is the effect of developmental algebra on students' success in a college -level liberal arts math class?

3. For non-STEM students, what is the effect of developmental algebra on number of credits earned over a 3-year period?

Research question 1. The first research question was designed to examine the content of liberal arts math courses at all New Jersey community colleges. Multiple colleges were used in this study so that the results could have the greatest statewide impact for general education policy. New Jersey community college general education recommendations are that all students (except those attaining a certificate) will take three credits of a mathematics course. The state has general educations guidelines that encourage all schools to have a general liberal arts math course with an elementary algebra prerequisite but does not define what content needs to be in that course. The purpose of this research question was to ensure that the colleges used in the study all had similar content in their general math course, yet an interesting find was misalignment between New Jersey educational policy for community colleges and actual practice at those colleges.

After all content was analyzed, 17 of the 19 community colleges had liberal arts math courses that contained at least six of the following topics: set theory, mathematical logic, basic geometry, ancient number and modern numeration systems, consumer mathematics, problem solving, modular arithmetic, descriptive statistics, and basic probability. While it was initially encouraging for this study that so many of New Jersey colleges had similar course content, the actual type of content found made the value of this study even more appropriate. All of the students entering these college-level courses were required to have a proficiency in basic algebra and if they could not show it on a placement test, they were required to pay for and take a course in algebra. Often, this course was four credits, which was one credit more than the college-level course it was meant to be a foundation for. Yet, the content of a common college-level math course found at most colleges did not build upon this foundation of algebra. The NCEE (2013) found this foundation of algebra unnecessary for most general college-level math courses across the country. The NCEE argued that the math needed to be successful in most community college liberal arts math courses is content found in a basic math course (arithmetic, ratios, proportions, expressions, and simple equations), a proficiency that students who place into elementary algebra already possess.

Research question 2. The purpose of the second research question was to examine the impact that elementary algebra has on student success in a college-level math course by examining students' grades in college-level math and their rate of successfully completing college-level math in 3 years. The fact that the state's general education policies currently require the algebra proficiency implies that there is a belief that the algebra course helps prepare them for the college-level math course and ultimately helps them perform better in it.

The impact of the elementary algebra course on non-STEM student success in college math was examined by comparing two groups of students using an independent *t* test and an RD design. The first group, control group, consisted of those students who placed directly into the general college-level math course by showing their proficiency of algebra on the placement test. The second group, treatment group, consisted of the students who placed into the developmental algebra course. The independent *t* test included all non-STEM students in both groups and compared grade in the college-level course and rate of completion in the college level course over 3 years. For grade in college-level math, separate tests were conducted for students who took a traditional four-credit semester long algebra course and students who took a shortened one-credit algebra review course. Researchers have argued that this type of comparison leads to too much bias as students who place in elementary algebra are very different from those who place out of it (Bailey et al., 2013; Goudas & Boylan, 2012; Melguiza et al., 2011). To limit this bias, the RD approach was used to examine students who placed right below and right above the state placement cut-off score of 76, eliminating differences between the groups by using the testing error associated with placement to create two random groups (Belfield & Crosta, 2012; Scott-Clayton, 2012; Shadish et al., 2002).

The two groups were tested for success by looking at both grade in college-level math and completion of college-level math in 3 years. Bailey et al. (2010), in a national study, found that, of the 45% of students who successfully complete elementary algebra, only 61% enroll in the first college-level course, implying that a little over 27% of students who place in elementary algebra actually take the college-level course. For this study, 216 of the 479 (45.7%) students who placed in elementary algebra enrolled in college-level math. Bailey et al. examined all students, while this study looked only at non-STEM students. Although there is a difference in the number of students who actually were able to enroll in the developmental course, in both studies this number is low: less than 50%. This emphasizes the need to examine overall completion of college-level math as well as grades in the course. The students who placed in elementary algebra and took a college-level math course have an advantage over those students who placed directly into college-level math in that they have already shown success in a math course in college.

