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Predicting First-Year Mathematics Success at the Community College: Modifications on High School Grade Point Average and the Impact of High School Quality

C. Caleb Marsh
Old Dominion University

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by

C. Caleb Marsh
B.S. August 2004, Appalachian State University
M.A. May 2008, Appalachian State University

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Approved by:

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Christopher Glass (Director)

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Anthony Perez (Member)

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Mitchell Williams (Member)

Abstract

Predicting First-Year Mathematics Success at the Community College: Modifications on High School Grade Point Average and the Impact of High School Quality

C. Caleb Marsh
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Director: Christopher Glass

In recent years, student completion in the first-year college mathematics curriculum has become a significant barrier to student success and retention. Many states, such as North Carolina and Virginia, have been innovative in developing new strategies for placing students into an appropriate mathematics curriculum. A centerpiece of these strategies is to use student performance in high school, as measured by *high school grade point average*, as a predictor for course success and completion. However, in each system, what is largely absent from their placement models is any attempt to account for the quality of the institution that issued the high school graduation credential. The purpose of this study was to examine the application of high school grade point average as a predictor for success in a first-year mathematics course as modified by characteristics of the high school that issued the credential using *multilevel modeling*.

For this study, student level data was obtained from randomly selected two-year institutions in the North Carolina Community College System and was matched with descriptive data of North Carolina high schools that issued credentials for students selected at the college level. Logistic regression was then employed to ascertain what characteristics of high school quality explained additional variability in student course completion beyond high school grade point average. After exhaustive analysis, application of group-level performance indicators for f*aculty with advanced degrees* and *student performance on the Math 1 end of course examination*, modified the use of high school grade point average as a predictor for success in mathematics at the community college. Practitioners can use these findings to inform placement strategies and student success interventions at the community college level.

Keywords: high school grade point average, mathematics success, community college, high school quality, predictive analytics

This dissertation is dedicated to my wife, Jessica, and my children, Liam and Colin. Without them, none of this would have been possible.

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Chapter 1

Introduction

Over the last 20 years, there has been increased scrutiny on student experiences in high school as a predictor for college success (Kowski, 2013). Viewing the student experience as a continuum of skills and construction of a knowledge base has the potential to better inform advisors in the development of a pathway for success (Wilmer, 2008). However, despite vertical alignment efforts and partnerships with institutions of higher education, entering college students are less prepared for college level coursework than ever before (Crist, Jacquart, & Shupe, 2002). The skills gap between high school and college students is most prominent in mathematics (Kowski, 2013).

According to Scott-Clayton (2012), 92% of all community colleges in the United States administer some form of placement testing to recognize where students' lack content knowledge in preparation for college coursework. Even though the vast majority of institutions utilize placement testing, researchers have argued that high stakes testing provides little insight to a student's preparation for college (Belfield & Crosta, 2012; Burdman, 2012; Hodara, Jaggars, & Karp, 2012). In 2010, systems like the Virginia Community College System (VCCS) and the North Carolina Community College System (NCCCS) began to scrutinize college placement strategies. In accordance with the national recognition of high school experiences, systems undergoing placement reforms began to utilize high school grade point average as a placement tool. For those significantly removed from high school graduation, a series of new placement tests were developed for students failing to show evidence of recent content mastery (Collins, 2008).

Underlying the attempts to reform placement policies was one basic assumption: student high school experiences are identical. Policies resulting from 2010 reforms made no assessment of *high school quality* and depended, exclusively, on a set of metrics reported by high schools (Collins, 2008). Researchers have argued that the exclusion of such characteristics diminishes the utility of past performance in high school as a predictor for college success (Dexter, Tai, & Sadler, 2006; Pike & Saupe, 2002; Wolniak & Engberg, 2010). This study explored relationships between student performance in high school, high school quality, and *first-year mathematics success*. Such an exploration expanded the body of literature regarding the utility of student performance in high school as a predictor for student success in community colleges in the United States.

Background

Open access is a central tenet to the mission of most two-year colleges in the United States (Hodara, Jaggars, & Karp, 2012; Kolajo, 2004; Scott-Clayton, 2012). Open access institutions subscribe to a philosophy that affords all individuals admission to the institution regardless of their academic background or personal experiences. However, open access does not imply guaranteed access to college level coursework (Scott-Clayton, 2012). According to Kolajo (2004), more than 90% of community colleges offer developmental coursework to help students remediate skills requisite for success in college level coursework. For many students, developmental education is the pathway for access to these courses. For others, their skill set is sufficient to begin college level coursework. Declaring a student *college ready* requires evidence of academic preparation beyond the developmental education curriculum. Institutions and students are best served by limiting the amount of remediation a student needs before beginning college level coursework.

Developmental education is a costly endeavor. Although remedial courses tend to cost less than curriculum level courses, the national cost of developmental education is estimated to be between one and two billion dollars per year (Martinez & Bain, 2014). Beyond the fiscal costs, students required to take developmental courses take more time to complete a credential (Bailey, Jeong, & Cho, 2010). In many cases, students are unable to remediate their skills to the level required for college level coursework (Jaggars, Hodara, Chu, & Xu, 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011). These facts have left practitioners and researchers wondering if developmental education placement policies and procedures are in need of revision (Goudas & Boylan, 2012; Jaggars et al., 2015; Martinez & Bain, 2014).

When addressing placement policies, it is inappropriate to treat all prospective two-year college students as a homogenous group. Some students have a wealth of workforce experience while others are recent high school graduates. Historically, entering students have been required to take a placement examination (Belfield & Crosta, 2012; Burdman, 2012; Hodara et al., 2012; Mellard & Anderson, 2007). The goal of such an examination is to prescribe the precise amount of remediation necessary to prepare any student for college level coursework (Hodara et al., 2012). However, many researchers have questioned the validity of such instruments (Belfield & Crosta, 2012; Burdman, 2012; Hodara et al., 2012; Mellard & Anderson, 2007). Evidence of poor placement strategies have led many two-year college systems to reform their placement policies.

Evidence suggests as many as 30% of all students graduating high school and entering higher education are unprepared for the rigors of college level mathematics (Berghmans, Michiels, Salmon, Dochy, & Struyven, 2014; Calcagno & Long, 2008; Pittman, 2010; Wilmer, 2008). This number increases to 60% for students applying to community colleges **(**Calcagno & Long, 2008**)**. Lack of student preparation for college level coursework creates a barrier to completion for students attempting to obtain a credential. Financial burdens and lack of support for first generation students also contribute to the completion problem, but from a curricular perspective, the course that presents the largest barrier to college completion for all students is the introductory mathematics course (Bailey et al., 2010; Kowski, 2013; Zeidenberg & Scott, 2012).

Students required to take remedial courses in mathematics incur additional debt, and less than 20% persist to graduation (Jaggars, Hodara, Chu, & Xu, 2015). Retention and graduation efforts can be significantly affected by not addressing issues with proper placement in the mathematics curriculum. Most introductory mathematics curricula, referred to as gatekeeper courses, include content that is requisite for success in other courses taken within a student's program of study. Topics can include planar geometry, business and financial math, elementary statistical methods, algebra skills, and basic linear programming (Wilmer, 2008; Zeidenberg & Scott, 2012). College readiness for the introductory mathematics course has been, traditionally, gauged through placement testing or student performance on college readiness examinations such as the Scholastic Aptitude Test (SAT) and the American College Testing (ACT) examination (Bettinger & Baker, 2014; Dow, 2013; Burdman, 2012). Although researchers have noted the effectiveness of using these methods for college placement, others have argued that a student's *high school grade point average* is just as effective at gauging a student's ability to succeed in college (Bracco, Dadgar, Austin, Klarin, Broek, Finkelstein, Mundry, & Bugler, 2014; Geiser & Santelices, 2007; Scott-Clayton & Hughes, 2010). Evidence regarding the use of high school grade point average as a predictor for college success has led the NCCCS to redesign approaches for placing students in a college level mathematics course.

The NCCCS policy for college placement is a set of specific guidelines delineating a hierarchy for placement according to a student's high school grade point average, college entrance exam scores, and standardized placement test scores (Ralls & Morrissey, 2013). Although the policy takes a holistic view of student performance, the primary student characteristic used for placement is a student's high school grade point average. Early findings from similar redesign efforts in the Virginia Community College System (VCCS) indicated that 81% of entering college students in 2012 met the criteria for college level mathematics compared to 57% in a comparison cohort from 2010 (Kalamkarian, Raufman, & Edgecombe, 2015). Even though more students met the criteria for college level mathematics placement, practitioners have argued that student performance has declined (Marsh & Roughton, 2017).

Changing the metrics for placing students into college level mathematics has had the effect of reducing the enrollment in developmental coursework and increasing the percentage of students who are college ready (Duffy, Schott, & Beaver, 2014; Kalamkarian et al., 2015). However, decreasing enrollment in developmental mathematics alone is not sufficient evidence to declare the use of the high school grade point average as an adequate placement tool. Even though high school grade point average provides a snapshot of student performance in secondary education, the quality of the performance is significantly correlated with the institution that issued the graduating credential (Dexter, Tai, & Sadler, 2006; Pike & Saupe, 2002; Wolniak & Engberg, 2010). Researchers investigating high school quality, as it relates to post-graduation performance, indicated that examining quality alongside student performance, indicated by grade point average, was a more powerful predictor of overall college success than using high school grade point average alone (Wolniak & Engberg, 2010).

Researchers applying high school quality metrics as modifiers for high school grade point average when predicting student success in college have produced seminal publications. However, what remains largely absent from the scholarly literature is an examination of this same modifying effect applied specifically to community colleges and first-year mathematics success. The purpose of this study was to examine whether the relationships, identified in scholarly literature, exist when applied to first-year mathematics performance at North Carolina Community Colleges. More specifically, does incorporating high school quality as a predictor modify the hypothesized association between high school grade point average and first-year mathematics success?

Problem Statement

There is a national movement in community colleges to address college placement strategies (Goudas & Boylan, 2012; Jaggars, Hodara, Chu, & Xu, 2015; Martinez & Bain, 2014). Central to this movement are issues related to student success, retention, and budget stewardship. Researchers agree that placement testing strategies are inadequate and a more holistic view of the student's experiences is necessary to better inform this process (Belfield & Crosta, 2012; Burdman, 2012; Hodara, Jaggars, & Karp, 2012). The utility of high school grade point average has been shown to be a valid predictor of college success (Bracco et al., 2014; Geiser & Santelices, 2007; Kobrin, Patterson, Shaw, Mattern, & Barbuti, 2008; Scott-Clayton, 2012), but can be further modified by examining the quality of the source of the credential (Betts, 1995; Card & Krueger, 1992; Dexter, Tai, & Sadler, 2006; Goldhaber & Brewer, 2000; Pike & Saupe, 2002; Wolniak & Engberg, 2010). However, the issues relating to student success must be further narrowed to identify specific content discrepancies. With first-year mathematics presenting a significant barrier to student completion and success (Jaggars et al., 2015; Martinez

& Bain, 2014; Rutschow & Schneider, 2011), it is appropriate to examine the relationships of high school grade point average and high school quality as it relates specifically to mathematics. This study explored literature related to current placement strategies, valid predictors for student success in mathematics, and explored these relationships within the NCCCS by examining student data within the system. Such an exploration addressed the placement problem regarding first-year mathematics success through the lens of prior student learning. Findings presented in later chapters will define the breadth of the relationship between high school grade point average, as modified by high school quality, and student success in introductory mathematics courses. Examination of these findings will help guide stakeholders in the development of intrusive advising practices to better serve students in their personal academic goals.

Research Questions

This research was guided by three specific questions that were addressed through data collection and analysis:

1) Is there a statistically significant, positive relationship between students' high school grade point average and success in a first attempt at a college level mathematics course?
2) What characteristics of high school quality have a significant relationship with student success in a first attempt at a college level mathematics course?
3) What are the relative strengths of high school quality and high school grade point average as predictors of student success in a first attempt at a college level mathematics course?

Professional Significance

The results of this study will be used to scrutinize the use of high school grade point average as a predictor for first-year mathematics performance in North Carolina community colleges. Researchers have identified high school grade point average as a valid metric for gauging student success in postsecondary coursework (Bracco et al., 2014; Geiser & Santelices, 2007; Scott-Clayton & Hughes, 2010). This study has provided further evidence regarding the use of such a metric in college placement, particularly in mathematics coursework. Although the methods utilized in this research differ from those used in previous studies, further investigation into the application of the high school grade point average metric has further validated application of such a metric in the NCCCS and other systems like it. Furthermore, examining high school quality as a modifier of high school grade point average has the potential to expand on the body of existing literature as it pertains to first-year mathematics success.

Administrators in secondary education will use the results to inform practices regarding characteristics of quality and student performance after graduation. Professional educators at the secondary level have engaged in initiatives such as *Vertical Alignment* to make better curricular connections throughout a student's educational experiences (Abatayo, Arabejo, & Kunwar, 2017). As stakeholders in secondary education look to better understand how to prepare students for coursework beyond high school, explorations into the quality of their high school programming can provide direct evidence as to what interventions significantly impact performance in college level mathematics.

Community colleges can use the results of this study to construct intrusive advising practices to better direct students on a pathway to success in first-year mathematics courses at the community college level. The NCCCS employs a prescriptive placement model; however, providing students the opportunity to self-select their mathematics programming can lead to confusion and improper placement. The results of this study can aid advisors in examining a student's academic background and offering guidance in the selection of a pathway in which a student can be most successful.

