RISING TO THE CHALLENGE: POSTSECONDARY DEVELOPMENTAL MATHEMATICS AND COLLEGE SUCCESS

by

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ABSTRACT OF THE DISSERTATION

Rising to the challenge: Postsecondary developmental mathematics and college success

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Commitment to educational access for all students is the primary mission for many community colleges. Postsecondary developmental education is a path to achieve educational equity for many students not prepared for the rigor of college-level courses. In community colleges postsecondary developmental education gives incoming freshmen a place where they can obtain the necessary prerequisite proficiencies needed to achieve success in their college-level courses (Armstrong, 2000; Brothen & Wambach, 2004; McCabe 2000).

This paper includes a literature review of developmental education reform initiatives throughout the country, as well as effective past studies regarding postsecondary developmental education in mathematics and its impact on postsecondary success. The primary research focus is to determine if community college students who require and successfully pass developmental mathematics exhibit similar academic outcomes as those not requiring any developmental mathematics. Since this is a clustered sample, students clustered by the high school from which they graduated, hierarchical generalized linear modeling (HGLM) is used to compare the long-term academic outcomes of traditional age (directly out of high school), first time in college (FTIC) students attending a New Jersey, *Achieving the Dream* (ATD) community college. Initial findings from the fall 2009 cohort show that students requiring developmental education in mathematics, once successfully remediated, experience comparable college-level mathematics course grades to those not requiring developmental mathematics; indicating that developmental mathematics programs can in effect repair initial educational deficiencies for those who pass all courses in the required developmental mathematics sequence with grade of C or better. Unfortunately, also found significant was that developmental mathematics students who started in the lowest level of developmental mathematics are the least likely to persist until successful remediation, thereby eliminating any aspirations of graduating and/or transferring.

This study validates the initial findings from one freshmen cohort to another with regard to successful mathematics remediation, as well as expands predictors to include developmental English, financial aid and demographics such as ethnicity, gender, and socioeconomic status. Furthermore, since many students in developmental mathematics do not complete their remediation in a timely manner and/or drop-out of college, this study also investigates what factors increase or decrease the likelihood of successful mathematics remediation, thereby enhancing or inhibiting persistence to graduation or transfer to a four-year institution.

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Dedication

To my husband Bill, who reminded me during those times when I wanted to give up,

"If it was easy, everyone would do it."

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CHAPTER I. INTRODUCTION

Across the nation, many high school graduates are not academically prepared for college. Approximately one-third of today's high school graduates require some form of developmental education in verbal and/or quantitative skills before entering a college-level course (Armstrong, 2000; Bettinger & Long, 2008). For community college students, the percentage is much higher (Armstrong, 2000). Most postsecondary institutions offer courses in developmental education. While developmental education is a means to ensure academic equity, at a cost of over $1 billion a year, some feel the cost outweighs the benefits (Bettinger & Long, 2008). To decide if the benefits are worth the investment, more research is needed to determine the consequences of developmental programs on both persistence and graduation rates.

Whether a high school graduate is entering college or the workforce, a high school diploma is intended to signify that the recipient is prepared for the demands of postsecondary education and/or a meaningful career (Moore, Slate, Edmonson, Combs, Bustamante & Onwuegbuzie, 2010). Too often high school students demonstrate success in the required classes and tests, fulfilling all their graduation requirements, yet as a result of a college placement or employment exam, find themselves not proficient and requiring developmental education or missing out on a prospective employment opportunity (Achieve, 2005). Even though postsecondary developmental education is designed to promote equity between high school graduates prepared for the rigors of college-level coursework and those who are not, for those who are not college-ready developmental education has the detrimental effect of added time and money towards their degree (Bettinger & Long, 2008; Levin & Calcagno, 2008).

To try to determine success of postsecondary developmental education, Bahr (2007) compared students enrolled in a freshmen college-level course who successfully remediated in mathematics and/or English to those not requiring developmental education. Bahr's research (2007) revealed that the depth (the number of semesters required in mathematics *or* English) and the breadth (requiring remediation in both mathematics *and* English) of initial developmental education requirements are significantly "negatively associated with the likelihood of achieving college-level competency in those subjects", therefore making persistence and/or graduation even more unlikely for students with the largest developmental education need (Bahr, 2007).

Bettinger and Long (2008) while examining colleges using placement tests for recommendation rather than enforcement of developmental courses, found that when comparing students of similar backgrounds and test scores, those who followed the placement recommendation and took the prerequisite developmental course before the college-level course were more successful, thereby more likely to persist, than those who chose to ignore the placement recommendation, i.e. go directly into the college-level course without taking the recommended developmental course first. At community colleges in New Jersey, developmental education need is determined by the Accuplacer® placement test which all entering students are required to take before registering for courses. Hence, many New Jersey community college students start their postsecondary education in developmental courses with about twice as many in developmental mathematics than developmental English (Bailey, 2009; Biswas, 2007; Parker, 2005). Therefore, when placement tests are used to decide rather than recommend developmental education, what short- and long-terms effects does developmental education have on educational attainment? This body of research investigates both the beneficial and detrimental effects of developmental mathematics on educational achievement, specifically in community colleges.

Statement of the Problem

Over the past few decades there has been much disagreement on whether the benefits of developmental education outweigh the increased cost and time for a degree. For high school graduates not ready for the rigors of a college curriculum, developmental education enables those students to compete on the same level as students not requiring developmental education. Unfortunately, developmental education also has the undesired consequence of increased time and cost to obtain a college degree, therefore possibly negatively impacting educational results such as perseverance, choice of major, and eventual job opportunities. On the other hand, developmental education promotes equity for many ill-prepared high school graduates, the majority of whom are from lower socio-economic groups. Without developmental education programs, college would not be an option for many students, and for those who do attend college, the risk of failure or academic suspension could be greater (Bettinger & Long, 2008; Boylan, 1999). Thus, developmental education provides a necessary role in helping students obtain their educational goals. Even though developmental education creates equity for all college students regardless of high school background, the additional expense is significant (Bettinger & Long, 2008; Boylan, 1999). Therefore, some states have enacted limits on government funding of developmental coursework and several other states are considering similar policies (Bettinger & Long, 2008; Boylan, 1999).

On July 14, 2009, during his speech on the *American Graduation Initiative,* President Barack Obama mentioned one way for the United States to increase the number of college graduates is for community colleges to increase their number of graduates by 5 million students over a 10-year period, resulting in a 50 percent increase (Boggs, 2010; Obama, 2009). In his White House summit spotlighting two-year institutions, President Obama once again discussed the community colleges' unique ability to increase the nation's number of college graduates. He stated that "community colleges are more important than ever to the country's competitiveness" (Biden, 2011). He called them the "unsung heroes of America's education system" (Biden, 2011). Obama said community colleges "may not get the credit they deserve, they may not get the same resources as other schools, but they provide a gateway to millions of Americans to good jobs and a better life" (Biden, 2011).

Vice President Biden in a letter in the Summit Report on community colleges (2011) noted that due to global technological advancements, some form of postsecondary education has become a minimal requirement for most meaningful job opportunities. A high school diploma alone no longer enables one to be qualified for a successful career. Since community colleges offer certificate programs and Associate degrees, both postsecondary education, they have the unique ability to increase the number of graduates and return the United States back to one of the global leaders in postsecondary degree attainment, while also making graduates employable for today's technological market thus leading the nation towards a stronger economy (Achieving the Dream, 2012; Boggs, 2010).

Despite recent policy initiative to ensure high school accountability through state-mandated testing, high school assessments are presently not aligned with college-level expectations in many states, including New Jersey (Perkins, Kleiner, Roey, Westat & Brown, 2004). Focusing on mathematics, in order for high school graduates to achieve success in college or the workforce, they need to be proficient in mathematical content beyond algebra II, content taught in a four-year sequence ending with statistics or some other applied mathematics course (Achieve, 2004, 2005). Unfortunately, the algebra content assessed in high school during a student's junior year tends to focus on basic algebra concepts (Achieve, 2004, 2005). Higher level mathematical concepts found in advanced algebra and applied mathematics such as statistics are often optional courses that students may or may not choose to take their senior year (Achieve, 2004, 2005).

As a consequence, many high school graduates are not ready for the rigors of college-level mathematics. In 2001, colleges across the nation found that nearly one-third of their freshmen students needed to take a developmental course in mathematics, with the proportion higher for community colleges (Achieving the Dream, 2012; National Center for Education Statistics, 2003). In community colleges, more than half of incoming freshman require developmental mathematics courses such arithmetic, elementary algebra and/or intermediate algebra based on their placement test results (Bettinger & Long, 2008).

Postsecondary developmental education is an issue of extensive debate, especially in connection to educational policy; thereby developmental education has become an area of increased focus among researchers (Adelman 2004; Bahr, 2007, 2008, 2009, 2010; Bettinger & Long, 2008; Levin & Calcagno, 2008; Parsad, Lewis & Greene, 2003). Since more students require postsecondary developmental education in mathematics than in English, this has become the primary focus for educational researchers and administrative policy makers alike (Bahr, 2007). For example, in the fall 2000, 22 percent of first-time college students enrolled in developmental mathematics coursework, compared with 14 percent who enrolled in developmental writing courses and 11 percent who enrolled in developmental reading courses (Parsad, et al., 2003). Almost twice as frequent as postsecondary developmental education in reading and writing, postsecondary developmental education in mathematics serves the greatest number of students.

With many students not prepared for the expectations of postsecondary education, especially in terms of basic mathematics education, community colleges by offering courses in developmental mathematics, have taken the lead role in getting underprepared students ready for the rigor of college-level mathematics courses. Therefore, if there is to be an increase in college success rates, then there must be an improvement in the successful matriculation of developmental mathematics students through entry-level college credit mathematics (Boylan, 1999; McCabe, 2000).

In a recent large-scale California study, Bahr (2007, 2008) found that only 25 percent of students in community colleges who begin in developmental mathematics pass a college-level mathematics course with a grade of C or better. Due to the recent economic crisis and the rising cost of a college education, many students choose community college as their first choice for postsecondary developmental education. Therefore finding that only 25 percent of these students pass their developmental mathematics sequence into college-level courses is quite disturbing. More empirical research needs to be devoted to this area to possibly reveal those factors that enhance or inhibit successful mathematics remediation (Adelman, 2004; Bahr, 2007, 2008; Parsad, et al., 2003).

To improve graduation and transfer rates, there must be more than a 25 percent pass rate in postsecondary developmental mathematics. More students need to successfully remediate into college-level courses. In 2004 the national *Achieving the Dream: Community Colleges Count initiative* (ATD) was the first major push to improve student completion rates in community colleges (Achieving the Dream, 2010). The goal of ATD is to "help more community college students succeed, especially students of color, working adults, and students from low-income families" (Achieving the Dream, 2010). ATD (2010) defines success by the rates at which students: (1) remediate into college-level courses; (2) pass gateway college-level courses in mathematics and English with a grade of C or better; (3) persist semester to semester; and (4) earn a certificate or Associate degree (Achieving the Dream, 2010). Overall the ATD initiative emphasizes "a culture of data-driven decision-making" (Achieving the Dream, 2010; Boggs, 2010)

Starting with only 26 colleges, the ATD initiative as of this writing has a cohort of 128 colleges in 24 states, including the District of Columbia (Achieving the Dream, 2010). ATD efforts have focused on improving or expanding developmental education, gatekeeper courses, first-year experience, learning communities, academic and personal advising, student support services, and tutoring. Along with their efforts to improve postsecondary interventions, ATD colleges strive to improve K-12 partnerships (Achieving the Dream, 2010). ATD colleges focus on data-driven decisions from identifying problems to measuring success and progress; all with the goal of improving student success. From the data-driven evidence, ATD colleges hope to revise policies, programs and/or services with the intention of improving student success (Achieving the Dream, 2012). This study while filling gaps among the current research also nicely aligns with ATD and Presidential initiatives for community colleges and developmental education.

The Common Core State Standards (CCSS), along with the two assessment tools, the Partnership for Assessment of Readiness for College and Careers (PARCC) and Smarter Balanced, were developed to better align the K-12 curriculum and assessments with what both the colleges and workforce find important in terms of reading, writing, mathematics, science and technology, resulting in improving the high school standards as well (Achieve, 2005; Common Core, n.d.). These curricula enhancements and assessments are scheduled to be implemented starting first at the lower grade levels in the 2014-2015 academic year (Partnership, n.d.). Although these developments have not yet occurred, there are still benefits in examining today's developmental mathematics students and examining at what factors enhance or hinder successful mathematics remediation and/or degree attainment.

Nature of the Study

To ascertain potential descriptors of student success as well as nonsuccess indicators, research pertaining to successful postsecondary developmental mathematics education through credit-bearing freshmen-level mathematics courses is necessary. The conceptual framework that will guide this study is the Effective Institutional Decision Making (EIDM) model (Perin, 2005). Perin's EIDM model (2005) involves four primary steps: (1) gather data, (2) determine outcomes, (3) identify areas that will improve outcomes, and (4) prioritize and implement data-driven decisions. The basis of this study is to gather data and determine outcomes that would inform faculty and administrators regarding areas that may need improvement for increased success in college-level mathematics. The EIDM conceptual framework aligns with the academic goals for the ATD community college in this study, which include academic excellence and identifying opportunities to improve academics. Application of this model will identify prospective areas of improvement, provide relevant data for making data-driven decisions, and add to the existing literature on developmental education.

Significance of the Study

Prior research on postsecondary developmental mathematics focused on either the successful remediation itself or on equity based qualitative factors such as gender, ethnicity, socioeconomic status, etc. There is insufficient research combining both quantitative and qualitative factors that may have a positive, negative, or neutral effect on successful postsecondary mathematics remediation. In addition to addressing this gap, this study includes the ATD perspective on data-driven successful remediation by studying two cohorts from an ATD New Jersey community college.

This body of research focuses on what factors inhibit, enhance, or have no effect on successful mathematics remediation. The primary and secondary research questions are:

1. Do students who successfully negotiate the developmental mathematics sequence and acquire college-level mathematics proficiency achieve academic success (passing college-level mathematics and/or graduating with a credential) comparable to those students who acquire college-level mathematics proficiency without the need for developmental mathematics?

2. What factors significantly hinder success for developmental mathematics students who fail to pass their developmental mathematics sequence?
3. For developmental and non-developmental mathematics students, which predictor(s), if any, correlate and/or help predict those students' success in their first college-level mathematics course?

In addition to mathematics variables such as level of developmental mathematics, this study examines other characteristics such as gender and ethnicity, and any relationship between developmental and non-developmental mathematics students. Also examined is to what extent individual or clusters of characteristics differentiate success or nonsuccess in mathematics remediation as determined by passing a college-level mathematics course with a grade of C or better. Identifying student characteristics that differentiate success could potentially assist administrators and instructors in improving programs and increasing student success in developmental mathematics and college-level mathematics.

This research combines hierarchical linear modeling (HLM) and logistic regression to reveal qualitative and quantitative factors that either hinder or enhance successful mathematics remediation. Successful postsecondary mathematics remediation in a timely manner is the key to persistence and continued educational success towards postsecondary graduation. The results of this study will help guide future postsecondary developmental mathematics policies and curricula.

CHAPTER II. LITERATURE REVIEW

Introduction

In today's economy college-educated people find themselves in higher demand and earning better wages than those whose highest level of education is a high school diploma. The United States is no longer one of the top five countries whose young adults (ages 25 to 34) have earned a postsecondary degree (Baum & Ma, 2007). The United States having only about 40 percent of these young adults earning an Associate degree or better is behind Canada which has about 56 percent with at least an Associate degree (Baum & Ma, 2007).

Unfortunately many high school graduates find themselves not prepared for the rigors of a postsecondary curriculum. A large percentage of incoming freshman require developmental education in mathematics and/or English before taking their first college-level course in these subjects. Furthermore, because of today's demand for college educated employees, many students who would have previously stopped their education with a high school diploma continue their education regardless of academic preparedness (Esch, 2009).

Since inception, community colleges by offering developmental education, have provided postsecondary opportunities for students that might not otherwise attend college. Community colleges since close to home and cost effective, provide academic access for students who otherwise would not have the resources to obtain a postsecondary education (Coylar & Stich, 2011; Floyd & Walker, 2009). It is estimated that community colleges now educate about 44 percent of all undergraduates in the United States (American Association of Community Colleges, 2012). Community colleges are postsecondary institutions that have solidified their role in the area of higher education (Goldrick-Rab, 2010). These institutions have created ways to enhance student development and have become known for their initiatives to increase student success (Balog & Search, 2006; Culp, 2005; Levin, Cox, Cerven & Haberler, 2010; McClenney & Marti, 2006).

The foundation of the community college mission is educational access for all students. Developmental education is the path from which that commitment is realized (Armstrong, 2000). Developmental education in open admission community colleges provides students with opportunities to acquire the academic foundation for collegiate success. Aside from a high school diploma, since community colleges require no basic academic aptitudes for admission, the student body encompasses a wide range of academic proficiencies, financial statuses, and life experiences (Armstrong, 2000; Brothen & Wambach, 2004; McCabe 2000; Ritze, 2005). Therefore due to the varied student body along with recent national initiatives for improving graduation rates, community colleges are facing challenges that will require evidence-based decisions (Armstrong, 2000).

Many community college freshman students are not prepared for the rigor required for success in a college course, regardless of whether they enter college immediately after graduating high school or are returning years later. Moreover, of the many community college students requiring postsecondary developmental education, few will find themselves remediating into college-level mathematics and English courses. (Hagedorn, Lester & Cypers, 2010; Marcus 2000; Parker 2005). Although compared to four-year institutions, in community colleges where there is a larger percentage of students requiring developmental education with twice as many in developmental mathematics as in developmental English, Bahr (2008, 2009) found that there is a higher student success rate through the developmental mathematics sequence (Bahr, 2008, 2009).

The main objective of developmental education is equity. For example, students who remediate successfully in mathematics or English should exhibit similar graduation rates as those students who do not require developmental mathematics or English (Adelman 2004; Bahr, 2008; Parsad, et al., 2003). Although the need for postsecondary developmental education is on the rise, it is a controversial topic. Proponents of postsecondary developmental education feel developmental education fills an important function by offering academic opportunities for all students regardless of high school preparation. Postsecondary developmental education offered at community colleges allow students not academically prepared for college-level courses to obtain prerequisite competencies at an affordable price. On the other hand some argue that the benefits do not outweigh the added costs of education (Bahr 2008).

The research presented here represents a step forward towards answering the question of whether developmental education achieves equity among developmental and non-developmental education students, with particular attention to developmental mathematics. In this study, the efficacy of the developmental mathematics program for traditional-age college freshmen will be investigated by comparing the academic outcomes, such as passing a college-level mathematics course and degree attainment, of students who successfully remediated into college-level mathematics with those students who placed directly into college-level mathematics.

Background

About half of the United States undergraduate population attend community colleges (American Association of Community Colleges, 2012). Therefore community colleges are crucial in helping the United States to become one of the top worldwide leaders with regard to postsecondary educational achievement (Achieving the Dream, 2010, 2012). An open-access community college means that the student body will comprise of diverse financial and educational levels thereby encompassing varied precollege experiences. Thus, depending on their background, many community college freshmen will find themselves not adequately prepared for the rigor of college-level courses (Brothen & Wambach, 2004; Hagedorn, et al., 2010; McCabe 2000).

As a consequence of only two to three years high school mathematics required for graduation, along with numerous students opting not to continue taking mathematics classes in high school once their minimal requirements are met, many high school graduates find themselves inadequately prepared for college-level mathematics. According to one study by Hoyt & Sorensen (2001), over half the high school graduates who successfully completed intermediate algebra and geometry find themselves taking developmental mathematics their first semester of attendance. According to the college placement exam, these students were not proficient in high school mathematics even though there was a passing grade on their high school transcript.

To be better prepared for college-level mathematics courses, high school students not only need more challenging mathematics courses beyond high school algebra, but also need to take these courses throughout their entire high school education (Bourquin, 1999; Kowski, 2013). In a recent study Kowski (2013) found that when controlling for the other variables, students who take any high school mathematics course beyond the New Jersey state required algebra I-geometry-algebra II sequence are more than three times as likely to place beyond basic algebra than students who do not. Students taking courses beyond the required sequence not only gain deeper understanding of mathematics, but are often taking mathematics during their senior year in high school. A high school transcript study conducted by the National Center for Education Statistics (2003) revealed a correlation between mathematics assessment scores and the amount of time since a student was last exposed to mathematics. Scores were highest for students who took mathematics during their senior year of high school, with lower scores for those who finished taking mathematics their junior year. Student whose last mathematics class was their sophomore year had the lowest scores (National Center for Education Statistics, 2003; Perkins, et al., 2004).

Regardless of the number of years of high school mathematics required, K-12 and collegiate mathematics educators need to come to an agreement on the level of mathematics proficiency required to graduate high school and that of college level mathematics prerequisites. Unfortunately, K-12 and postsecondary education are often focused on different outcomes (Achieve, 2004; Orlich, 2003). High school proficiency exams taken during a student's junior year, tend to assess basic algebra and geometry knowledge, material traditionally taught in ninth or tenth grade (Achieve, 2004, 2005). With such basic mathematics expectations, the cut scores required to pass the high school exit exams reflect modest expectations; well below the mathematical content required before taking a college-level mathematics course (Achieve, 2004, 2005). Overall, high school proficiency exams need to assess higher level mathematics content more aligned with what postsecondary institutions require as a prerequisite to college-level mathematics (Achieve, 2004; Achieve, 2005). The mathematical proficiency gap between what high schools require for graduation and what postsecondary institutions require before taking college-level mathematics courses, reveal that the current high school proficiency exams are not a reliable measure of a high school graduate's readiness for college-level mathematics (Achieve, 2004; Foley-Peres & Poirier, 2008).

As a consequence, a large proportion of high school graduates are not adequately prepared for the rigor of a college education and will require varying levels of developmental education, especially in mathematics (Adelman, 2004; Hughes & Scott-Clayton, 2011; Parsad, et al., 2003). Unfortunately even after two years of college education, more than half of these developmental mathematics students fail to remediate into college-level mathematics courses (Bahr, 2008, 2009, 2010). Previous research has found the grade in the first mathematics course taken in college is a strong link to successful developmental mathematics (Bahr 2008; Farkas, 2003). Why this occurs is an area for further research. How well a student performs in any mathematics class is based on a variety of factors such as the time elapsed from when the last mathematics class was taken, how much mathematics was retained from high school, attitude and self-efficacy, as well as other outside factors such as employment and family obligations (Farkas 2003; Robbins, Lauver, Le, Davis, Langley & Carlstrom, 2004).

Additionally, educational researchers have found that previous academic performance, such as a earning an A- or B-grade rather than a just-passing C-grade in any prerequisite mathematics course, correlated with a higher rate of success in the subsequent mathematics course along with a greater level of persistence (Bahr, 2009;

Hagedorn, et al., 2010; Kowski, 2013). While a student's grade in his or her first mathematics course in college has been proven to correlate with collegiate success, there is also significant evidence that continued success in mathematics strongly relates to persistence and overall college success, well beyond freshmen year (Bahr, 2009; Hagedorn, et al., 2010).

Educational researchers have also found that depth and breadth of developmental education has effects on the probability of successful remediation (Bahr, 2007, 2008; Hagedorn & Lester, 2006; McCabe, 2000). Depth relates to the number of semesters postsecondary developmental education required in any given subject. For example in postsecondary developmental mathematics there can be three levels of developmental mathematics, intermediate algebra, elementary algebra, and the lowest level basic mathematics, i.e. arithmetic. While breadth refers to the number of developmental education subject areas required, i.e. in both mathematics and English (Bahr, 2007, 2008; Hagedorn & Lester, 2006; McCabe, 2000). In 2008, Bahr explored the effect depth had on developmental education need with respect to college-level mathematics attainment. In Bahr's (2008) study only 1 out of 15 basic arithmetic students achieved college-level mathematics skills, compared to almost 1 out of 2 intermediate algebra students. Thus, the more semesters of developmental mathematics required the less likely the student will successfully remediate in mathematics (Bahr, 2008).

Although, Bahr (2008) found that developmental mathematics students who successfully remediated into college-level mathematics courses had similar pass rates along with similar graduation rates as those who did not require developmental mathematics before entering college-level mathematics. Unfortunately, many students do not pass their developmental mathematics sequence, repeatedly failing their developmental mathematics courses leading to a discontinuation of their postsecondary education. Only the students who persist and successfully navigate the developmental mathematics sequence achieve positive academic results (Bahr 2008).

As a consequence, first-time, full-time, degree-seeking community college students in developmental education, less than a third graduate with a certificate or an Associate degree within three years and fewer than half within six years (Bradley, 2010). For minority and/or low-income developmental mathematics students the percentages are even lower (Achieving the Dream, 2012; The National Center for Higher Education Management Systems, 2009).

Developmental education

Developmental education is a comprehensive process that focuses on the intellectual, social and emotional growth and development of all students. Described as ‘‘the most important educational problem in America today,’’ the need for postsecondary developmental education is particularly concerning as the economic and social value of the high school diploma declines (Astin, 1998, p. 12). Studies estimate that across the nation, 25 to 45 percent of students entering college directly from high school require developmental education (Adelman, 2004; Hughes & Scott-Clayton, 2011; Parsad, et al., 2003). Intended to equalize attainment, developmental education reduces inconsistencies between the educational opportunities of those students college-ready and those who are not college-ready. Developmental education is intended to reestablish educational prospects for those who otherwise may have decreased economic opportunities attributable to consequences resulting from a lack of higher education (Roueche &

Roueche, 1999; Roueche, Rouche, & Ely, 2001). Therefore, developmental education serves as an essential passage to postsecondary education by closing the gap as a result of insufficient groundwork hindering student success in acquiring college-level achievement (Brothen & Wambach, 2004; McCabe, 2000).

In terms of retention, developmental education influences college success, but its significance has been found contingent upon where the developmental education occurs. Adelman (1999) while studying a cohort of students who graduated high school in 1982, found that compared to students not requiring developmental education, graduation rates were significantly lower for students requiring developmental education. Adelman (2004) replicated this pattern with a cohort of students from the high school class of 1992. Both of Adelman’s studies (1999, 2004) reveal that due to the increased time and costs, along with possible lowered self-efficacy, developmental education students exhibit a greater risk of dropping out. Attewell, Lavin, Domina, and Levey (2006) confirm and dispute these findings. They found that persistence rates for developmental education students compared to those not requiring developmental education was dependent on what type of postsecondary institution students were remediating. Developmental education had no negative consequence with regard to earning a degree for community college students but exhibited decreased probability of graduating for students attending a four-year institution by 6 to 7 percent. Since many students attend community college for the sole purpose of getting a fresh start, i.e. getting college-ready before attending a four-year institution, taking developmental courses did not have an adverse effect on persistence and academic success, even if more than one developmental course was required (Attewell, et al., 2006). Thus, depending on whether the study is from a four-year or two-year postsecondary institution, as well as what factors are being controlled and what predictors are in the model, developmental education may either help or hinder retention and graduation rates. Since the Obama administration is relying on community colleges to increase the graduation rates, developmental education for those not college-ready needs to be improved to increase both access and quality of postsecondary education, thereby increasing student success and completion (Boggs, 2010; Esch, 2009). (Boggs, 2010).