The independent *t* test showed that there was little to no differences in average grade in college-level math for those students who completed a traditional elementary algebra course compared to those who placed in college-level math, yet the number of students who were able to complete college-level math in 3 years was significantly higher for those who placed in college-level math than those who placed in elementary algebra. This is consistent with Bahr's (2008) research showing that, for students who were able to complete developmental math, their performance in college level is equal to those who place in college level, but he found that so few students actually make it to the college-level math course. This study showed that non-STEM students who placed in elementary algebra completed their college-level math at a rate of 40%, which is significantly lower than those who placed out of elementary algebra at 77%. While the *t* test can illustrate the difference between the two groups, it cannot inform if taking the elementary algebra course contributes to this difference.

The RD design allowed the researcher to compare two similar groups of students by using the margin of error associated with the cut-off score as a way to mimic randomization (Shadish et al., 2002). If the two groups are considered random, with the only difference between them whether or not they took elementary algebra, then any differences in findings can be attributed to the algebra course. Other studies using the RD approach to assess developmental courses argue that if the developmental course is doing what it is designed to do, which is to prepare students for success in college-level courses, then the data would show a jump at the cut-off point in favor of the developmental group of students (Bettinger & Long, 2005; Calcagno & Long, 2008; Martorel & McFarlin, 2007). Consistent with the results of other studies using the RD approach, this one showed no discontinuity at the cut-off point. Any differences in completion of college-level math or grade in college-level math that did exist between non-STEM students who placed in elementary algebra and those who did not disappeared when examining students at the cut-off point. Taking an elementary algebra course had no effect on students' success in college-level math, whether they took a traditional full-semester algebra course or a shortened review course.

Though this study evaluated non-STEM students only, the results are similar with other studies that looked at student success in any college-level math course, algebra based or not (Bettinger & Long, 2005; Calcagno & Long, 2008; Martorel & McFarlin, 2007). Clearly, in all studies, including this one, students who place in developmental math have less success in in college-level math than those who do not; however, when studies such as this one try to isolate the elementary algebra course as the cause of those differences, no evidence can be provided. This leads to a conclusion that other factors, such as those that cause the students to place so low in the first place, are the cause of those differences.

Algebra has consistently through educational history been recognized as a subject in math that is necessary to all learning in mathematics and has, therefore, been mandated as a college-level math proficiency (Bahr, 2008; Ball, 2003). Yet, psychological studies on students' ability to transfer of knowledge from algebra to other disciplines dispute this notion (Barnett & Ceci, 2002; Mayer & Wittrock, 2006). The independent *t* test showed that students who enrolled directly in the college-level math had equal if not higher grades in college-level math than those who placed in and took either a traditional elementary algebra course or a shortened review course. Considering that the students who were successfully able to complete an algebra course prior to taking the college-level course did not outperform those who did not take the algebra course, one could certainly argue that the students in this study were not able to transfer the knowledge learned in algebra to the college-level math course, which supports the findings reported in transfer of knowledge studies (Barnett & Ceci, 2002; Mayer & Wittrock, 2006). Quarles and Davis (2016) further found that common developmental algebra classroom practices that stress procedural learning over conceptual learning greatly affect the ability of students to transfer their knowledge of algebra to other college-level math classes.

Research question 3. The third research question addresses the belief that placement in developmental courses is a barrier to student persistence in college. The total credits earned in 3 years by non-STEM students who place in elementary algebra were compared to those who placed in the general college-level math course. The non-STEM students who took the traditional full-semester elementary algebra course earned significantly fewer credits than those who were not required to take the algebra course. Yet, when the RD design was applied and only students near the cut-off point were analyzed, those differences disappeared as there was no discontinuity at the cut-off point. The shortened algebra review course had different results. When total credits earned for all students were compared, the *t* test showed no significant difference between those who took the algebra course and those who did not. The RD design also showed no discontinuity at the cut-off point for the algebra review students.