Overview of Methods

Examining relationships between student performance and prior learning experiences is an exploratory approach. This study, guided by existing literature, has defined variables describing student performance in introductory mathematics at the community college level, scrutinized that performance according to a student's high school experiences, and, ultimately, built models that provide insight regarding student performance for future cohorts. This study applied *multilevel regression techniques*, a quantitative approach for data analysis (Field, 2013), in a search for truth while maintaining a guarded perspective with respect to personal bias. Studies investigating the search for truth under the guise of probabilistic comparison regularly follow the post-positivist theory of research (Leedy & Ormrod, 2015). This study has employed such a perspective.

Sampling frame. The North Carolina Community College System contains 58 separate institutions that offer coursework according to a common course catalog. Using a cluster sampling model, twenty-two colleges within that system were solicited for data and five submitted data for this research. Those that submitted data returned information regarding student performance in first-year mathematics as well as demographic information describing the student. Each site was selected to represent different geographic regions of the state. Additionally, colleges were selected of varying size: 2 institutions with Full-Time Enrollment (FTE) less than 2500 students, 2 institutions with FTE between 2500 and 6000, and 1 institution with FTE greater than 6000. Selecting institutions of different sizes and service populations reduced overall bias and were representative of the NCCCS as a whole.

Multilevel, hierarchical, logistic regression analyses were performed using high school grade point average as a primary predictor, and other variables were added, at multiple levels, to assess student performance in a first attempt at a college level mathematics course. *Pearson's correlation coefficient*, *Eta-squared*, and *Chi-squared* statistics were used to determine the relationship between selected variables and student performance. Finally, appropriate fit for predictor variables was calculated using two sample t-tests, ANOVA, and *Intraclass Correlations Coefficients* to determine differences between the baseline models and the modified models including high school quality.

Participants. Students from the five research sites were analyzed based on their performance in an introductory mathematics course in the 2016 - 2017 academic year. The NCCCS common course catalog indicated that there were three courses that met the criteria for universal college transfer that also met the criteria for completion of mathematics requirements for transfer credentials: Quantitative Literacy (MAT143), Statistics 1 (MAT152), and Pre-Calculus Algebra (MAT171) (Board of Governors, 2014). Participants in this study must have attempted their first college level mathematics course within five years of graduation from a North Carolina high school. Significant separation from graduation has the potential to diminish the validity of high school grade point average as a predictor for college success (Collins, 2008). Additionally, students that completed developmental coursework at the college prior to attempting an introductory mathematics course were omitted from this study so that the data are not biased towards any college coursework that may have already occurred. Finally, students that had not yet completed their high school credential, students under the age of 18, and military service members were also omitted.

Data Collection. Data collection occurred in two phases. During phase one, each of the five selected colleges submitted de-identified student data reporting demographic information as well as student performance. This information included gender, ethnicity, the high school that granted the secondary education credential, other characteristics that described student prior content knowledge, and their performance in college level coursework.

In a second collection phase, data were collected from high schools, granting graduation credentials for students identified in phase one, regarding several characteristics that describe the quality of the school. These metrics included end of grade test performance, number of certified teachers, number of national board certified teachers, attendance, the percentage of students eligible for free and reduced lunch, and others. High school quality data are publically available from the North Carolina Department of Public Instruction (NCDPI). The data from these high schools was paired with a cohort of graduates from those high schools that attended the selected community college.

Data Analysis. Data analysis happened in several stages. Once the data were compiled in a spreadsheet, SPSS (Version 24) was used to run all analytical procedures.

First, a matrix of associations was constructed to assess any relationships between the independent and dependent variables. Any dependent variables paired with the independent variable that did not indicate a statistically significant correlation coefficient, measured by *correlation coefficient*, *eta-squared*, or *chi-square* statistics, were reported as not significant. Additionally, the matrix of associations was used to identify independent variable pairs that are significantly correlated. These pairs were evaluated and variables were removed to prevent heteroscedasticity.

Second, since the independent variables occur at two different levels of observation, analysis as a single level could have missed a source of variability explanation. As such, two baseline models were developed, using hierarchical, multilevel, logistic regression, predicting college performance in mathematics by high school grade point average. The first model explored relationships at the individual, student level (Level One). Final model selection, at Level One, was indicated by a significant change in *Chi-square* statistics. Such analysis worked to align the findings of this study with literature examining the behavior of the student without the consideration of group level indicators (Level Two). Once a Level One model was found, several Level Two models were built to explain variability across the high schools that issued the graduating credentials for each student in the sample. Final model selection at Level Two was decided by significant *t-tests* and overall model fitness.

Delimitations

The goals of this study were broad, and the implications of the findings have the potential inform a variety of stakeholders regarding student success in college level mathematics. However, the design for this study was built to answer specific questions while keeping timeliness and generalizability in mind.

The NCCCS was a system undergoing significant change at the time of this study. Implementation of new placement procedures within the system adjusted data acquisition practices on behalf of the college system. Prior to implementation, transcript analysis was minimal. Post-implementation, colleges were required to track student high school grade point average, future ready codes, and other data relevant to this study. These new procedures provided an avenue for access to data that addressed issues discussed in this study. The selection of the NCCCS, however, limits the scope of the findings to this system due to the nature of the common course catalog. Generalizing the findings to similar, but uniquely defined, curriculum in other systems should be done with caution.

The cluster sampling model employed by this study was selected to meet conditions of random selection (Field, 2013; Leedy & Ormrod, 2015). In a system with 58 community colleges, the selection of these five was appropriate to generalize the findings to the entire NCCCS. Grouping each of these colleges by size protected the interests of all institutions regardless of size, but is not, entirely, representative of the NCCCS as a whole. This method for selection provided insight to service areas, both rural and urban. Since the larger schools service more constituents, the number of students meeting criteria for selection was, naturally, larger and sufficiently met representativeness requirements.

There were several prerequisites for student inclusion as members of the sampled data. Restricting the sampling frame to recent North Carolina high school graduates, students over the age of 18, non-incarcerated citizens, and students having no college treatment of mathematics prior to their first attempt limits application and generalizability. As such, any applications of the findings outside of this specific cohort of the student population would be inappropriate and should be noted as a delimitation.

Finally, selection of hierarchical regression as an analytical technique best served the research questions posed by this study. Since the goals of this research are not deep individual description, but overall characterization of relationships, quantitative methods were appropriate. Further research will be necessary for deep description exploring individual student experiences in college mathematics courses resulting from the quality of their secondary education.

Definitions of Key Terms

- College (Curriculum) Level Coursework - a sequence of courses that is typical of content offered at the postsecondary education level (Bracco et al., 2014; Scott-Clayton, 2012; Wilmer, 2008).
- College Ready - a declaration of student preparedness to engage in college level coursework (Burdman, 2012; Ganzert, 2014).

- Developmental Education - a sequence of courses offered at institutions of higher education designed to remediate skills requisite for student success in college level coursework. Most developmental education curricula address skills in the English and mathematics content areas (Burdman, 2012; Hodara et al., 2012; Kolajo, 2004).
- First-Year Mathematics Courses - coursework, typically offered at the freshman level, that is an introduction to the study of mathematics at the postsecondary level.
- Gatekeeper Courses - courses offered at the introductory level that are, generally, pre-requisite courses for additional content within the curriculum (Jenkins, Jaggars, & Roksa, 2009).
- High School Grade Point Average - an average of quality points achieved in a student's pursuit of a secondary education credential. This average is a scale score ranging from 0 to 4; 0 indicating a failure to perform and 4 indicating exemplary performance.
- High School Quality - metrics that assess the quality of an institution granting a secondary credential. These metrics can include access to technology, student-teacher ratio, percentage of highly qualified teacher, and others (Pike & Saupe, 2002).
- Multiple Measures - a set of policies that uses a variety of metrics to gauge student content knowledge for placement into college level coursework. Although many systems use this set of policies in different ways, much of this document focuses on the NCCCS model for placement via Multiple Measures (Collins, 2008; Ralls & Morrisey, 2013).
- North Carolina Community College System (NCCCS) - the system that is charged with oversight of the 58 member institutions in the State of North Carolina.
- North Carolina High School Report Card - an evaluative instrument, produced by the North Carolina Department of Public Instruction (NCDPI), that describes variables

regarding school quality.

- Retention - maintaining a student's enrollment within a curriculum from term to term.
- Two-Year Colleges - institutions that offer training and credentials that, generally, take two years to complete. These institutions can include junior colleges, community colleges, and trade schools.
- Virginia Community College System (VCCS) - the system that is charged with oversight of the 22 member institutions in the State of Virginia.
- Workforce Experience - experiences from individuals engaged in industry outside of academia.

Summary

This study was designed to expand the body of literature regarding mathematics success viewed through the lens of student experiences. Following this chapter is an analysis of existing literature related to topics addressed by this study. Chapter 3 is a description of the methods used by this study to answer the research questions posed in the introduction. Chapter 4 is a detailed analysis of the data and Chapter 5 will conclude the study with a discussion of the findings related to the existing literature.

Chapter 2

Literature Review

High school grade point average has been identified by researchers as a valid predictor for college success (Bracco et al., 2014; Geiser & Santelices, 2007; Scott-Clayton & Hughes, 2010). The result of such findings have led policymakers to include high school grade point average in placement strategies for entering college students (Collins, 2008; Kalamkarian et al., 2015; Ralls & Morrisey, 2013). Further research into the high school grade point average predictor indicated that the source of the institution issuing the credential can also account for variability when measuring student preparation for college level coursework (Dexter et al., 2006; Pike & Saupe, 2002; Wolniak & Engberg, 2010) while others have focused on performance in academic content areas (Kowski, 2013). The purpose of this chapter is to synthesize the academic conversation regarding high school grade point average, high school quality, and policies related to college placement as described in scholarly literature.

Methodology

A broad search strategy was used to identify resources related to the research proposed in this document. Electronic searches were completed using ERIC, EBSCO, and Google Scholar. Search terms were identified across three content areas: High School Grade Point Average, High School Quality, and Multiple Measures. Combinations of the following terms were searched: student success, first-year mathematics, retention, completion, community college, college placement, open access, transcript, and placement tests. All relevant literature was stored and evaluated using a Mendeley database.

Chapter structure. This chapter is structured with two major sections. The first is background information to construct the setting for studies related to the research. This background will include a detailed description of the community college service population, barriers to student completion of a credential, policies related to student placement, and a description of high school quality. The second section of this chapter will synthesize previous studies related to the research questions for this document. For inclusion, the following criteria were followed:

1) examination of high school grade point average as a predictor for college success;
2) examination of high school quality as a predictor for content level success;
3) publication of research after 1999;
4) quantitative methodology.

This chapter will conclude with a synthesis of the findings from relevant research.

Background

The following sections comprehensively describe the environment of all pertinent aspects of higher education related to this study.

Community college service population. Community Colleges in the United States have a unique service population. Historically, junior colleges were developed as part of the Servicemen's Readjustment Act of 1944 (the GI Bill) (Geiger, 2011). As soldiers returned home from World War II, the benefits of the GI Bill created an environment that led to an influx of students attempting to earn credentials close to home. Residential colleges were formed around the nation to meet the demand. In fact, during the late 1960s and early 1970s new colleges were opened at a rate of one new institution per week (Geiger, 2011).

As the number of military personnel leaving combat diminished, amendments to the Higher Education Act renewed a national commitment to student access (Geiger, 2011). Access, one of the fundamental pillars to the comprehensive model used in community colleges, began in

California and gained national notoriety in the 1960s (Meier, 2013). The open access pillar of community colleges, traditionally, attracted minority students, low-income students, first generation college students, and adult learners (Malcolm, 2013).

Demographics. The American Association of Community Colleges (AACC) tracks national trends in student demographics. In February 2016 the AACC reported the national student demographics at Community Colleges (American Association of Community Colleges, 2016) shown in Table 1.

Table 1

National Community College Student Demographics

Characteristic	Percentage
Gender	
Female	57%
Male	43%
Ethnicity	
White	49%
Hispanic	22%
Black	14%
Asian / Pacific Islander	6%
Multiple Races / Other	8%
Age	
Average Student Age	28
Median Student Age	24
Under 21	37%
22-39	49%
40 or older	14%
College Family History	
First Generation Students	36%
Student Financial Aid	
Any Aid Recipients	58%
Federal Grant Recipients	38%
Federal Loan Recipients	19%
State Aid Recipients	12%
Institutional Aid Recipients	13%

Characteristics	Percentage
Employment Characteristics	
Full-time Student / Full-time Employee	22%
Full-time Student / Part-time Employee	40%
Part-time Student / Full-time Employee	41%
Part-time Student / Part-time Employee	32%

Barriers to college completion. Community colleges served approximately 25% of all students pursuing higher education at a public institution in the fall 2012 (Dow, 2013). The community college share of the higher education enrollment has been steadily increasing over time (Dow, 2013). With this increase in enrollment coupled with the community college mission of open-access and comprehensive curriculum, colleges have been challenged with creating course work that meets the needs of all students that apply. Applicants to the community college system have varying levels of prior education. Some are capable of handling the rigors of college coursework, but as many as 50% are required to take at least one remedial course in either mathematics or English (Bailey et al., 2010; Kolajo, 2004). Many authors have noted that remedial education is expensive for students while simultaneously retarding their progress towards completion of a credential (Belfield & Crosta, 2012; Kolajo, 2004).