One obvious downside of developmental education is the increase of time to degree. To acquire the necessary skills to complete required degree-credit courses, students requiring developmental education must first enroll in extra coursework that is not part of the degree requirements. Attewell, et al. (2006) found that the percentages of developmental education students graduating from two-year (28 percent) and four-year (52 percent) colleges are significantly lower than those not requiring developmental education, 43 percent and 78 percent respectively. However, as evidenced by additional studies, once a developmental education student remediates, his or her academic attainment is similar to those not requiring developmental education (Bettinger and Long, 2005; Attewell, et al., 2006). Both demonstrate the effectiveness of developmental education as it pertains to graduation. Bettinger and Long (2005) found that in Ohio remediated developmental mathematics students in public four-year colleges taking college-level mathematics courses exhibited graduation rates comparable to students prepared for college-level mathematics courses. Using data from the National Educational Longitudinal Study, Attewell, et al. (2006) confirms these results. Remediated developmental education students were just as likely to graduate as students college-ready without the need for developmental education. These similarities were consistent for any type of postsecondary institution. Thus, once a student has successfully remediated, the fact that the student started in a developmental course does not affect his or her graduation rates and time to degree. Starting in a developmental course is solely a reflection of the student's skill deficiencies carried over from high school (Attewell, et al., 2006; Bettinger & Long, 2005).

In New Jersey community colleges, developmental education is a requirement as a result of placement. In the study by Hughes & Scott-Clayton (2011) placement examinations were found more reliable determining mathematics requirements than English requirements for reading, comprehension and writing. Although, the assessment reliability will vary depending on the purpose of the test. For example, a Clarion University study where placement tests are used for advising rather than mandating a student to a particular course, determined that if a student takes the suggested course within the first year of his or her college experience, there is an 85 to 90 percent pass rate in that course (Parker, 2005). Whereas after a student's first year of attendance the placement exam's effectiveness at predicting success rates in recommended courses diminishes. A major limitation of test validity studies is that they cannot assess whether or not a student's success in the college-level course was a result of taking the prerequisite developmental education course first since students either take the prerequisite developmental education course placed in or do not (Hughes & Scott-Clayton, 2011). In addition, students do not place into developmental courses indiscriminately. Generally those in developmental courses lack proficiency in that particular subject, and thus are expected to perform worse in subsequent courses than those not requiring developmental education regardless of whether or not taking developmental education courses are effective (Hughes & Scott-Clayton, 2011).

Policy Changes

Based on the goals of the Obama administration, community colleges have become a vital venue from which the United States can reclaim their position as a global economic leader. In his 2009 summit address, President Obama, by offering a substantial monetary grant, enticed community colleges to develop ways to increase by 50 percent, the number of graduates over the next ten years (Boggs, 2010). Community colleges offer the most cost-effective way to meet the nation's need for a better educated public, ensuring the United States worldwide competiveness. Therefore the Obama administration sees community colleges as leaders in educating the underprepared high school graduates, making those students college-ready and thereby increasing the overall number of college graduates across the nation (Boggs, 2010; Esch, 2009).

Obama's American Graduation Initiative

On July 14, 2009, President Obama announced a $12 billion community college initiative intended to increase graduation rates and expand services as well as improve technology (Kellog & Tomsho, 2009; Obama, 2009: Superville, Gorski & Turner, 2010). This $12 billion allotment is a huge increase in federal spending on community colleges from the previous $2 billion a year, which was only a tenth of the amount spent on four-year institutions (Kellog & Tomsho, 2009; Obama, 2009; Superville, Gorski & Turner, 2010). The expected return of investment is that by the year 2020 community colleges across the nation will increase the number of graduates by five million students, resulting in a 50 percent increase (Kellog & Tomsho, 2009; Obama, 2009; Superville, Gorski & Turner, 2010). Community colleges aim to meet the completion challenge while maintaining their traditional mission of access, opportunity and quality of education while serving a wide range of students, thereby offering easy accessibility to all (American Association of Community Colleges, 2012).

Community colleges, already educating 44 percent of all United States undergraduates, are responding to the challenge with greater focus on student completion and accountability (American Association of Community Colleges, 2012). Since over 60 percent of incoming community college students require some form of developmental education, in order for community colleges to accomplish these graduation goals, they will need to improve their remediation rates, thereby improving persistence and graduation rates for community college students (American Association of Community Colleges, 2012). Far too few students successfully navigate the developmental education sequence into college-level courses. As a consequence they find themselves unable to complete their degree or certificate programs. Community colleges recognize that their open door policy must not be a revolving door, and the institution as well as the student must take responsibility for student success (American Association of Community Colleges, 2012).

Both unique to New Jersey and before President Obama’s American Graduation initiative, New Jersey had in place an educational agreement enabling students to earn a quality, yet cost-effective, postsecondary education. In 2008, all New Jersey community colleges and public four-year institutions devised a general education transfer agreement (State of New Jersey: Higher Education, 2008). Due to this general education agreement between New Jersey community colleges and public four-year institutions, a general education Associate of Arts (A.A.) or Associate of Science (A.S.) degree from a New Jersey community college seamlessly articulates into any New Jersey public four-year institution, fulfilling the first two years of education at the transfer four-year institution (State of New Jersey: Higher Education, 2008). Hence students graduating from a New Jersey community college with a general education Associate's degree enter the New Jersey four-year institution at junior-level status (State of New Jersey, 2008).

Achieving the Dream

In addition to the New Jersey General Education Agreement and also before the Obama administration community college initiative, New Jersey became involved in another national effort to improve community college persistence and graduation rates. In 2004, the Lumina Foundation for Education launched the *Achieving the Dream: Community Colleges Count* initiative (Achieving the Dream, 2012). The goal of this initiative is to make "data-driven decisions" to increasing community college student success, especially "among minority students, working adults, and students from low-income families" (Achieving the Dream, 2012; Boggs, 2010).

Achieving the Dream (ATD) allows all community colleges involved the use of comparable community college's relevant data as a benchmark from which to measure and guide their decision- and policy-making actions (Boggs, 2010). Data-informed decision-making at the community college level is helping students progress and persist to completion. This data is used to improve student success by identifying problems, setting goals, establishing institutional priorities, allocating resources and measuring progress (Achieving the Dream, 2012). ATD community colleges, by focusing more attention on evidence that identifies what promotes student achievement, are able to make positive changes in the interest of student success and college completion (American Association of Community Colleges, 2012).

As of 2012, ATD, a non-government conglomerate aimed at improving postsecondary student success, encompassed almost 200 colleges, 100 coaches and advisors, and 15 state policy teams, in 32 states and the District of Columbia (Achieving the Dream, 2012). As a consequence ATD guides community colleges across the nation along the path helping millions students obtain more reliable developmental and general education, along with workforce development and training (Achieving the Dream, 2012). When ATD was launched in 2004, most states were focusing on college access as a central policy agenda for community colleges. Since then ATD has altered its focus to low-income, minority and underprepared community college students and their college success (Achieving the Dream, 2012). For those students requiring developmental education in mathematics or English, success is defined by how quickly these students successfully remediate into college-level courses (Achieving the Dream, 2012). For both developmental and non-developmental students, achievement is defined by completing gateway college-level courses with a grade of C or better, continuing semester after semester until graduating with an Associate degree or certificate (Achieving the Dream, 2012). ATD encompasses a wide-ranging group of people, i.e. educators, administrator, government employees, local businesses, and of course students, all working together in their dedication to student achievement (Achieving the Dream, 2012).

Common Core State Standards/Partnership for Assessment of Readiness for College and Careers

As a follow up to ATD data-driven results directed at better aligning high school graduation requirements and college readiness entrance requirements, on June 2, 2010, the National Governors Association and State Education Chiefs launched the Common Core State Standards (CCSS). As of May 2012, 49 states, including New Jersey, and the District of Columbia adopted the CCSS along with a consortium assessment tool. In the United States, to improve mathematics proficiency upon entrance to postsecondary education, the CCSS replace each state's mathematics curriculum with standards substantially more articulate and fixated. The revised standards are an attempt to ensure that teaching and learning in high school will better reflect the demands of postsecondary education. The CCSS strengthens the curriculum by revising expectations to those more developmentally suitable (Common Core, n.d.).

While the knowledge and skills contained in the CCSS are necessary for success in postsecondary education, there needs to be an assessment to measure and ensure student proficiency in the CCSS content. There are two consortiums that at the time of this writing are designing an assessment tool for the CCSS, Smarter Balanced and The Partnership for Assessment of Readiness for College and Careers (PARCC). As of this writing, PARCC is an 18-state consortium, including New Jersey, District of Columbia (DC) and the United States Virgin Islands; working together to create the next generation CCSS knowledge and skills based assessments for both English and mathematics. Besides high school educators and administrators, other constituents involved include about 200 postsecondary institutions across the country working together to develop various grades 3 to 8 plus three high school course assessments to determine a student's high school and college-readiness ("About PARCC," n.d.). The primary goal of the

CCSS and new assessments is better align high school graduation expectations with those expected of college freshmen or those entering the workforce (“About PARCC,” n.d.). Prototype assessments measuring the critical content and skills found in the CCSS will be ready for states to administer during the 2014-2015 school year (“About PARCC,” n.d.).

For the College-Ready (CR) determination, PARCC intends to make two determinations, one for ELA/literacy and one for mathematics. Students who are ready to take college-level courses in either of these subjects will earn a CR score on the assessment. CCSS connected with the PARCC or Smarter Balanced assessments are to ensure that a proficient score of CR translates to being college- and career-ready (“PARCC charts pathway,” 2012).

Relevant Research

For the past two decades, postsecondary developmental education research has been on the rise, especially in mathematics and at community colleges. The following recounts the most relevant studies driving the focus of this research covering successful postsecondary developmental mathematics education.

Grades and Success

Most community college freshmen have educational aspirations of earning an Associate’s degree and continuing on to earn a Bachelor’s degree. Unfortunately, many students after an unsuccessful first semester, revise their academic plans by either ending their education with an Associate’s degree or certificate, or discontinuing their education all together (Driscoll, 2007). The first semester in community college is a critical point in students’ academics. Students who have a successful first semester, earning a C or better in all classes taken, are more likely to continue their community college education to better prepare themselves for transfer to a four-year institution (Driscoll, 2007).

Driscoll (2007) found that full-time community college freshmen who took all college-level courses in their first semester were more likely to continue their education at a four-year institution after graduating, than freshmen students taking developmental courses. Additionally, Driscoll (2207) found that the higher a student's first semester grade point average (GPA) the more likely he or she would graduate before transferring to a four-year institution. Therefore, community college freshmen who enroll and succeed in college-level courses are more likely to first obtain an Associate's degree and then transfer to a four-year institution with junior-class status (Driscoll, 2007).

Focusing on successful remediation and subsequent college-level mathematics grades, the results from two separate postsecondary studies suggest that the grade earned in the developmental mathematics prerequisite help and predict student success in the subsequent college-level mathematics course (Hagedorn, et al., 2010; Kowski, 2013). Students passing their prerequisite mathematics course with an A- or B-grade exhibited decreased delay with increased success with respect to enrolling and passing the subsequent college-level course (Hagedorn, et al., 2010). Conversely, results from both of these studies also revealed what Hagedorn, et al. (2010) called a "C-problem". Students who earned the lowest passing C-grade in the prerequisite developmental mathematics course demonstrated academic non-success similar to those who received failing grades. Both studies determined that students receiving a grade in the prerequisite developmental mathematics course of B or better were approximately four times more likely to pass the subsequent college credit course with at least a C-grade compared to those students who earned only a C in the prerequisite developmental mathematics course (Hagedorn, et al., 2010; Kowski, 2013).

Therefore future focus should be spent not only on increasing the number of students who remediate quickly but also improve the developmental course achievement level. This will enable students to take transfer credits sooner with continued success, thereby keeping their goals and expectations intact and completing their community college education via graduation and/or transfer.

Developmental Education: Depth versus Breadth

Regarding postsecondary developmental education, there is interest with respect to any correlation between the depth (the number of semesters required in one subject) and breadth (the number of different subjects required) and the effectiveness of postsecondary developmental education (Bahr, 2007, 2010). Continuing with previous research regarding the effectiveness of postsecondary developmental education in community colleges (Attewell, et al., 2006; Bettinger & Long, 2005, 2009), Bahr (2010) investigated if the same rewards from remediating successfully were experienced from all developmental education students regardless of how many semesters were required in any given subject. Also investigated were if students who require developmental education in multiple areas (English and mathematics) benefit as much from successful remediation as students who face only a single deficiency (English or mathematics). Irrespective of the number of semesters or the number of subjects of developmental education required, all combinations were compared to freshmen who were college-ready in English and/or mathematics without developmental education. This study was distinct from his prior work testing the effectiveness of developmental education, in that it examines both the different levels of deficiency as well as the different combinations of deficiencies (Bahr, 2010).

Results from this analysis (Bahr, 2010) and his prior research (Bahr, 2007) indicate that the greater the depth and/or breadth of developmental education requirements in mathematics and/or English by an incoming freshman, the less likely the student will persist and become college-ready in those subjects. In addition, Bahr (2007, 2010) found that the negative consequences of mathematics non-proficiency increased when coupled with insufficient English capabilities in reading, writing and/or comprehension. Overall Bahr (2007, 2010) found that the possibility of successful mathematics remediation becomes even more dismal the less proficient the same student is in college-level English. However, Bahr (2007, 2010) also revealed that students requiring the maximum number of developmental mathematics semesters, i.e. those starting in basic arithmetic, the added negative consequence of English deficiency on mathematics remediation becomes negligible. Overall, the greater a student's initial postsecondary mathematics skills, then the smaller the effect of English incompetency has on successful mathematics remediation (Bahr, 2007, 2010).

More obvious and a major predictor of successful mathematics remediation is the number of semesters of developmental mathematics required before the student is eligible to enroll in college-level mathematics (Bahr, 2007, 2008, 2010). The weaker the mathematics skills, the less likely the student will remediate into college-level mathematics. Fortunately, no matter how much developmental education is needed nor in how many subject areas, once remediated developmental education students enrolled in college-level English and mathematics exhibit comparable academic success as those requiring no developmental education; thereby showing that developmental education is valuable regardless of the number of subjects or the number of semesters required (Bahr, 2008, 2010).

Successful Remediation and College Readiness

In some studies of postsecondary developmental mathematics comparing developmental education students to those not requiring developmental education, developmental education students who successfully remediate into college-level mathematics courses were found to experience similar academic results to those not requiring developmental mathematics, thus providing statistical evidence that developmental education can rectify initial mathematics deficiencies (Bahr, 2008; Bettinger & Long, 2008; Waycaster, 2001). When mathematics remediation is successful, the academic outcomes of mathematics students who remediate are encouraging. Thus, although those opposing the effectiveness of developmental education might argue that developmental education is consuming resources better employed elsewhere, they cannot say that developmental mathematics programs are not accomplishing their objectives for remediated students. However, those who oppose developmental education may question the definition of success in program where more than half of the students who start an educational path towards college-level mathematics never successfully pass developmental mathematics. Additionally, those students who have the greatest deficiencies within one subject area or over multiple subject areas are even less likely to successfully remediate (Bahr, 2008, 2010).

The main focus of developmental education is that the academic outcomes for those requiring developmental education and those not requiring developmental education before entering college-level courses, should be relatively equivalent. Prior analyses support the hypothesis that those requiring developmental mathematics display patterns of credential achievement in terms of passing their credit mathematics course, comparable to those not requiring developmental education (Bahr, 2008; Bettinger & Long, 2008; Waycaster, 2001). In general, developmental education is similarly successful with respect to educational achievement across various initial levels of mathematics deficiency upon enrollment. Therefore, as long as developmental mathematics students remediate successfully, their academic performance in the subsequent college-level mathematics course is comparable to those not requiring developmental mathematics. This is important, indicating that developmental mathematics has the capability to resolve the mathematics deficiencies needed for success in college-level mathematics. Thus for remediated developmental mathematics students, the primary objective of postsecondary developmental mathematics is achieved (Bahr, 2008; Bettinger & Long, 2008; Waycaster, 2001). Unfortunately most of the students who enroll in developmental mathematics coursework do not remediate successfully and subsequently experience less encouraging academic outcomes such as failing to graduate or transfer, than students who successfully remediate by passing their developmental mathematics sequence with a grade of C or better (Bahr, 2008).

Successful Remediation and Persistence

Bahr (2009) found that compared to postsecondary institutions with a small percentage of developmental mathematics students, students enrolled where the number of students placed into developmental mathematics is considerably larger than the number placed into college-level mathematics, are more likely to successfully navigate the developmental mathematics curriculum. Unfortunately even in community colleges where more students require developmental mathematics, i.e. arithmetic, elementary algebra, or intermediate algebra, than developmental English, i.e. reading, writing, or comprehension, the proportion of students remediating in mathematics tends to be lower than the proportion of remediated developmental English students (Bahr, 2007, 2008; Bailey, 2009). Students who require more than one semester of developmental mathematics rarely find themselves ready for college-level mathematics, even as much as six years later (Biswas, 2007; Parsad, et al., 2003). Overall, the more severe the mathematics deficiencies at college entry the less likely the student will achieve college-level mathematics proficiency (Bahr, 2007, 2008, 2010; Bailey, Jeong & Cho, 2010). An unfortunate consequence is that students who fail to remediate into college-level courses will never obtain a degree or certificate nor transfer to a four-year institution (Bahr, 2008, 2010; Biswas, 2007).

There exist two crucial differences across levels of initial mathematics deficiency in the relationship between persistence and the rate of successful remediation. First, the more severe a student’s mathematics deficiencies, the longer the student must persist in college to have any chance of remediating successfully. Developmental education lengthens the time required to achieve any given academic outcome of interest. Hence comparable levels of persistence across different levels of mathematics deficiency do not exhibit parallel results because poorer mathematics skills necessitate a longer period of time to remediate. Thus the greater the mathematics deficiency the higher level of persistence required to achieve successful remediation (Bahr, 2010). Additionally, the more severe the mathematics deficiencies are, the less likely the chances of remediating successfully from each incremental increase in persistence. The significance of a one-semester increase in persistence diminishes as initial mathematics deficiency rises (Bahr, 2010). Therefore, there are great inconsistencies in the rate of successful remediation among students of various levels of initial mathematics deficiency. In contrast to the conclusions of prior work, Bahr (2010) found that the relationship between persistence and the chance of successful remediation is not equivalent across different levels of initial mathematics deficiency. Put simply, Bahr (2010) found that students requiring only one semester of developmental mathematics were twice as likely to successfully remediate into college-level courses than those requiring two semesters of developmental mathematics (Bahr, 2010).

Overall, there is detrimental decline in the likelihood of successful mathematics remediation within two years, especially for those entering college with the weakest mathematics skills. In a preliminary study this author found that more than 2 out of 3 (69 percent) developmental mathematics students did not complete their remediation in two years; and only 1 in 4 (25 percent) remediated successfully i.e. passed their credit mathematics course. Of those students still enrolled in the college after two years, only 1 in 10 (10 percent) completed a credential. Even though remediated developmental mathematics students experience similar academic outcomes as those not requiring developmental mathematics, regardless initial mathematics skill deficiency, the probability of successful remediation becomes progressively smaller the more deficient the student’s initial mathematics capabilities. Without successful remediation, declining mathematics skills remove graduation prospects for developmental education students (Adelman, 2004; Bahr, 2008).

Then again, Kreysa (2006) and Waycaster (2001) each separately in their studies concerning persistence of developmental students compared to those requiring no developmental education, exhibited results that contrasted with the pessimism of the above studies. Kreysa (2006), comparing academic outcomes for freshmen students requiring developmental education and those college-ready, found both groups statistically the same with respect to graduation and retention rates. Specifically Kreysa (2006) found that incoming low income and/or minority freshmen requiring developmental education persist semester to semester at rates comparable to freshmen who are college-ready. This reveals how developmental education programs are fundamental to improving the academic performance of these students thereby enabling them to persist semester to semester (Kreysa, 2006). Even more interesting and contrary to results found by other researchers, Waycaster (2001) found in some community colleges retention rates for developmental students were significantly higher than those for non-developmental students. Waycaster (2001) surmised that the high percentage of community college graduates with a developmental education background gives supporting evidence of the significance of the added support structures offered to developmental education students. Regardless of whether more, less, or the same number of developmental students persist than those not requiring developmental education, results of all studies discussed above reiterate the community college mission of enabling underprepared students to become college-ready, allowing them to experience academic achievements on the same level as postsecondary students not requiring developmental education.

Summary

Hughes & Scott-Clayton (2011) and Sawyer (2007) both stated that when a placement test reveals developmental education is needed, students who pass all required developmental courses must retain the knowledge base necessary for college success as exhibited by their achievements in subsequent college-level courses. Unfortunately, most developmental mathematics students do not remediate successfully. While developmental education is valuable for those who remediate into college-level courses, additional investigation is necessary to identify what factors hinder successful remediation for some, as well as what factors enhance successful remediation for others (Bahr, 2008).

Based on previous literature and research results, this body of research encompasses two cohorts of first-time fulltime students in a New Jersey *Achieving the Dream* (ATD) community college using hierarchical linear modeling (HLM) and logistic regression to model successful mathematics remediation. Variable selection is largely driven by existing literature research results and subsequent accessibility in the community college's data base. This research encompasses valuable information to help increase successful remediation, and subsequently decrease dropout rates while increasing graduation rates. It is necessary to know which factors improve or hinder successful remediation before changes are made to developmental programs and/or pedagogy. The research presented ensures that any new enhancements are targeting the significantly influential aspects regarding successful remediation. Thus the following research questions guided this body of research.

This study primarily focuses on what factors inhibit, enhance, or have no effect on successful remediation. Do students who successfully remediate in developmental mathematics and enter college-level mathematics obtain academic outcomes comparable to college-ready students who enter college-level mathematics directly, without the need of developmental mathematics? A secondary question is: Which predictor(s), if any, correlate and/or help predict a student's success in his or her first college mathematics course?

Therefore, for this study, the efficacy of the developmental mathematics program for traditional age college freshmen in two cohorts from a New Jersey *Achieving the Dream* community college is investigated by comparing the academic outcomes of students who enter college-level mathematics through developmental education with those students who did not require developmental education to enter college-level mathematics.

CHAPTER III. STUDY DESIGN AND METHODOLOGY

Developmental Mathematics Defined

In 2008, as a means to increase graduation and transfer rates from community colleges to four-year institutions, New Jersey passed the Lampitt Bill, a bill demanding that community colleges and four-year institutions create a general education transfer agreement (State of New Jersey: Higher Education, 2008). From that bill, New Jersey community colleges and public four-year institutions came to agree upon what constitutes a general education Associate's degree. Students graduating from a New Jersey community college with a general education Associate's degree will seamlessly transfer to a New Jersey public four-year institution with the first two years of a baccalaureate degree program completed, thereby enabling them to transfer with junior status (State of New Jersey: Higher Education, 2008). Along with this transfer agreement was the agreement amongst the community colleges to use the Accuplacer® placement test, a computer adaptive test that can evaluate proficiencies from developmental to college-level mathematics and English. Since the computer test is adaptive, easier or more difficult questions are presented as the student gets questions incorrect or correct, respectively (James, 2006). A statewide elementary algebra cut-off score of 76 was implemented for mathematics placement. Thus, if a student on the algebra portion of the placement exam scores 76 or above he or she will not require developmental mathematics in elementary algebra. Depending on the desired degree, mathematics intensive degrees, degrees requiring precalculus or statistics, versus non-mathematics intensive, the student may require no developmental mathematics. For mathematics intensive STEM (science, technology, engineering, mathematics) Associate degrees, scoring 76 on the placement exam would require one semester of developmental intermediate algebra. Alternatively for non-STEM Associate degrees, a score of 76 would allow direct entry into a college-level liberal arts mathematics course. The New Jersey general education agreement solidified the developmental mathematics requirement as a result of placement for community colleges (State of New Jersey: Higher Education, 2008).

As previously discussed, prior research uncovered that students with the weakest mathematics proficiencies, i.e. arithmetic students compared to intermediate algebra students, were the least likely to remediate into college-level mathematics (Bahr 2008). Can one also assume that the benefits of successful mathematics remediation for those students placing into arithmetic are less than those who place into intermediate algebra? In other words, is successful developmental mathematics remediation the same at every level of mathematics deficiency? For example, comparing two groups of students who have successfully remediated in developmental mathematics, do students who require only one semester of developmental mathematics education compared to students who require two to three semesters of developmental mathematics experience equivalent academic outcomes? Once remediated, does the number of semesters of developmental mathematics education affect the likelihood of passing college-level mathematics with a grade of C or better?

Comparing the academic outcomes of remediated developmental mathematics students with those requiring no developmental mathematics, this body of research examines various predictors, i.e. passing college-level mathematics and graduating with a credential, of successful mathematics remediation for traditional-aged students from two cohorts; those who graduated high school in spring 2009 and attended community college fulltime for the first time in fall 2009 and those who graduated high school in spring 2010 and attended community college fulltime for the first time in fall 2010. Independent predictor variables investigated include placement level, developmental mathematics requirements as well as grades in each developmental mathematics course, grades earned in each credit mathematics course, and time delay when the first developmental or college-level mathematics course was taken, while controlling for developmental English, gender, socioeconomic status, ethnicity, and financial aid. Significance is determined by those variables that help explain the variation of the different response variables, successful mathematics remediation, earning a grade of C or better in college-level mathematics, and graduating with a degree or certificate.

Regression Modeling

Hierarchical Linear Modeling

Various analyses, especially in the in the social sciences and education, exhibit an inherent hierarchical or clustered structure. For hierarchical data, statistical analysis adjustments "allows bias-free testing for main effects and interactions both between and within levels without loss of information" (Goldstein, 1995). Statistical methods recognizing this hierarchical structure and thus adapting the analysis has become more prevalent in educational research (Bickel, 2007; Brambor, T., Clark, W. R., & Golder, M., 2006; Osborne, 2000).

Correlated data can arise when repeated measurements of the same individuals have a nested (hierarchical) structure. For example, if repeated measurements are performed on a set of students, such as a before and after test, the measurement circumstances are not consistent since some learning has happened between the two tests, thus the multiple observations should be considered nested within students. Each student might also be nested within some organizational unit such as a high school or postsecondary educational course. They may then be further nested within a high school sending district, county, or state. Within the hierarchical linear model, each level of clustering (repeated testing in a mathematics course within students, students within high schools, etc.) is analyzed within its own sub-model (Osborne, 2000; Raudenbush, Bryk, Cheong, Congdon & du Toit, 2011).

Carrying out conventional statistical procedures at the individual student or aggregate school level can produce biased results in favor of the alternate hypothesis, increasing the likelihood of a type I error, or loss of information based on the hierarchical structure. Thus there is a need for a more complicated statistical model that recognizes and incorporates the hierarchical structure of the data, i.e. students with similar mathematical aptitude placing within the same developmental mathematics level. Other classifications such as the high school from which each student graduates, result from happenstance and are less dependent on individual student characteristics. Once hierarchies such as mathematics placement are formed, regardless of randomness, they still have a tendency towards additional distinction, implying that the clusters influence and are influenced by hierarchy classification (Bickel, 2007; Goldstein, 1995; Osborne, 2000; Raudenbush, et al., 2011). To overlook these multi-level groups disregards the significance of group effects and at the same time makes traditional statistical analyses for this type of data structure ineffective (Bickel, 2007; Goldstein, 1995; Osborne, 2000; Raudenbush, et al., 2011).