The fact that the students who took the algebra review course had no significant difference in total college credits earned than those who placed out of algebra, while those students who took the full semester course earned significantly fewer credits than students who placed out of algebra, is not surprising. Venezia and Hughes (2013) examined multiple programs throughout the country that utilized some form of accelerated or shortened developmental course and found higher persistence of developmental college students who took the accelerated courses than those who took a traditional course. While the results of the *t* tests in this study seem consistent with the findings of Venezia and Hughes, there is another explanation that is backed up by the results of the RD design. The RD design showed no discontinuity at the cut-off point for either group of students: traditional algebra or review algebra. The *t*-test population for the traditional students consisted of all students who scored below the Accuplacer cut-off score, which is a range of 29 to 76. The *t*-test population for the shortened algebra review course students consisted of all students who scored below but near the Accuplacer cut-off score, which is a range of 63 to 76. Like the RD design, the second *t* test was only evaluating students who were placing close to the cut-off score, and like the RD design, there was no significant difference in total college credits earned between students who placed in developmental and those who did not.

The RD design for both groups of students, traditional algebra course and review algebra course, had no significant discontinuity at the Accuplacer cut-off score of 76. This study provided no evidence that the placement in a developmental algebra course impacts the total college level credits a student earns in 3 years of community college. Yet, the independent *t*-test comparison showed that students who placed in and took a traditional elementary algebra course earned significantly fewer total college-level credits than those who did not need elementary algebra. Earning credits in college is a way of persisting toward one's degree. College persistence can be affected by many cognitive and noncognitive factors. The RD design compared students who scores on the placement test were statistically the same, implying they entered the college at the same cognitive level, and, at that level, placement in an algebra course had no impact on their persistence. Yet, when the *t* test evaluated students who scored much further away from the placement score, persistence greatly decreased. If student persistence was based solely on cognitive factors, the developmental courses should fill the gap in knowledge, and students who take the traditional algebra course would ultimately earn the same credits after 3 years as those who did not need it.

The fact that this did not happen in this study reconfirms theories of noncognitive factors that influence student persistence in college. Academic self-efficacy and lack of motivation are two credible factors that could greatly inhibit a student's ability to persist in college (Cohen & Brawer, 2008; Cox, 2009; Lindley & Borgen, 2002; Stolp, 2005; Zajacova et al., 2005). Poor academic self-efficacy can contribute to lower scores on the Accuplacer, leading to placement in developmental algebra. Even if cognitive factors lead to the placement in algebra, poor self-efficacy could then cause the students to see their placement as an expectation of their future success in college, leading to self-doubt and failure (Zajacova et al., 2005). Another factor that could contribute to a student's persistence in college is lack of or the wrong type of motivation. Students who are not intrinsically motivated may not put appropriate effort on the placement test and subsequently in the developmental course they were placed in (Cohen & Brawer, 2008).

Limitations

Several limitations of this study need to be noted. The study focused on non-STEM students in mathematics classes. The non-STEM students were initially chosen because of the inconsistencies in content between the developmental algebra course and the general liberal arts math course that non-STEM students will take in college. The outcomes cannot be generalized to STEM students. The impact of algebra on a STEM math class such as College Algebra or Precalculus may be very different due to the consistent transition of content. Also the study only examined the impact an elementary algebra course had on non-STEM student success, and the outcomes cannot be used to examine the impact elementary algebra had on students who placed below elementary algebra.

The use of a *t* test in comparing students who place into developmental math to those who place out of it is limited to selection bias. The purpose of the *t* test was to examine the difference between students who placed in and took an elementary algebra course and placed out of it. The lack of control and random assignment of the two groups indicates the possibility that there are untested factors that could bias the results and influence the outcomes (Melguizo et al., 2011). No causal inferences could be made with the *t* test alone.

The RD design was used to lessen the bias associated with the *t* test and attempt to examine any possible causal relationships. The RD design limits the sample size to a statistically calculated window surrounding a predetermined cut-off score, mimicking random assignment. This limiting of the sample size restricts any outcomes to those students who fall within that window around the cut-off score (Shadish et al., 2002). The RD design was paired with the *t* test to balance the limitations of both approaches for more comprehensive analysis.