Beyond specific courses or knowledge deficiencies, many students in the service demographic suffer with transitioning to the role of a college student (Wilmer, 2008). Although colleges have spent significant resources in developing programs to help students transition into this new role, many find that these changes insurmountable. Wilmer (2008) further pointed out that many colleges that offer such services do a poor job in educating students about these programs and services, adding to the transition problem. Beyond transitioning to the role of a student, other areas of have been identified as significant barriers to student success. Such barriers can be the open-access mission of the community college, student life, and the required curriculum; particularly courses related to the study of mathematics.

Open-access as a barrier. Researchers investigating demographics that predict student success have noted that many of these characteristics describing the community college student population are problematic. Non-traditional students and returning students are more likely to be deficient in skills required for success at the college level (Collins, 2008). First-generation college students are less likely to complete their first-year of a college credential and are even less likely to complete the full credential than students whose parent(s) hold a college credential (Pascarella, Pierson, Wolniak, & Teren, 2004).

Regarding the ethnicity of students at the community college, researchers have identified that colleges with a large proportion of minority students tend to have lower than average completion and success rates (Calcagno, Bailey, Jenkins, Kienzl, & Leinbach, 2008). Researchers noted that their findings tended to be consistent across community colleges and other institutions of higher education. Although this may appear to have implications across racial lines, the researchers argued that their findings are more about the experiences of minorities in higher education as opposed to a statement on academic ability (Calcagno et al., 2008).

Student life. Students pursuing credentials at the community college level are engaged in multiple societal roles. Beyond the student role, many are employed and / or have family responsibilities. Data from the American Association of Community Colleges (2016) indicated that more than 60% of students at community colleges are employed full-time. By most conventional definitions, this would indicate that in addition to taking classes, students are required to report to work in excess of 34 hours per week. Career aspirations and employment opportunities have the potential of placing further stress on students beyond classroom activities

(Wilmer, 2008).

The AACC (2016) also noted that as much as 17% of the community college population were single parents. These students bear the primary responsibility of caring for another human life. For many parents, caring for a child supersedes all other responsibilities and as their children require attention, it is likely that these students will not be as focused on their coursework (Price & Tovar, 2014).

The required curriculum. The comprehensive curriculum inherent to the mission of community colleges was designed to prepare students for the rigors of advanced coursework in pursuit of a baccalaureate credential or in preparation for the workforce (Geiger, 2011). Although this curriculum contains coursework typical of general education in all sectors of higher education, the mathematics curriculum presents a significant barrier to student completion and success (Jaggars et al., 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011). Jaggars et al. (2015) identified three specific culprits in creating this barrier: demotivating curriculum; external pressures; and improper placement into mathematics coursework. Efforts to address this barrier were derived both within community colleges and from external agencies.

The first-year mathematics curriculum in community colleges has been evolving as a result of pressures from transfer institutions and partnerships with business and industry. North Carolina, a state whose community college system has undergone significant reform, provided evidence of such curricular shifts. In 2012, SuccessNC, a project in North Carolina Community Colleges, funded efforts to evaluate the mathematics curriculum for rigor and relevance and to make adjustments to the curriculum as needed (SuccessNC, 2013). The end result of the Curriculum Improvement Project (CIP) was an overhaul of the North Carolina Community College Common Course Library. Existing courses that were rarely offered at North Carolina

Community Colleges were deleted and several new courses, under the recommendation of mathematics faculty from member institutions, were added to meet the needs of future graduates pursuing college transfer or workforce employment (SuccessNC, 2013).

Although the North Carolina Community College Common Course Library provides many courses for students as their first curriculum mathematics experience, most colleges have elected to offer students a choice of three different courses; Quantitative Literacy (MAT 143), Statistical Methods 1 (MAT 152), and Pre-calculus Algebra (MAT 171). Colleges elect to offer these three courses as a result of the Comprehensive Articulation Agreement (CAA) between North Carolina Community Colleges and University of North Carolina System. This agreement details a list of courses that are universally accepted by University of North Carolina System member institutions as transfer coursework for students (Board of Governors, 2014). Since as much as 28% of the University of North Carolina System student population is composed of transfer students having attained credit at other institutions (SuccessNC, 2013), North Carolina Community Colleges view these three specific courses as gateway courses to university transfer.

Quantitative Literacy. A general education mathematics course is a norm in most higher education programs. Since the 1950s policymakers in the mathematics curriculum, such as the Mathematics Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM), have debated the content inherent to these general education courses (Sons, 1996). Ganter (2006) argued that as our society evolves, every student must be minimally literate in the language of mathematics. A lack of such skills will leave students deficient when handling situations in everyday life (Ganter, 2006). In 1989, the MAA and NCTM, along with other vested parties, developed a committee to build a set of recommendations regarding the implementation of a quantitative literacy curriculum in higher education (Sons, 1996). Sons

(1996) noted that the committee generated five standards:

> It is… defined that a quantitatively literate college graduate in terms of five capabilities. That is, such a graduate should be able to:
>
> 1) Interpret mathematical models such as formulas, graphs, tables, and schematics, and draw inferences from them.
> 2) Represent mathematical information symbolically, visually, numerically, and verbally.
> 3) Use arithmetical, algebraic, geometric, and statistical methods to solve problems.
> 4) Estimate and check answers to mathematics problems in order to determine reasonableness, identify alternatives, and select optimal results.
> 5) Recognize that mathematical and statistical methods have limits. (p. 6)

In accordance with the standards, the North Carolina CIP created a course called Quantitative Literacy.

The course, offered in all 58 North Carolina community colleges, builds on the recommendations of the Quantitative Literacy committee and offers specific content in personal finance, basic statistics, and content related to election theory and the apportionment process (North Carolina Community College System, n.d.a). This course was designed to be a terminal mathematics course for most students pursuing an associate's credential.

Statistics. Making the case for a quantitative literacy course in higher education is not unlike the case for an introductory statistics course. Students entering the classroom have more access to data than ever before in United States history due to the internet and social media (Everson, Gundlach, & Miller, 2013). The American Statistical Association (ASA) has called for the reform of the introductory statistics curriculum by limiting rote memorization and embracing data applications (Everson et al., 2013). As such, the introductory statistics curriculum at North Carolina Community Colleges, and others nationwide, was designed using a project based approach emphasizing statistical literacy and recommends the use of relevant, real-world data applications (North Carolina Community College System, n.d.a).

*Pre-Calculus***.** The final course available to students in their first-year is a traditional, pre-calculus course. Although the content of this course has evolved with changes in quantitative literacy and statistics, the goal of this course was to give students a treatment of mathematics necessary to study calculus. Students are expected to solve linear equations and inequalities, analyze functions, and apply this knowledge in a variety of contexts (North Carolina Community College System, n.d.a).

College placement in first-year mathematics. The method used to place students into college coursework varies from state to state and, in some cases, college to college (Melguizo, Kosiewicz, Prather, & Bos, 2014). Historically, colleges have used placement testing for students lacking standardized college entrance scores (Belfield & Crosta, 2012). Many researchers contended that placement tests were not as efficient or accurate in placing students as using a student's high school grade point average (Belfield & Crosta, 2012; Burdman, 2012; Hodara, Jaggars, & Karp, 2012). As the researchers advocated for a movement away from standardized testing, California, North Carolina, Virginia, and Wisconsin began using some level of testing combined with examination of high school transcripts for college placement (Hodara et al., 2012). States that use a combination of testing materials and other metrics describing student skills are using multiple measures for college placement (Duffy, Schott, Beaver, & Park, 2014; Hodara et al., 2012; Ralls & Morrissey, 2013).

Comparison of placement testing instruments. Several types of placement testing instruments exist and are currently used around the United States. Many states using multiple measures allow the use of many, if not all of the most popular testing services. The most common instruments are commercially produced and claim to assist counselors and advisors in assessing student deficiencies across several content areas (Mellard & Anderson, 2007). The Compass instrument is the most popular test (see figure 1) but popularity of each instrument is largely regional (see figure 2).

Figure 1

States Using Placement Instruments in 2008

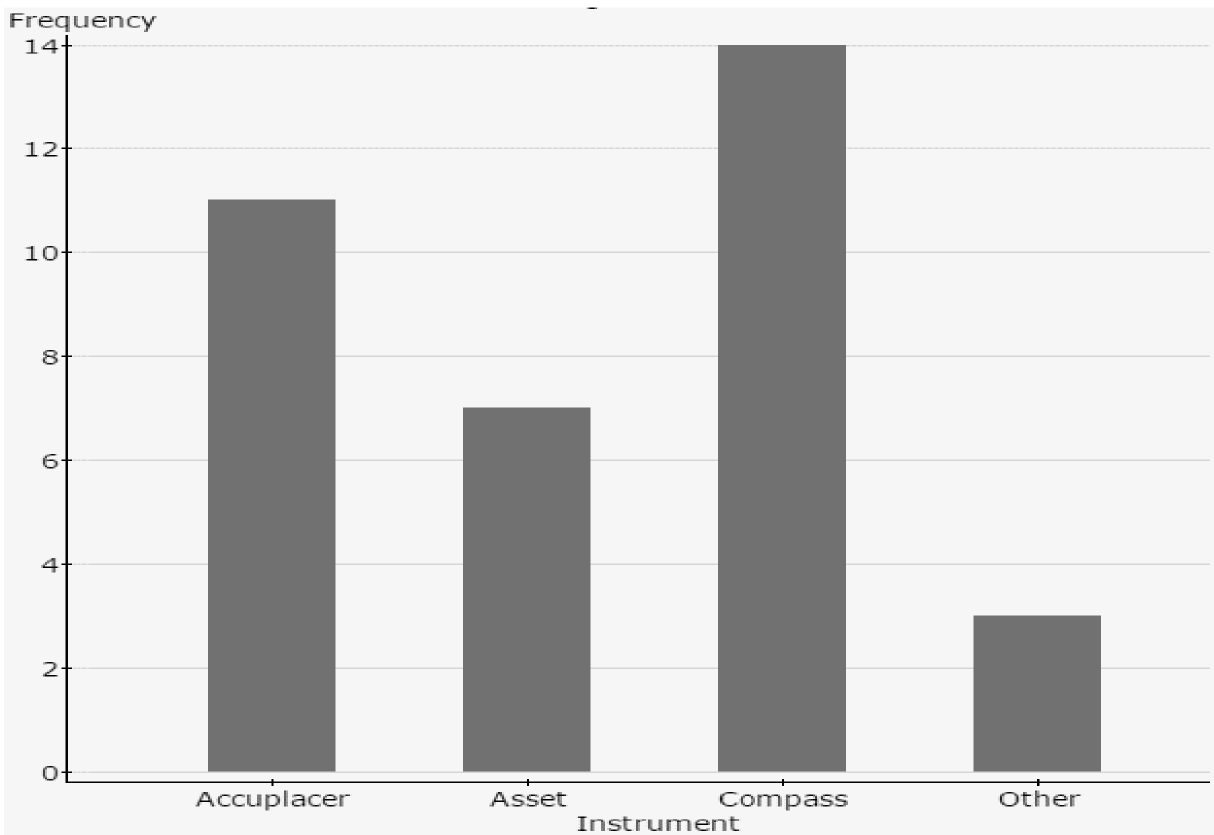


Figure 1. Number of States Using Each Instrument in 2008. Figure 1 shows the raw counts of the number of states using each of the testing instruments (Collins, 2008).

North Carolina, Florida, and Wisconsin have developed their own instrumentation and as many as twenty other states use none at all (Collins, 2008). North Carolina uses an instrument developed in 2013 that replaced the use of any commercial product by the fall of 2014 (State Board of Community Colleges, 2014). Prior to the development of the North Carolina Diagnostic and Placement test, North Carolina community colleges allowed the use of any of the nationally recognized placement tests (Collins, 2008). Figure 2 is a map of the United States indicating what instrument is the preferred medium for placement testing in that state.

Figure 2

Map of Preferred Assessment Instruments in 2008 by State

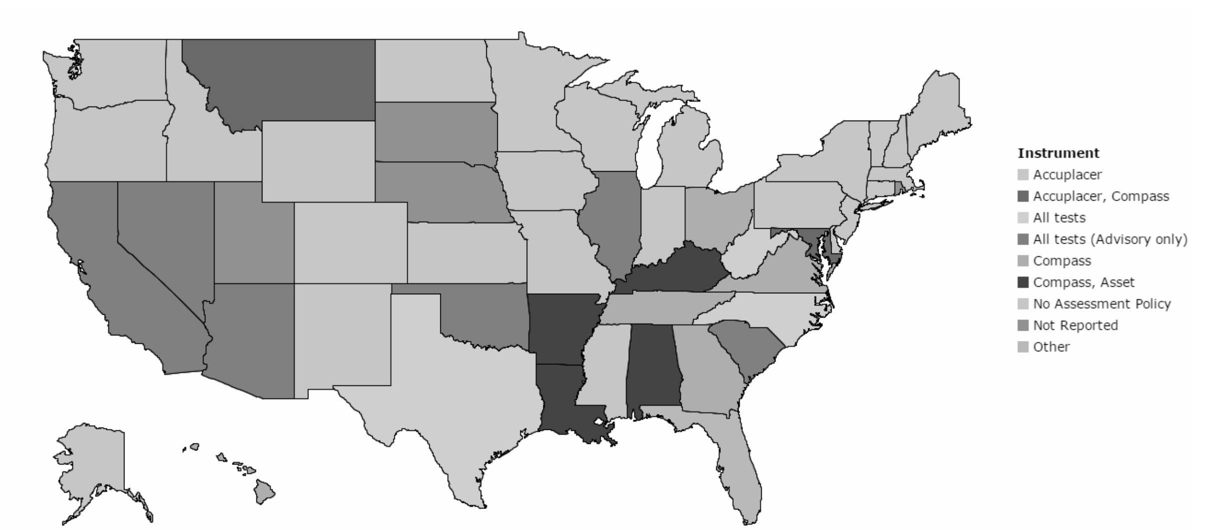


Figure 2. States using Assessment Instruments in 2008. The map illustrates which instruments are used for college placement by state (Collins, 2008). Each state is shaded according to the type of instrument used in that state for placing students into developmental coursework.