Hierarchical linear models (HLMs) deal with clustered data and statistical methods created to compensate for the pitfalls of ordinary least-squares (OLS) methods (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002; Obsborne, 2000). With clustered data, individuals within these clusters will have some similar qualities. Thus analyses based on clustered data are not fully independent. For example students placed in postsecondary developmental algebra have more in common with each other than students in college-level mathematics or students randomly chosen from the entire community college. Students placed in a particular mathematics course tend to be more homogeneous in terms of retained mathematics knowledge, educational preparation, and attitude and opinion regarding postsecondary developmental mathematics, than the general community college student body. Furthermore, students within a particular mathematics placement level have similar retained mathematical knowledge and since they are placed into the same mathematics class will learn the same mathematical content with similar experiences, resulting in even greater homogeneity throughout the semester (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002; Obsborne, 2000). This homogeneity occurrence violates a basic independence assumption for most traditional statistical analyses. As a consequence, for hierarchical data, failure to adapt to the inherence dependent nature of the hierarchies, OLS regression results in misleading small standard errors which in turn leads to a higher probability of type I errors, rejecting a true null hypothesis than if: (a) a statistical analysis compensating for the dependent nature of these hierarchies was used, or (b) the data encompassed truly independent observations (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002; Obsborne, 2000). The statistical methods of HLMs take into account that individuals within a particular group, i.e. those who place into Elementary Algebra, may be more similar in terms of mathematics retention, self-efficacy, attitude, etc., to each other than to individuals from other groups, i.e. those who place into college-level mathematics. Since these observations are not truly independent, HLM models both individual and group level residuals, accounting for the partial correlation of individuals within the same group (Bickel, 2007; Raudenbush & Bryk, 2002; Obsborne, 2000).

Furthermore, using HLM enables one to look at both student-level unit and high school-level unit variances in the outcome variable without resulting in an erroneous type I error, false rejection of the null hypothesis (Bickel, 2007; Raudenbush & Bryk, 2002; Obsborne, 2000). HLM allows one to model both individual and group level variance in individual outcomes while employing individual predictors at the individual level and group predictors at the group level. While sustaining the applicable level of analysis, HLM overcomes the disadvantages of OLS approaches by modeling both within and between group variance and at the same time looking at the influences of the different hierarchies (Bickel, 2007; Raudenbush & Bryk, 2002; Obsborne, 2000).. Hierarchical modeling methods enable the researcher to separate hierarchical individual and group effects on the outcome variable (Bickel, 2007; Raudenbush & Bryk, 2002; Obsborne, 2000). In addition, with HLM the effects can be fixed or random, balanced design is not required, and the results give valid standard error estimates when determining statistical significance (Bickel, 2007; Raudenbush & Bryk, 2002; Obsborne, 2000). Lastly, HLM has been extended to handle binary outcome variables, a focus in this study, as well as dealing with missing data (Raudenbush & Bryk, 2002).

Overall, for this study using HLM, a statistical method that models students within a particular mathematics course who graduated from different high schools, has many benefits. First, HLM gives statistically valid estimates of the regression coefficients. Second, by compensating for the hierarchical structure HLM results in statistically sound standard errors, confidence intervals and significance tests. Finally, by generating covariate outputs measured at any level of hierarchy, HLM allows the exploration of the differences in average results between schools determining which influence certain student characteristics, while also revealing whether some high school factors are better at explaining the variation among the developmental mathematics students than individual student factors (Bickel, 2007; Goldstein, 1995).

This study treats each community college cohort separately, fitting each with its own regression model (Goldstein, 1995; Raudenbush & Bryk, 2002). For each community college cohort and the various high schools the students graduated from, a multilevel approach is necessary with each high school considered as a random sample from the population of all New Jersey high schools. This allows generalized inferences about the variation between schools to be made (Figure 3.1) (Goldstein, 1995; Raudenbush & Bryk, 2002). This is vital for repeated measures data, as in this body of research, where there may be very few level-1 students graduating from a particular level-2 high school (Goldstein, 1995; Raudenbush & Bryk, 2002). Therefore, a two-level hierarchical linear regression model, corresponding to both the student level predictors and various high schools within each community college cohort, is used to model the natural variation in successful mathematics remediation, earning a grade of C or better in college-level mathematics, and graduating with a credential (Raudenbush & Bryk, 2002).

At the student level, using traditional regression methods, a linear level-1 model is fitted to individual students from each high school. At the high school level estimates of the student level-1 model parameters are treated as dependent variables linearly dependent on the high school level-2 independent variables (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002). The high school level-2 independent variables measure high school characteristics, not individual students (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002). High school level-2 regression parameters are established by a type of linear regression analysis. There can be multiple levels in an HLM analysis where all the effects of lower order are included in the final model (Bickel,

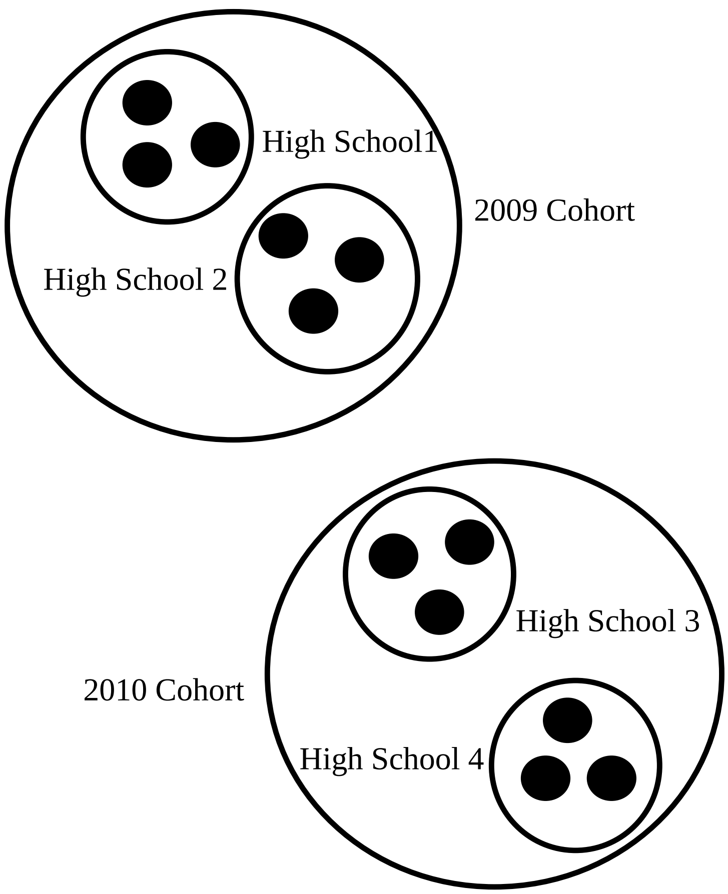

Figure 3.1. Hierarchical Data. Each student (black dot) is nested within a single high school which is nested within a single community college.

2007; Goldstein, 1995; Raudenbush & Bryk, 2002).

A two-level model consists of two submodels, one at level-1 and another at level-2. For example, since this body of research covers data on community college mathematics students nested within New Jersey high schools, the level-1 model examines the correlations among the student-level predictors and the level-2 model looks at the effect of the high school-level variables. Formally, there are $i = 1, \ldots, n_j$ level-1 units (for example, students) nested within $j = 1, \ldots, J$ level-2 units (for example, high schools) (Raudenbush, et al., 2011, p. 8).

The representation in the level-1 model with the outcome for case *i* within unit *j* is (Raudenbush, et al., 2011, p. 9):

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \cdots + \beta_{Qj}X_{Qij} + r_{ij} \tag{3.1}$$

where

β_{qj} ($q = 0, 1, \ldots, Q$) are level-1 coefficients;

X_{qij} is the level-1 predictor q for case i in unit j;

r_{ij} is the level-1 random effect; and

σ^2 is the variance of r_{ij}, that is the level-1 variance.

Each of the level-1 coefficients, β_{qj}, defined in the level-1 model becomes an outcome variable in the level-2 model (Raudenbush, et al., 2011, p. 9):

$$\beta_{qj} = \gamma_{q0} + \gamma_{q1}W_{1j} + \gamma_{q2}W_{2j} + \cdots + \gamma_{qS_q}W_{S_qj} + u_{qj} \tag{3.2}$$

where

γ_{qs} ($q = 0, 1, \ldots, S_q$) are level-2 coefficients;

W_{sj} is the level-2 predictor; and

u_{qj} is the level-2 random effect.

Each level-1 coefficient "can be modeled at the level-2 as one of three general forms: 1) a fixed level-1 coefficient, 2) a non-randomly varying level-1 coefficient, or 3) a randomly varying level-1 coefficient or a level-1 coefficient with both non-random and random sources of variation" (Raudenbush, et al., 2011, p. 10).

From a previous pilot study, the relationship between developmental mathematics placement levels and successful remediation were found to differ across the high schools the community college students graduated from (Kowski, 2013). Since the previous study utilized OLS methods on a sample where students were clustered by high schools and developmental mathematics classes, this significance implied further investigation was needed using methods of HLM to measure effects on an individual student, placed at a specific mathematics level, clustered within the New Jersey high school from which he or she graduated. A two-level HLM first models a regression equation at the student level, and then allows the parameters of the student-level regression equation to vary by high school. The second-level high school variables help explain the variation in the lower student-level parameters enabling testing of the main effects and any interactions, both within and between levels (Bickel, 2007; Goldstein, 1995; Raudenbush & Bryk, 2002).

Hierarchical Generalized Linear Models (Multilevel Logistic Regression)

Due to the binomial characteristic of the student level-1outcome, (successful remediation or not, passing a college-level mathematics course or not, attaining a degree or not), a logistic regression model is used for the HLM student level-1 (Raudenbush & Bryk, 2002). The procedure operates by modeling the probability of a new occurrence under different factor considerations, making interpretations in terms of the log-odds of the outcome rather than in terms of the raw outcome itself (Garson, 2009). Because the dependent variable is binary in nature, and the independent variables are a mixture of categorical and continuous variables, logistic regression is the most appropriate statistical technique (Mertler & Vannatta, 2010). In addition, these considerations allow comparisons with similar research that investigated individual characteristics and the efficacy of developmental mathematics education on college outcomes such as persistence and graduation (Armstrong, 2000; Bahr, 2007, 2008, 2009, 2010; Bettinger & Long, 2005, 2008; Bourquin, 1999; Fike &Fike, 2008; Hagedorn, et al., 2010; Kowski, 2013; Kreysa, 2006; Parker, 2005, Waycaster, 2001).

Rather than modeling a continuous numerical outcome variable with one or more linear predictors as in standard linear regression, by comparing the natural logarithms of the odds ratio, logistic regression models the probability of a successful outcome based on one or more linear predictors (3.3) (Bickel, 2007; Mertler & Vannatta 2010).

$$\ln\left(\frac{P(Y_i=1)}{P(Y_i=0)}\right) = \beta_0 + \beta_1 X_i \tag{3.3}$$

Therefore, due to the binomial characteristic of the student level-1 outcome, a hierarchical generalized linear model (HGLM), specifically a multi-level logistic regression model, corresponding to both the student level predictors and various high schools within each community college, is used to model the variation in the natural logarithm of the odds ratio, converted to the probability of each binomial outcome (remediate successfully, earn a grade of C or better in college-level mathematics, or graduate) (Raudenbush & Bryk, 2002).

The level-1 model in the HGLM may be viewed as consisting of three parts: “a sampling model, a link function, and a structural model” (Raudenbush, et al., 2011, p. 105). “The level-1 predicted value, μ_{ij}, is transformed to a log-odds ratio, η_{ij}, to insure that the predictions are constrained to lie within a given interval" (Raudenbush, et al., 2011, p. 105). This transformation is called a link function. The HLM uses a normal distribution sampling model and an identity link function, while the binary HGLM uses a binomial sampling model and a logit link function. Therefore, between HLM and HGLM only the level-1 models differ (Raudenbush, et al., 2011, p.105).

Let Y_{ij} be the number of successes in m_{ij} trials. Then

$$Y_{ij}|\emptyset_{ij} \sim B(m_{ij}, \emptyset_{ij}) \tag{3.4}$$

denotes that Y_{ij} has a binomial distribution with m_{ij} trials and probability of success $\emptyset_{ij}$. The binomial distribution where the outcome variable has only two values, zero (failure) or one (success), is also known as a Bernoulli distribution. In a Bernoulli situation, the predicted value of the binary Y_{ij} is equal to the probability of a success, $\emptyset_{ij}$ (Raudenbush, et al., 2011, p.106).

When the level-1 sampling model is binomial, HGLM uses the logit link function

$$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right) \tag{3.5}$$

where η_{ij} is the natural logarithm of the odds of success. "When the probability of success is less than 0.5 the odds are less than one and the logit is negative; when the probability is greater than 0.5, the odds are greater than one and the logit is positive" (Raudenbush, et al., 2011, p.107). So even though the probability of success or failure can only take on values between zero and one inclusively, the natural logarithm of the odds of success, η_{ij}, can be any real number (Raudenbush, et al., 2011, p.107).

Using the general format for a HGLM plus the binomial characteristic of the student level outcome, the model for this study is quantified according to equations (3.6) and (3.7). The left-hand side of the first equation represents the natural log of the odds of the probability that individual *i*, graduating from high school *j*, experiences a success (outcome 1), versus a failure (outcome 0) in terms of successful remediation, earning a grade of C or better in college-level mathematics, or graduating. This outcome varies for high school *j* (β_{0j}) as a linear function of a group of variables representing each student's developmental mathematics placement level (Arithmetic, Elementary Algebra, Intermediate Algebra, or none) before college-level mathematics (Table 3.1), the corresponding coefficients for high school *j* (β_{1j}, β_{2j}, β_{3j}), a group of *k* student-level control (SLC) variables (gender, race/ethnicity, mathematics enrollment pattern, grade in first mathematics course, English competency at college entry, and financial aid status), and the coefficients associated with these control variables (β_{kj}) (Raudenbush, et al., 2011). Hence, the intercept for high school *j* (β_{0j}) varies from the intercept for all high schools (γ_{00}) as a function of a group of *q* high school-level control (HSLC) variables, (district factor group (DFG), analogous to socioeconomic status (SES), high school rank, grade twelve enrollment, average combined Scholastic Assessment Test (SAT) score, and percent advanced mathematics proficiency on the New Jersey High School Proficiency Assessment (HSPA), and the coefficients connected to these high school-level variables (γ_{0q}), plus a random high school-level error term (ε_{0j}) (Raudenbush, et al., 2011). With HGLM, the coefficients correlated with students' developmental mathematics requirements (β_{1j}, β_{2j}, β_{3j}) are allowed to freely vary at the high school level (ε_{1j}, ε_{2j}, ε_{3j}), relieving the model of the independence assumption, noting that the effect of the developmental mathematics placement is not the same for all high schools. The coefficients associated with the student-level control variables (β_{kj}) are fixed across high schools. Students are assigned to the high school in which they graduated in June 2009 or June 2010. The models are specified as follows (Raudenbush, et al., 2011, p. 106):

$$\ln\left(\frac{P(Y_i=1)}{P(Y_i=0)}\right) = \beta_{0j} + \beta_{1kj}(MATH)_{ij} + \beta_{2kj}(ENGL)_{ij} + \beta_{3j}(GENDER)_{ij} + \beta_{4kj}(RACE)_{ij} + \beta_{4kj}(AID)_{ij} \tag{3.6}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01k}(DFG)_j + \gamma_{02}(RANK)_j + \gamma_{03}(ADVMATH)_j + \gamma_{04}(SAT)_j + \gamma_{05}(ENROLL)_j + \varepsilon_{0j} \tag{3.7}$$

The estimates of the β's in (3.6) make it possible to generate a predicted log-odds ratio (η_{ij}) for any student which can be converted to a probability by first calculating the exponential of (η_{ij}), the log-odds ratio (Raudenbush, et al., 2011, p.107).

Hierarchical generalized linear modeling (HGLM) produces estimates for both the unit-specific and population-average models. The population-average results are based on generalized least squares given the variance-covariance estimates from the unit-specific model. In addition, HGLM produces robust standard error estimates for the both the unit-specific and population-average models (Zeger, Liang, & Albert, 1988). These standard errors are "unaffected by misspecification of the variances and covariances at the two levels as well as the distributional assumptions at each level" (Raudenbush, et al., 2011, p.119).

Overall hierarchical linear modeling (HLM) and hierarchical generalized linear modeling (HGLM), also known as multi-level analyses, are more advanced forms of both simple and multiple linear regressions. This cluster analysis enables outcome variable variances to be investigated at all hierarchical levels together, rather than modeling the effects at a single level (Bickel, 2007; Goldstein, 1995; Osborne, 2000; Raudenbush & Bryk, 2002).

Defining and Measuring the Data Set

At the time of this study, there were substantial changes occurring at both the national and state levels, as well as the community college level, especially with regard to developmental mathematics, financial aid and persistence to graduation. In reference to financial aid, for the academic year 2011-2012, Pell requirements were altered to a maximum of 6 years or 12 fulltime semesters for an Associate or Bachelor degree, whereas before there was no recipient time limit. Coincident with the decreased amount of time allowed to receive Pell awards, the Pell Grant program had a sizeable cut in funding. For those who are the most financially needy who might have previously been awarded the maximum amount needed per semester now only received partial awards, whereas many students who previously received partial Pell grants found themselves ineligible due to the decreased funding (Hopkins, 2011).

Furthermore, the substantial changes within the community college used for this study involved the acquisition of the local county technology institute in the summer of 2010 (Stirling, 2010). Thus, by fall 2010 there was an increase in certificate program options as well as terminal Associate degrees such as medical assistant, interior design, cosmetology, etc. For many of these programs the mathematics requirements are either Elementary Algebra competency, or at most only one semester of liberal arts mathematics, which needed to be completed sometime before graduation. Also the addition of many of these new programs in traditionally female-oriented fields provide female students more opportunities for graduation than male students.

To determine the effect of these changes on developmental mathematics education, rather than investigating one cohort, two consecutive-year cohorts were investigated with the intention of parceling out any significant differences. Using various statistical analyses to analyze the effectiveness of postsecondary developmental mathematics, this quantitative study assesses predictors of successful remediation for traditional age students who graduated a high school spring 2009 or spring 2010, took the placement test summer 2009 or summer 2010, respectively, and attended the community college fall 2009 or fall 2010, respectively. The sample from the New Jersey *Achieving the Dream* (ATD) community college that is examined in this study comprised four years of data for fulltime students who first enrolled in fall 2009 and three years of data for fulltime students who first enrolled in fall 2010. Several predictor and control variables are investigated such as placement level (predictor) and ethnicity (control). Significance is determined by those variables that help explain the variation of the response variables such as successfully completing the developmental mathematics sequence, earning a grade of C or better in a college-level mathematics course, and graduating with a credential.

Variable selection

Variables for the proposed study are determined based upon both the review of the literature and availability from the community college database. An underlying assumption of the study is that the majority of postsecondary developmental mathematics takes place at community colleges where successful remediation is a common focus throughout. As a consequence community colleges have a unique perspective concerning postsecondary developmental education and according to the literature have higher success rates than their corresponding four-year institutions (Adelman, 2004; Attewell, et al., 2006; Boggs, 2010; Parsad, et al, 2003). Even more directed when investigating developmental education are the ATD institutions. Therefore this body of research is drawn from a New Jersey ATD community college, whose mission is to shorten developmental education time and increase success rates as well as increasing persistence to graduation or transfer (Achieving the Dream, 2010). Both quantitative and qualitative variables are included in this investigation.

Data

To analyze the effectiveness of developmental mathematics, all traditional-age students who graduated high school June 2009 or June 2010 and attended the New Jersey ATD community college first-time fulltime in fall 2009 or fall 2010, respectively, are used for this study. The data was extracted from Banner, the data base system used by the community college in this study. The data was analyzed and coded according needs of the various analyses (Tables 3.1-3.3). Variables that are dichotomous are coded 1 for *yes* and 0 for *no*, or in the case of gender, coded 1 for *male* and 0 for *female*. Similarly, ordinal variables are discrete-coded starting from 0 for the base-level, and nominal variables were dummy-coded with a zero-coded reference group. The categorical variables with more than two outcomes have the reference group coded zero, and the other groups are recoded into a series of binary variables.

Outcome Variable

A number of different outcome measures are employed in testing the efficacy of mathematics developmental education. All three outcomes for this body of research are based on a community college student's mathematics placement level and his or her academic attainment as measured by either successful remediation, passing a college-level course with a grade of C or better, or graduating with an Associate's degree or certificate. For any mathematics student, success is judged as effectively completing developmental mathematics (if needed) and passing college-level mathematics. Since D-grades are not transferrable to a four-year institution, the only measure of interest is college-level competency defined as a passing grade of C or better in college-level mathematics.

For community college students taking any level of mathematics, it is necessary to look at what factors enhance or hinder academic success where academic success is measured by graduating with a degree or certificate and/or transferring to a four-year institution (Bahr, 2008; Grubb & Gardner, 2001). Furthermore, since the successful completion of each developmental mathematics course is not necessarily equal, in addition to looking at mathematics placement and its effect on the successful completion of the entire developmental mathematics sequence as an outcome variable, additional predictor variables included what factors enable developmental mathematics students to take college-level mathematics as well as the successful completion (grade of C or better) of a college-level mathematics course for both developmental and college-level mathematics students, and determining if any differences exist due to gender, developmental English, ethnicity, or financial aid. Is a female student more or less likely to successfully remediate from developmental mathematics than a male student? Is the success rate for college-level mathematics dependent on financial aid award? For those placing directly into a college-level mathematics course, is the success rate higher than those students who entered by passing their required developmental mathematics sequence?

All mathematics courses taken were tracked including the semester each mathematics course was taken and grade earned in each mathematics course. Also, the student's grade point average (GPA) was tracked each semester of attendance, and the date of graduation if the student graduated within the four years (2009 cohort) or three years (2010 cohort) of this study. (Note: students who do not take any mathematics course while enrolled in the college, such as non-graduated transfer students or certificate students, were dropped from the cohort for HGLM analyses.)

Explanatory Variables

There are a number of student-level explanatory variables that other educational researchers deemed significant with respect to successful mathematics remediation (Bahr, 2007, 2008, 2010; Driscoll, 2007; Hagedorn et al., 2010). The mathematics-related explanatory variables considered for the hierarchical generalized linear model are a student's initial level of competency as determined from the Accuplacer® mathematics placement exam, noting any delay in his or her mathematics sequence, and the grade earned in each mathematics course completed. Due to the New Jersey General Education Agreement and the development of two mathematics tracks, mathematics-intensive and non-mathematics-intensive, placement level is defined by the prerequisite developmental mathematics course taken followed by the college-level mathematics course enrolled. Successful mathematics remediation happens when a developmental students passes all levels of required developmental mathematics with a minimum C-grade, thereby fulfilling all prerequisites for his or her college-level mathematics.

Developmental mathematics at the community college in this study is a linear sequence of courses beginning with one semester of basic mathematics split into two half semester courses called Arithmetic I (basic computation) and Arithmetic II (pre-algebra), followed by two full semesters of algebra, Elementary Algebra and Intermediate Algebra (Table 3.1). Since the completion of each developmental mathematics course is not equal, rather than using ordinal values for number of levels of developmental mathematics required, the mathematics placement level is treated as a categorical variable with more than two outcomes. The college-level placement is the reference group coded zero, and the other groups are recoded into a series of binary variables. Furthermore, when looking at passing a college-mathematics course, not all students enter the course the same way. Some students place directly into the course via the mathematics placement test, while others remediated into the course by passing the prerequisite developmental mathematics course. A dummy variable, identifying if the student placed into the college-level course (0) or remediated into the course (1), identified the two groups and determines if the way a student entered into the college-level course influences the probability of passing the course (Table 3.1).

In addition, due to the New Jersey General Education Agreement, categorization of the college-level mathematics courses is coded as mathematics intensive courses (Precalculus or Statistics) or as non-mathematics intensive courses (all other college-level mathematics courses). Therefore, if a student requires Precalculus or Statistics for his or her major, depending on placement, there may be a maximum of three semesters of developmental mathematics, while a student not requiring either of these college-level mathematics courses, may have only a maximum of two semesters of developmental mathematics since Intermediate Algebra is only a prerequisite for Precalculus and Statistics. Therefore, college-level mathematics courses are any of the following courses:

Finite Mathematics, Number Systems, Problem Solving Strategies, and Quantitative Literacy for non-STEM majors, and Statistics, Precalculus, and Calculus for STEM majors. Using this type of coding allows each student in the cohort to be identified as either a developmental mathematics student or a college-level mathematics student based upon his or her first mathematics course (Table 3.1).

Regardless of placement, students move through the developmental mathematics sequence at different rates. Therefore additional explanatory variables considered are each student's mathematics enrollment pattern as well as the grade of C or better in the first mathematics course taken whether the course is developmental or college-level.

TABLE 3.1
Coding of Data - Explanatory Variables

Variable	Detail	Coding
Grade	A	4.0
	B+	3.5
	B	3.0
	C+	2.5
	C	2.0
	D	1.0
	F	0.0
Math Placement Level	Arithmetic	1 0 0
	Elementary Algebra	0 1 0
	Intermediate Algebra	0 0 1
	College-level mathematics	0 0 0
Developmental Math	Yes	1
	No	0
Entrance College-Level Math	Placement	0
	Pass Developmental Math	1
Math First Semester	Yes	1
	No	0

Note. Minus grades and D+ grades are not an option for any course. Plus grades and D grades are not an option for developmental mathematics courses.

Furthermore, students from the same cohort who place into the same level of developmental mathematics will not necessarily go through the developmental sequence at the same pace. Students achieve success at different rates and students enter the developmental mathematics sequence at different levels. For example, students in a particular Elementary Algebra course will consist of those students taking the course for the first time, some via placement others via passing developmental Arithmetic, while still others in the course will be taking Elementary Algebra for a second or third time due previously failing the course. Note, in this body of research successful mathematics remediation is a binary variable, only two outcomes identifying if the student successfully passes developmental mathematics successfully remediating into college-level mathematics or does not. For this particular study, how many times a student took a particular course before passing is not taken into consideration.

Control Variables

In addition, this body of work includes a number of student-level and high school-level control variables found in previous research to be significant when referring to successful developmental mathematics remediation, passing college-level courses or obtaining a degree or certificate (Bahr, 2007, 2008, 2010; Burley et al., 2001; Levin & Calcagno, 2008; Chen & DesJardins, 2008; Crosta, Bailey & Jenkins, 2006; Hagedorn et al. 2010; Hoyt 1999; Koski & Levin, 1998; Kowski, 2013; Kreysa, 2006; Parsad, et al., 2003; Roueche & Roueche, 1999). Student-level control variables considered within the hierarchical generalized linear model are gender, race/ethnicity, English competency at college entry, and financial aid status. English courses, similar to the mathematics courses, are categorized and coded in terms of the two combined developmental reading and writing levels and college-level English I. Among the HGLM high school-level control variables included are the District Factor Group (DFG), high school rank (out of 322 New Jersey public high schools) , grade-twelve enrollment, average combined scholastic assessment test (SAT) score (maximum value 2400), and percent advanced mathematics proficiency on the New Jersey high school proficiency assessment (HSPA) (New Jersey Monthly, 2010).

The vocational public high schools have a separate ranking based on the 35 vocational public high schools in New Jersey (New Jersey Monthly, 2012). Therefore to put all New Jersey public high schools within the same ranking list, the vocational high school ranking was proportionally adapted to an equivalent value out of 322. For example, Warren County Technical School is ranked 18 out of 35 which is proportionally equivalent to 166 out of 322. Also for the vocational high schools, since there is no DFG listing, the DFG assigned was the same as the corresponding public high school DFG. Therefore, Warren County Technical School was assigned DFG FG, the same as Warren Hills Regional High School.