Other limitations have been associated with any data-driven research on developmental education. Goudas and Boylan (2012) argued that vast pedagogical differences among schools, programs, and instructors confound any outcomes if these differences are not controlled. Although this study did attempt to control for these through careful selection of colleges used in the study, the group with the algebra review course was taken from data that represented only one college, a college not included in the group with the traditional algebra course. Any comparisons made between the two groups of students (those in a traditional algebra course and those in a review algebra course) should be made with this understanding.

Implications

Research. Assessing the true impact of developmental education has been met with varying opinions and contradictions for good reason. The only research method that is considered the most valid is the one that cannot be done within the context of developmental education: random assignment. The pairing of the RD design with the simpler independent two-sample *t* test addresses some of the issues when the designs are done individually, specifically bias and random assignment. The RD design is a useful tool to evaluate the effectiveness of a developmental course for those students who fall just below the cut-off score and is recommended for any institution interested in evaluating whether or not the cut-off score could be lowered, similar to the study done by Melguizo, Bos, Ngo, Mills, and Prather (2016).

This study specifically focused on non-STEM students due to content inconsistencies between developmental algebra and a general college-level liberal arts math course. An underlying purpose of this study was to evaluate the impact the algebra course had on non-STEM students' success considering so many are referred to developmental algebra and so few are able to pass and persist in college (i.e., determine how useful elementary algebra is to non-STEM students). A follow-up study could be conducted to look at the impact of the same elementary algebra course on the next level algebra course for STEM students and examine if, using the same research design, the results are similar. It may be that, although elementary algebra does not appear to have an impact on non-STEM student success, it has great impact on underprepared STEM student success.

Other research should involve identification and assessment of noncognitive factors that lead to community college success and failure. This could include a long-term study using a student self-assessment completed at the time of taking the placement test. Then successful and nonsuccessful student characteristics could be compared for consistencies and differences.

Policy. Results of this study provide some evidence that the use of elementary algebra as a prerequisite to a general liberal arts math class needs to be examined more closely. When no clear evidence can be provided that a costly course is providing sufficient benefit for students, then that course must be evaluated at the college and most importantly at the state level. All 2-year and 4-year colleges should work together to define what an appropriate non-STEM college-level math course is and how students can best be prepared for that course.

Statewide policies recommend a general liberal arts math course that builds upon foundations learned in algebra and further lists a proficiency in algebra as prerequisite for those courses. All community colleges throughout the state require the basic algebra prerequisite, yet the content of most of the community college's general liberal arts math courses do not contain content the builds upon this algebra foundation, a foundation that the NCEE (2013) argued is unnecessary for students entering the work force in nonmathematical jobs. Considering recent research by Hodara and Xu (2016) that highlights the negative effects of taking developmental math credits on future earnings, state policy makers should carefully consider the necessity of this algebra foundation for non-STEM students.

At the college level, additional resources should be utilized to counsel students about what it takes to be successful in college. Too often, developmental students are quick to blame the placement into extra remedial courses as the cause of their failures. As this study has demonstrated, no concrete evidence can be found that the placement in elementary algebra has any impact on non-STEM student success in college-level math or persistence in college. Colleges need to get creative with additional intrusive advising and counseling about how to guide students through their developmental and college level pathways.

Conclusions

At the start of this study, redesign efforts in development math education were focused on getting students through all their developmental sequence with the most mastery of content in the shortest amount of time. Fortunately, research completed in the last few years, especially by the Community College Research Center and published in Bailey et al.'s (2015) book entitled *Redesigning America's Community Colleges*, indicates that there is now a focus on the appropriateness of developmental education (Hodara & Xu, 2016; Quarles & Davis, 2016). With movements such as Carnegies' Statway and Quantway, and the Dana Center's Pathways programs, educators are moving toward a realization that all students do not need to master algebra to learn meaningful mathematics and be successful in college (Baker, 2013). By focusing on the impact of a developmental algebra course on non-STEM student success, this study can contribute to the growing trend to evaluate if mastering algebra is necessary for success in college.