Accuplacer. The Accuplacer is an online, multiple choice assessment, produced by The College Board that measures test-takers skills across nine different academic disciplines (Mellard & Anderson, 2007). The following states have used the Accuplacer for college placement: Colorado, Connecticut, Maryland, Massachusetts, Minnesota, North Carolina, Texas, Vermont, West Virginia, Montana, and New Jersey (Collins, 2008). The test is adaptive in the sense that local controls are in place so that standards and placement rules can be interpreted by the institution using the instrument. Developers and placement testing experts contend that the Accuplacer instrument is highly valid, noting high internal consistency ratings (α=.9) and also very reliable, noting moderate to high test/retest reliability (α=.7) (Mellard & Anderson, 2007). Critics of the instrument note that correlations with course completion are low to moderate depending on the discipline. Critics also note a fundamental disagreement with using cutoff scores to place students across several levels of developmental education and first-year mathematics (Belfield & Crosta, 2012; Mellard & Anderson, 2007). Students pursuing admissions into college level coursework have a variety of content knowledge developed during their time in secondary education and from experiences outside of the classroom. A cutoff score indicating that a student is, simply, prepared for college coursework or not is disingenuous to a placement process meant to place students in a series of content driven courses (Belfield & Crosta, 2012).

Asset. The Asset is an instrument produced by American College Testing taken using pencil and paper (Mellard & Anderson, 2007). The following states have used the Asset for college placement: Alabama, Arkansas, Kentucky, Louisiana, North Carolina, Texas, and West Virginia (Collins, 2008). The test is distributed in two versions: a basic skills test (arithmetic, grammar, etc.) and an advanced mathematics test. The content is derived from surveying community college mathematics and English departments around the United States. Test authors note high rating of internal validity and reliability while also providing standard error measurements to further aid counselors with proper placement determinations (Mellard & Anderson, 2007; Scott-Clayton & Hughes, 2010). Critics of the Asset contend that the instrument lacks dimension by measuring over few variables in its basic skills version. Critics also argue that since the Asset is administered differently than most other college placement tests, it is difficult to compare and contrast scores (Belfield & Crosta, 2012; Burdman, 2012; Mellard & Anderson, 2007). Ideally, being college ready should not vary from state to state, institution to institution, or student to student. A placement test like the Asset that lacks dimension regarding variable measurement has the potential to yield wildly different results in placing students in college level coursework.

Compass. The Compass is another instrument produced by American College Testing but is a computer-based assessment measuring student deficiencies across the disciplines of reading, writing, mathematics, and English (Mellard & Anderson, 2007). The following states have used the Compass for college placement: Alabama, Arkansas, Georgia, Hawaii, Kentucky, Louisiana, Maryland, North Carolina, Ohio, Tennessee, Texas, Virginia, West Virginia, and Montana (Collins, 2008). The content is derived from a similar survey to the one used for the Asset test. Proponents of this instrument note that student scores are highly correlated with student classroom final assessments (Mellard & Anderson, 2007; Scott-Clayton & Hughes, 2010). Critics note that test/retest reliability is not reported by American College Testing (Mellard & Anderson, 2007). Lacking reliability further exacerbates the issue with a national definition of college readiness and who should be taking developmental coursework.

NC DAP. Oregon, Texas, Wisconsin and North Carolina have elected to create an instrument for the purposes of placement within their states (Hodara et al., 2012). The North Carolina Diagnostic and Placement instrument (NC DAP) is appropriate for specific scrutiny due to its use in North Carolina, the state that this paper examines most closely. The NC DAP was completed in 2013. Fifty-three mathematics educators from across the state of North Carolina met at a summit to devise the content for the instrument. North Carolina has not yet published its final English assessment (State Board of Community Colleges, 2014). North Carolina elected to create this instrument resulting from the unique compartmentalization of developmental coursework implemented in the state. Students taking developmental mathematics and English coursework enroll in modules lasting either four or eight weeks covering specific content with regard to content deficiencies. The main advantage of offering coursework in this fashion is expedition of completion. If students are placed properly, then the time spent taking developmental coursework is limited only to areas where students need remediation. Students who are college ready in specific content areas are exempt from those modules (Duffy et al., 2014). Proponents of this instrument note that it is specific to the needs of North Carolina students and addresses developmental education specific to that state better than other existing measures (State Board of Community Colleges, 2014). Few critics have published research on this instrument due to its relatively new development; however, interviews conducted with authors of the document note that the instrument contains over eighty questions and would take many students longer than three hours to complete. These authors have expressed concerns that students may not be capable of appropriately attending to an instrument this long (D. Joyner, personal communication, June 16, 2015; M. Bradshaw, personal communication, June 16, 2015). There is certainly an opportunity for further research of the NC DAP instrument.

Issues with college placement tests. Remediating students in higher education is an expensive proposition. In 2008, the annual cost of remediation programs in the two-year college sector was estimated to be in excess of $2 billion annually with another $500 million spent by four-year colleges (Collins, 2008). With such an enormous amount of money being spent, ensuring the reliability and the validity of the previously mentioned instruments is paramount to keeping costs from spiraling out of control. Since the 1970s, these tests have been the vehicle used in community colleges for placement (Scott-Clayton & Hughes, 2010). Current research is very critical of these instruments for many reasons. Lack of common cut scores, deficiencies in standardization, and binary placement standards for a breadth of coursework are just a few of these reasons.

Lack of common cut scores and poor standardization at the local-level greatly diminishes the predictive nature of these instruments (Mellard & Anderson, 2007). Although autonomy is something that is valued by most community colleges, without common standards for college readiness every college will define on its own what it means to be college ready (Mellard & Anderson, 2007). The problem of standardization is amplified by the nature of the system itself. Policy and governance varies from state to state. In some states, policy is handled at the system office. In other states, each college develops its own approach (Burdman, 2012).

Other researchers asserted that although the purpose of all placement testing is to identify deficiencies in student learning, the culture around placement testing makes the consequences of failure very large (Burdman, 2012). These consequences include an increased financial burden as well as increased time to degree completion (Burdman, 2012). Furthermore, the binary nature of cut scores fails to note differences between students that score one point above the cut score or ten points above the cut score. In most states, developmental education happens in stages. As such, advisors should place students on a scale of readiness as opposed to ready or not ready (Belfield & Crosta, 2012).

Researchers do not suggest complete removal of placement testing from the placement process (Hodara et al., 2012). Although many authors have voiced significant criticisms of the instruments, if policy were to include these assessments as only part of the placement puzzle, the information they provide would give advisors better picture of college readiness (Belfield & Crosta, 2012; Burdman, 2012; Mellard & Anderson, 2007).

High school grade point average. Researchers have suggested that the use of a student's high school grade point average has the potential to be a much better predictor for college success than placement testing alone (Belfield & Crosta, 2012; Bracco et al., 2014; Scott-Clayton & Hughes, 2010). As a measure of student performance, a student's high school grade point average is typically available to colleges when the student applies to college. Belfield and Crosta (2012) argued that high school grade point average can be used to assess a student's effort and potential in college coursework. Beyond the pure predictive utility of the high school grade point average, it can also be used in error reduction in college placement. Bracco et al. (2014) noted that the use of high school grade point average can decrease the likelihood of a placement error by as much as 30%.

Although high school grade point average has been widely used as a predictor of college success, researchers have also noted that high school grade point average alone does not provide enough information to paint a complete picture of student aptitude. Belfield and Crosta (2012) note that a full transcript review allows counselors to assess student aptitude by examining grades in specific courses. However, due to the ever changing landscape of secondary education, applicants that graduated many years prior to enrollment will have transcript data that is no longer applicable to a student's current aptitude (Belfield & Crosta, 2012).

Multiple Measures. In response to low success rates, inconsistent standards for placement, and limited alignment between secondary and postsecondary institutions, policymakers proposed using many indicators of student success for placing students in college level coursework (Collins, 2008). Using multiple measures for college placement first began in the California with the passage of the Seymore-Campbell Student Matriculation Act of 1986 and was revised under the Seymore-Campbell Student Success Act of 2012. These acts enacted several policies within the state for students matriculating from community colleges to the University of California system (Seymore-Campbell Student Success Act, 2012). A lawsuit filed several years later and settled in 1991 led to the development of the nation's first multiple measures policies for college placement (Duffy et al., 2014; Seymore-Campbell Student Success Act, 2012). Since that time, three other states have followed suit developing their own multiple measures policies (Hodara et al., 2012; Duffy et al., 2014).

California. College placement in California is a holistic approach to understanding and communicating student content deficiencies. Up until 2014, each institution in the state was provided a certain level of autonomy with regard to using a specific testing instrument. The state recently approved the development of a new statewide instrument for common assessment (Gimes-Hillman, Holcroft, Fulks, Lee, & Smith, 2014). Policy dictates that institutions may not use a placement test alone for placing a student into college level coursework. In addition to placement test scores, institutions must also consider interviews with the student, other aptitude instruments, vocational or career inventories, certifications or licensures, employment history, previous coursework, and any existing transcript data (Gimes-Hillman et al., 2014).

Wisconsin. Multiple measures in Wisconsin is a policy that, unlike California, only applies to placement in English developmental coursework. In the 1970s Wisconsin began developing its own statewide placement test, the Wisconsin Placement Test (WEPT). In fact, Wisconsin is one of a few centralized systems that has created its own statewide placement test, and all entering students must take the WEPT (Hodara et al., 2012). The University of Wisconsin English department developed a set of recommendations to the community college system concerning other measures to incorporate with regard to placement in English courses. Each college is provided the autonomy of selecting which measures best fit the needs of their student populations, but measures include ACT scores, high school grade point average, transcripts, and questionnaires. No measures exist for mathematics placement beyond the WEPT (Duffy et al., 2014).

North Carolina. The model currently being piloted in North Carolina differs from California and Wisconsin. North Carolina diverges from established norms, predominantly, in that the model proposes a hierarchy of placement according to several predictive factors of student success. This scrutiny begins with high school grade point average benchmarks and progresses through a series of test scores (Ralls & Morrissey, 2013).

Policymakers in North Carolina have begun the process of aligning high school transcripts with the needs of advisors using the proposed multiple measures model by adding a Future Ready Code (FRC) to every student transcript (Ralls & Morrissey, 2013). The FRC is a scale score from 1 to 9 indicating a student's completion of high school mathematics curricula. Scores of 1, 2, 3 and 4 indicate that the student has completed coursework in Algebra 1, Geometry, Algebra 2 and a fourth math course (Ralls & Morrissey, 2013). High school transcripts also indicate any student standardized test scores. The North Carolina Community College System office provides benchmarks for SAT and ACT scores. SAT benchmarks for English are 500 for critical reading or writing and ACT benchmarks for English are 20 for reading or 18 for writing. Benchmarks for Mathematics are 500 on the SAT Mathematics section or 22 on the ACT Mathematics section (Ralls & Morrissey, 2013). Figure 3 provides a detailed chart of the hierarchy of placement factors including FRC scores and standardized test scores.