The DFGs are determined from the following six areas (State of New Jersey: Department of Education, 2004):

1. Percent of adults with no high school diploma
2. Percent of adults with some college education
3. Occupational status
4. Unemployment rate
5. Percent of individuals in poverty
6. Median family income

Refer to Tables 3.2 and 3.3 for the coding of the binomial variables and ordinal variables such as gender, English competency, financial aid status, and DFG.

Interactions

Finally in terms of independent variables, based on findings in the literature, a number of interactions are examined, along with any applicable three-way interactions (Adelman, 1999; Adelman, 2004; Bailey, et al., 2010; Chen & DesJardins, 2008; Fike & Fike, 2008; Hoyt, 1999; Illich, Hagan & McCallister, 2004; Johnson & Kuennen, 2004).

TABLE 3.2
Coding of Data - Binomial, Nominal and Ordinal Control Variables

Variable	Detail	Coding
English Placement Level	Intro College Read & Comp 1	1 0 0
	Intro College Read & Comp 2	0 1 0
	College-Level English I	0 0 0
Developmental English	Yes	1
	No	0
Race/Ethnicity	Hispanic	1
	American Indian	2
	Asian	3
	African American	4
	Pacific Islander	5
	Caucasian	6
	Two or More Races	7
	Non-Resident Alien	8
	Unknown	9
Race Dummy-Coded	Hispanic	1 0 0 0
	African American	0 1 0 0
	Caucasian	0 0 0 1
	Other	0 0 0 0

Note. Introduction to College Reading and Composition 1 and 2 are both developmental English courses, equaling a maximum of two semesters of developmental English.

According to the literature, the socioeconomic status (SES) of the student has various interactions with the variables being examined in this study. Since there is no access to the student’s household income in the Banner database system, for this study each student’s SES is defined according the DFG of the high school from which he or she graduated. Also, for those interactions between the HGLM high school level-2 predictors and student level-1 predictors, Zhang and Willson (2006) advise when looking at interactions between the two levels to bring the high school level-2 variable down to the student level-1 model.

TABLE 3.3
Coding of Data - Nominal Control Variables

Variable	Detail	Dummy Coding
Gender	Male	1
	Female	0
Financial Aid	Pell	
	Grants (other than Pell)	Yes 1
	Loans	No 0
	Work-Study	
DFG	High	1 0 0
	Medium	0 1 0
	Low	0 0 0
DFG	J	1 0 0 0 0 0 0
	I	0 1 0 0 0 0 0
	GH	0 0 1 0 0 0 0
	FG	0 0 0 1 0 0 0
	DE	0 0 0 0 1 0 0
	CD	0 0 0 0 0 1 0
	B	0 0 0 0 0 0 1
	A	0 0 0 0 0 0 0

Note: A student may be awarded more than one type of financial aid, thus coded 1 for each type of financial aid awarded. The group coded all zeros is the reference group. DFGs A and B are identified as low; DFGs I and J are identified as high.

The most prevalent interaction found in the literature was for developmental mathematics students who also required developmental English, developmental reading and/or writing (Bahr, 2007; Bailey, et al., 2010; Fike & Fike, 2008; Hoyt, 1999). Fike and Fike (2008) found that students who completed both a developmental reading course and a developmental mathematics course had a higher probability of academic success. They found that the strongest predictor for successful mathematics remediation was passing a developmental reading course. Much of the literature supports these findings. For developmental mathematics students also requiring developmental English in reading, writing and/or comprehension, their probability of success in their first developmental mathematics course is significantly reduced. For college freshmen, the greater the developmental English deficiency, the less likely for successful remediation in developmental mathematics (Bahr, 2007; Bailey, et al., 2010; Fike & Fike, 2008; Hoyt, 1999). In addition, Bahr (2007) found that the significance of developmental English on developmental mathematics varies with respect to developmental mathematics deficiency. The lower a student’s mathematics placement level, the less detrimental effect the lack of English competency will have on successful mathematics remediation, i.e. the effect of a student’s additional deficiencies in English reading and comprehension are lessened when in the presence of extreme mathematics insufficiencies (Bahr, 2007).

One apparent interaction noted in much of the literature is between socioeconomic status (SES), as identified in this study by district factor group (DFG), and financial aid (Adelman, 1999; Bailey, et al., 2010; Chen & DesJardins, 2008). Regardless of the type of financial aid, there are regularly higher rates of dropout and consequently unsuccessful mathematics remediation for students from low-income families. The likelihood of not remediating successfully and dropping out for students from low-income families is greater than students from middle-income families whose odds are greater than students from upper-income families (Adelman, 1999; Bailey, et al., 2010; Chen & DesJardins, 2008). Yet not all financial aid affects successful remediation equally. Chen & DesJardins (2008) found that financial aid benefits vary depending on the type of financial combined with the student's family income level. For instance, compared to students from upper-income families, students from lower-income families benefit more from Pell grants, but show no beneficial differences from receiving federal loans or work-study awards. The receipt of a Pell grant has been found to reduce the probability of dropping for those with the greatest need, whereas loans and work-study awards have the same academic benefit regardless of family income levels (Adelman, 1999; Bailey, et al., 2010; Chen & DesJardins, 2008).

Another interaction discussed in the literature is student ethnicity and SES in conjunction with its relationship to postsecondary developmental education. Students graduating from large, urban high schools, with predominantly minorities and low-income populations have been revealed persisting at significantly lower rates than high schools of different student populations. Of these high school graduates requiring postsecondary developmental education, they were found to be less likely to successfully remediate than developmental education students who graduated from non-minority middle- and upper-income level high schools (Adelman, 2004; Bailey, et al., 2010; Hagedorn & Lester, 2006). In terms of the proportion of those requiring developmental education, entering freshmen of both African-American and Hispanic descent had a greater proportion of developmental education students than any other race/ethnicity groups. In addition, students from inner-city high schools more often began college in developmental mathematics and or English compared to students from suburban and rural high schools (Adelman, 2004; Bailey, et al., 2010; Hagedorn & Lester, 2006).

An additional group of interactions found in the literature concern gender (Bailey, et al., 2010; Hoyt, 1999; Johnson & Kuennen, 2004). Johnson and Kuennen (2004) discovered that "men are significantly more likely to delay taking developmental mathematics than women, despite the fact that there is no significant difference between males and females in terms of who places into developmental mathematics". Bailey, et al. (2010) found that men and African Americans were less likely to successfully remediate through the postsecondary developmental education sequence than women and Caucasian students. Finally, Hoyt (1999) found relevance of SES dependent on gender. Socioeconomic status was significant for females, but not as significant for males.

The last interaction to be included in this study covered in the literature discusses successful remediation and semester GPA of college-level courses (Hoyt, 1999; Illich, et al., 2004; Johnson & Kuennen, 2004). Hoyt (1999) found that non-developmental education students' first semester GPA was higher than developmental education students, with most developmental education students earning only C-grades in their college-level courses. Furthermore, he found that the first-semester GPA significantly decreased as the number of subject areas and/or number of semesters of developmental education requirements increased, with the lowest first semester GPA for students deficient in all areas (mathematics, reading, writing, and comprehension) (Hoyt, 1999). Illich, et al. (2004) confirming these results, found that developmental education students also enrolled in college-level courses exhibited lower pass rates in their college-level courses than students who either successfully remediated before taking in college-level courses, or did not require any developmental education. Finally, in a more directed study concerning developmental mathematics and college-level microeconomics, Johnson and Kuennen (2004) found that students who did not take or pass their developmental mathematics courses before taking college-level microeconomics were not as successful in the course as those who remediated first or did not require any developmental mathematics. Students who completed their developmental mathematics requirements before taking microeconomics performed better in microeconomics than students who also required developmental mathematics but did not successfully remediate before enrolling into the microeconomics course (Johnson and Kuennen, 2004). Overall, students who are college-ready either directly from high school or after developmental education significantly increase their likelihood of academic success. Students who fail their developmental courses even if the developmental course is not a prerequisite course, do not achieve the same level of academic success as those students who first pass their developmental courses and then enroll in their college-level courses, regardless of whether or not the developmental course is a prerequisite for the college-level course (Hoyt, 1999; Illich, et al., 2004; Johnson & Kuennen, 2004).

Data Analysis

Descriptive statistics of each student cohort, displayed in two-way or three-way contingency tables, are provided to describe each variable to get a comprehensive statistical description of the data, along with characterizing the relationship between the various explanatory and control variables with developmental mathematics.

To model successful mathematics remediation as defined by earning a grade of C or better in college-level mathematics, hierarchical generalized linear modeling, specifically multilevel logistic regression for the Bernoulli case was run on both the 2009 and 2010 student cohort data set to estimate the associations both within the explanatory and control variables as well as between the explanatory and control variables, and the dependent variable earning a grade of C or better in college-level mathematics. Additional dependent variables investigate successful mathematics remediation and graduating with a credential. The hierarchical generalized linear model fit is evaluated using estimates for the unit-specific models. Each model estimates the associations both within the explanatory and control variables as well as between the explanatory and control variables, and each dependent variable, successful mathematics remediation, earning a grade of C or better in college-level mathematics, and graduating with a credential.

CHAPTER IV. RESULTS

In this chapter, a detailed discussion is given of the results obtained following the application of the methodology outlined in chapter 3. Specific descriptive statistics are provided for the various criterion cohorts. This includes both the student-level and high school-level hierarchical generalized linear model (HGLM) predictors along with the three outcome variables. Results from the HGLM on both the 2009 and 2010 cohorts are then presented, as well as interpretation of the individual parameter estimates and model fit.

Cohort Criteria

Two groups of student data were obtained for this body of research. Initially included in this study was any student who graduated from any high school June 2009 or June 2010 and started attending the suburban New Jersey community college being studied as a fulltime student fall 2009 or fall 2010, respectively. Due to the HGLM methodology outlined in chapter 3 for this body of research, certain high school criteria needed to be enacted with the aim of diminishing confounding results.

Inclusion Criteria

As described in chapter 3, the HGLM methodology utilized in this body of research allows clustering of the students attending the community college of this study by the high school from which they graduated. The level-2 high school predictor variables for inclusion in the model are the district factor group (DFG), high school rank (out of 322 high schools), grade twelve enrollment, average combined scholastic assessment test (SAT) score (maximum value 2400), and percent advanced mathematics proficiency on the New Jersey high school proficiency assessment (HSPA). Since this information is only obtainable for New Jersey public high schools and to include each of these high school level-2 predictor variables, the data set considered for this study was limited to those students who graduated from a New Jersey public high school (Figure 4.1). Removal of students who graduated from an unknown (possibly home-schooled students), out-of-state, or foreign high school resulted in a 2.1 percent and 2.5 percent reduction for the 2009 and 2010 cohorts, respectively. Since there was not enough variability with regards to the private schools to include them in the model, focusing solely on New Jersey public high schools, further reducing the data by 1.9 and 3.5 percent for the 2009 and 2010 cohorts respectively, gives rise to a more robust analysis.

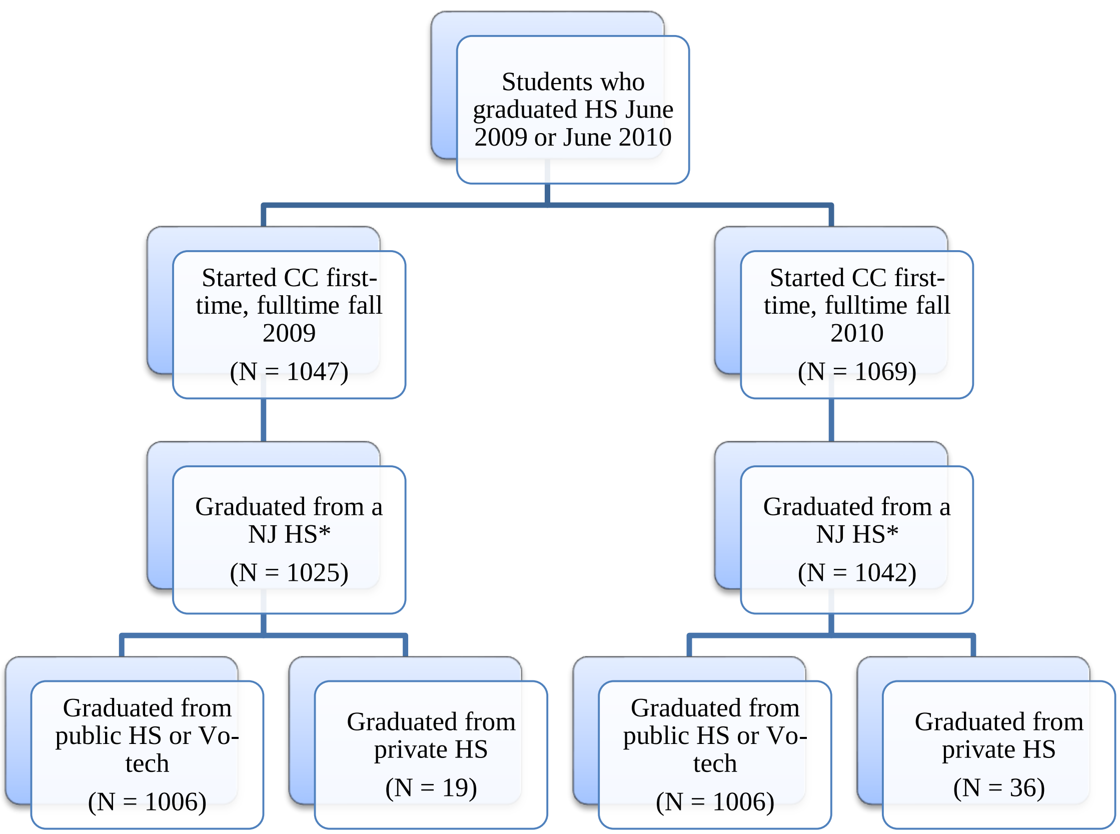

Figure 4.1. Inclusion criteria. Students whose high school was listed as unknown (possibly home-schooled), out-of-state, or foreign, were removed from the study.

Furthermore, since most of the high school level-2 variables information is not available for private schools, including students who graduated from private high schools would have required using the average public high school values for the missing private high school level-2 variables. Hence, whatever model developed would clearly be more applicable to students who graduated from public high schools than private high schools. Therefore, after first verifying and running each initial analysis with and without including students who graduated from private high schools and seeing no statistically significant differences, continued analyses investigated only those groups of students who graduated from a New Jersey public high school June 2009 or June 2010 and attended the community college of this study first-time, full-time either fall 2009 or fall 2010, respectively.

Analysis Criteria

To fully address the research questions posed, the HGLM outcomes being investigated in this study are successful mathematics remediation, earning a grade of C or better in college-level mathematics, and graduating with a credential from the community college of this study. Therefore, the two cohorts of students who graduated from any New Jersey public high school either June 2009 or June 2010 and started attending community college fulltime fall 2009 or fall 2010 respectively, obtained from the inclusion criteria above in Figure 4.1 were further parceled down into three different subsets; those students who took a mathematics course (developmental or college-level) while attending the community college, those students, via placement, who started out in developmental mathematics, and those students who took a college-level mathematics course, via placement or successful mathematics remediation (Figure 4.2). For the 2009 cohort, of the 585 students enrolled into college-level mathematics, 319 (54.5 percent) entered by passing developmental mathematics first. Whereas for the 2010 cohort, of the 531 students enrolled into college-level mathematics, 275 (51.8 percent) entered by passing developmental mathematics first. For both cohorts a little more than half the students talking college-level mathematics successfully remediated into the course.

Descriptive Statistics

2009 Cohort

A summary description of each 2009 cohort analysis group (students who took any mathematics course, students who started in developmental mathematics, and students who took a college-level mathematics course) is provided in Tables 4.1, 4.2 and 4.3, respectively. Regardless of the subset, students in the sample placed into Elementary Algebra more than any other mathematics course. This implies that students attending

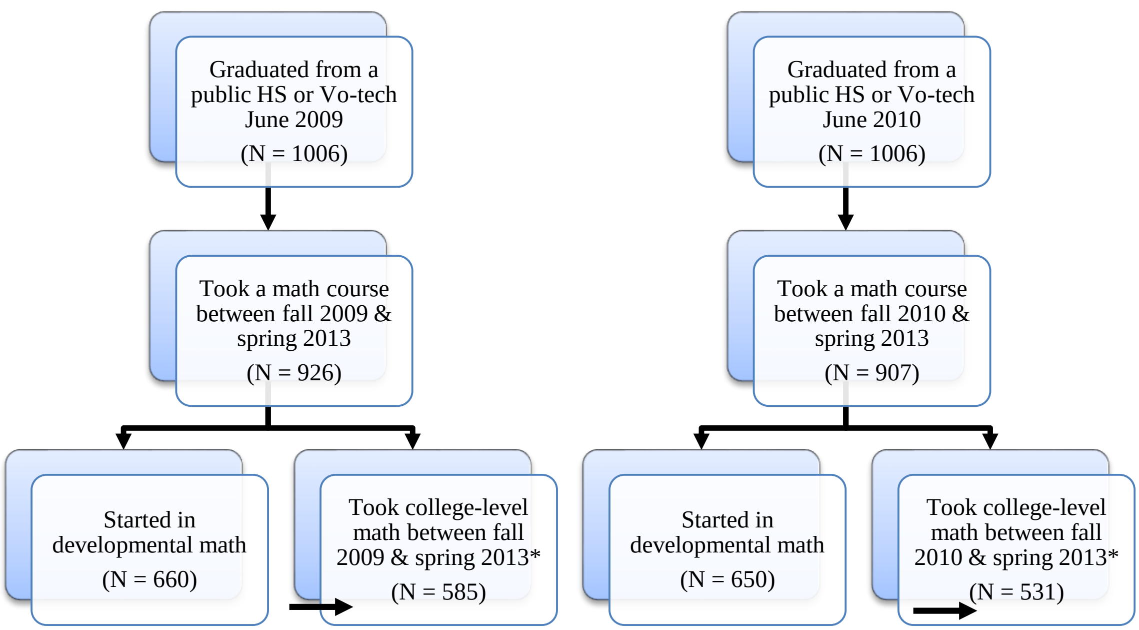

Figure 4.2. Analysis criteria. Students who took a college-level mathematics course include those who placed into college-level mathematics as well as those who started in developmental mathematics and successfully remediated into college-level mathematics.

this community college directly out of high school are not college-ready in mathematics, requiring one to two semesters of postsecondary developmental mathematics (non-STEM (science, technology, engineering, mathematics) versus STEM majors, respectively). Descriptive statistics in regards to ethnicity and financial aid, find more than half the

TABLE 4.1
Descriptive Statistics - Students Who Took Any Mathematics Course (2009)

Variable	Label	n	%
First Mathematics Course	STEM College-Level	160	17.3
	Non-STEM College-Level	106	11.4
	Intermediate Algebra	171	18.5
	Elementary Algebra	374	40.4
	Arithmetic	115	12.4
English Placement	College-Level English I	792	85.5
	Intro College Read & Comp 2	107	11.6
	Intro College Read & Comp 1	27	2.9
Gender	Male	515	55.6
	Female	411	44.4
Race/Ethnicity	Caucasian	580	62.6
	Hispanic	125	13.5
	Unknown	99	10.7
	African American	55	5.9
	Asian	37	4.0
	Non-Resident Alien	16	1.7
	Two or More Races	6	0.6
	American Indian	4	0.4
	Pacific Islander	4	0.4
Financial Aid	Pell	272	29.4
	Grants (other than Pell)	262	28.4
	Loans	131	14.1
	Work-Study	8	0.9
	None	530	57.2

Note. Non-STEM mathematics courses are Number Systems, Quantitative Literacy, Problem Solving Strategies, and Finite Mathematics. STEM mathematics courses are Statistics, Precalculus, and Calculus. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 926.

students sampled are Caucasian and not receiving financial aid. An overall synopsis of for the 2009 cohort, regardless of the subset, is that most are Caucasian male students not awarded any financial aid, requiring developmental mathematics, specifically Elementary Algebra, but not requiring any developmental English.

Table 4.4 illustrates descriptive statistics for those students who began their postsecondary education fall 2009, took at least one mathematics course, and graduated

TABLE 4.2
Descriptive Statistics - Students Who Started in Developmental Mathematics (2009)

Variable	Label	n	%
Dev Math Placement	Intermediate Algebra	173	26.2
	Elementary Algebra	374	56.7
	Arithmetic	113	17.1
English Placement	College-Level English I	536	81.2
	Intro College Read & Comp 2	100	15.2
	Intro College Read & Comp 1	24	3.6
Gender	Male	348	52.7
	Female	312	47.3
Race/Ethnicity	Caucasian	394	59.7
	Hispanic	94	14.2
	Unknown	72	10.9
	African American	52	7.9
	Asian	24	3.6
	Non-Resident Alien	12	1.8
	Two or More Races	5	0.8
	Pacific Islander	4	0.6
	American Indian	3	0.5
Financial Aid	Pell	207	31.4
	Grants (other than Pell)	183	27.7
	Loans	100	15.2
	Work-Study	6	0.9
	None	369	55.9

Note. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 660.

by spring 2013. Of the 926 students took a mathematics course between fall 2009 and spring 2013, almost more than two-thirds started in developmental mathematics. Of those students who started in developmental mathematics, only about half took a college-level mathematics course. Overall based on the descriptive statistics, the greater the developmental mathematics deficiency the less likely that the student will successfully

TABLE 4.3

Descriptive Statistics - Students Who Took College-Level Mathematics (2009)

Variable	Label	n	%
Developmental Math	None	266	45.5
	Intermediate Algebra	124	21.2
	Elementary Algebra	175	29.9
	Arithmetic	20	3.4
Developmental English	None	535	91.4
	Intro College Read & Comp 2	43	7.4
	Intro College Read & Comp 1	7	1.2
Gender	Male	327	55.9
	Female	258	44.1
Race/Ethnicity	Caucasian	390	66.7
	Hispanic	73	12.5
	Unknown	60	10.3
	Asian	26	4.4
	African American	19	3.2
	Non-Resident Alien	9	1.5
	Pacific Islander	3	0.5
	Two or More Races	3	0.5
	American Indian	2	0.3
Financial Aid	Pell	167	28.5
	Grants (other than Pell)	211	36.1
	Loans	83	14.2
	Work-Study	7	1.2
	None	330	56.4

Note. This includes those students who entered college-level mathematics via placement and those who entered via passing prerequisite developmental mathematics. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 585.

remediate into college-level mathematics.

With respect to earning a grade of C or better in college-level mathematics, once a developmental mathematics student successfully remediates the pass rates are as favorable as those students who entered college-level mathematics without the need for remediation (Table 4.4). Unfortunately many developmental mathematics students do not successfully remediate and enter college-level mathematics, the worst scenario for those starting in the lowest developmental level, Arithmetic. Lastly, with reference to graduating, the results are less promising for developmental mathematics students. Table 4.4 shows descriptive statistics concerning developmental mathematics students earning a grade of C or better in college-level mathematics and graduation. Based on the descriptive statistics for this cohort, the greater the developmental mathematics

TABLE 4.4
Descriptive Statistics - Students in College-Level Mathematics and Graduation (2009)

Earning a grade of C or better in College-Level Mathematics

Developmental Math Requirements	n (grade ≥ C)	n (take) C-L Math	%	n (take) Math	%
None	220	265	83.0	265	83.0
Intermediate Algebra	97	125	77.6	172	56.4
Elementary Algebra	123	174	70.7	374	32.9
Arithmetic	19	21	90.5	115	16.5

Earning a Credential

Developmental Math Requirements	n (graduate)	n (take) C-L Math	%	n (take) Math	%
None	118	265	44.5	265	44.5
Intermediate Algebra	49	125	39.2	172	28.4
Elementary Algebra	74	174	42.5	374	19.8
Arithmetic	13	21	61.9	115	11.3

Note. College-level mathematics sample size is 585. Any mathematics sample size is 926. Non-graduation rates include those both those who discontinue their postsecondary education and those who transfer to another institution before earning a credential.

deficiency, the less likely a student is to graduate.

Descriptive statistics for the hierarchical generalized linear modeling (HGLM) level-2 high school variables for the 2009 students who started first-time, fulltime and took any mathematics course (combined total of students who started in developmental and college-level), started in developmental mathematics, or took any college-level mathematics course (combined total of students who placed into college-level and those who remediated into college-level) are displayed in Figure 4.3 and Table 4.5. Looking at the DFG, regardless of the subset, approximately one-third of students attending this community college are from a DFG I high school, the second highest DFG high school classification. There are no students who come from the lowest DFG A high school.

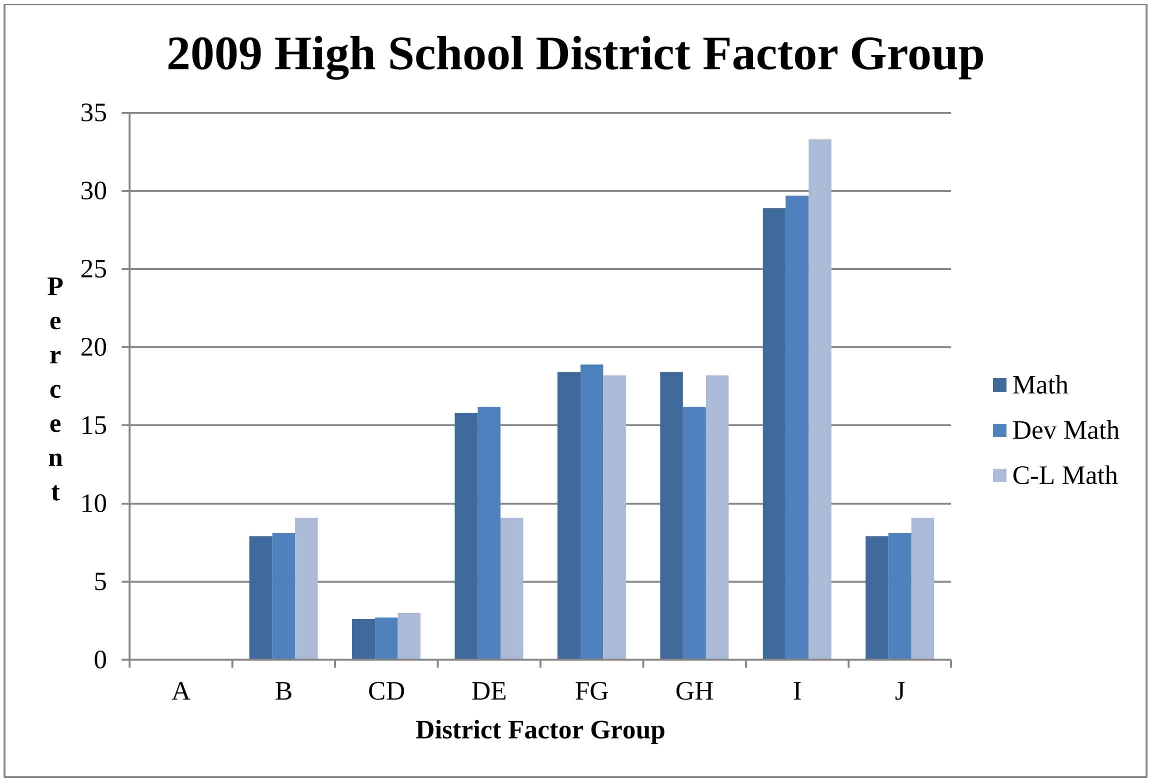

Figure 4.3. High school DFG 2009 cohort. Math: students who took any mathematics course, developmental or college-level. Dev Math: students who required developmental mathematics. C-L Math: students who took any college-level mathematics course.