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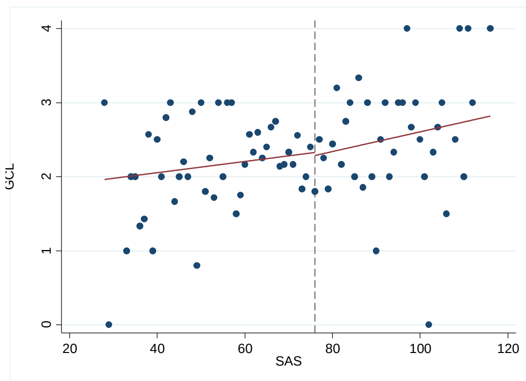
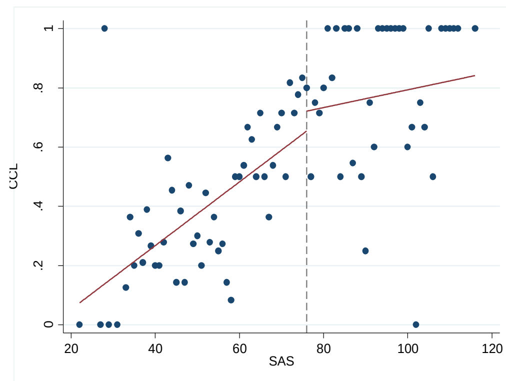
Appendix

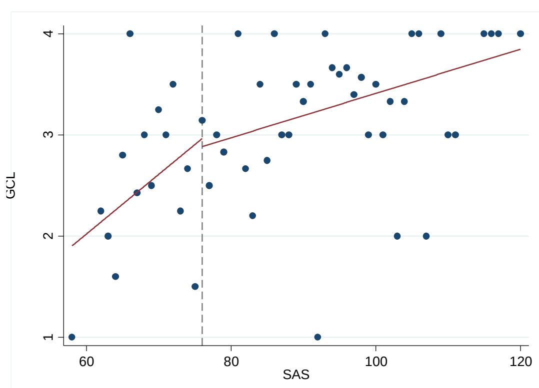
Scatter Plot of Each Process with Discrete Binning



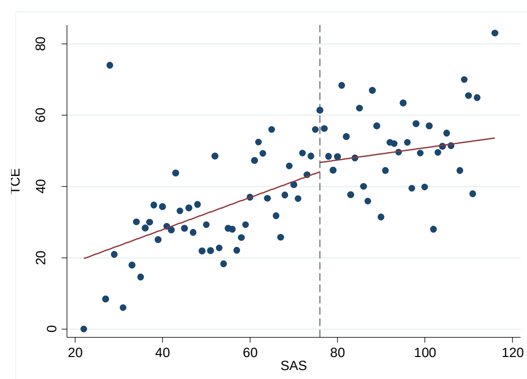
Discrete binned scatter plot of grades in college-level math and placement score for Process A. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.



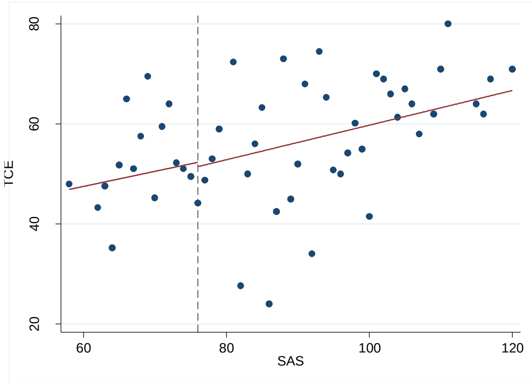
Discrete binned scatter plot of completion rate of college-level math and placement score for Process B. Relationship between completion of college-level math (CCL) and student Accuplacer score (SAS) from schools with traditional 4 credit Algebra course.



Discrete binned scatter plot of grades in college-level math and placement score for Process C. Relationship between grade in college-level math (GCL) and student Accuplacer score (SAS) from schools with 1 credit review Algebra course.



Discrete binned scatter plot of total college-level credits earned and placement score for Process D. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with traditional 4 credit Algebra course.



Discrete binned scatter plot of total college-level credits earned and placement score for Process E. Relationship between total college credits earned (TCE) and student Accuplacer score (SAS) of students from schools with 1 credit review Algebra course.