Figure 3

The North Carolina Model for College Placement using Multiple Measures

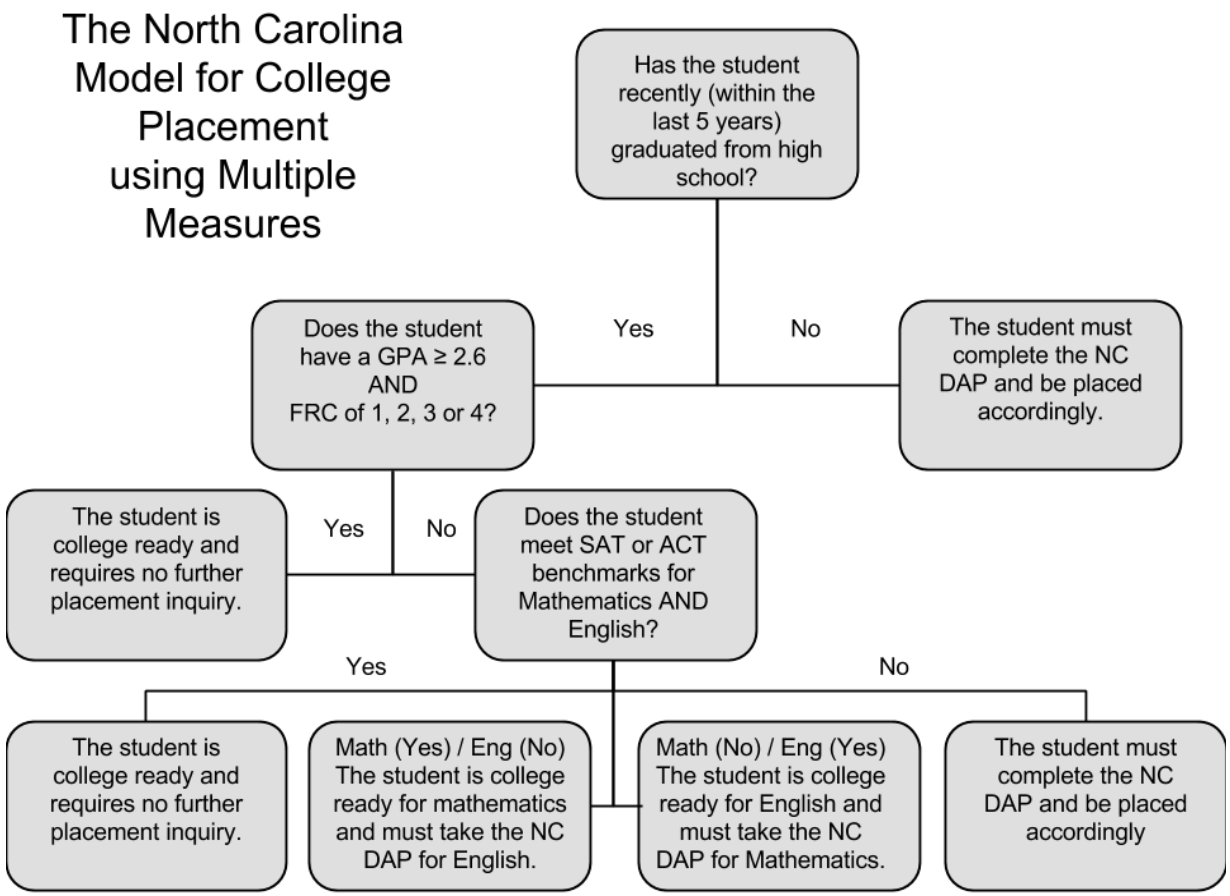


Figure 3. The North Carolina Model for College Placement Using Multiple Measures. Figure 3 displays the North Carolina Community College System model for college placement using multiple measures. As the NC DAP instruments are developed, the NCCCS recommends using previous institutionally established guidelines for placing students using the Accuplacer, Compass, or Asset tests (Ralls & Morrissey, 2013).

High school quality. Secondary education is the pipeline that students must successfully navigate in order to gain access to higher education. The quality of the education students receive at this level is fundamental to their completion of not only a high school credential (Dotson, 2014; Ejiwale, 2012; Mills, 2015; Ross & Bruce, 2007; Yoon Yoon, Evans, & Strobel, 2014) but also to their matriculation to college (Belfield & Crosta, 2012; Kowski, 2013).

Student completion of a high school credential is strongly correlated with school experiences in earlier grade levels (Alexander, Entwisle, & Horsey, 2016). These experiences can include student success in coursework, end of course testing results, and experiences with school administrators and teachers. Furthermore, Mills (2015) argued that poor experiences are correlated with higher dropout rates and an increased likelihood that the student will become a violent crime offender at some point in the future.

As students successfully matriculate to their college studies, the experiences in high school tend to also be highly correlated with performance in college, particularly in the Science Technology, Engineering, and Mathematics (STEM) fields. Belfield and Crosta (2012) argued that using a student's high school grade point average can indicate student effort in academics and aptitude for academic material. Furthermore, the authors argued that student course selection in high school can be an indicator of “a balanced portfolio of academic skills” (p. 3). However, inasmuch as these factors can indicate a student’s effort and personal, academic characteristics, the high school curriculum is poorly aligned with college coursework and had the potential of creating a skills gap even in high performing students (Kowski, 2013)

Mathematics is particularly problematic for students moving from high school into their first-year of college. Kowski (2013) argued that unless a student has taken a robust sequence of mathematics studies through all four years of high school, the potential exists for students to be unprepared, and often surprised, for the rigors of college mathematics. Addressing the gap between high school and college curricula has been the focus of many vertical alignment efforts, but many of these efforts are still in their infancy (Kowski, 2013). Since course selection is ultimately in the hands of students and their parents, creating an environment where students are advised to pursue a rigorous curriculum in mathematics is a key to future success (Bailey et al., 2010; Kowski, 2013). The quality of such an environment is, therefore, as much a predictor of student success as student performance in that environment.

High school report cards. State and Federal departments of education have attempted to keep educators and the public at large informed regarding public school performance and quality. The primary motivator of such information is to translate awareness into increased school performance and parental engagement (Dotson, 2014). In 2012, the North Carolina Department of Public Instruction instituted a program that grades each school in the state on a scale from A to F. Each grade is calculated using an accumulation of data indicating services that are offered to students, student performance, teacher credentials, and other metrics defined by the state (North Carolina Report Cards, n.d.a). Each of the items used in the report cards were agreed upon by soliciting input from administrators, educators, teachers and policymakers (Dotson, 2014). Each school report card has five sections that provide information about the school: School/District Profile, School Performance, School Indicators, School Environment, and Personnel (North Carolina Report Cards, n.d.b). Researchers investigating high school quality have used performance measures, such as those used in the High School Report Cards, as measures indicating quality (Dexter et al., 2006; Pike & Saupe, 2002; Wolniak & Engberg, 2010)

Summary. The open-access mission of community colleges both uniquely defines this sector of higher education and creates a litany of challenges for students and other stakeholders. With the ultimate goal of community colleges being student success, researchers have expended significant resources on understanding the student population, designing a curriculum appropriate for post-graduate success, and investigating best practices on a placement and curricular level. Efforts to align policies between high schools and institutions of higher education have led researchers to focus on predictors of success from one sector to another. The following section of this chapter reviews eight studies gauging the validity of certain predictors of overall college and content area specific success.

Review of Studies

After an exhaustive search of electronic databases, eight articles were identified to meet the criteria for further review. The determination of these eight articles was made by first analyzing twenty-four abstracts that were revealed in an initial search according to the parameters established earlier in this chapter. A full-text review of those twenty-four articles was narrowed to the eight selected by further scrutinizing the methodology and results of each study for relevance to this study. A brief synopsis of the eight articles is given in Table 2 identifying the authors of the study, number of participants, design, and prevalence.

Table 2

Relevant Studies

Study	Participants	Design	Prevalence
Belfield & Crosta (2012)	Sample size varied depending on the placement test examined. 6,180 ACCUPLACER Reading, 6,123 ACCUPLACER Sentence Skills, 11,151 COMPASS Reading, and 11,171 COMPASS Writing.	Regression analysis to study the extent that placement test scores predict college grade point average beyond the use of High School Grade Point Average.	Placement test scores, by themselves, were a strong predictor of college grade point average, but when controlling for High School Grade Point Average, that effect disappeared. Ultimately, High School Grade Point Average explained approximately 21% of the variation in college grade point average.
Cyrenne & Chan (2012)	5,136 students from 84 Manitoba High Schools attending the University of	Regression analysis to study the extent High School Grade Point Average predicts undergraduate college performance	High School Grade Point Average was a significant predictor of undergraduate success (*p-value* $<.001$). High School Grade Point Average modified by

Study	Participants	Design	Prevalence
	Winnipeg between 1997 and 2002.	modified by expenditures per student at the high school level and funding mechanisms (public or private) of the high school.	expenditures per student, however, decreased undergraduate grade point average by one point. High school funding mechanism as well as the religious affiliation of the school also exhibited significant interaction effects.
Geiser & Santelices (2007)	62,147 college students in 2-year and 4-year institutions in the United States.	Regression analysis to study the extent High School Grade Point Average and test scores predict long-term college outcomes (cumulative GPA, graduation, etc.).	High School Grade Point Average was the best predictor of cumulative, fourth-year college GPA; accounting for 20.4% of the variance in a model controlling for other factors such as standardized test scores, and socioeconomic background variables.
Goldhaber & Brewer (2000)	Sample size varied depending on content area. 3,786 math and 2,524 science students in their 12th grade year at public schools in the United States.	Regression analysis to study the extent teacher certification credentials and level of experience impact student performance on standardized tests.	Teachers holding a standard certification yielded standardized test scores 1.3% higher than those holding a private school or emergency certificate. Furthermore, teachers that hold content area specific credentials and have more classroom experience produce higher test scores in both mathematics and science.
Kobrin, Patterson, Shaw, Mattern & Barbuti (2008)	151,216 college students in 2-year and 4-year institutions in the United States.	Regression analysis to study the extent High School Grade Point Average and SAT scores predict First-Year Grade Point Average (FYGPA).	High School Grade Point Average was shown to have the highest individual correlation with FYGPA (*adj. r*=.54). However, when High School Grade Point Average was combined with all three SAT content area tests, this variable pairing increased overall correlation (*adj. r*=.62).

Study	Participants	Design	Prevalence
Kowski (2013)	659 first-time, full-time students in a New Jersey suburban community college.	Logistic regression analysis to study the extent that High School Grade Point Average, high school math grade point average, number of high school math classes, highest level of high school math, and math beyond the basic high school math sequence (BEYONDHS) predicted student placement beyond elementary algebra.	Three of the tested variables indicated a significant probability of a student placing beyond the elementary algebra sequence: High School Grade Point Average (B=.9985, *p-value*<.0001); Socioeconomic Status (SES_B) (B=.8802, *p-value*=0.0148); and BEYONDHS (B=1.1978, *p-value*<.0001).
Pike & Saupe (2002)	8,764 freshman at a research university in the United States	Regression analysis to study three different student success models: traditional model; high school effects model; and hierarchical regression.	Precollege characteristics (test scores, High School Grade Point Average, and courses taken) accounted for 33% of the variability in students' first-year GPA. Including measures of the graduating high school (mean ACT, public or private, course requirements, and class rank profile) improved overall variability accounted for in first-year GPA by 7%.
Scott-Clayton (2012)	Sample size varied depending on the academic content area. 6,100 math students and 9,628 English students from a 2004-2007 cohort of community college students in the United States.	Regression and ANOVA analysis studying the extent Placement Tests scores predicting success in college level mathematics and English courses modified by High School Grade Point Average and years since graduation.	Placement test scores only accounted for 12.9% of the variation in successfully completing a first-year math course. However, when combined with High School Grade Point Average, that proportion of variation increased to 18.3% and when all three units of analysis (Placement Tests, High School Grade Point Average,

Study	Participants	Design	Prevalence
			and Years since graduation) were combined the proportion of accounted for variation increased to 20.4%.

Findings. Several themes were apparent after review of the literature. First, student success was gauged through the use of either course level performance (Goldhaber & Brewer, 2000; Kowski, 2013; Scott-Clayton, 2012), student grade point average reported at the conclusion of the first-year in college (Kobrin et al., 2008; Pike & Saupe, 2002) or at credential completion (Belfield & Crosta, 2012; Cyrenne & Chan, 2012; Geiser & Santelices, 2007). Second, High School Grade Point Average accounted for significant variation in predictor variables in all studies examining student success in college (Belfield & Crosta, 2012; Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kobrin et al., 2008; Kowski, 2013; Pike & Saupe, 2002; Scott-Clayton, 2012). Third, authors identified several factors of high school quality that accounted for additional variability in dependent variables. These factors include expenditures per student (Cyrenne & Chan, 2012), public / private or religious affiliation (Cyrenne & Chan, 2012; Pike & Saupe, 2002), teacher certification and credentials (Goldhaber & Brewer, 2000), and aggregate performance of students on standardized tests (Pike & Saupe, 2002).

Measuring student success. Student success, as defined by these eight studies, was viewed through the lens of successful academic performance. Academic performance has been measured through a calculation of grade point average (Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kobrin et al., 2008; Pike & Saupe, 2002), performance on standardized tests (Belfield & Crosta, 2012; Goldhaber & Brewer, 2000; Kowski, 2013), or course / credential completion (Geiser & Santelices, 2007; Scott-Clayton, 2012). In many ways, this perspective of student success ignores student perceptions of success or certain other benchmarks to higher education. However, from an institutional perspective, academic performance has been shown to be a useful variable for student success (Belfield & Crosta, 2012; Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kobrin et al., 2008; Kowski, 2013; Pike & Saupe, 2002; Scott-Clayton, 2012).

High school grade point average. When evaluating predictors for student success, at the individual level, researchers have examined high school grade point average (Belfield & Crosta, 2012; Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kobrin et al., 2008; Kowski, 2013; Pike & Saupe, 2002; Scott-Clayton, 2012), standardized student test scores (Geiser & Santelices, 2007; Kobrin et al., 2008), socioeconomic status (Geiser & Santelices, 2007; Kowski, 2013), course selection (Kowski, 2013), class rank (Pike & Saupe, 2002), years since graduation (Scott-Clayton, 2012) and performance on placement tests (Belfield & Crosta, 2012; Pike & Saupe, 2002; Scott-Clayton, 2012) as having possible relationships with academic performance. Although each of these variables accounted for some level of variability in academic performance, high school grade point average emerged as the single variable in all studies that accounted for the most variability. This would indicate that any study examining predictors for academic performance should include high school grade point average.

High school quality. The source of the institution granting a high school graduation credential has also been scrutinized, but at the group level. Researchers have attempted to gauge high school quality by examining the funding mechanism of the school (Pike & Saupe, 2002), aggregate student performance on standardized tests (Kobrin et al, 2008; Pike & Saupe, 2002), local graduation requirements (Pike & Saupe, 2002; Cyrenne & Chan, 2012), teacher certification and credentials (Goldhaber & Brewer, 2000), and expenditures per student (Cyrenne & Chan, 2012). In the eight articles, there was no attempt to aggregate these metrics to a single score that indicated overall high school quality. Such an aggregation would be appropriate given the researchers' assertions that each of the variables mentioned above exhibit the ability to modify high school grade point average as a predictor and can account for varying level of variability regarding academic performance (Cyrenne & Chan, 2012; Goldhaber & Brewer, 2000; Kobrin et al, 2008; Pike & Saupe, 2002).