Considering the bi-county community college studied in this body of research services one of the wealthiest counties in New Jersey, the distribution of DFGs in Figure 4.3 is to be expected.

Table 4.5 reveals the descriptive statistics for the other high school variables (high school ranking, grade-twelve enrollment, combined Scholastic Assessment Test (SAT) score, and advanced-mathematics proficiency on the New Jersey High School

TABLE 4.5
Descriptive Statistics - High School HLM Level-2 (2009)

High School Rank (out of 322)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	38	133.4	14.4	88.7	121.0	5	307
Dev Math	37	133.6	14.8	89.9	115.0	5	307
C-Level	33	127.3	15.4	88.2	110.0	5	307

Grade 12 Enrollment

Cohort Subset	n	mean	SE	SD	median	min	max
Math	38	300.8	27.9	171.8	323.0	36	669
Dev Math	37	296.9	28.4	172.5	313.0	36	669
C-Level	33	307.9	30.2	173.3	333.0	36	669

High School Average Combined SAT Score (maximum value 2400)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	38	1539.0	24.8	153.1	1543.5	1156	1782
Dev Math	37	1536.6	25.4	154.5	1538.0	1156	1782
C-Level	33	1554.0	25.7	147.7	1579.0	1156	1782

HSPA Advanced Mathematics Proficiency (percent)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	38	27.2	2.6	15.8	24.5	0	56
Dev Math	37	27.0	2.6	16.0	23.0	0	56
C-Level	33	28.3	2.8	16.1	26.0	2	56

Note. High school data for students who started first time, fulltime fall 2009.

Proficiency Assessment (HSPA)) included in this study. The sample size indicates the number of New Jersey public high schools represented in each grouping. The high school ranking is out of the 322 New Jersey public high schools. Higher ranking is reflected in lower numerical values (New Jersey Monthly, 2010). Since the New Jersey Monthly (2010) high school rating report is based on the combined Scholastic Assessment Test (SAT) score, this score is used rather than the individual mathematics SAT score. The advanced-mathematics proficiency on the High School Proficiency Assessment (HSPA) is in terms of percentage of grade-eleven students in the high school who took the test.

Due to the location of the community college employed for this research, the majority of students come from high schools of higher DFGs, with higher state ranking and above average test scores. Only a minority of students come from high schools of lower DFGs and subsequent lower ranking and test scores, making much of the aggregate data skewed. Therefore in relation to generalities based on the descriptive statistics, median may be better measure of central tendency.

2010 Cohort

A summary description of each 2010 cohort analysis group (students who took any mathematics course, students who started in developmental mathematics, and students who took a college-level mathematics course) is provided in Tables 4.6, 4.7 and 4.8, respectively. Parallel with the 2009 cohort, regardless of the subset, students in the sample placed into Elementary Algebra more than any other mathematics course, implying that students attending this community college directly out of high school are not college-ready in mathematics. Once again descriptive statistics in regards to ethnicity and financial aid, find more than half the students sampled are Caucasian and not awarded financial aid. An overall synopsis of for the 2010 cohort, regardless of the subset, is that most are Caucasian male students not awarded any financial aid, requiring developmental mathematics, specifically Elementary Algebra, but not requiring any developmental English.

TABLE 4.6
Descriptive Statistics - Students Who Took Any Mathematics Course (2010)

Variable	Label	n	%
First Mathematics Course	STEM College-Level	141	15.5
	Non-STEM College-Level	116	12.8
	Intermediate Algebra	141	15.5
	Elementary Algebra	417	46.0
	Arithmetic	92	10.1
English Placement	College-Level English I	659	72.7
	Intro College Read & Comp 2	194	21.4
	Intro College Read & Comp 1	54	6.0
Gender	Male	479	52.8
	Female	428	47.2
Race/Ethnicity	Caucasian	556	61.3
	Hispanic	157	17.3
	African American	80	8.8
	Unknown	44	4.9
	Asian	40	4.4
	Two or More Races	18	2.0
	Non-Resident Alien	10	1.1
	American Indian	1	0.1
	Pacific Islander	1	0.1
Financial Aid	Pell	303	33.4
	Grants (other than Pell)	250	27.6
	Loans	145	16.0
	Work-Study	11	1.2
	None	486	53.6

Note. Non-STEM mathematics courses are Number Systems, Quantitative Literacy, Problem Solving Strategies, and Finite Mathematics. STEM mathematics courses are Statistics, Precalculus, and Calculus. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 907.

Table 4.9 illustrates descriptive statistics for those students who began their postsecondary education fall 2010, took at least one mathematics course, and graduated by spring 2013. Of the 907 students took a mathematics course between fall 2010 and spring 2013, almost more than two-thirds started in developmental mathematics. Of those students who started in developmental mathematics, less than half took a college-level mathematics course. Overall based on the descriptive statistics, the greater the

TABLE 4.7
Descriptive Statistics - 2010 Students Who Started in Developmental Mathematics

Variable	Label	n	%
Dev Math Placement	Intermediate Algebra	141	21.7
	Elementary Algebra	417	64.2
	Arithmetic	92	14.2
English Placement	College-Level English I	430	66.2
	Intro College Read & Comp 2	168	25.8
	Intro College Read & Comp 1	52	8.0
Gender	Male	316	48.6
	Female	334	51.4
Race/Ethnicity	Caucasian	379	58.3
	Hispanic	124	19.1
	African American	70	10.8
	Unknown	31	4.8
	Asian	24	3.7
	Two or More Races	11	1.7
	Non-Resident Alien	10	1.5
	American Indian	1	0.2
	Pacific Islander	0	0.0
Financial Aid	Pell	237	36.5
	Grants (other than Pell)	182	28.0
	Loans	102	15.7
	Work-Study	10	1.5
	None	336	51.7

Note. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 650.

developmental mathematics deficiency the less likely that the student will successfully remediate into college-level mathematics.

On the other hand, with respect to earning a grade of C or better in college-level mathematics, once a developmental mathematics student successfully remediates the pass rates are as favorable as those students who entered college-level mathematics without

TABLE 4.8
Descriptive Statistics - Students Who Took College-Level Mathematics (2010)

Variable	Label	n	%
Developmental Math	None	256	48.2
	Intermediate Algebra	97	18.3
	Elementary Algebra	168	31.6
	Arithmetic	10	1.9
Developmental English	None	441	83.1
	Intro College Read & Comp 2	82	15.4
	Intro College Read & Comp 1	8	1.5
Gender	Male	285	53.7
	Female	246	46.3
Race/Ethnicity	Caucasian	341	64.2
	Hispanic	84	15.8
	Asian	32	6.0
	Unknown	31	5.8
	African American	25	4.7
	Two or More Races	13	2.4
	Non-Resident Alien	3	0.6
	Pacific Islander	1	0.2
	American Indian	1	0.2
Financial Aid	Pell	168	31.6
	Grants (other than Pell)	156	29.4
	Loans	82	15.4
	Work-Study	8	1.5
	None	291	54.8

Note. This includes those students who entered college-level mathematics via placement and those who entered via passing prerequisite developmental mathematics. Students may receive more than one type of financial aid, thus percentages for aid and no aid total greater than 100. Sample size = 531.

the need for remediation. Unfortunately many developmental mathematics students do not successfully remediate and enter college-level mathematics, the worst scenario for those starting in the lowest developmental level, Arithmetic. Lastly, with reference to graduating, the results are less optimistic for developmental mathematics students. Based on the descriptive statistics for this cohort, the greater the developmental mathematics deficiency, the less likely a student is to graduate.

Descriptive statistics for the hierarchical generalized linear modeling (HGLM) level-2 high school variables for the 2010 students who started first-time, fulltime and took any mathematics course (combined total of students who started in developmental and college-level), started in developmental mathematics, or took any college-level mathematics course (combined total of students who placed into college-level and those

TABLE 4.9
Descriptive Statistics - Students in College-Level Mathematics and Graduation (2010)

Earning a grade of C or better in College-Level Mathematics

Developmental Math Requirements	n (grade ≥ C)	n (take) C-L Math	%	n (take) Math	%
None	202	256	78.9	256	78.9
Intermediate Algebra	77	98	78.6	141	54.6
Elementary Algebra	109	165	66.1	418	26.1
Arithmetic	7	12	58.3	92	7.6

Earning a Credential

Developmental Math Requirements	n (graduate)	n (take) C-L Math	%	n (take) Math	%
None	80	256	31.3	256	31.3
Intermediate Algebra	27	98	27.6	141	19.1
Elementary Algebra	58	165	35.2	418	13.9
Arithmetic	6	12	50.0	92	6.5

Note. College-level mathematics sample size is 531. Any mathematics sample size is 907. Non-graduation rates include those both those who discontinue their postsecondary education and those who transfer to another institution before earning a credential.

who remediated into college-level) are displayed in Figure 4.4 and Table 4.10. Once again, regardless of the subset, approximately one-third of students attending this community college are from a DFG I high school, the second highest DFG high school classification, while less than half that amount, less than 15 percent come from the two lowest district factor groups (DFG A or B). Considering the bi-county community college studied in this body of research services one of the wealthiest counties in New Jersey, the distribution of DFGs in Figure 4.4 is to be expected.

Table 4.10 reveals the descriptive statistics for the other high school variables (high school ranking, grade-twelve enrollment, combined Scholastic Assessment Test (SAT) score, and advanced-mathematics proficiency on the New Jersey High School Proficiency Assessment (HSPA)) included in this study. The sample size indicates the

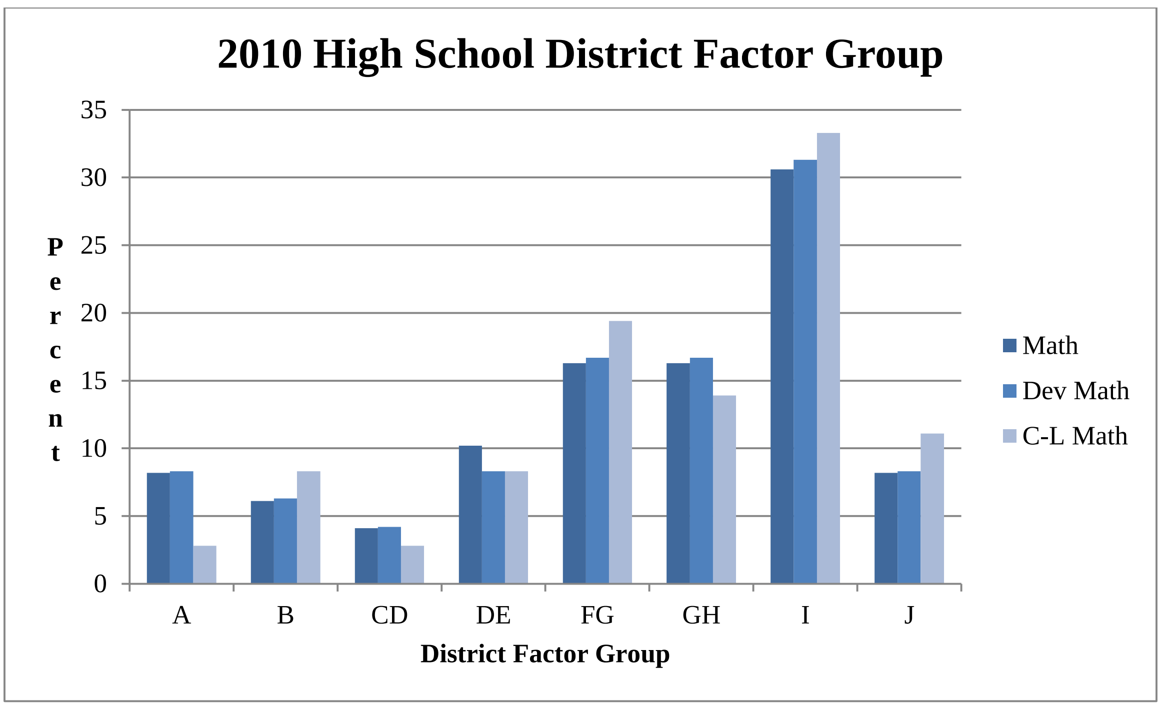

Figure 4.4. High school DFG 2010 cohort. Math: students who took any mathematics course, developmental or college-level. Dev Math: students who required developmental mathematics. C-L Math: students who took any college-level mathematics course.

number of New Jersey public high schools represented in each grouping. The high school ranking is out of the 322 New Jersey public high schools. Higher ranking is reflected in lower numerical values (New Jersey Monthly, 2010). Since the New Jersey Monthly (2010) high school rating report is based on the combined Scholastic Assessment Test (SAT) score, this score is used rather than the individual mathematics SAT score. The advanced-mathematics proficiency on the High School Proficiency Assessment (HSPA) is in terms of percentage of grade-eleven students in the high school who took the test.

TABLE 4.10
Descriptive Statistics –High School HLM Level-2 (2010)

High School Rank (out of 322)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	49	135.5	13.8	96.6	108.0	5	318
Dev Math	48	133.1	13.9	96.1	98.5	5	318
C-Level	36	126.2	15.3	91.5	88.5	5	307

Grade 12 Enrollment

Cohort Subset	n	mean	SE	SD	median	min	max
Math	49	320.7	26.0	181.7	313.0	36	711
Dev Math	48	325.0	26.1	181.1	315.0	36	711
C-Level	36	318.8	33.1	198.6	275.0	36	711

High School Average Combined SAT Score (maximum value 2400)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	49	1525.4	26.1	183.0	1538.0	1058	1782
Dev Math	48	1526.6	26.7	184.7	1550.5	1058	1782
C-Level	36	1558.9	26.5	158.8	1580.0	1156	1782

HSPA Advanced Mathematics Proficiency (percent)

Cohort Subset	n	mean	SE	SD	median	min	max
Math	49	27.6	2.4	16.5	27.0	1	56
Dev Math	48	27.9	2.4	16.6	28.5	1	56
C-Level	36	30.0	2.7	16.2	33.0	2	56

Note. High school data for students who started first time, fulltime fall 2010.

As noted when discussing the high school level-2 variables for the 2009 cohort, due to the location of the community college in this research, the majority of students come from high schools of higher DFGs, with upper ranking and above average test scores. Only a minority of students come from high schools of lower DFGs and subsequent lower ranking and test scores, making much of the aggregate data skewed. Therefore in relation to generalities based on the descriptive statistics, median may be a better measure of central tendency.

Hierarchical Generalized Linear Modeling (HGLM)

As previously discussed, in this study HGLM is used to compare the long-term academic outcomes of traditional age (directly out of high school) first time in college (FTIC) students attending a New Jersey, *Achieving the Dream* (ATD) community college. HGLM, a multi-level logistic regression model corresponding to the various student and high school level predictors within each community college cohort, is used to model the natural logarithmic ratio of success to failure which can then be converted to the probability of success for each binomial outcome (remediate successfully, earn a grade of C or better in college-level mathematics, or graduate) (Raudenbush & Bryk, 2002). The basic concepts underlying HGLM analysis are reviewed to reorient the reader to the methodology.

HGLM yields "estimates for both the unit-specific and population-average models. Unit-specific models model the expected outcome for a level-2 unit conditional on a given set of random effects" (Raudenbush, et al., 2011, p. 118). For example, in the Bernoulli case (m_{ij} = 1), the generic level-1(within-school) model is:

$$\eta_{ij} = \beta_{0j} + \beta_{qj}X_{ij} \tag{4.1}$$

and a generic level-2 (between-school) model is:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}W_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} \qquad (4.2)$$

where η_{ij} is the log of the odds of success and γ_{10} is the expected difference in the log-odds of success between two students who attend the same school but differ by one unit on *X* (holding u_{0j} constant); γ_{01} is the expected difference in the log-odds of success between two students who have the same value on *W* but attend schools differing by one unit on *W* (holding u_{0j} constant) (Raudenbush, et al., 2011, p. 118). Population-average models look at the average difference between log-odds of success of students having the same *X* but attending schools differing by one unit on *W*, that is, "the difference of interest *averaging over all possible values of* u_{0j}." (Raudenbush, et al., 2011, p. 118). For this study the interest lies in students who differ on *X*, therefore HGLM models reported are *unit-specific* rather than *population-average*.

In addition, HGLM produces robust standard error estimates for the both the unit-specific and population-average models (Raudenbush, et al., 2011; Zeger, et al, 1988). These standard errors are somewhat unaffected to misspecification of the variances and covariances at the two levels and to the distributional assumptions at each level, i.e. robust standard errors are consistent even when the assumptions of normality, linearity and homogeneity are violated (Raudenbush, et al., 2011, p.129). Furthermore, robust standard errors are appropriate for datasets when the number of higher-level units (minimum of 33 high schools) is moderately large relative to the number of explanatory variables at that higher level (five high school-level variables) , i.e. degrees of freedom greater than 20, such as is the case for this body of research (Raudenbush, et al., 2011, p.144).

Process. To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. This model is used for calculating the intraclass correlation coefficient (ICC), “the usual test of whether multilevel modeling is needed” (Garson, 2009, p. 61). If the intercept is determined significant, then the ICC is also significant, “indicating that a multilevel model is appropriate and needed. At the extreme, when ICC approaches 0 or is negative, hierarchical modeling is not appropriate” (Garson, 2009, p. 64).

To uncover significant student level-1 variables devoid of confounding results, rather than entering all the student level-1 and high school level-2 independent variables together in one model, first an HGLM model was run with each student level-1 independent variable by itself. This enabled determining individual student level-1variable significance with regards to predicting a particular outcome. Once all significant student level-1 variables for a particular model were revealed, then those significant student level-1 variables were entered into the model together to determine if any were no longer significant with the presence of other significant student level-1 variables also in the model. Once the significant student level-1 variables were discovered, then each high school level-2 variable was entered into the model to determine its significance with respect to enhanced predictive probability of the outcome in question. These steps helped focus which variables should be considered together in addition to any follow up interactions. (Bickel, 2007; Garson, 2009; Goldstein, 1995;

Mertler & Vannatta, 2010; Raudenbush, et al., 2011; Raudenbush & Bryk, 2002; Zhang & Willson, 2006).

The last step, examining any interactions, was based on published literature and previously discussed in chapter 3 (Adelman, 1999; Adelman, 2004; Bailey, et al., 2010; Brambor, et al., 2006; Chen & DesJardins, 2008; Fike & Fike, 2008; Hoyt, 1999; Illich, Hagan & McCallister, 2004; Johnson & Kuennen, 2004). Therefore for each outcome, five tables are presented; one with each individual student level-1variable entered into the model, one with significant student level-1 variables entered together into the model, one with the set of significant student level-1 variables and each individual high school level-2 variable entered into the model, one with the set of significant student level-1and high school level-2 variables and literature-based interactions, and the final model with remaining significant variables and interactions.

HGLM 2009 Cohort

Outcome: Successful Mathematics Remediation

As previously discussed, many students start their postsecondary education in developmental mathematics, especially prevalent for community college students. The following HGLM investigation is for those students who graduated high school June 2009, took the Accuplacer® placement test summer 2009, and were placed into one of three levels of developmental mathematics: Arithmetic (MATH-013), Elementary Algebra (MATH-020) or Intermediate Algebra (MATH-030). Tables 4.11 through 4.15 are the HGLM results investigating which factors enhance or hinder a student's progress towards successful mathematics remediation. For this study, successful remediation means passing all developmental mathematics courses required with a grade of C or better, to enter college-level mathematics. For example, developmental mathematics students who want to take Statistics or Precalculus must pass the developmental sequence up through Intermediate Algebra. If the student started in Arithmetic, he or she would need to pass Arithmetic, Elementary Algebra, and Intermediate Algebra with a C or better to be considered successfully remediated. Remember for some students this means taking one developmental course and passing that course on the first try, while for other students this means taking more than one level of developmental mathematics and/or attempting a course more than once before passing with a grade of C or better.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant ($p < 0.001$), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the developmental mathematics students, with respect to successful mathematics remediation, when each student level-1variable is individually put into the HGLM model the only significant explanatory variables are the level of developmental mathematics at which the student started in reference to Arithmetic, and whether the student began his or her mathematics remediation the first semester of attendance, fall 2009. The significant control variables for this group are the student's gender, whether he or she received financial aid in the form of Pell or grants other than Pell, and whether the student required any level of developmental English in addition to developmental mathematics (Table 4.11).

Once all the individual significant student level-1 variables, i.e. the level of developmental mathematics in reference to Arithmetic, taking developmental mathematics the first semester of attendance, gender, financial aid in the form of Pell or grants other than Pell, and either level of developmental English, are entered together into the HGLM model with the outcome of passing the developmental mathematics sequence, developmental English is no longer significant (Table 4.12). In other words, once the other significant explanatory and control level-1 variables are in the model, developmental English no longer helps predict the comparative odds of whether or not a student starting in developmental mathematics will successfully remediate within four years of attendance.

The next steps for discovering what variables aid in predicting whether or not a developmental mathematics student will successfully remediate were to identify any significant high school level-2 variables along with any significant interactions of the

TABLE 4.11
HGLM Student Level-1 Variables: Successful Mathematics Remediation (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.370	0.188	622	0.050
RACE-WHITE	-0.008	0.180	620	0.967
RACE-BLACK	-0.462	0.256	620	0.072
RACE-HISPANIC	-0.171	0.229	620	0.456
PELL	-0.575	0.213	619	0.007
GRANT	0.571	0.278	619	0.040
LOAN	-0.198	0.229	619	0.388
WORK-STUDY	0.974	1.117	619	0.384
ENGL-050	-1.142	0.323	621	<0.001
ENGL-060	-0.581	0.212	621	0.006
MATH-1ST-SEMESTER	0.989	0.239	622	<0.001
MATH-020	1.585	0.268	621	<0.001
MATH-030	2.143	0.267	621	<0.001

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-020 is Elementary Algebra, MATH-030 is Intermediate Algebra, and Arithmetic (MATH-013) is the reference group, i.e. dummy-coded zero.

TABLE 4.12
HGLM Significant Student Level-1 Variables: Successful Mathematics Remediation (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 615)
GENDER	-0.635	0.223	0.005
PELL	-0.618	0.230	0.007
GRANT	0.684	0.302	0.024
ENGL-050	-0.463	0.434	0.286
ENGL-060	-0.341	0.253	0.178
MATH-1ST-SEMESTER	1.170	0.262	<0.001
MATH-020	1.728	0.258	<0.001
MATH-030	2.268	0.276	<0.001

Note. ENGL-050 is Reading/Comprehension 1 and ENGL-060 is Reading/Comprehension 2. MATH -020 is Elementary Algebra, MATH-030 is Intermediate Algebra, and Arithmetic (MATH-013) is the reference group, i.e. dummy-coded zero.

variables in the model. As noted in Tables 4.13 and 4.14, none of the high school level-2 variables, nor any interactions, are significant with respect to the comparative odds of a developmental mathematics student successfully remediating into college-level mathematics.

The summary and individual parameter estimates of the final HGLM model for

TABLE 4.13
HGLM High School Level-2 Variables: Successful Mathematics Remediation (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	0.302	0.446	34	0.504
MED-DFG	0.162	0.465	34	0.730
HS-RANK	-0.001	0.001	35	0.365
GRD12-ENROL	0.001	0.000	35	0.116
COMBO-SAT	0.001	0.001	35	0.178
ADV-MATH	0.009	0.005	35	0.099

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Gender, Pell, Grant, Math-1st-Semester, MATH-020, and MATH-030, also in the model (MATH-013 reference group).

the 2009 developmental mathematics cohort successfully remediating are displayed in Table 4.15. Controlling for the other variables, a developmental mathematics student awarded a non-Pell grant, one who took mathematics his or her first semester of attendance, or one who placed into Elementary Algebra or Intermediate Algebra, rather than Arithmetic, is more likely to successfully remediate, passing his or her developmental mathematics sequence (probability greater than 0.5). Whereas a developmental mathematics student awarded a Pell grant or a male student, is less likely to successfully remediate, passing his or her developmental mathematics sequence (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when compared to a student who started developmental mathematics in Arithmetic, a student who started in Elementary Algebra is 5.8 times more likely to successfully remediate in postsecondary developmental mathematics, while an Intermediate Algebra student is 10.5 times more likely to successfully remediate. This is not surprising as a student who places into Arithmetic has two to three semesters of developmental mathematics depending on

TABLE 4.14
HGLM Significant Variables and Interactions: Successful Mathematics Remediation (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 614)
GENDER*MATH-1ST-SEMESTER	-0.899	0.505	0.076
MATH-020*MATH-1ST-SEMESTER	0.015	0.825	0.986
MATH-030*MATH-1ST-SEMESTER	-0.641	0.943	0.497
With only Gender*Math-1st-Semester Interaction			(*d.f.* = 616)
GENDER*MATH-1ST-SEMESTER	-0.928	0.498	0.063

Note. Interactions were analyzed with remaining significant level-1 variables Gender, Pell, Grant, Math-1st-Semester, MATH-020, and MATH-030, also in the model (MATH-013 reference group).

the major, whereas an Elementary Algebra student has one to two semesters of developmental mathematics and an Intermediate Algebra student, a student with stronger basic algebraic skills, has only one semester of developmental mathematics. In addition, a student who begins his or her developmental mathematics sequence the first semester of attendance is 3.2 times more likely to successfully remediate in mathematics than a student who delays, controlling for the other variables. Taking postsecondary developmental mathematics the first semester of attendance may possibly decrease the likelihood of forgetting mathematical concepts gleaned from high school.

Furthermore, looking the comparative odds ratios and examining control variables in terms of successful mathematics remediation while controlling for the other variables in the model, a male student is about half as likely as a female student to successfully remediate in postsecondary developmental mathematics. Finally examining the

TABLE 4.15
HGLM Final Model: Successful Mathematics Remediation (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 617)	Odds Ratio	Probability
GENDER	-0.648	0.223	0.004	0.523	0.344
PELL	-0.683	0.220	0.002	0.505	0.336
GRANT	0.736	0.281	0.009	2.087	0.676
MATH-1ST-SEMESTER	1.174	0.263	<0.001	3.233	0.764
MATH-020	1.753	0.251	<0.001	5.771	0.852
MATH-030	2.348	0.270	<0.001	10.467	0.913

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.022	0.000	36	31.155	> 0.500

Note: MATH-020 is Elementary Algebra, MATH-030 is Intermediate Algebra, and Arithmetic (MATH-013) is the reference group. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-\text{(coefficient)}})$.

significant factors of financial aid, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant has twice the likelihood of successful remediation; while a student receiving a Pell grant is about half as likely to successfully remediate in postsecondary developmental mathematics, compared to one not awarded a Pell grant.