Summary, Implications, and Discussion

There is a wealth of literature investigating the mathematics completion problem as it relates to high school student performance. From student experiences in high school, through demographic and personal challenges, students at the community college level have faced a litany of challenges and barriers to success. Investigation of the literature would indicate that primary among these barriers is the student's first attempt at a college level mathematics course.

The problem of the first-year mathematics course. Kowski (2013) argued that students are unprepared for college coursework for a variety of reasons, first among them is an inadequate treatment of the mathematics curriculum in high school. Lack of content knowledge directs students to an expensive and timely remedial curriculum that presents another barrier to graduation (Belfield & Crosta, 2012; Burdman, 2012). Although developmental education will continue to be scrutinized and researched, as community colleges move more towards the use of high school credentials as a method for placing students into college mathematics, the quality of that credential is brought to the forefront.

Addressing the placement issue. Researchers have argued that practices using a placement instrument, such as the ASSET, ACCUPLACER, and COMPASS tests, offer little predictive ability beyond the use of high school grade point average (Belfield & Crosta, 2012; Kowski, 2013; Scott-Clayton, 2012). Others have argued that standardized tests, such as the

SAT and ACT, can offer some additional guidance for placement (Geiser & Santelices, 2007; Kobrin et al., 2008; Pike & Saupe, 2002) however, the open-access nature of community colleges requires no such scores for admission. Ultimately, no single variable or cluster of variables will be able to place all students appropriately in their college level coursework. Applying a policy like Multiple Measures has the potential to apply what information exists for each individual student and, if no such information is available, applying some form of placement instrument to guide advisors in selecting coursework for students.

Where data are available, researchers argue that information regarding high school quality can further aid in the placement process (Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kowski, 2013; Pike & Saupe, 2002; Scott-Clayton, 2012). Scrutiny applied to secondary education institutions has made a wealth of data publically available for such analyses. Increased emphasis on student success makes such investigations necessary to ensure a holistic view of student preparation for college level coursework.

Finally, researchers have identified that first-year mathematics is the single, largest academic barrier to student success and completion (Jaggars et al., 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011). Although some research exists on placement in first-year mathematics (Belfield & Crosta, 2012; Scott-Clayton, 2012) it is limited to evaluating placement instruments and the high school grade point average predictor alone. With first-year mathematics presenting such a significant barrier to success and completion, investigations into predictors for this specific content area are necessary.

Gaps in the literature. Belfield and Crosta (2012) argued for increased emphasis on high school experiences when placing students into college mathematics, however, other authors (Dotson, 2014; Kowski, 2013; Mills, 2015) have argued that these experiences vary from school to school. The North Carolina Department of Public Instruction has instituted policies to alert the public regarding a high school's individual performance. The presence of such policies would indicate that performance varies from school to school. However, placement policies, like the ones instituted in NCCCS member institutions, largely, ignore these differences and treat students' experiences in these schools as common to each individual. Ignoring or failing to account for possible variability between these experiences has been referred to as an ecological fallacy (Robinson, 1950). One glaring gap in the literature addresses the question of the correlation between high school quality characteristics and the ability of the student grade point average from that institution to predict success in first-year mathematics coursework.

The chapters that follow detail a research plan, data analyses, and findings that address this specific gap in the literature. Chapter 3 will focus on methods for the design of the study that examines High School Grade Point Average and high school quality regarding success in first-year mathematics coursework at the community college level. Chapter 4 will detail the results of such an analysis. Finally, chapter 5 will conclude with a discussion and implications for the findings for practitioners and researchers in higher education.

Chapter 3

Methods

This chapter will detail the settings of the study. First, this chapter will restate the problem as well as the research questions described in chapter one. Second, this chapter will examine scholarly literature that follows a similar framework to the study proposed in this document. Third, the sampling frame, data collection procedures, data analytics, and justification for such procedures will be described in detail. This chapter will conclude with limitations of the design of the study.

Problem Statement

There is a national movement in community colleges to address college placement strategies (Goudas & Boylan, 2012; Jaggars et al., 2015; Martinez & Bain, 2014). Central to this movement are issues related to student success, retention, and budget stewardship. Researchers agree that placement testing strategies are inadequate and a more holistic view of the student's experiences is necessary to better inform this process (Belfield & Crosta, 2012; Burdman, 2012; Hodara et al., 2012). The utility of high school grade point average has been shown to be a valid predictor of college success (Bracco et al., 2014; Geiser & Santelices, 2007; Kobrin et al., 2008; Scott-Clayton, 2012), but can be further modified by examining the quality of the source of the credential (Betts, 1995; Card & Krueger, 1992; Dexter et al., 2006; Goldhaber & Brewer, 2000; Pike & Saupe, 2002; Wolniak & Engberg, 2010). However, the issues relating to student success must be further narrowed to identify specific content discrepancies. With first-year mathematics presenting a significant barrier to student completion and success (Jaggars et al., 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011), it is appropriate to examine the relationships of high school grade point average and high school quality as it relates specifically to mathematics.

This study explored literature related to current placement strategies, valid predictors for student success in mathematics, and explored these relationships within the NCCCS by examining student data within the system. Such an exploration addressed the placement problem regarding first-year mathematics success through the lens of prior student learning. Findings presented in later chapters will define the breadth of the relationship between high school grade point average, as modified by high school quality, and student success in an introductory mathematics courses. Examination of these findings will help guide stakeholders in the development of intrusive advising practices to better serve students in their personal academic goals.

Research Questions

This research was guided by three specific questions that were addressed through data collection and analysis:

1) Is there a statistically significant, positive relationship between students' high school grade point average and success in a first attempt at a college level mathematics course?
2) What characteristics of high school quality have a significant relationship with student success in a first attempt at a college level mathematics course?
3) What are the relative strengths of high school quality and high school grade point average as predictors of student success in a first attempt at a college level mathematics course?

Hypotheses

After data collection and analysis, the following three hypotheses are expected:

H1) There is a significant, positive relationship between a student's high school grade point average and their success in a first attempt at a college level mathematics course.

H2) Variables indicative of high school quality will exhibit a significant relationship with average student success in a first attempt at a college level mathematics course. The strongest relationships with student success in this course will be high school achievement scores, faculty credentials, average class size, student access to technology, and service area economic indicators.

H3) High school quality characteristics will vary in relative strength to student success in college mathematics. Characteristics that exhibit significant relative strength to average student performance will serve as predictor variables in the construction of a predictive model for student success in college mathematics.

Research Design

This study utilized a post-positive perspective to investigate the previously stated research questions. Leedy & Ormrod (2015) regarded this perspective as an objective approach to research. Such an approach is a continual effort to search for truth while maintaining a guarded perspective to personal bias. Ultimately, post-positivists view truth searching as a process that builds evidence through probabilistic comparison and constructs conclusions based on the most likely outcome (Leedy & Ormrod, 2015). The questions under scrutiny for this study were best suited for this research perspective. The sample of data obtained provided evidence of existing relationships between first-year mathematics success, high school grade point average and high school quality. The results of data analysis will build an on body of academic work that has already shown evidence for such relationships in other contexts.

Post-positivists, commonly, rely on quantitative methods of analysis to provide evidence within the scope of a sampling frame (Johnson & Onwuegbuzie, 2004; Leedy & Ormrod, 2015). The study described in this document used such methods, specifically regression techniques, to explore hypothesized relationships. Even though regression techniques are common when describing relationships found in bivariate datasets in all fields, several authors have applied this technique in researching relationships between success in college and high school experiences.

Pike and Saupe (2002) examined three approaches to predicting student success in college. In a primary model, the authors examined success in college using traditional predictors: standardized tests, high school performance, and high school coursework. Robinson (1950) discussed an ecological fallacy regarding data aggregation. In short, this fallacy alludes to the idea that as data are aggregated at a single level, evidence of association can be mistakenly identified as being associated at that level alone (Robinson, 1950). To address this hypothesis, Pike and Saupe (2002) built another model using the student level predictors from model one as well as including a series of variables that described the source high school originating the student metrics. Finally, the authors utilized hierarchical regression techniques to compare and contrast the variables utilized in the previous two models. Their findings indicated that the inclusion of measures describing quality characteristics of the sending high schools improved the overall accuracy of the prediction of college performance by an additional 7% over using only student level predictors. Such findings support the use of their methods when investigating relationships modified by high school quality (Pike & Saupe, 2002).

In another study, Dexter, Tai, and Sadler (2006) examined student success in science coursework correlated with block scheduling at the high school level using regression techniques. Block scheduling is method of course design where total class time is extended from a 50-minute period repeated for a full academic year to a 90-minute block only lasting the length of one semester. Although total seat time is reduced, the authors argued that the extended block is particularly advantageous for science courses allowing for uninterrupted laboratory experiences and allow for “varied and innovative methods of teaching” (Dexter et al., 2006, p. 23). Analysis of the data indicated a small, but significant correlation between the use of block scheduling and student performance in college science coursework (Dexter et al., 2006). Furthermore, resulting models predicting success in college coursework based on block scheduling yielded a predicted increase of 3 points towards a student's final grade for those that received the block scheduling treatment (Dexter et al., 2006).

Applying regression analyses when examining relationships for multivariate datasets has been codified in academic texts (Field, 2013; Leedy & Ormrod, 2015) and scholarly literature investigating predictors for college success (Betts, 1995; Card & Krueger, 1992; Dexter et al, 2006; Geiser & Santelices, 2007; Goldhaber & Brewer, 2000; Kobrin et al., 2008; Pike & Saupe, 2002; Wolniak & Engberg, 2010). This study, under the post-positivist theory of research, was guided by these examples applying regression techniques in an attempt to address the research questions as previously stated.

Research Setting

North Carolina reforms in placing students at the college level have provided the research community a unique opportunity to explore first-year mathematics success. Prior to these reforms, NCCCS member institutions collected data from student high school transcripts, but rarely applied the results of student success in projecting a pathway for students in college. Using student high school experiences as a guide for placing students in college level coursework has made a wealth of data available in scrutinizing the use of high school grade point average as a predictor for college success.

The NCCCS has been the setting for a variety of academic studies. The system contains 58 member institutions and serviced an estimated 735,000 students during the 2014 - 2015 academic year (North Carolina Community College System, n.d.b). In addition to its size, the NCCCS maintains an articulation agreement with the University of North Carolina System that codifies a set of courses for universal transfer (Board of Governors, 2014). This partnership recognizes the quality of the NCCCS in preparing students for further study at the university level. The size and quality of the NCCCS has prompted studies investigating developmental education reforms (Clotfelter, Ladd, Muschkin & Vigdor, 2015; Kalamkarian et al., 2015; Pittman, 2010), dual enrollment policies (Ganzert, 2014; Sciuletti, 2016), and multiple measures implementation (Bracco et al., 2014; Duffy et al., 2014).

Past precedent provided that the NCCCS is a microcosm of the United States higher education sector unified under a singular mission. Reforms in the state regarding placement practices provided a unique opportunity to examine high school quality as modifier of high school grade point average when predicting student success in first-year mathematics. Given these facts, the study described in this document examined relationships exclusively within the NCCCS.

Variables. The regression analysis employed in this study investigated relationships between several criterion variables (independent variables) on a single response variable (dependent variable) (Field, 2013). Although many of the variables used in this analysis are common to all sectors of higher education, many are unique to the NCCCS setting. The following sections of this document will define and describe each of these variables.

Dependent variables. Students sampled from the NCCCS setting were evaluated on their performance in first-year mathematics by the grade they achieved in their first attempt at that course. Since the NCCCS characterized three different courses as first-year mathematics courses, student performance was observed as a unique performance aligned by the course taken. The result of this description produced a unifying model of first-year mathematics success by aggregating student performance in three courses: Quantitative Literacy (MAT 143); Statistics 1

(MAT 152); and Pre-Calculus Algebra (MAT 171). The NCCCS recommended that all member institutions use a 10-point grading scale. College records only required faculty to record a letter grade to indicate the student's performance in the course. Each grade was the evaluated for student success and coded using a binary outcome. Any student record that indicated a grade of "A", "B", or "C" was coded as a successful attempt (1), all other grades were recorded as an unsuccessful attempt (0). The choice of coding, in this fashion, was a direct result of policies and procedures implemented in the Common Articulation Agreement (CAA) with the NCCCS. The CAA requires that in order for a student to gain credit at a transfer institution for approved coursework taken at another institution, the student must have attained a grade of "C" or higher (Board of Governors, 2014). Table 3 describes this variable in more detail.

Table 3

Description of Dependent Variables

Variable Name	Type of Variable	Description
Success	Binary (0) - Unsuccessful (1) - Successful	A code indicating a student's successful completion of a first-year mathematics course. Grades of A, B, or C recorded by an institution for students in a first attempt at a mathematics course was coded as "1". All other grades were coded unsuccessful "0".

Independent variables. The design of the regression model required data from two different sources: individual student characteristics maintained by the NCCCS (forthwith, referred to as Level One Variables) and high school characteristics described in the North Carolina High School Report Card (forthwith, referred to as Level Two Variables). Each of these variables is operationally defined in Table 4.

Table 4

Description of Independent Variables

Variable Name	Variable Type / Level	Description
High School Grade Point Average	Continuous / One	The grade point average reported to the community college at student application from the high school transcripts.
High School Name	Categorical / One	The name of the high school where each student graduated.
Graduation Year	Continuous / One	The year each student graduated from high school.
Mat-143	Binary (Dummy) / One (0) - Unenrolled (1) - Enrolled	A dummy code indicating that the student took Mat-143 as their first attempt at college mathematics.
Mat-152	Binary (Dummy) / One (0) - Unenrolled (1) - Enrolled	A dummy code indicating that the student took Mat-152 as their first attempt at college mathematics.
Traditional Delivery	Binary (Dummy) / One (0) - Unenrolled (1) - Enrolled	A dummy code indicating that the student took their first attempt at college mathematics delivered in a traditional setting.
Hybrid Delivery	Binary (Dummy) / One (0) - Unenrolled (1) - Enrolled	A dummy code indicating that the student took their first attempt at college mathematics delivered in a hybrid or web-assisted setting.
Female	Binary (Dummy) / One (0) – Not Female (1) - Female	A dummy code indicating that the respondent reported themselves as female.
White	Binary (Dummy)/ One (0) – Not White (1) – White	A dummy code indicating that the respondent reported their ethnicity as white.
Free and Reduced Lunch	Continuous / Two	The percentage of students that receive free or reduced lunch at each high school.

Variable Name	Variable Type / Level	Description
Achievement	Continuous / Two	Achievement is a composite score obtained by accumulating student performance on standardized testing reported by NCDPI.
Growth	Continuous / Two	Growth is a composite score representing student growth in academics reported by NCDPI.
Composite Performance	Continuous / Two	Performance is a numerical grade calculated by taking 80% of the achievement score and 20% of the growth score for the school.
Attendance	Continuous / Two	Attendance represents the average percentage of students that attend the school daily.
Percentage Scoring 3 or Higher	Continuous / Two	Percentage of students achieving level 3 or higher proficiency on the Math 1 end of course test.
Percentage Scoring 4 or Higher	Continuous / Two	Percentage of students achieving level 4 or higher proficiency on the Math 1 end of course test.
Percentage Scoring 5 or Higher	Continuous / Two	Percentage of students achieving level 5 or higher proficiency on the Math 1 end of course test.
Fully Licensed Teachers	Continuous / Two	The percentage of faculty that have obtained a full teaching license recognized by NCDPI.
Faculty Holding Advanced Degrees	Continuous / Two	The percentage of faculty that have received an advanced degree as recognized by NCDPI.
National Board Certified	Continuous / Two	The percentage of faculty that have received National Board Certification.
Beginning Faculty	Continuous / Two	The percentage of faculty that have work experience in education between 0 and 3 years.
Early Career Faculty	Continuous / Two	The percentage of faculty that have work experience in education between 4 and 10 years.
Late Career Faculty	Continuous / Two	The percentage of faculty that have work experience in education for more than 10 years.

Variable Name	Variable Type / Level	Description
Teacher Turnover	Continuous / Two	Teacher turnover rate represents the percentage of positions that are vacated by faculty leaving the school during the reporting year.
Course Size	Continuous / Two	Course size is the average number of students per section in Math 1 at the high school.
Technology	Continuous / Two	The ratio of the number of students per technology device at the high school as reported by NCDPI.

Participants

Participants in this study were drawn from a random selection of NCCCS member institutions. To be eligible for selection, students must have met the following criteria: 18 or older; have graduated from a North Carolina high school after 2012; must have taken Quantitative Literacy, Statistics 1, or Pre-Calculus Algebra in the fall of 2016, the spring of 2017, or the summer of 2017; must not have taken any math course prior to their first attempt at a first-year mathematics course (this includes developmental education); must not be an active military service member; and must not be incarcerated by any state jail or prison. Limiting participants in this fashion ensured that all human subjects' protections were preserved while maintaining a cohort of students that met the guidelines for first-year mathematics observation described in this document.

Each participant's high school was recorded at Level One of the data collection. At Level Two, any high schools were evaluated by the number of students graduating from that institution and matriculating to a selected community college. For the purposes of aggregation, high schools reporting fewer than two students taking first-year mathematics at a selected institution were removed from aggregated analyses.

Sampling procedures. This study employed a multistage, cluster sampling design (Brase & Brase, 2016). The NCCCS contained 58 member institutions subdivided, by the system, according to the number of students enrolled. Small institutions reported an annual enrollment of less than 2500 full-time enrolled (FTE) students. Medium institutions reported an annual enrollment of between 2500 and 6000 students. Large institutions reported an annual enrollment of more than 6000 students (North Carolina Community College System, n.d.b). In the first stage of the sampling design, all 58 institutions were stratified according to their reported size. Then, two institutions were randomly selected from each stratum, with the exception of large institutions. So not to bias the sample towards more urban service areas, only one large school was selected, yielding five total institutions. Finally, each of the five selected schools were solicited for all student level data, meeting participant requirements, from the 2016 - 2017 school year. In order to address Level Two analyses, if two selected institutions had adjacent service areas, one of the institutions was sampled and the other was replaced by another institution within the same size strata. The determination of the institution to be removed was done by the flip of a coin.

Data Sources and Collection Procedures

The study utilized ex post facto data collected from NCCCS member institutions as well as data describing North Carolina High Schools. All student data were housed in Colleague, the common database for the NCCCS, and permission to access such data was granted by each institution solicited for collection. Each data file was downloaded from a source file provided by each college to a flash drive or flat file. The solicited institutions created pseudo-ids for students. The nature of the data did not place respondents at risk of liability or be damaging to their financial standing, employability, or reputation if disclosed.

Data collected describing North Carolina High Schools was obtained from a publically available, electronic database maintained by the North Carolina Department of Public Instruction (NCDPI). High school data were only collected if a student in the first phase of the data collection graduated from the institution. The researchers to protect the anonymity of each institution created pseudo-ids for each high school. Since the data were publically available, collecting and reporting these data did not place any institution at risk of liability or damage to the reputation of the institutions if disclosed.

Description of the Sample

Five member institutions of the North Carolina Community College System (NCCCS) contributed data for the purposes of analysis. After initial sorting and tabulation, according to the methods laid out in Chapter 3, a data set was compiled in SPSS (Version 24.0). Individual records were removed if data from the contributing college was incomplete or contained miscalculations attributed to human error. The final set contained 1,155 complete records from graduates of 67 public, North Carolina high schools. Tabulated results for frequency and descriptive statistics at each level one variable can be found in Table 5.

Table 5

Descriptive Statistics of Level One Variables

Variable Name	Characteristic	Frequency	Relative Frequency
Gender	Female	608	52.64%
	Male	547	47.36%
Ethnicity	Black	165	14.29%
	Hispanic	149	27.19%
	White	753	65.19%
	Other	88	7.62%
Success	Unsuccessful (0)	396	34.29%
	Successful (1)	759	65.71%

Variable Name	Characteristic	Frequency	Relative Frequency
Course Name	Mat-143	391	33.85%
	Mat-152	272	23.55%
	Mat-171	492	42.60%
Course Delivery Mode	Hybrid	113	9.78%
	Online	168	14.55%
	Traditional	874	75.67%

Comparing these frequencies with the AACC report from 2016, there are some differences, which was expected. Each classroom, college, and system, inherently, serves different student populations. However, some common themes are evident. The first is that the sample of students, much like the national student population, is predominately white. Black students make up around 14% of the student population and Hispanics approximately 27%. For the purposes of analysis, any other ethnicity reported by the solicited college was reported as "Other". Furthermore, a majority of students identified as being female. National demographic trends would indicate a similar finding, although this majority is more pronounced in national figures (AACC, 2016).

Regarding course selection, delivery mode, and success, several themes were also evident. First, 65.71% of students successfully completed their first attempt at a college mathematics course. Although this percentage is higher than what national statistics would indicate (Jaggars et al., 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011) requiring that all students be placed into their mathematics attempt without additional coursework eliminated individuals within the sampling frame that would have taken developmental coursework. This fact should have a positive effect on course success, which is evident in the sample. Second, a plurality of students elected to enroll in Mat-171 as their first mathematics attempt, followed by Mat-143, and Mat-152. Third, 75.67% of students elected to enroll in a course that was offered in a traditional setting.

In addition to demographic characteristics, solicited colleges also reported the High School Grade Point Average for each student. Descriptive statistics for this variable can be found in Table 6.

Table 6

Descriptive Statistics for High School Grade Point Average

Variable Name	N	Mean	Standard Deviation	Minimum	Maximum
High School Grade Point Average	1155	3.06	.54	1.13	4.00

During phase two of the data collection process, each high school that issued a graduating credential for students in the sample was examined for Level Two variables. The descriptive statistics for each Level Two variable can be found in Table 7.

Table 7

Descriptive Statistics for Level Two Variables

Variable Name	N	Mean	Standard Deviation	Minimum	Maximum
Free and Reduced Lunch	67	45.04	14.08	9.99	93.22
Achievement	67	68.57	9.95	32.00	95.00
Growth	67	74.88	14.47	50.00	100.00
Composite Performance	67	69.87	9.86	37.00	94.00
Attendance	67	93.59	2.06	86.40	98.40
Percentage Scoring 3 or Higher	67	51.19	15.98	14.5	90.8
Percentage Scoring 4 or Higher	67	38.49	16.00	7.30	80.3

Variable Name	N	Mean	Standard Deviation	Minimum	Maximum
Percentage Scoring 5 or Higher	67	7.61	7.24	0.00	33.20
Fully Licensed Teachers	67	91.86	5.13	75.90	100.00
Faculty Holding Advanced Degrees	67	26.84	7.52	10.00	42.90
Beginning Faculty	67	20.13	8.00	2.70	37.00
Early Career Faculty	67	21.03	5.33	0.00	32.40
Late Career Faculty	67	58.61	8.85	39.20	75.00
Teacher Turnover	67	13.62	5.55	2.50	33.30
Course Size	67	19.16	4.18	8.00	28.00
Technology	67	1.43	1.03	.31	6.19

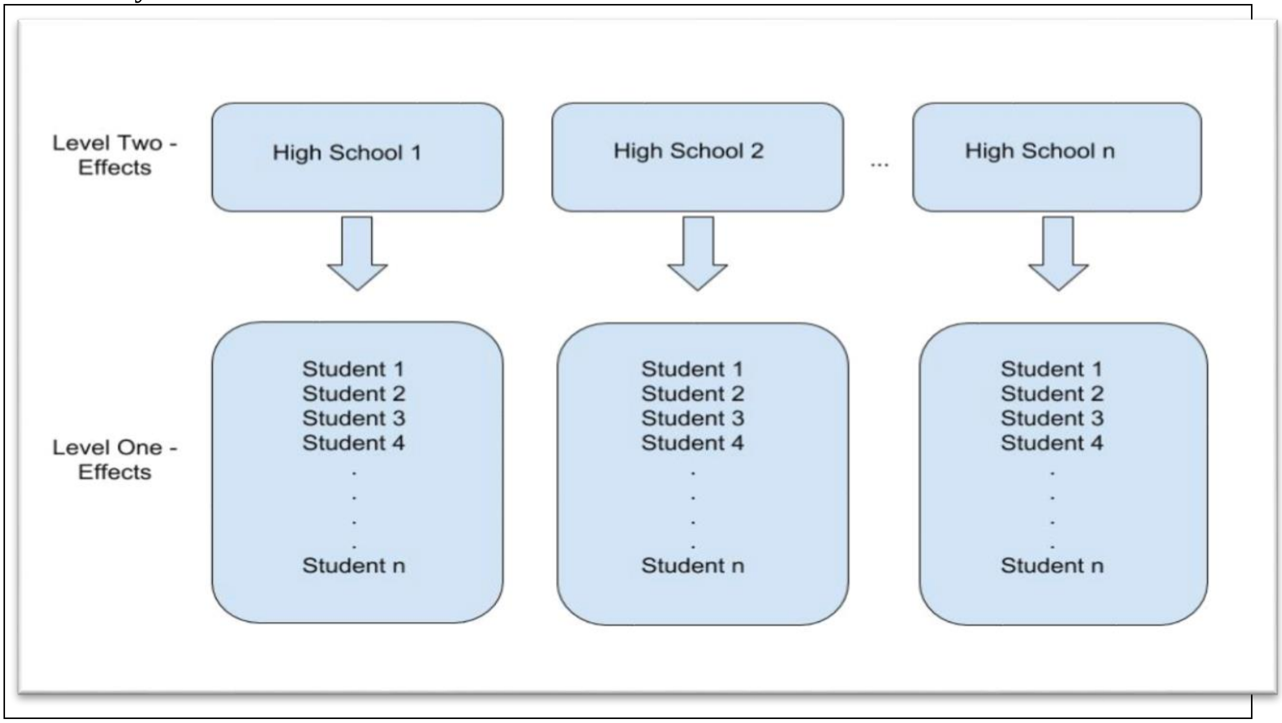
For each of the variables listed in Table 7, statistics were computed based upon percentage pursuant to the variable description in Chapter 3. There is a wealth of information contained in the Table 7, but there are several statistics that are particularly noteworthy. First, the average percentage of students on Free and Reduced lunch from the sampled high schools is 45.04%. Although there is a moderate amount of variability around this average, this average percentage is indicative of a system that services many students living in poverty. Second, average student attendance is 93.59%. Geiser and Santelices (2007) argued that student attendance is vital to course success. As such, observing high attendance rates has the potential to increase student performance. Finally, the average class size for a Math 1 course is 19.16 students. With a standard deviation of 4.18, there is observable variability around the average class size, indicating that student to teacher ratio varies from school to school.