The chi-square statistic along the bottom row of Table 4.15 identifies the variability among the high schools given the student level-1 factors modeling successful mathematics remediation. In the present study the chi-square test is not significant, $\chi^2(36, N = 37) = 31.16,\ p > 0.50$. In other words, there is no evidence that the association between successful mathematics remediation and significant student level-1 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2009 and began his or her postsecondary education at this New Jersey community college fall 2009 in developmental mathematics, with the outcome of successful mathematics remediation is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (GENDER_{ij}) + \beta_{2j} * (PELL_{ij}) + \beta_{3j} * (GRANT_{ij}) + \beta_{4j} * (MATH1STSEM_{ij}) + \beta_{5j} * (MATH020_{ij}) + \beta_{6j} * (MATH030_{ij}) \qquad (4.3)$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(SuccessRemediate_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2, 3, 4, 5 or 6) are the level-1 coefficients (Table 4.15).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

$$\beta_{6j} = \gamma_{60} \tag{4.4}$$

where

γ_{qs} (q = 0, 1, 2, 3, 4, 5 or 6) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

Outcome: College-Level Mathematics Grade ≥ C

To graduate with a credential, almost all degrees and certificates require one or more college-level mathematics courses. Some students place directly into college-level mathematics while others successfully remediate into college-level mathematics. The following HGLM investigation is for those students who graduated high school June 2009 and took a college-level mathematics course sometime between fall 2009 and spring 2013, regardless of initial placement. Tables 4.16 through 4.20 are the HGLM results investigating which factors enhance or hinder a student's progress towards successful completion of college-level mathematics; i.e. earning a grade of C or better in college-level mathematics.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant (p <

0.001), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2009 cohort of students who took college-level mathematics, in reference to passing, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is whether a student entered college-level mathematics by successfully remediating from Elementary Algebra compared to placing directly into the college-level course. Furthermore, the only significant control variable is a student's gender (Table 4.16).

Once the two significant student level-1 variables, successfully remediating from Elementary Algebra and gender, are entered together into the HGLM model with the

TABLE 4.16
HGLM Student Level-1 Variables: College-Level Mathematics Grade ≥ C (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.474	0.182	551	0.009
RACE-WHITE	-0.121	0.269	549	0.652
RACE-BLACK	-0.405	0.321	549	0.208
RACE-HISPANIC	-0.217	0.373	549	0.560
PELL	-0.018	0.279	549	0.950
GRANT	0.431	0.278	549	0.121
LOAN	-0.451	0.264	549	0.088
WORK-STUDY	-0.332	0.835	549	0.691
ENGL-050	-0.346	0.975	550	0.723
ENGL-060	-0.319	0.209	550	0.127
MATH-1ST-SEMESTER	0.199	0.351	551	0.571
MATH-013	0.750	1.113	549	0.501
MATH-020	-0.645	0.246	549	0.009
MATH-030	-0.302	0.322	549	0.348

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

TABLE 4.17
HGLM Significant Student Level-1 Variables: College-Level Mathematics Grade ≥ C (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 550)
GENDER	-0.577	0.190	0.003
MATH-020	-0.674	0.236	0.004

Note. MATH -020 is Elementary Algebra.

outcome of earning a grade of C or better in college-level mathematics, both variables remain significant (Table 4.17). Simply stated, once Elementary Algebra and gender are in the model, both help predict the comparative odds of whether or not a student who takes college-level mathematics will successfully pass with a grade of C or better. Once again the next steps for discovering what variables aid in predicting whether or not a college-level mathematics student will successfully pass with a grade of C or better are to identify any significant high school level-2 variables along with any significant interactions of the variables in the model. As noted in Tables 4.18 and 4.19, none of the high school level-2 variables, nor any interactions, are significant with respect to the comparative odds of a student who takes a college-level mathematics course successfully

TABLE 4.18
HGLM High School Level-2 Variables: College-Level Mathematics Grade ≥ C (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	0.090	0.497	30	0.858
MED-DFG	0.555	0.507	30	0.282
HS-RANK	0.001	0.002	31	0.615
GRD12-ENROL	0.000	0.001	31	0.665
COMBO-SAT	-0.000	0.001	31	0.802
ADV-MATH	-0.010	0.009	31	0.269

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Gender and MATH-020 also in the model.

TABLE 4.19

HGLM Significant Variables and Interactions: College-Level Mathematics Grade ≥ C (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER*MATH-020	0.577	0.530	549	0.277

Note. Interactions were analyzed with remaining significant level-1 variables Gender and MATH-020, also in the model.

passing that course with a grade of C or better.

The summary and individual parameter estimates of the final HGLM model of the 2009 college-level mathematics cohort earning a grade of C or better in college-level mathematics are displayed in Table 4.20. Controlling for the other variables, a student who remediated into college-level mathematics from Elementary Algebra, compared to a student who placed directly into college-level mathematics, or a male student, is less likely to pass his or her college- level mathematics course with a grade of C or better (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when comparing to a student who places directly into college-level mathematics without the

TABLE 4.20

HGLM Final Model: College-Level Mathematics Grade ≥ C (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 550)	Odds Ratio	Probability
GENDER	-0.577	0.190	0.003	0.561	0.360
MATH-020	-0.674	0.236	0.004	0.510	0.338

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTRCPT1, u_0	0.267	0.071	32	42.660	0.099

Note: MATH-020 is Elementary Algebra. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

need for remediation, a student who starts in Elementary algebra is about half as likely to pass college-level mathematics. Since a student who successfully remediates into college-level mathematics from either Intermediate Algebra or Arithmetic exhibits no significant differences in terms of earning a grade of C or better in college-level mathematics, further investigation is needed to determine why the results are different for remediated Elementary Algebra students.

Furthermore, looking the comparative odds ratios and examining the control variables with respect to passing college-level mathematics with a grade of C or better, while controlling for the other variables in the model, a male student is about 0.6 times as likely as a female student to pass college-level mathematics.

Additional information in terms of model fit is the chi-square statistic. The chi-square statistic found along the bottom row of table 4.20 identifies the variability among the high schools given the student level-1 factors modeling earning a grade of C or better in college-level mathematics. In the present study the chi-square test is not significant, $\chi^2(32, N = 33) = 42.66,\ p = 0.10$. In other words, there is no evidence that the association between successful completion of college-level mathematics and significant student level-1 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2009 and took college-level mathematics sometime between fall 2009 and spring 2013 at this New Jersey community college with the outcome of passing that college-level mathematics course is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (GENDER_{ij}) + \beta_{2j} * (MATH020_{ij}) \tag{4.5}$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(CLMath \geq C)_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1 or 2) are the level-1 coefficients (Table 4.20).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20} \qquad (4.6)$$

where

γ_{qs} (q = 0, 1or 2) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

Outcome: Graduate

While some students attend a to community college to get a new academic start or save money before transferring to a four-year institution, many community college students instead look to graduate with a certificate to enter directly into the workforce, or with an Associate degree before either entering into the workforce or transferring to a four-year institution. In New Jersey as a result of the general education agreement established in 2008, students graduating from community college with a general education Associate degree experience a seamless transition into a four-year institution with junior-class status (State of New Jersey: Higher Education, 2008). With respect to graduating with a credential, two subsets of students from the 2009 cohort are investigated; 1) students who took at least one mathematics course, developmental or college-level, and 2) those who took at least one college-level mathematics course, regardless of whether they remediated into that college-level course or placed into the college-level course without the need for developmental mathematics first.

Mathematics students. As previously discussed, to graduate with a credential, all degrees and certificates minimally require basic algebra competency. Therefore some students, via placement testing and credential sought, will not require any postsecondary mathematics, while other students will have to obtain basic algebra competency by earning a grade of C or better in Elementary Algebra and/or pass one or more college-level mathematics courses. The following HGLM investigation is for those students who graduated high school June 2009 and took any postsecondary mathematics course, developmental or college-level, sometime between fall 2009 and spring 2013. Tables 4.21 through 4.24 are the HGLM results investigating which factors enhance or hinder a student's progress towards graduating with a certificate or an Associate degree.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant ($p < 0.001$), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2009 cohort of students who took any level of postsecondary mathematics, in reference to graduating, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is the level of developmental mathematics from which the student started. The significant control variables are whether a student received financial aid in the form of Pell or non-Pell grants and whether the student required any level of developmental English (Table 4.21).

Once all the significant individual student level-1 variables, the level of developmental mathematics, financial aid in the form of Pell and non-Pell grants, and any level of developmental English, are entered together into the HGLM model with the outcome of graduating with a credential, developmental English is no longer significant (Table 4.22). In other words, once the other significant explanatory and control level-1 variables are in the model, developmental English no longer helps predict the comparative odds of whether or not a student who has taken any level of mathematics will graduate from community college with a credential within four years of enrollment.

Follow-up steps for discovering what variables aid in predicting whether or not a student who takes any mathematics course, developmental or college-level, will graduate community college with a credential identifies any significant high school level-2

TABLE 4.21
HGLM Student Level-1 Variables: Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.253	0.183	887	0.167
RACE-WHITE	-0.043	0.196	885	0.826
RACE-BLACK	-0.424	0.245	885	0.083
RACE-HISPANIC	-0.348	0.214	885	0.104
PELL	-0.948	0.251	884	<0.001
GRANT	1.187	0.248	884	<0.001
LOAN	0.024	0.208	884	0.910
WORK-STUDY	0.139	0.772	884	0.857
ENGL-050	-1.732	0.774	886	0.025
ENGL-060	-0.683	0.278	886	0.014
MATH-1ST-SEMESTER	0.499	0.365	887	0.172
MATH-013	-1.676	0.285	885	<0.001
MATH-020	-1.113	0.140	885	<0.001
MATH-030	-0.699	0.171	885	<0.001

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

TABLE 4.22

HGLM Significant Student Level-1 Variables: Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 880)
PELL	-0.639	0.260	0.014
GRANT	0.951	0.251	<0.001
ENGL-050	-1.167	0.821	0.156
ENGL-060	-0.267	0.266	0.314
MATH-1ST-SEMESTER	0.574	0.378	0.130
MATH-013	-1.561	0.284	<0.001
MATH-020	-1.028	0.149	<0.001
MATH-030	-0.690	0.162	<0.001

Note. ENGL-050 is Reading/Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH -020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

variables along with any significant interactions of the variables in the model. As noted in Table 4.23 the only significant high school level-2 variable with respect to the odds of a student who takes a postsecondary mathematics course, developmental or college-level, to graduate with a credential is the percent of graduating students possessing advanced mathematics proficiency on the grade-eleven HSPA. Lastly, in reference to testing any interactions in the model, based on the literature and remaining significant variables, no

TABLE 4.23

HGLM High School Level-2 Variables: Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	-0.301	0.491	35	0.544
MED-DFG	0.046	0.485	35	0.924
HS-RANK	0.002	0.001	36	0.179
GRD12-ENROL	0.000	0.000	36	0.333
COMBO-SAT	-0.001	0.001	36	0.329
ADV-MATH	-0.012	0.006	36	0.036

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Pell, Grant, MATH-013, MATH-020 and MATH-030, also in the model.

viable interactions exist, thus none are assessed for this model (Adelman, 1999; Adelman, 2004; Bailey, et al., 2010; Chen & DesJardins, 2008; Fike & Fike, 2008; Hoyt, 1999; Illich, Hagan & McCallister, 2004; Johnson & Kuennen, 2004).

The summary and individual parameter estimates of the final HGLM model of the 2009 cohort who took any mathematics course, developmental or college-level, and graduated with a credential are displayed in Table 4.24. Controlling for the other variables, a student who took any mathematics course (developmental or college-level) and awarded a non-Pell grant, is more likely to graduate (probability greater than 0.5). Whereas a student starting in developmental mathematics (compared to one with no developmental mathematics requirement) or awarded a Pell grant is less likely to graduate (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when

TABLE 4.24
HGLM Final Model: Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 883*)	Odds Ratio	Probability
ADV-MATH	-0.013	0.006	0.036	0.988	0.497
PELL	-0.739	0.251	0.003	0.478	0.323
GRANT	0.934	0.252	<0.001	2.545	0.718
MATH-013	-1.669	0.285	<0.001	0.188	0.159
MATH-020	-1.090	0.166	<0.001	0.336	0.252
MATH-030	-0.662	0.171	<0.001	0.516	0.340

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.120	0.014	36	39.471	0.317

Note: MATH-013 is Arithmetic, MATH -020 is Elementary Algebra, and MATH-030 is Intermediate Algebra. High school level-2 predictor ADV-MATH *d.f.* = 36. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

compared to a student who had no developmental mathematics requirement, a student starting in Arithmetic is about one-fifth as likely to graduate, a student starting in Elementary Algebra is about one-third as likely to graduate, while a student starting in Intermediate Algebra is a little less than half as likely to graduate. Developmental mathematics students require additional semesters of mathematics (one to three, depending on the major), extending the time and cost towards their degree, thereby possibly increasing the likelihood of attrition and drop-out. Overall, the greater the mathematics deficiency upon entry, the less likely a student is to graduate with a credential.

Furthermore, looking the comparative odds ratios and examining the significant factors of financial aid, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant has 2.5 times the likelihood of graduating; while a student receiving a Pell grant is less than half as likely graduate, compared to one not awarded a Pell grant.

Finally with regards to the significant high school level-2 variable, a decrease in the high school's advanced mathematics proficiency (AMP) from which a student graduated from exhibits an decrease in the likelihood of the student graduating from this community college with a credential (probability less than 0.5). While the HGLM regression results indicate that this predictor is statistically significant in distinguishing between students who graduated from high schools with different AMP scores ($p = 0.036$), the odds ratio for this variable indicates little change in the likelihood of graduation.

The chi-square statistic along the bottom row of Table 4.24 identifies the variability among the high schools given the student level-1and high school level-2 factors modeling students graduating with a credential. In the present study the chi-square test is not significant, $\chi^2(36, N = 37) = 39.47,\ p = 0.32$. In other words, there is no evidence that the association between graduating with a credential and significant student level-1 and high school level-2 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2009, began his or her postsecondary education at this New Jersey community college fall 2009 and took either developmental or college-level mathematics sometime between fall 2009 and spring 2010, with the outcome of graduating with a credential is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (PELL_{ij}) + \beta_{2j} * (GRANT_{ij}) + \beta_{3j} * (MATH013_{ij}) + \beta_{4j} * (MATH020_{ij}) + \beta_{5j} * (MATH030_{ij}) \quad (4.7)$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1 - \emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(Graduate_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2, 3, 4 or 5) are the level-1 coefficients (Table 4.24).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (ADVMATH_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50} \tag{4.8}$$

where

γ_{qs} (q = 0, 1, 2, 3, 4 or 5) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

College-level students. As previously introduced, to graduate with a credential, many degrees and certificates require one or more college-level mathematics course. Therefore, the following HGLM investigation is for those students who graduated high school June 2009 and took any college-level mathematics course, regardless of whether the student successfully remediated or entered via placement into college-level mathematics, sometime between fall 2009 and spring 2013. Tables 4.25 through 4.28 are the HGLM results investigating once a student enters college-level mathematics those factors that enhance or hinder a student's progress towards graduating with a certificate or an Associate degree.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant (p = 0.003), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2009 cohort of students who took college-level mathematics, with respect to graduating with a credential, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is if the student remediates into college-level mathematics from Arithmetic. Moreover the only significant control variable is whether a student receives financial aid in the form of a Pell or non-Pell grant (Table 4.25).

Once all the individual significant student level-1 variables, successful remediation into college-level mathematics from Arithmetic and financial aid in the form of Pell and non-Pell grants, are entered together into the HGLM model with the outcome of graduating with a credential, both variables remain significant (Table 4.26). In other words, once Arithmetic and the significant portions of financial aid are in the model, both help predict the comparative odds of whether or not a student who takes college-level mathematics will graduate with a credential.

Follow-up steps for discovering what variables aid in predicting whether or not a college-level mathematics student will graduate community college with a degree or

TABLE 4.25
HGLM Student Level-1 Variables: College-Level Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.365	0.202	551	0.071
RACE-WHITE	-0.200	0.191	549	0.294
RACE-BLACK	0.416	0.410	549	0.310
RACE-HISPANIC	-0.375	0.281	549	0.183
PELL	-0.964	0.352	548	0.006
GRANT	1.179	0.386	548	0.002
LOAN	0.000	0.273	548	0.998
WORK-STUDY	-0.234	0.881	548	0.791
ENGL-050	-0.648	0.730	550	0.375
ENGL-060	0.029	0.322	550	0.930
MATH-1ST-SEMESTER	0.391	0.395	551	0.322
MATH-013	0.724	0.365	549	0.048
MATH-020	-0.076	0.174	549	0.664
MATH-030	-0.221	0.172	549	0.200

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

TABLE 4.26
HGLM Significant Student Level-1 Variables: College-Level Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 549)
PELL	-0.988625	0.353563	0.005
GRANT	1.183937	0.390016	0.003
MATH-013	0.809207	0.391583	0.039

Note. MATH-013 is Arithmetic.

certificate identify any significant high school level-2 variables along with any significant interactions of the variables in the model. As displayed in Table 4.27 the only significant high school level-2 variable in reference to the odds of graduating with a credential for a student who takes a postsecondary college-level mathematics course, regardless whether the student places or successfully remediates into the college-level mathematics course, is the high school's percent of graduating students possessing advanced mathematics proficiency (AMP). Once again with regard to testing any interactions in the model, based on the literature and remaining significant variables, no viable interactions exist, thus none are assessed for this model (Adelman, 1999; Adelman, 2004; Bailey, et al., 2010; Chen & DesJardins, 2008; Fike & Fike, 2008; Hoyt, 1999; Illich, Hagan &

TABLE 4.27
HGLM High School Level-2 Variables: College-Level Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	-0.333	0.422	30	0.436
MED-DFG	0.189	0.411	30	0.648
HS-RANK	0.003	0.001	31	0.071
GRD12-ENROL	0.000	0.000	31	0.554
COMBO-SAT	-0.001	0.001	31	0.095
ADV-MATH	-0.021	0.007	31	0.007

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Pell, Grant and Math-013, also in the model.

McCallister, 2004; Johnson & Kuennen, 2004).

The summary and individual parameter estimates of the final HGLM model of the 2009 college-level mathematics cohort who took any college-level mathematics course, regardless of direct placement or via passing prerequisite developmental mathematics, and graduated with an Associate's degree or certificate are displayed in Table 4.28. Controlling for the other variables, a student who took a college-level mathematics course and awarded a non-Pell grant or whose first mathematics course was Arithmetic, is more likely to graduate (probability greater than 0.5). Whereas a student who took a college-level mathematics course and awarded a Pell grant is less likely to graduate (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when compared to a student who had no developmental mathematics requirement, a student remediating into a college-level course from Arithmetic is 2.4 times more likely to graduate. Overall, an Arithmetic student who achieves mathematical success will tend to

TABLE 4.28
HGLM Final Model: College-Level Mathematics and Graduate (2009)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 549*)	Odds Ratio	Probability
ADV-MATH	-0.021	0.007	0.007	0.980	0.495
PELL	-0.975	0.380	0.011	0.377	0.274
GRANT	1.050	0.428	0.015	2.858	0.741
MATH-013	0.879	0.395	0.026	2.408	0.707

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.173	0.030	31	34.504	0.303

Note: MATH -013 is Arithmetic. High school level-2 predictor ADV-MATH *d.f.* = 31. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

finish his or her community college education before either going into the workforce or transferring to a four-year institution.

Furthermore, looking the comparative odds ratios and examining the significant factors of financial aid and graduation, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant is almost three times as likely to graduate; while a student receiving a Pell grant is only about 0.4 times as likely to graduate, compared to a student not awarded a Pell grant.

Lastly with regards to the significant high school level-2 variable, as noted in the previous analysis, a decrease in the high school's advanced mathematics proficiency from which a student graduated from exhibits a decrease in the likelihood of the student graduating from this community college. Once again while the HGLM regression results indicate that this predictor is statistically significant in distinguishing between students who graduated from high schools with different AMP scores ($p = 0.007$), the odds ratio for this variable indicates little change in the likelihood of graduation.

The chi-square statistic along the bottom row of Table 4.28 identifies the variability among the high schools given the student level-1and high school level-2 factors modeling students graduating with a credential. In the present study the chi-square test is not significant, $\chi^2(31, N = 32) = 34.50,\ p = 0.30$. In other words, for a student who take college-level mathematics there is no evidence that the association between graduating with a credential and significant student level-1 and high school level-2 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2009, began his or her postsecondary education at this New Jersey community college fall 2009 and took college-level mathematics sometime between fall 2009 and spring 2013, with the outcome of graduating with a credential is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (PELL_{ij}) + \beta_{2j} * (GRANT_{ij}) + \beta_{3j} * (MATH013_{ij}) \tag{4.9}$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(Graduate_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2 or 3) are the level-1 coefficients (Table 4.28).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (ADVMATH_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30} \tag{4.10}$$

where

γ_{qs} (q = 0, 1, 2 or 3) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

HGLM 2010 Cohort

Outcome: Successful Mathematics Remediation

Recalling that many students start their postsecondary education in developmental mathematics, especially prevalent for community college students, the following HGLM investigation is for those students who graduated high school June 2010, took the Accuplacer® placement test summer 2010, and were placed into one of three levels of developmental mathematics: Arithmetic (MATH-013), Elementary Algebra (MATH-020) or Intermediate Algebra (MATH-030). Tables 4.29 through 4.33 are the HGLM results investigating which factors enhance or hinder a student's progress towards successful mathematics remediation. For this study, successful remediation means passing all developmental mathematics courses required with a grade of C or better, to enter college-level mathematics. Remember for some students this means taking one developmental course and passing that course on the first try, while for other students it means taking more than one level of developmental mathematics and/or attempting a course more than once before passing with a grade of C or better.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant ($p < 0.001$), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2010 cohort of developmental mathematics students with respect to successful mathematics remediation, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is the level of developmental mathematics the student started, compared to Arithmetic, the lowest level of developmental mathematics. Significant control variables are a student's gender, whether he or she is African American, whether he or she receives financial aid in the form of Pell or grants other than Pell, and whether the student requires any level of developmental English in addition to developmental mathematics (Table 4.29).

Once all the individual significant student level-1 variables, the level of developmental mathematics (in reference to Arithmetic), gender, African American ethnicity, financial aid in the form of Pell or non-Pell grants, and any level of developmental English, are entered together into the HGLM model with the outcome of successful mathematics remediation, developmental Engl-060, Reading and Comprehension 2, and financial aid is no longer significant (Table 4.30). (Note: without Pell grant in the model, non-Pell grant is no longer significant with the remaining significant variables in the model.) Stated another way, once the other significant explanatory and control student level-1 variables are in the model, the higher level of developmental English and financial aid in the form of Pell and non-Pell grants no longer help predict the comparative odds of whether or not a student starting in developmental

TABLE 4.29
HGLM Student Level-1 Variables: Successful Mathematics Remediation (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.452	0.149	601	0.002
RACE-WHITE	-0.226	0.314	599	0.472
RACE-BLACK	-1.564	0.358	599	<0.001
RACE-HISPANIC	-0.178	0.316	599	0.574
PELL	-0.550	0.287	598	0.056
GRANT	0.487	0.220	598	0.027
LOAN	0.138	0.252	598	0.583
WORK-STUDY	1.007	0.768	598	0.191
ENGL-050	-1.868	0.342	600	<0.001
ENGL-060	-0.696	0.225	600	0.002
MATH-1ST-SEMESTER	0.011	0.239	601	0.962
MATH-020	2.096	0.198	600	<0.001
MATH-030	2.438	0.226	600	<0.001

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading& Comprehension 2. MATH-030 is Intermediate Algebra, MATH-020 is Elementary Algebra, and Arithmetic (MATH-013) is the reference group, i.e. dummy-coded zero.

TABLE 4.30
HGLM Significant Student Level-1 Variables: Successful Mathematics Remediation (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 594)
GENDER	-0.445	0.173	0.010
RACE-BLACK	-1.156	0.319	<0.001
PELL	-0.311	0.300	0.300
GRANT	0.529	0.254	0.038
ENGL-050	-1.154	0.349	0.001
ENGL-060	-0.393	0.245	0.109
MATH-020	1.846	0.194	<0.001
MATH-030	2.037	0.243	<0.001

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-030 is Intermediate Algebra, MATH -020 is Elementary Algebra, and Arithmetic (MATH-013) is the reference group, i.e. dummy-coded zero.

mathematics will successfully remediate within three years of attendance.

Additional steps for uncovering what variables aid in predicting whether or not a developmental mathematics student will successfully remediate identifies any significant high school level-2 variables along with any significant interactions of the variables in the model. As shown in Tables 4.31 and 4.32, none of the high school level-2 variables, nor any interactions, are significant with regards to the comparative odds of a

TABLE 4.31
HGLM High School Level-2 Variables: Successful Mathematics Remediation (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	0.125	0.591	45	0.833
MED-DFG	0.018	0.573	45	0.975
HS-RANK	0.001	0.001	46	0.722
GRD12-ENROL	0.000	0.000	46	0.530
COMBO-SAT	0.000	0.001	46	0.925
ADV-MATH	0.004	0.007	46	0.542

Note. LOW-DFG and MATH-013 are reference groups. Level-2 variables were analyzed with remaining significant level-1 variables Gender, Race-Black, ENGL-050, MATH-020, and MATH-030, also in the model.

developmental mathematics student successfully remediating into college-level mathematics.

The summary and individual parameter estimates of the final HGLM model for the 2010 developmental mathematics cohort successfully remediating are displayed in Table 4.33. Controlling for the other variables, a developmental mathematics student who placed into Elementary Algebra or Intermediate Algebra, rather than Arithmetic, is more likely to successfully remediate, passing his or her developmental mathematics sequence (probability greater than 0.5). Whereas a developmental mathematics student awarded who is an African American or a male student, or in addition to developmental mathematics required the lowest level of developmental English, is less likely to

TABLE 4.32
HGLM Significant Variables and Interactions: Successful Mathematics Remediation (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 589)
GENDER*RACE-BLACK	0.841	0.655	0.200
GENDER*ENGL-050	1.272	0.596	0.033
GENDER*MATH-020	0.253	0.584	0.665
GENDER*MATH-030	-0.049	0.666	0.942
RACE-BLACK*ENGL-050	-0.319	0.972	0.743
RACE-BLACK*MATH-020	0.557	0.641	0.385
RACE-BLACK*MATH-030	-0.359	1.035	0.729
ENGL-050*MATH-020	-0.355	0.575	0.537
With only Gender*Engl-050 Interaction			(*d.f.* = 596)
GENDER*ENGL-050	1.274	0.686	0.064

Note. Interactions were analyzed with remaining significant level-1variables Gender, Race-Black, ENGL-050, MATH-020, and MATH-030, also in the model (MATH-013 reference group). Only 3 out of 650 students placed in the lowest developmental English (ENGL-050) *and* the highest developmental mathematics (MATH-030) thus due to near singularity, no interaction could be assessed.

successfully remediate, passing his or her developmental mathematics sequence (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when compared to a student who started developmental mathematics in Arithmetic, a student who started in Elementary Algebra is 6.8 times more likely to successfully remediate in postsecondary developmental mathematics, while an Intermediate Algebra student is 8.8 times more likely to successfully remediate. As previously stated, a student who placing into Arithmetic has two to three semesters of developmental mathematics depending on the major, whereas an Elementary Algebra student has one to two semesters of developmental mathematics and an Intermediate Algebra student, a students with stronger basic algebraic skills, has only one semester of developmental mathematics.

Furthermore, looking the comparative odds ratios and examining control variables in terms of successful mathematics remediation while controlling for the other variables

TABLE 4.33
HGLM Final Model: Successful Mathematics Remediation (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 597)	Odds Ratio	Probability
GENDER	-0.486	0.170	0.004	0.615	0.381
RACE-BLACK	-1.197	0.288	<0.001	0.302	0.232
ENGL-050	-0.938	0.316	0.003	0.391	0.281
MATH-020	1.922	0.184	<0.001	6.836	0.872
MATH-030	2.176	0.245	<0.001	8.815	0.898

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.088	0.008	47	55.053	0.196

Note: ENGL-050 is Reading & Comprehension 1, MATH-020 is Elementary Algebra, MATH-030 is Intermediate Algebra, and Arithmetic (MATH-013) is the reference group. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

in the model, a male student is compared to a female student is 0.6 times as likely to successfully remediate in postsecondary developmental mathematics. An African American student compared to other ethnicities, is 0.3 times as likely to pass his or her developmental mathematics sequence. Finally examining Reading and Comprehension 1 (ENGL-050), the lowest level of developmental English, a student starting in ENGL-050 is 0.4 times as likely to successfully remediate in postsecondary developmental mathematics, compared to one not requiring any developmental English.

The chi-square statistic along the bottom row of Table 4.33 identifies the variability among the high schools given the student level-1 factors modeling successful mathematics remediation. In the present study the chi-square test is not significant, $\chi^2(47, N = 48) = 55.05,\ p = 0.20$. Stated another way, there is no evidence that the association between successful mathematics remediation and significant student level-1 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2010 and began his or her postsecondary education at this New Jersey community college fall 2010 in developmental mathematics, with the outcome of successful mathematics remediation is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (GENDER_{ij}) + \beta_{2j} * (RACEBLACK_{ij}) + \beta_{3j} * (ENGL050_{ij}) + \beta_{4j} * (MATH020_{ij}) + \beta_{5j} * (MATH030_{ij}) \qquad (4.11)$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1 - \emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(SuccessRemediate_{ij} = 1 | \beta_j)$; and

β_{qj} (q = 0, 1, 2, 3, 4 or 5) are the level-1 coefficients (Table 4.33).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50} \tag{4.12}$$

where

γ_{qs} (q = 0, 1, 2, 3, 4 or 5) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

Outcome: College-Level Mathematics Grade ≥ C

Recalling that to graduate with a credential, almost all degrees and certificates require one or more college-level mathematics courses, the following HGLM investigation is for those students who graduated high school June 2010 and took a college-level mathematics course, regardless of remediating or placing into the course, sometime between fall 2010 and spring 2013. Tables 4.34 through 4.38 are the HGLM results investigating which factors enhance or hinder a student's progress towards successful completion of college-level mathematics, i.e. earning a grade of C or better in college-level mathematics.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant (p <

0.001), then the ICC is also significant, “indicating that a multilevel model is appropriate and needed” (Garson, 2009, p. 64).

In relation to earning a grade of C or better in college-level mathematics, for the 2010 cohort of students, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is whether the student entered college-level mathematics by successfully remediating from Elementary Algebra compared to placing directly into the college-level course. The only significant control variables are a student’s gender, placing into developmental English Reading and Comprehension 2 (ENGL-060), and financial aid status in the form of receiving a Pell or non-Pell grant, or a federal loan (Table 4.34).

TABLE 4.34
HGLM Student Level-1 Variables: College-Level Mathematics Grade ≥ C (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.403	0.183	494	0.028
RACE-WHITE	0.193	0.334	492	0.563
RACE-BLACK	-0.539	0.385	492	0.162
RACE-HISPANIC	-0.265	0.374	492	0.479
PELL	-0.639	0.243	491	0.009
GRANT	1.104	0.220	491	<0.001
LOAN	-0.672	0.262	491	0.010
WORK-STUDY	0.767	1.213	491	0.527
ENGL-050	-0.703	0.860	493	0.414
ENGL-060	-0.767	0.248	493	0.002
MATH-1ST-SEMESTER	0.115	0.266	494	0.665
MATH-013	-0.982	0.849	492	0.248
MATH-020	-0.653	0.269	492	0.016
MATH-030	-0.020	0.283	492	0.944

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

TABLE 4.35
HGLM Significant Student Level-1 Variables: College-Level Mathematics Grade ≥ C (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 489)
GENDER	-0.482	0.187	0.010
PELL	-0.485	0.268	0.070
GRANT	1.033	0.234	<0.001
LOAN	-0.734	0.259	0.005
ENGL-060	-0.592	0.286	0.039
MATH-020	-0.672	0.243	0.006

Note. ENGL-060 is Reading & Comprehension 2. MATH -020 is Elementary Algebra.

Once all the individual significant student level-1 variables, successful remediation from Elementary Algebra, gender, developmental ENGL-060, and the significant parts of financial aid are entered together into the HGLM model with the outcome of earning a grade of C or better in college-level mathematics, the only variable no longer significant is whether a student is awarded a Pell grant (Table 4.35). In other words, once Elementary Algebra, gender, ENGL-060 and financial aid in the form of a non-Pell grant or a loan are in the model, all help predict the comparative odds of whether or not a student who takes college-level mathematics successfully passes with a grade of C or better.

The final steps for this group of students to assess what variables aid in predicting whether or not a college-level mathematics student will successfully pass with a grade is C or better are to identify any significant high school level-2 variables along with any significant interactions of the variables in the model. As noted in Tables 4.36 and 4.37, none of the high school level-2 variables nor any interactions, are significant with respect to the comparative odds of a student who takes a college-level mathematics course successfully passing that course with a grade of C or better.

TABLE 4.36

HGLM High School Level-2 Variables: College-Level Mathematics Grade ≥ C (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	0.260	0.386	25	0.506
MED-DFG	0.196	0.385	25	0.616
HS-RANK	0.000	0.001	26	0.793
GRD12-ENROL	0.000	0.000	26	0.489
COMBO-SAT	0.000	0.001	26	0.570
ADV-MATH	-0.000	0.006	34	0.951

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Gender, Grant, Loan, ENGL-060 and MATH-020, also in the model.

The summary and individual parameter estimates of the final HGLM model of the 2010 cohort, modeling success as outlined by earning a grade of C or better in college-level mathematics are displayed in Table 4.38. Controlling for the other variables, compared to a student not receiving a non-Pell grant, a student awarded a non-Pell grant is more likely to pass college-level mathematics (probability greater than 0.5). Whereas a student who remediated into college-level mathematics from Elementary Algebra, compared to a student who placed directly into college-level mathematics, or a student

TABLE 4.37

HGLM Significant Variables and Interactions: College-Level Mathematics Grade ≥ C (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 486)
GENDER*ENGL-060	0.559	0.545	0.305
GENDER*MATH-020	0.113	0.380	0.766
ENGL-060*MATH-020	0.615	0.349	0.078
With only ENGL-060*MATH-020 Interaction			(*d.f.* = 488)
ENGL-060*MATH-020	0.537	0.369	0.146

Note. Interactions were analyzed with remaining significant level-1 variables Gender, Pell, Grant, Loan, ENGL-060 and MATH-020, also in the model.

who required one semester of developmental English (Reading and Comprehension 2), a male student, or a student awarded a federal loan, is less likely to pass his or her college-level mathematics course with a grade of C or better (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when comparing to a student who places directly into college-level mathematics without the need for developmental mathematics, a student who remediates from in Elementary algebra is half as likely to pass college-level mathematics. As with the 2009 cohort, since a student who successfully remediates into college-level mathematics from either Intermediate Algebra or Arithmetic exhibits no significant differences in terms of earning a grade of C or better in college-level mathematics, further investigation is needed to determine why a remediated Elementary Algebra student does not experience the same success of earning a grade of C or better in college-level mathematics as a student who either remediated from Intermediate Algebra or Arithmetic, and a direct-placement college-level student.

TABLE 4.38
HGLM Final Model: College-Level Mathematics Grade ≥ C (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 490)	Odds Ratio	Probability
GENDER	-0.480	0.188	0.011	0.619	0.382
GRANT	0.661	0.155	<0.001	1.937	0.659
LOAN	-0.726	0.251	0.004	0.484	0.326
ENGL-060	-0.618	0.286	0.031	0.539	0.350
MATH-020	-0.697	0.239	0.004	0.498	0.332

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.022	0.000	35	41.927	0.196

Note: ENGL-060 is Reading & Comprehension 2 and MATH-020 is Elementary Algebra. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

Furthermore, looking the comparative odds ratios and examining the control variables with respect to passing college-level mathematics with a grade of C or better, while controlling for the other variables in the model, a male student is about 0.6 times as likely as a female student to pass college-level mathematics. Comparing to a student not requiring any developmental English, a student requiring Reading and Comprehension 2 (ENGL-060) is about half as likely to pass college-level mathematics. Finally examining the significant factors of financial aid, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant has almost twice the likelihood of passing college-level mathematics; while a student receiving a federal loan is about half as likely to pass college-level mathematics, compared to a student not awarded a federal loan.

Moreover, the chi-square statistic along the bottom row of Table 4.38 identifies the variability among the high schools given the student level-1 factors modeling students earning a grade of C or better in college-level mathematics. In the present study the chi-square test is not significant, $\chi^2(35, N = 36) = 41.93,\ p = 0.20$. In other words, there is no evidence that the association between successfully earning a grade of C or better in college-level mathematics and significant student level-1 factors varies among the high schools from which the community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2010 and took college-level mathematics sometime between fall 2010 and spring 2013 at this New Jersey community college with the outcome of earning a grade of C or better in that college-level mathematics course is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (GENDER_{ij}) + \beta_{2j} * (GRANT_{ij}) + \beta_{3j} * (LOAN_{ij}) + \beta_{4j} * (ENGL060_{ij}) + \beta_{5j} * (MATH020_{ij}) \tag{4.13}$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(CLMath \geq C)_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2, 3, 4 or 5) are the level-1 coefficients (Table 4.38).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

$$\beta_{6j} = \gamma_{60} \qquad (4.14)$$

where

γ_{qs} (q = 0, 1, 2, 3, 4 or 5) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

Outcome: Graduate

As stated previously for the 2009 cohort, while some students attend community college to get a new academic start or save money before transferring to a four-year institution, many community college students in New Jersey instead look to graduate with a certificate to enter directly into the workforce or with an Associate degree, achieving a seamless transition into a four-year institution with junior-class status (State of New Jersey: Higher Education, 2008). In reference to graduating with a credential, two subsets of students from the 2010 cohort were investigated; those who took any mathematics course, developmental or college-level, and those who took any college-level mathematics course, regardless of original placement.

Mathematics students. Recalling that to graduate with a credential all degrees and certificates require minimally a basic algebra competency, hence some students via placement testing and credential sought, will not require any postsecondary mathematics, while other students will have to obtain basic algebra competency by passing Elementary Algebra and/or pass one or more college-level mathematics courses. The following HGLM investigation is for those students who graduated high school June 2010 and took any postsecondary mathematics course, developmental or college-level, sometime between fall 2010 and spring 2013. Tables 4.39 through 4.43 are the HGLM results investigating which factors enhance or hinder a student's progress towards graduating with a certificate or an Associate degree.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant ($p < 0.001$), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2010 cohort of students who took any level of postsecondary mathematics, with regards to graduating, when each student level-1variable is individually put into the HGLM model the only significant explanatory variable is the level of developmental mathematics the student started. The significant control variables are a student's gender, whether he or she is African American, whether he or she receives financial aid in the form of Pell or grants other than Pell, and whether the student requires any level of developmental English in addition to developmental mathematics (Table 4.39).

As displayed in Table 4.40, once each significant individual student level-1 variable, the level of developmental mathematics, gender, race-African American, financial aid in the form of Pell or non-Pell grants, and any level of developmental English, are entered together into the HGLM model with the outcome of graduating with a credential, race-African American and developmental Engl-050, Reading and Comprehension 1, are no longer significant (Table 4.40). In other words, once the other significant explanatory and control level-1 variables are in the model, Engl-050 and race-African American no longer help predict the comparative odds of whether or not a student taking any mathematics course will graduate from community college within

TABLE 4.39
HGLM Student Level-1 Variables: Mathematics and Graduate (2010)

Predictor	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.679	0.235	857	0.004
RACE-WHITE	0.311	0.205	855	0.131
RACE-BLACK	-0.915	0.380	855	0.016
RACE-HISPANIC	-0.345	0.272	855	0.205
PELL	-0.999	0.303	854	0.001
GRANT	1.226	0.249	854	<0.001
LOAN	-0.360	0.206	854	0.082
WORK-STUDY	-0.127	0.619	854	0.837
ENGL-050	-1.585	0.714	856	0.027
ENGL-060	-1.337	0.249	856	<0.001
MATH-1ST-SEMESTER	-0.220	0.296	857	0.457
MATH-013	-1.893	0.487	855	<0.001
MATH-020	-1.026	0.169	855	<0.001
MATH-030	-0.623	0.219	855	0.005

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

three years of attendance.

TABLE 4.40
HGLM Significant Student Level-1 Variables: Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 849)
GENDER	-0.809	0.265	0.002
RACE-BLACK	-0.745	0.476	0.118
PELL	-0.625	0.299	0.037
GRANT	0.962	0.268	<0.001
ENGL-050	-0.979	0.759	0.197
ENGL-060	-1.002	0.249	<0.001
MATH-013	-1.479	0.568	0.009
MATH-020	-0.980	0.166	<0.001
MATH-030	-0.685	0.214	0.001

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH -020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

Follow-up steps discovering what variables aid in predicting whether or not a student who takes any mathematics course, developmental or college-level, will graduate community college include identifying any significant high school level-2 variables along with any significant interactions of the variables in the model. As noted in Tables 4.41

TABLE 4.41
HGLM High School Level-2 Variables: Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	-0.360	0.752	46	0.634
MED-DFG	-0.441	0.766	46	0.568
HS-RANK	0.001	0.002	47	0.765
GRD12-ENROL	0.001	0.001	47	0.451
COMBO-SAT	0.001	0.001	47	0.440
ADV-MATH	0.002	0.007	47	0.753

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Gender, Pell, Grant, Engl-060, Math-013, Math-020 and Math-030, also in the model.

and 4.42, for this cohort and outcome, the comparative odds of a student who takes a postsecondary mathematics course, developmental or college-level, to graduate with a credential, none of the high school level-2 variables nor any interactions, were statistically significant.

The summary and individual parameter estimates of the final HGLM model of the 2010 cohort who took any mathematics course, developmental or college-level, and graduated with a credential are displayed in Table 4.43. Controlling for the other variables, a student who took any mathematics course (developmental or college-level) and awarded a non-Pell grant is more likely to graduate (probability greater than 0.5). Whereas a student starting in developmental mathematics (compared to one with no developmental mathematics requirement), requiring developmental English Reading and Comprehension 2 (ENGL-060), or awarded a Pell grant is less likely to graduate

TABLE 4.42
HGLM Significant Variables and Interactions: Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 845)
GENDER*ENGL-060	0.433	0.719	0.547
GENDER*MATH-013	-0.129	0.748	0.863
GENDER*MATH-020	-0.617	0.377	0.102
GENDER*MATH-030	-0.608	0.594	0.306
ENGL-060*MATH-020	1.205	0.670	0.073
ENGL-060*MATH-030	-0.009	1.057	0.993
With only Engl-060*Math-020 Interaction			(*d.f.* = 850)
ENGL-060*MATH-020	1.047	0.816	0.200

Note. Interactions were analyzed with remaining significant level-1 variables Gender, Pell, Grant, ENGL-060, MATH-013, MATH-020 and MATH-030, also in the model. Only 34 out of 907 students placed in the lowest developmental mathematics (MATH-013) *and* the highest developmental English (ENGL-060) thus due to near singularity, no interaction could be assessed.

(probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when compared to a student who had no developmental mathematics requirement, similar to the results for the 2009 cohort, a student starting in Arithmetic is about one-fifth as likely to graduate, a student starting in Elementary Algebra is about one-third as likely to graduate, while a student starting in Intermediate Algebra is a little less than half as likely to graduate. Developmental mathematics students require additional semesters of mathematics (one to three, depending on the major), extending the time and cost towards their degree. , thereby possibly increasing the likelihood of attrition and drop-out. Once again as noted with the 2009 cohort for this outcome, the greater the mathematics deficiency upon entry the less likely a student is to graduate from this community college.

TABLE 4.43
HGLM Final Model: Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 851)	Odds Ratio	Probability
GENDER	-0.829	0.256	0.001	0.436	0.304
PELL	-0.696	0.313	0.027	0.499	0.333
GRANT	0.943	0.271	<0.001	2.568	0.720
ENGL-060	-0.956	0.243	<0.001	0.385	0.278
MATH-013	-1.793	0.487	<0.001	0.166	0.143
MATH-020	-1.040	0.145	<0.001	0.353	0.261
MATH-030	-0.690	0.201	<0.001	0.502	0.334

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.445	0.198	48	57.931	0.154

Note: ENGL-060 is Reading/Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra and MATH-030 is Intermediate Algebra. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

Furthermore, looking the comparative odds ratios and examining control variables with regard to graduating with a credential while controlling for the other variables in the model, a male student 0.4 times as likely as a female student to graduate. Compared to a student not requiring any developmental English, a student placing into developmental ENGL-060 is also 0.4 times as likely to graduate. Finally examining the significant factors of financial aid, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant is 2.6 times more likely to graduate; while a student receiving a Pell grant is half as likely to graduate, compared to a student not awarded a Pell grant.

The chi-square statistic along the bottom row of Table 4.43 identifies the variability among the high schools given the student level-1and high school level-2 factors modeling students graduating with a credential. In the present study the chi-square test is reveals no significance, $\chi^2(48, N = 49) = 57.93,\ p = 0.15$. In other words, there is no evidence that the association between graduating with a credential and significant student level-1 factors varies among the high schools from which the incoming community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2010, began his or her postsecondary education at this New Jersey community college fall 2010 and took either developmental or college-level mathematics sometime between fall 2010 and spring 2010, with the outcome of graduating with a credential is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (GENDER_{ij}) + \beta_{2j} * (PELL_{ij}) + \beta_{3j} * (GRANT_{ij}) + \beta_{4j} * (ENGL060_{ij}) + \beta_{5j} * (MATH013_{ij}) + \beta_{6j} * (MATH020_{ij}) + \beta_{7j} * (MATH030_{ij}) \tag{4.15}$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(Graduate_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2, 3, 4, 5, 6 or 7) are the level-1 coefficients (Table 4.43).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$
$$\beta_{5j} = \gamma_{50}$$
$$\beta_{6j} = \gamma_{60}$$
$$\beta_{7j} = \gamma_{70} \tag{4.16}$$

where

γ_{qs} (q = 0, 1, 2, 3, 4, 5, 6 or 7) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

College-level students. Recalling that to graduate with a credential, many degrees and certificates require one or more college-level mathematics course, therefore the following HGLM investigation is for those students who graduated high school June 2010 and took any college-level mathematics course, regardless of whether the student successfully remediated into college-level mathematics or entered via placement, sometime between fall 2010 and spring 2013. Tables 4.44 through 4.48 are the HGLM results investigating which factors enhance or hinder a student's progress towards graduating with a certificate or an Associate degree, once achieving college-level mathematics.

To verify that multilevel modeling is necessary, the first model created is the intercept model, a model with no predictors. Since the intercept is found significant ($p < 0.001$), then the ICC is also significant, "indicating that a multilevel model is appropriate and needed" (Garson, 2009, p. 64).

For the 2010 cohort of students who took college-level mathematics, with respect to graduating, when each student level-1 variable is individually put into the HGLM model, none of the explanatory variables are significant. In other words, regardless of how a student enters the college-level mathematics course, remediation or placement, the likelihood of graduating is statistically the same. Also in reference to graduating, taking mathematics the first semester of attendance or delaying produces no statistical differences. The significant control variables revealed are whether a student is Caucasian, whether he or she receives financial aid in the form of a federal loan, or Pell or non-Pell grants, and whether the student requires the higher level of developmental English (Table 4.44).

Once all the individual significant student level-1 variables of gender, race-Caucasian, financial aid in the form of federal loans, Pell and non-Pell grants, and developmental Reading and Comprehension 2, are entered together into the HGLM model with the outcome of graduating with a credential, all variables except receiving a Pell grant, remain significant (Table 4.45). In other words, once gender, race-Caucasian, financial aid in the form of federal loans, non-Pell grants, and developmental Reading and Comprehension 2, are all in the model, all help predict the comparative odds of whether or not a student who started first-time fulltime, fall 2010 and took a college-level mathematics course will graduate with a certificate or an Associate degree.

Additional steps for discovering what variables aid in predicting whether or not a student taking college-level mathematics, either via remediation or direct placement, will graduate community college include identifying any significant high school level-2 variables along with any significant interactions of the variables in the model. As noted in Tables 4.46 and 4.47, none of the high school level-2 variables nor any interactions, are significant with respect to the comparative odds of a student who takes a postsecondary college-level mathematics course, regardless whether the student was placed in or successfully remediated into college-level mathematics, and graduated with a certificate

TABLE 4.44
HGLM Student Level-1 Variables: College-Level Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
GENDER	-0.828	0.241	494	<0.001
RACE-WHITE	0.507	0.194	492	0.009
RACE-BLACK	-0.242	0.3161	492	0.443
RACE-HISPANIC	-0.326	0.289	492	0.259
PELL	-0.702	0.313	491	0.025
GRANT	0.941	0.254	491	<0.001
LOAN	-0.475	0.227	491	0.037
WORK-STUDY	-0.200	0.619	491	0.747
ENGL-050	-0.317	0.819	493	0.699
ENGL-060	-0.972	0.275	493	<0.001
MATH-1ST-SEMESTER	-0.249	0.318	494	0.433
MATH-013	0.431	0.700	492	0.538
MATH-020	-0.054	0.223	492	0.808
MATH-030	-0.225	0.233	492	0.336

Note. ENGL-050 is Reading & Comprehension 1 and ENGL-060 is Reading & Comprehension 2. MATH-013 is Arithmetic, MATH-020 is Elementary Algebra, and MATH-030 is Intermediate Algebra.

TABLE 4.45
HGLM Significant Student Level-1 Variables: College-Level Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 489)
GENDER	-0.866	0.243	<0.001
RACE-WHITE	0.718	0.191	<0.001
PELL	-0.426	0.338	0.208
GRANT	0.727	0.279	0.010
LOAN	-0.569	0.202	0.005
ENGL-060	-0.914	0.300	0.002

Note. ENGL-060 is Reading & Comprehension 2.

or an Associate degree.

The summary and individual parameter estimates of the final HGLM model of the 2010 college-level mathematics cohort who took any college-level mathematics course, regardless of direct placement or passing prerequisite developmental mathematics first, and graduated are displayed in Table 4.48. Controlling for the other variables, a student who took any college-level mathematics course and is Caucasian (compared to other ethnicities) or awarded a non-Pell grant, is more likely to graduate (probability greater than 0.5). Whereas a student starting in developmental mathematics (compared to one

TABLE 4.46
HGLM High School Level-2 Variables: College-Level Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	Approx. *d.f.*	*p*-value
HIGH-DFG	0.141	0.567	33	0.805
MED-DFG	0.186	0.588	33	0.754
HS-RANK	0.000	0.002	34	0.816
GRD12-ENROL	0.000	0.001	34	0.977
COMBO-SAT	0.000	0.001	34	0.795
ADV-MATH	-0.000	0.009	34	0.963

Note. LOW-DFG is the reference group. Level-2 variables were analyzed with remaining significant level-1 variables Gender, Race-White, Grant, Loan, Engl-060, also in the model.

TABLE 4.47
HGLM Significant Variables and Interactions: College-Level Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 487)
GENDER*ENGL-060	0.193	0.709	0.785
GENDER*RACE-WHITE	0.300	0.397	0.450
ENGL-060*RACE-WHITE	-1.269	0.684	0.064
With only Engl-060*Race-White Interaction			(*d.f.* = 489)
ENGL-060*RACE-WHITE	-1.236	0.668	0.065

Note. Interactions were analyzed with remaining significant level-1 variables Gender, Race-White, Grant, Loan and ENGL-060, also in the model.

with no developmental mathematics requirement), requiring developmental English Reading and Comprehension 2 (ENGL-060), or awarded a federal loan is less likely to graduate (probability less than 0.5).

Looking at the comparative odds ratios and controlling for other variables, when compared to a student who had no developmental mathematics requirement, none of the levels of developmental mathematics is significant. Therefore once a developmental

TABLE 4.48
HGLM Final Model: College-Level Mathematics and Graduate (2010)

Fixed Effect	Coefficient	Standard error	*p*-value (*d.f.* = 450)	Odds Ratio	Probability
GENDER	-0.869	0.240	<0.001	0.419	0.295
RACE-WHITE	0.768	0.197	<0.001	2.154	0.683
GRANT	0.418	0.163	0.011	1.518	0.603
LOAN	-0.563	0.205	0.006	0.570	0.364
ENGL-060	-0.941	0.302	0.002	0.390	0.281

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTERCEPT	0.307	0.094	35	39.650	0.270

ENGL-060 is Reading & Comprehension 2. The coefficients are the expected log odds of successful mathematics remediation which convert to probabilities by calculating $1/(1 + e^{-(\text{coefficient})})$.

mathematics student remediates into college-level mathematics, his or her likelihood of graduating is statistically the same as a student who is in college-level mathematics by direct placement.

Additionally, looking the comparative odds ratios and examining control variables with respect to taking a college-level mathematics course and graduating with a credential while controlling for the other variables in the model, a male student 0.4 times as likely as a female student to graduate. Compared to a student not requiring any developmental English, a student placing into developmental ENGL-060 is also 0.4 times as likely to graduate. Finally examining the significant factors of financial aid, compared to a student not awarded a non-Pell grant, a student receiving a non-Pell grant is 1.5 times more likely to graduate; while a student receiving a federal loan is 0.6 times as likely to graduate, compared to a student not awarded a federal loan.

The chi-square statistic along the bottom row of Table 4.48 identifies the variability among the high schools given the significant student level-1 factors modeling college-level mathematics students graduating with a certificate or an Associate degree. In the present study the chi-square test is not significant, $\chi^2(35, N = 36) = 39.65,\ p = 0.27$. In other words, for students who take college-level mathematics there is no evidence that the association between graduating and significant student level-1 factors varies among the high schools from which the entering community college students graduated.

The representation of the final level-1 model for a student who graduated high school June 2010, began his or her postsecondary education at this New Jersey community college fall 2010 and took college-level mathematics sometime between fall

2010 and spring 2013, with the outcome of graduating with a certificate or an Associate degree is specified as follows:

$$\eta_{ij} = \beta_{0j} + \beta_{1j} * (PELL_{ij}) + \beta_{2j} * (GRANT_{ij}) + \beta_{3j} * (MATH013_{ij}) \tag{4.17}$$

where

$\eta_{ij} = \log\left(\frac{\emptyset_{ij}}{1-\emptyset_{ij}}\right)$;

$\emptyset_{ij} = P(Graduate_{ij} = 1|\beta_j)$; and

β_{qj} (q = 0, 1, 2 or 3) are the level-1 coefficients (Table 4.47).

Each level-1 coefficient defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (ADVMATH_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30} \tag{4.18}$$

where

γ_{qs} (q = 0, 1, 2 or 3) are level-2 coefficients; and

u_{0j} is the level-2 random effect.

CHAPTER V. SUMMARY AND CONCLUSIONS

Developmental education, although a controversial issue, is especially central to the community college mission through its commitment to educational access for all students. Developmental education in open admission community colleges provides students with opportunities obtain necessary academic proficiencies not retained from high school to become college-ready. A substantial proportion of community college freshmen require developmental education, with more requiring developmental mathematics than other developmental subjects such as developmental English (Bahr, 2010; Bailey, 2009; Biswas, 2007; Parker, 2005; Parsad, et al., 2003).

The primary focus of this research was to examine developmental mathematics students alone as well as compare them to those not requiring developmental mathematics to determine what individual student and average high school factors hinder or promote academic success as measured by successful mathematics remediation, passing college-level mathematics, and graduating with a certificate or an Associate degree. Furthermore this research developed a better understanding of developmental education, especially developmental mathematics, and its relationship to persistence and graduation behaviors.

In this study, hierarchical generalized linear modeling (HGLM) was used to compare the long-term academic outcomes of traditional age (directly out of high school) first time in college (FTIC) students attending a New Jersey, *Achieving the Dream* (ATD) community college. The results from this research begin to answer questions of the pros and cons of developmental mathematics with regard to how developmental mathematics affects academic success, specifically at community colleges by revealing qualitative and quantitative factors that increase or decrease the likelihood of successful mathematics remediation, thereby enhancing or inhibiting persistence to graduation and/or transfer to a four-year institution. Successful postsecondary mathematics remediation in a timely manner is the key to persistence and continued educational success towards postsecondary graduation. Consistent with other studies, this body of research found that the more deficient an entering freshmen student was in mathematics, the lower chance that student would successfully remediate (Bahr 2007, 2010; Kowski, 2013). In addition, if the developmental education need spanned developmental English as well, academic success was even less likely. One promising finding was that once successfully remediated, first-time, fulltime developmental mathematics community college students were found to be statistically equivalent with respect to graduation behavior as their peers who had no need for mathematics remediation. This finding suggests that developmental mathematics education in this New Jersey community college serves the traditional-age developmental mathematics student population quite well and should be examined further to identify practices and policies that diminish the academic barriers typically experienced during postsecondary developmental education.

In the following sections, a detailed discussion is given of the results obtained in Chapter 4, specifically focusing on similarities and differences of the results from both the 2009 and 2010 cohorts for each outcome. The HGLM outcomes investigated in this study were successful postsecondary mathematics remediation, earning a grade of C or better in college-level mathematics, and graduating with a certificate or an Associate degree by spring 2013 from the New Jersey ATD community college utilized in this investigation.

Results 2009 Cohort versus 2010 Cohort

Outcome: Successful Mathematics Remediation

For those students who graduated high school June 2009, took the Accuplacer® placement test summer 2009, and were placed into either developmental Arithmetic (MATH-013), Elementary Algebra (MATH-020) or Intermediate Algebra (MATH-030), this HGLM analysis investigated which factors enhanced or hindered a student's progress towards successful mathematics remediation, i.e. passing all levels the required of developmental mathematics sequence with a minimum grade of C.

Consistent with other studies, this study revealed that the less the developmental mathematics requirements the more likely successful mathematics remediation was achieved. (Bahr, 2010; Kowski, 2013). Compared to students who placed into Arithmetic, students who began in either Elementary Algebra or Intermediate Algebra were found more likely to successfully remediate in postsecondary developmental mathematics. This was not surprising as students who place into Arithmetic will have two to three semesters of developmental mathematics (non-STEM major versus STEM major), whereas students starting in to Elementary Algebra will have one to two semesters of developmental mathematics, and Intermediate Algebra students, STEM major students with stronger basic algebraic skills, will only require one semester of developmental mathematics.

Also consistent with previous studies with respect to successful remediation from developmental mathematics, there was a statistical difference between males and females (Bailey, et al., 2010; Bourquin, 1999; Hoyt, 1999; Johnson & Kuennen, 2004). With regard to successful mathematics remediation and controlling for the other variables in the model, compared to female students, male students were found less likely to successfully remediate in postsecondary developmental mathematics. Could one reason for females evidenced as more likely to successfully remediate than males be due to females found less likely to delay taking their developmental mathematics sequence? Recall, Johnson and Kuennen (2004) revealed that men who require developmental mathematics were more likely than women to delay taking developmental mathematics, even though there was no statistical difference between males and females with regard of developmental mathematics placement.

Some curious differences occurred between the 2009 and 2010 cohorts with respect to successful mathematics remediation. For the 2009 cohort compared to students who delayed enrollment, students who took developmental mathematics the first semester of attendance increased the likelihood of successful remediation, while for the 2010 cohort delaying taking developmental mathematics was not statistically significant. Taking postsecondary developmental mathematics the first semester of attendance has been shown to increase academic success (Adelman, 1999; Driscoll, 2007; Johnson & Kuennen, 2004; Kowski, 2013). So why was this not be significant for the 2010 cohort? A possible explanation could be that in the summer of 2010 the community college used for this study acquired the local county technology institute (Stirling, 2010). Thus, by fall 2010 there was an increase in certificate program options, programs where either there was only a basic algebra competency requirement which needed to be completed sometime before graduation; or if there was a college-level mathematics requirement, the mathematics course requirement was not listed on the curriculum outline until after the first semester.

Another difference between the two cohorts was that for the 2010 cohort only, when comparing to students not requiring any developmental English, Reading and Comprehension 1 (ENGL-050), the lowest level of developmental English, was negatively significant. Consistent with Bahr's (2007) study investigating multiple postsecondary academic deficiencies, this study found that compared to developmental mathematics students not also requiring developmental English, developmental mathematics students who also required the lowest level of developmental English, were less likely to successfully remediate in postsecondary developmental mathematics, while there was no statistical difference between developmental mathematics students without developmental English need and those required the higher level of developmental English. This was not unexpected as developmental mathematics, especially algebraic skills, includes much reading and comprehension for effective problem solving. One potential explanation for why ENGL-050 was not significant for the 2009 cohort could be the low number of developmental mathematics students placing into ENGL-050. The 2010 cohort had twice as many students placing in ENGL-050 as the 2009 cohort, 52 out of 650 students versus 26 out of 660 students respectively. This may explain why ENGL-050 was revealed significant for the 2010 developmental mathematics cohort, yet not significant for the 2009 cohort. In addition, for the 2009 cohort out of the students in ENGL-050, the proportion of students passing their developmental mathematics sequence were not statistically different than those not successfully remediating in mathematics, whereas for the 2010 cohort only a quarter of the students in ENGL-050 passed their developmental mathematics sequence.

Finally, examining the significant factors of financial aid, for the 2009 cohort, developmental mathematics students receiving non-Pell grants were found more likely to successfully remediate, while students receiving Pell grants were found less likely to successfully remediate, compared to students not receiving that particular type of financial aid. A possible reason for the negative Pell grant relationship may be that while receiving a Pell grant may have given fiscally challenged students the opportunity to attend college, the additional money via Pell grant may not have provided the extra support to be successful. Since Pell grants often do not cover full tuition, Pell recipients may be more likely to spend time out of school working while also managing other family obligations. In addition, at the time of this study, there were no completion constraints for receiving a Pell grant, yet there were for receiving a non-Pell grant such as Tuition Aid Grant (TAG), grants that often cover the full cost of tuition (Higher Education, 2013). At the time of this writing, for a TAG recipient, at the community college level the state gave students only five fulltime semesters of eligibility, which possibly explains the positive relationship between non-Pell grant recipients and successful mathematics remediation. Furthermore, eligibility for TAG recipient, required students to be enrolled fulltime, a minimum of twelve credits (developmental courses included) by the end of each semester while maintaining a grade point average of 2.0 or higher (Higher Education, 2013).

The following discusses the lack of financial aid significance for the 2010 cohort in relation to successful mathematics remediation. For the academic year 2011-2012, Pell requirements were altered to a maximum of 6 years or 12 fulltime semesters for an Associate or Bachelor degree, whereas before there was no recipient time limit (Hopkins, 2011). Coincident with the decreased amount of time allowed to receive Pell awards, the Pell Grant program had a sizeable cut in funding (Hopkins, 2011). For those who were the most financially needy who might have previously been awarded the maximum amount needed per semester now were only receiving partial awards, whereas many students who previously received partial Pell grants found themselves ineligible due to decreased funding. Therefore for the 2010 cohort, students who may have received Pell or other grants at the start of their academic journey, by the time they successfully remediated were no longer eligible hence financial aid was no longer a significant factor with respect to mathematics remediation. On the other hand, the 2009 cohort had two years of postsecondary education before the eligibility changes, two years to successfully remediate while receiving financial aid in the form of Pell or other grants.

Outcome: Earn a Grade of C or Better in College-Level Mathematics

For those students who during the time of community college attendance took any college-level mathematics course regardless of direct placement or successful remediation into the course, this HGLM analysis investigated which factors enhance or hinder a student's progress towards successful completion of college-level mathematics, i.e. earning a minimum grade of C in college-level mathematics.

Similar to the previous results discussed for successful mathematics remediation, there was a statistical difference between male and female students with respect to successfully completing a college-level mathematics course with a minimum grade of C. Compared to female students, male students were found less likely to earn a grade of C or better in their college-level mathematics course. Bailey, et al. (2010) found that male students exhibited a lower probability of progressing through their developmental sequences than women students. Additionally, Johnson and Kuennen (2004) discovered that for students requiring developmental mathematics the likelihood that male students delayed taking the first developmental course was significantly greater than that of female students even though there was no statistical difference between males and females with regard of who places into developmental mathematics. Consequently, since this data set included both developmental mathematics students who remediated into college-level mathematics and those placing into college-level mathematics without any developmental mathematics requirement, a logical result for this outcome was male students less likely to achieve success with regard to earning at least a C-grade in college-level mathematics.

For students who entered college-level mathematics by remediating from Intermediate Algebra, the highest level of developmental mathematics, the probability of earning a grade of C or better in college-level mathematics was no different from those who did not have any developmental mathematics requirements. Comparable results were exhibited by students who started in Arithmetic, yet as noted in this and previous studies, the non-significance may have been due to the low number of Arithmetic students who successfully remediated into college-level mathematics, 3.6 percent of 585 for 2009 and 2.2 percent of 531 for (2010 Bahr, 2010; Waycaster, 2001). Regardless of whether observing the 2009 or the 2010 cohort, students who successful remediated into college-level mathematics from Elementary Algebra compared to students with no developmental mathematics need, were less likely to earn a grade of C or better in college-level mathematics. Why were these students passing postsecondary developmental mathematics yet not college-level mathematics? One possible explanation may due to the

2008 New Jersey general education agreement which resulted in major curriculum revisions in the developmental mathematics sequence for students placing into basic algebra (State of New Jersey: Higher Education, 2008). For the community college in this study, the Intermediate Algebra and Arithmetic courses were not affected by the general education agreement. Before this agreement, Elementary Algebra as a standalone course was not being taught, instead there were four half-semester modules covering content from both Elementary and Intermediate Algebra. Hence, at the time of this research, major curriculum adjustments were made, one of which was reconstructing content from an old Elementary Algebra course to fit new state-mandated requirements. With the Elementary Algebra course well established for many years now, additional investigation is needed to determine if the results uncovered in this study with regard to remediated Elementary Algebra students and earning a grade of C or better in college-level mathematics still transpire.

For the 2010 college-level mathematics cohort, students who received a federal loan compared to students not awarded any loan, were less likely to earn at least a C-grade in college-level mathematics. The significance of federal student loans for the 2010 cohort, yet not the 2009 cohort, may have been due to previously discussed financial aid eligibility changes occurring during this time (Higher Education, 2013; Hopkins, 2011). Students who may have previously received a Pell grant may find themselves no longer eligible and instead only qualified for a federal loan. In addition, students from the 2009 cohort who might have been receiving Pell, relying heavily on federal aid to finance their college education, due to policy changes and poor academic performance may no longer qualify for a Pell grant and had to instead finance their education through private student loans, a loan-type not considered within this study.

On the other hand, for the 2010 cohort, students who received a non-Pell grant such as TAG were found more likely to earn a grade of C or better in college-level mathematics. As previously discussed with the outcome successful mathematics remediation, for a TAG recipient, at the time of this writing, the state awarded a community college student a maximum of five fulltime semesters of eligibility. Furthermore, eligibility for TAG required the student to be enrolled fulltime, a minimum of 12 credits (developmental courses included) by the end of each semester while maintaining a minimum 2.0 grade point average (Higher Education, 2013). All of these requirements possibly explain the positive relationship between non-Pell grant recipients and students earning a C or better in college-level mathematics.

Outcome: Graduate

While some students take coursework at a community college to get a fresh academic start to reverse poor high school performance, or to save some money before transferring to a four-year institution, many New Jersey community college students instead look to graduate with a certificate or an Associate degree to either directly enter into the workforce or achieve a seamless transition into a four-year institution with junior-class status (State of New Jersey: Higher Education, 2008). With deference to graduating, two subsets of students were investigated; those who took any mathematics course, developmental or college-level, and those who took college-level mathematics, regardless of original placement. This section will examine any commonalities and differences between both sets of students from the 2009 and 2010 cohorts.

Mathematics students. Recalling that in at this community college all degrees and certificates require basic algebra competency; therefore, some students via placement testing and credential sought, did not require any postsecondary mathematics, while other students had to obtain basic algebra competency by passing Elementary Algebra and/or pass one or more college-level mathematics courses. The following are the results for those students who took any postsecondary mathematics course while attending the community college in this study.

Analogous with other studies and previous outcomes in this study, the greater the mathematics deficit upon entry the less likely a student was to graduate (Bahr, 2010; Bettinger & Long, 2005; Kreysa, 2006). Compared to students who placed into college-level mathematics, students placing in developmental mathematics were less likely to graduate with the comparative odds the lowest for those students who started in Arithmetic the lowest level of developmental mathematics.

Consistent with results previously discussed with the other outcomes, regardless of the cohort of students who took a mathematics course, students who received non-Pell grants were more likely to graduate, while students receiving a Pell grant were less likely to graduate when compared to students not receiving either type of financial aid. As previously discussed, receiving a Pell grant may have given a fiscally challenged student the opportunity to attend college, but the additional money may not have provided the extra support needed to be successful. Since Pell grants may not necessarily cover full tuition, Pell recipients may have spent more time out of school working and managing other family obligations. Also as previously noted, at the time of this writing a non-Pell grant such as Tuition Aid Grant (TAG), grants that often covered the full cost of tuition, had the additional constraint of fulltime enrollment and only covered a maximum of five successful community college semesters (Higher Education, 2013). This may help explaining its positive relationship in terms of graduating.

An interesting difference between the 2009 and 2010 cohorts with regard to graduating with a certificate or an Associate degree was the significance of gender for the 2010 cohort. Compared to female students, male students were found to be less likely to graduate. A possible account was the community college's attainment of the local technical institute during the summer of 2010. This acquisition resulted in the addition of new programs beginning the fall 2010 semester (Stirling, 2010). The addition of new programs included an increase in certificate programs as well as terminal Associate degrees such as medical assistant, interior design, cosmetology, etc., where the majority of graduates were females. For many of these programs the mathematics requirements were either Elementary Algebra competency or at most only one semester of liberal arts mathematics, resulting in significantly more females than males graduating.

Another curious difference between the two cohorts was the significance of the level-2 High School Proficiency Assessment (HSPA) advanced mathematics proficiency (AMP) variable. While the overall percent AMP for students who took the test their junior year of high school in 2008 or 2009 and graduated June 2009 or June 2010 respectively was relatively the same, in many of the subpopulations the percentage of AMP for the two cohorts were substantially different (State of New Jersey: Department of Education, 2008; State of New Jersey: Department of Education, 2009, spring). Future studies should examine if these differences are statistically significant, and if so, how these significant differences aimed at different subpopulations affect graduation from an open-access community college.

College-level mathematics students. An offshoot of the mathematics students are those students who entered college-level mathematics either via successful mathematics remediation or via direct placement. At the community college used in this study, all Associate transfer degrees and many terminal Associate degrees and certificates required a minimum of one semester college-level mathematics. The following results are for those students who took any college-level mathematics course while attending the community college in this study, regardless of the first mathematics course taken, and graduated with an Associate degree or certificate.

Analogous with other postsecondary education research investigating developmental mathematics and graduation, no statistical difference was revealed between students entering college-level mathematics by passing postsecondary developmental mathematics and students entering college-level mathematics without the need of developmental mathematics (Bettinger & Long, 2005; Kowski, 2013; Kreysa, 2006). The probability of graduating was no different between those who did and did not require any developmental mathematics. Once students entered college-level mathematics, it did not matter where those students began their mathematics sequence with regard to graduation; the likelihood of graduating was statistically the same. An unfortunate consequence was not many developmental mathematics students successfully remediate and enter college-level mathematics; hence many did not get the opportunity to graduate.

A promising area in need of further investigation was the results for the 2009 college-level mathematics students who started their sequence in Arithmetic. Students who successfully remediated into college-level mathematics from Arithmetic were found more likely to graduate as those students who placed directly into college-level mathematics. In contrast, there was non-significance for the 2010 college-level students who started in Arithmetic. Upon further investigation, only a small number of students (12 students, 2.2 percent) from the 2010 cohort successfully remediated from Arithmetic, a possible cause for lack of significance. The 2009 cohort exhibited a larger number of students (21 students, 3.6 percent) successfully remediating into college-level mathematics; of the 21 Arithmetic students in college-level mathematics, approximately 62 percent graduated, compared to only 44 percent of students without remedial need graduating. Even still, the number of 2009 Arithmetic students in college-level mathematics compared to those who placed directly was quite small. Therefore further investigation is required to validate these results.

The results for gender, non-Pell grant, and AMP significance were comparable to those previously discussed when examining students who took any mathematics course with the outcome graduating with a certificate or Associate degree. Therefore, refer to previous discussion in relation to the 2010 cohort gender significance, the non-Pell grant positive significance for both the 2009 and 2010 cohorts, and the 2009 cohort AMP significance.

Similar to the results with the previous outcome of earning a grade of C or better in college-level mathematics, here too when comparing to students not awarded a Pell grant, revealed a significant negative relationship of Pell grants for the 2009 cohort, while the 2010 cohort revealed the significance of a negative relationship for federal loans. As previously discussed, at the start of the fall 2011 semester there was a decrease in Pell grant maximum funding per postsecondary education student along with a stricter eligibility policy, both to first receive benefits and for continuation of benefits (Higher Education, 2013; Hopkins, 2011). For the 2010 cohort, the significance of federal loans rather than Pell grants was probably due to eligibility modifications. Students who previously received a Pell grant may have found themselves no longer be eligible and were instead only qualifying for a federal loan. Compared to students not awarded either of these types of financial aid, students receiving a Pell grant (2009 cohort) or a federal loan (2010 cohort) were less likely to graduate. As previously discussed, while a Pell grant or federal loan may have given a student from a low-income household the opportunity to attend college, the monetary award most likely did not cover the entire tuition while it also did not provide any additional support to be successful.

Overall, with respect to graduating with a certificate or an Associate degree, students who begin in developmental mathematics displayed the greatest obstacle. On the other hand, once a student successfully remediated in mathematics, the probability of graduating was statistically the same as those who did not require developmental mathematics.

In New Jersey a graduating high school student must demonstrate proficiency in four years of English and three years of mathematics (State of New Jersey: Department of Education, 2009, June 17). Therefore traditional-age postsecondary students will have had a maximum of just a few months since the last English education experience, with as much as fifteen months since the last mathematics education experience. This is especially detrimental in a subject matter such as mathematics, where lack of practice and application hinders retained knowledge and skills.

The purpose of this research was to cultivate a greater understanding of postsecondary developmental mathematics, especially as developmental mathematics pertains to community college graduation behavior. Recent studies on postsecondary developmental education and credential completion recognized hierarchical linear modeling (HLM) and hierarchical generalized linear modeling (HGLM) as more appropriate statistical methods for studying nested structures such as developmental mathematics students from various high schools sharing certain characteristics. Students within a specific mathematics placement level have shown a tendency to be more homogeneous with regard to retained mathematics knowledge, educational preparation, attitude and opinion regarding postsecondary developmental mathematics. Although the application of HLM and HGLM to educational research is relatively new, researchers have long recognized the shortcomings of the disaggregated and aggregated ordinary least-squares (OLS) approaches when dealing with data that violates the independence assumption (Bickel, 2007; Goldstein, 1995; Osborne, 2000; Raudenbush, et al., 2011).

Because hierarchical data inherently violates the independence assumption, OLS regression procedures will produce small standard errors resulting in an erroneous higher probability of statistical significance. To counteract this, HLMs and HGLMs take into consideration this violation of independence, adjusting the statistical methodology, thus preventing false significance. Hence by recognizing the lack of complete independence of students within the same mathematics placement level, using HGLM to study postsecondary developmental mathematics provides researchers with valid models for both individual and group level residuals, thereby providing more reliable information (Bickel, 2007; Goldstein, 1995; Osborne, 2000; Raudenbush, et al., 2011).

Limitations and Implications for Future Research

Limitations

As with all research, some limitations merit discussion. First, analyses conducted on a single institution are often criticized for the lack of generalization of the results beyond the study institution. When research is done across multiple institutions, the degree to which findings are relevant to any one institution is reduced by aggregation and the usefulness for implementing change at the campus level is decreased because the averaging of results across multiple institutions does not fit any one institution well. With the inconsistencies in successful postsecondary mathematics remediation rates from one institution to another and the push for colleges and universities to improve graduation rates, research should be conducted at the institutional level where the information has the greatest likelihood of effecting change in postsecondary developmental education and graduation rates. Furthermore, as New Jersey policy makers place more emphasis on time to degree completion to control the growing costs of higher education in the state, especially with respect to financial aid, HGLM models generated at the institutional level will provide important empirical evidence about why the majority of students are not successfully remediating in postsecondary developmental mathematics. As an ATD bi-county community college centrally located in New Jersey, the institution in the body of research has the capacity to take the lead in increasing mathematics remediation success rates and thereby reducing the time to degree completion.

Second, the present study did not incorporate the many recent changes to the increased academic standards in the primary and secondary grades and subsequent assessment (Common Core, n.d.). At the time of this writing Partnership for Assessment of Readiness for College and Careers (PARCC) began field testing assessment of the Common Core State Standards (CCSS), with full implementation geared for the academic year 2014-2015 (“PARCC key milestones,” 2013). With the full scale implementation of the CCSS paired with the PARCC assessment, future studies will be needed to determine if there is any positive impact with regard to postsecondary developmental mathematics and successful remediation (Common Core, n.d.; “PARCC charts pathway,” 2012).

Third, this study assumed perfect placement into developmental or college-level mathematics. There are drawbacks to the Accuplacer® mathematics placement exam. This adaptive test gives large penalties for incorrect answers early in the exam, resulting in later correct responses worth fewer points, making it more difficult to move up in mathematics placement level, than if answered correctly the first try (James, 2006). Therefore due to an initial poor start, many more correct responses are needed before the examinee is presented with questions of greater difficulty and higher point value (James, 2006). Consequently, one correct or incorrect response can determine a student's placement level (James, 2006). Due to large penalties for one incorrect response early on, there is concern that students are placed at lower mathematics levels and prohibited from enrolling in higher level mathematics courses where they might achieve success. Thus mathematics placement level is oftentimes based on whether or not the student score is above or below a certain cutoff (Hughes & Scott-Clayton, 2011).

With the assessment test as the only way to assess students' mathematical abilities, only students who have enrolled and taken their specified mathematics course were included in the study. As a result, the range of scores was restricted because students with lower or higher test scores than the allotted range as well as those who did not take their mathematics placement course, were excluded. Thus the correlation coefficients underestimated the magnitude of the relationships explored between placement and successful mathematics remediation. There was no way to know the grades earned had the student been permitted enrollment into a higher level course (Armstrong, 2000).

Fourth, the data did not investigate other control variables revealed significant in previous educational research of educational outcomes, namely the monetary amount of financial aid (this study only considered whether or not a particular aid was awarded), self-efficacy, employment, such as the number of hours per week a student works, and academic support programs outside of the classroom, such as tutoring and advising (Boylan, 1999; Chen & DesJardins, 2008; Culp, 2005; McClenney & Marti, 2006; Robbins, et al., 2004; Waycaster, 2001). The number of hours a student works per week, often to pay for school, has been found to be negatively associated with persistence and academic success. In other words, the more hours a student works per week, the less likely he or she will continue his or her education until a degree or certificate is earned. Furthermore, many other factors beyond the classroom found to contribute to academic success such as extra-curricular activities, tutor and other academic support services, clubs, sports, etc., were not considered in this body of research. Overall, the interactions of students beyond measureable academic outcomes was not taken into consideration.

Finally, selection bias is of particular concern in this analysis because community colleges that apply for and are granted approval to be an ATD institution are likely to differ from other community colleges. Therefore caution should be exercised when applying conclusions from this research to non-ATD community colleges. In addition only first-time fulltime college freshmen who graduated from a New Jersey public high school were considered in this study, eliminating the smaller population of students who graduated from either private or out-of-state high schools, were part-time, or took a hiatus after graduating high school before enrolling into college. Only those first-time, fulltime, college freshmen coming directly from a New Jersey public high school enrolled into developmental and/or college-level mathematics were considered. Consequently, any extrapolations inferred from this research must be limited to first-time, fulltime community college students who took at least one mathematics course, developmental or college-level. Also, the results did not account for students transferring out and completing their remediation and/or taking their college-level coursework elsewhere. In reference to graduation and attrition, these analyses were unable differentiate between students who transferred to another postsecondary institution and those who discontinued their postsecondary education altogether.

Implications

Continued postsecondary educational research is required to fully identify those obstacles preventing successful mathematics remediation for financial aid recipients, especially with respect to graduating. With the recent changes in Pell grant awards and eligibility, new exploration is required to investigate whether or not Pell grant recipients, similar to TAG recipients, now display a positive relationship, thereby an increased likelihood for graduation. Do the recent changes depict results similar to grants like TAG, which at the time of this study had limited duration and stringent continued eligibility requirements? Furthermore, does the monetary amount of aid, regardless of the type of aid, promote or hinder successful mathematics remediation and graduation rates?

In addition, why in this body of research were male students found less likely to pass their developmental mathematics sequence than female students, yet there was no gender significance with respect to passing college-level mathematics? Additional research is needed to uncover why gender is significant for some situations yet not for others.

Lastly, as noted previously and warrants mentioning again, is that when mathematics remediation is successful, its primary purpose is realized, college-readiness in mathematics. However, opponents of postsecondary developmental mathematics may justifiably challenge the value of developmental mathematics programs in which many students starting in developmental mathematics never reach their objective, passing a college-level mathematics course, an occurrence that increases the larger the mathematics deficiency.

Conclusion

In an era of increasing demand for college, declining economic resources, and the ever increasing expenses of undergraduate education, the study of community college postsecondary developmental education and graduation has been of great importance, especially since July 14, 2009, when President Obama announced his $12 billion community college initiative designed to boost graduation rates, improve facilities and develop new technology (Obama, 2009). Successful postsecondary developmental education, especially in mathematics, the area of greatest need, and subsequent postsecondary degree attainment, benefits individuals through increased higher-earning employment opportunities (Baum & Ma, 2007). As graduation rates are increasingly tied to institutional performance and resource allocation, community college administrators need to have a better understanding of postsecondary developmental education and subsequent graduation behaviors at their institution to develop effective interventions that help students not only successfully remediate and graduate, but do so in a timely manner.

As employed in recent research on postsecondary developmental mathematics education, this study used hierarchical generalized linear modeling (HGLM), clustering by high school to examine aspects that promote and hinder successful mathematics remediation, earning a minimum C-grade in college-level mathematics, as well as graduation. By focusing on one New Jersey ATD community college, this study produced in depth results that are more useful to college administrators at the study institution than those produced by analyses conducted at the national level. Although the present study was driven by a need to better inform community college administrators at the study institution, this study also benefits the higher education system by advancing HGLM as a methodology for studying developmental mathematics remediation. In conclusion, while postsecondary developmental mathematics education is valuable for those who remediate successfully, continued postsecondary developmental education research is required to reveal why so many developmental mathematics students either fail to complete their developmental mathematics sequence or require multiple attempts before successfully remediating. In reality, there could be a multitude of reasons why students may not successfully complete a course, especially a developmental course where a student's confidence level and attitude, as well as other personal issues, can and often do interfere with participation and completion.

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