Data Analysis

Analysis of the data occurred at two different levels and were sequenced to address each of the research questions. Since the research questions occurred at both the individual, student level (Level One) and the group, high school level (Level Two), the stages of the data analyses were partitioned by these levels. Figure 4 below indicates a map of this sequence.

Figure 4

Data Analysis Procedures



Level One Analyses. Level One Analyses investigated the relationship between High School Grade Point Average and Success. This investigation aided in answering research question 1, evaluating the relationship between a student's high school grade point average and their performance in a first attempt at a college level mathematics course. Evidence of a relationship was evaluated using a nominal by interval association analysis and evaluated using an eta-squared statistic. Once statistical significance was evaluated, indicated by a *p-value* < .05, a logistic regression equation was built regressing Success on High School Grade Point Average in the form of equations (1) and (2),

$$P(Y_i = 1) = [e^{(B_0+B_1*X_1+\varepsilon_i)}]\,/[1 + e^{(B_0+B_1*X_1+\varepsilon_i)}] \qquad (1)$$

$$Logit\left[\frac{P(Y_i=1)}{1-P(Y_i=1)}\right] = B_0 + B_1 * X_1 + \varepsilon_i \qquad (2)$$

In these equations, $Y_i$is the binary code representing success in a first-year mathematics course achieved by student *i* in the observed mathematics attempt (Success); $X_1$is the high school grade point average reported for student *i*; and $\varepsilon_i$is an error term that captures unobserved variation across the student level. Model significance will be evaluated using *Chi-Squared* statistics, *Wald* statistics, and *p-value*. The model will be deemed significant if *p-value* < .05. Furthermore, each *B* coefficient will be evaluated by calculating standardized beta values, *Chi-squared* statistics, and *p-values.*

Once an initial model using High School Grade Point Average was built, this model served as a forced step in a forward, stepwise hierarchical analysis regressing other, associated, Level One predictors on Success. Each step in the hierarchical was evaluated using the previously mentioned statistics as well as significant changes within steps of the *Chi-Squared* statistics. Overall model contribution to variable explanation was evaluated using *Cox and Snell R-Squared*. Each model step in the hierarchy was described in the form of equations (3) and (4).

$$P(Y_i = 1) = [e^{(B_0+B_1*X_1+B_2*X_2+\cdots+B_n*X_n+\varepsilon_i)}]\,/[1 + e^{(B_0+B_1*X_1+B_2*X_2+\cdots+B_n*X_n+\varepsilon_i))}] \qquad (3)$$

$$Logit\left[\frac{P(Y_i=1)}{1-P(Y_i=1)}\right] = B_0 + B_1 * X_1 + B_2 * X_2 + \cdots + B_n * X_n + \varepsilon_i \qquad (4)$$

In these equations, Y_i is the binary code representing success in a first-year mathematics course achieved by student *i* in the observed mathematics attempt (Success); $X_1$is the high school grade point average reported for student *i*; and $\varepsilon_i$is an error term that captures unobserved variation across the student level. Each proceeding X_n in the hierarchy are other significant contributors to variable explanation for Success from Level One. The hierarchical process was terminated when the addition of more predictor variables yielded no significant change to the *Chi-Squared* statistics.

Level Two Analyses. In order to address the hypothesized ecological fallacy present in student success predicted by high school grade point average, a second level of analysis was appropriate to examine relationships at the group, high school level when predicting student success. Although the premise behind analysis at multiple levels is not new, modern computational methods have made multilevel modeling much more robust. As such, a multilevel hierarchy was developed to address relationships between and within both levels of the variables. This is in contrast to the use of forward stepwise regression in the Level One Analyses. Due to the relative newness of multilevel techniques, parameter estimates cannot produce results to support direct model fit statistics such as log likelihoods. As further research into multilevel modeling continues, further estimation options may be available (Heck, Thomas, & Tabata, 2012). Be that as it may, Heck et al. (2012) suggested several stages of analysis to determine appropriate models under the multilevel theory. The hierarchy used in this study followed these recommendations.

Appropriateness of multilevel modeling. The first analysis performed was to address whether or not there was significant variability between student success and groups defined by Level Two variables. To address this, an unconditional model was created examining variability within Success by treating the intercept of a regression model as a random coefficient. Traditional ordinary least squares regression treats this coefficient as a fixed coefficient. By allowing the coefficient to vary across groups, the variability of the coefficients can be used to calculate the *Intraclass Correlation Coefficient (ICC)*. The *ICC* indicated the percentage of variability that existed within Success that can be attributed to between group effects. The scaling of the *ICC* is similar to *Pearson's Correlation Coefficient* in that a value not significantly different from zero indicates there is no between group difference evident in the sampled data. Conversely, an *ICC* equal to one would indicate perfect interdependence of residuals (Sommet & Morselli, 2017). A significant amount of variability, at this level, indicated that further investigation was necessary into intra-level analysis.

Review of the Level One Model. Once appropriateness of Level Two analysis was evidenced, the next step was to re-evaluate the Level One model incorporating a random intercept coefficient. Model significance was identified through *t-tests*, *Wald z* statistics, and *p-value.* The reporting of these statistics diverged for reported statistics at Level One. The shift was necessitated by the use of random intercept parameter estimates and the overall multilevel modeling theory. Although *Chi-Square* statistics are available, the requirements for application of such statistics require normality assumptions, robust sample sizes, and that variance assumptions were allowed to be both positive and negative. This study violated many of these assumptions and the overall impact of such a violation would result in *p-value* estimates that were too high (Heck et al., 2012).

Level Two predictor selection. Once a baseline, Level Two Model was developed, additional predictor variables at Level Two were examined for contribution of additional variability in Success. Each of the seventeen variables were clustered according to themes identified through analysis of the literature. Variables, were then compared to one another to identify possible contributions to multicollinearity using *Pearson's r* and accompanying significance tests. At this conclusion of this phase, variables that contributed non-unique variability explanation were eliminated.

Final model construction and selection. Variables selected at Level Two were added to the Baseline Level Two Model and models were examined for significance and fitness. The addition of these variables could have contributed variability to the random intercept calculation or as possible interactors with other Level One Variables, with each possible pairing receiving individual scrutiny. Final model selection was identified through *t-tests, Wald z* statistics, and *p-value.*

Limitations

The research design of this study was limited by several factors. First, cross-sectional data collections are limited to the scope and timeframe where the data were collected. This study lacks longitudinal aspects examining the behavior of several different cohorts over time. This study makes no attempt to examine relationships prior to this data collection. The final results of such a limitation renders any models produced less applicable to future cohorts.

Second, variables described in previous sections were selected for their ability to address the research questions but also for ease of access. Student success, for example, was generated by the research team to indicate overall, course-level, student success, as defined in previous sections. Assigning a numeric value to each alpha categorized grade lacks specificity in characterizing within group differences. Ideally, numeric grades would be a better measure to examine different levels within each reported grade. Since these data were not available, student success as characterized here served as an adequate proxy for student success. Other variables such as achievement, growth, performance, etc. were calculated by NCDPI. Since the quality of these variables cannot be controlled, there existed no opportunity to adjust or manipulate these values. This study used these variables as presented by NCDPI to ensure that stakeholders in the results of this research would be able to replicate the results and to apply the findings in institutional settings.

Third, multilevel logistic regression lacks defined mathematical hierarchical processes that are inherent to ordinal least squares regression. Lacking such processes introduces possible researcher bias as future stages were guided by choice. Furthermore, the selection of regression techniques limits the identification of causal relationships within measured variables. This study lacks aspects of true experimental design. As such, any relationships identified through data analysis indicated correlation but could not be deemed as cause and effect. Depending on the methods for any replication study, the authors of such a study could identify different relationships of varying strengths.

Finally, the research questions were best answered through a series of analyses using both individualized student data and aggregated high school group data. The aggregation process tends to filter certain extreme observations and has the potential to exclude certain data points from the process due to sample size constraints. Omitting data had the potential to bias this study against high schools that were underrepresented in the sampling frame and should be noted as a limitation.

Summary

The sampling frame, data collection, and data analyses were carefully crafted for this study and have been described in this chapter. Chapter Four will detail the results of data analysis for the study. This document will conclude with Chapter Five and will discuss the results of data analysis. Additionally, Chapter Five will explore implications of these findings and identify areas for future research.

Chapter 4

Results

The purpose of this study was to examine hypothesized relationships between student success in a first attempt at a college level mathematics course and predictors for student success. Although the literature focused, primarily, on individual, student level predictors, other researchers have expanded the depth of these predictors to other levels (Cyrenne & Chan, 2012; Goldhaber & Brewer, 2000; Kobrin et al, 2008; Pike & Saupe, 2002). Among these levels are characteristics of the high school that granted the graduating credential for the student. Using these authors as a guide, data were solicited and examined with the goal of producing a predictive model to aid in student placement and to identify students as possible beneficiaries of additional academic support. This chapter will detail the results of the study.

The results were organized into two sections. The first section the results of a binary logistic regression model, exclusively at Level One, examining the relationship between success in a first-year mathematics course and predictor variables such as high school grade point average, ethnicity, gender, type of course attempted, and method of course delivery. The second section will examine the necessity for analysis of these data at an additional level; high school characteristics. Once such a necessity is documented, this final section will employ multilevel, hierarchical logistic regression to identify each Level Two variable that accounts for additional variation over and above variables identified at Level One.

Level One Analyses

Research question one asked if there was a significant relationship between a student's high school grade point average and their performance in a first attempt at a college level mathematics course. To address this question, an initial association analysis was performed between High School Grade Point Average and Success. Since Success is a binary variable and High School Grade Point Average is of the ratio level, a nominal by ratio analysis was appropriate using an eta-squared statistic. Allowing Success to be dependent on High School Grade Point Average, there was a significant association between the two variables (*eta-squared* = .627, p <.001).

In addition to High School Grade Point Average, other Level One variables showed significant associations with student success. For model building purposes used in later steps of the Level One analysis, each Level One variable was recoded as a binary variable. Female (1=Female, 0=Not Female) was created to measure associations between the effect of being Female on other variables. White (1=White, 0=Not White) was created to measure associations between the effect of being White on other variables. Each course name was coded into its own binary variable to measure associations between the effects of enrolling in a specific course on other variables as was the delivery method. Associations were then measured using a *Chi-Square* measure of association statistic. Each flagged association was representative of a statistically significant association between the row and column variables. Table 8 contains the results of these analyses.

Table 8

Pearson Chi-Square Associations for Level One Variables

Variable Name	1.	2.	3.	4.	5.	6.
1. Success	-					
2. Female	7.74**	-				
3. White	6.89**	.09	-			
4. Mat-143	1.73	6.95**	.14	-		
5. Mat-152	4.34*	.15	.46	182.09**	-	
6. Traditional Delivery	26.54**	2.75	8.97**	7.48**	17.42**	-
7. Hybrid Delivery	5.52*	10.69**	.12	8.90**	.105	389.58**

*indicates an association that is significant at the .05 level
**indicates an association that is significant at the .01 level

The Chi-Square analyses in Table 8 indicated several noteworthy associations. Course success was significantly associated with both Female and White. These two associations indicate that there is an effect on course success when examining the gender and ethnic demographic characteristics of the student. However, both demographic characteristics also appear to be associated with course selection and the delivery method of the course. As such, these associations could be effected by inter-associations with other variables. Additionally, Success is associated with course selection, at the Mat-152 level, and course delivery method. Finally, the large associations between course selections and delivery methods can be attributed to the design of the study. Each student record is for a single course attempt. The effect of this on the association calculation is that no record can contain an attempt at two separate courses or two separate delivery styles. Taken together, the results of these analyses indicate that additional variability within Success can be explained beyond the use of High School Grade Point Average. In order to test this hypothesis, a stepwise, logistic regression of the level one variables on Success was appropriate.

Level One logistic regression. Analysis of the series of stepwise, logistic regression models began with a forced step regressing High School Grade Point Average on Success. Further steps in the process were evaluated through the change in a Chi-square statistic until the change from one step to the next contributed no additional explanation to overall model variability.

Logistic regression step one. The results of the forced first step regressing High School Grade Point Average on Success is displayed in Table 9.

Table 9

Regression of High School Grade Point Average on Success

	B	*Std. Error*	*Exp(B)*	*Wald*	*Sig*
(Constant)	-2.72	.38	.07	51.79	<.001
High School Grade Point Average	1.12	.12	3.05	80.00	<.001

This first step in the logistic regression analysis was a significant step, verifying High School Grade Point Average is a significant predictor for Success. For this study, significance was identified by examining two outcomes. The first is an Omnibus Test of Model Coefficients examining the Chi-square change from one step to the next. In the first step, the change is from an unconditional model using no predictors to the first step using High School Grade Point Average. In the case of step one, Chi-square change was significant (χ^2 *change* (1) = 87.858, $p <$ .001). The second outcome was to examine a Cox & Snell R squared statistic generated from a -2 Log likelihood statistic. This examination served to explain overall model fitness, much as R squared behaves in ordinary least squares regression. For step one, 7.3% of the variability within the residuals of Success can be attributed to the selection of High School Grade Point Average as a predictor (*-2 Log likelihood* = 1397.27, *Cox & Snell R Squared* = .073).

Logistic regression step two. Step two of the hierarchy added Traditional Delivery as a predictor in the regression of High School Grade Point Average on Success. The model results are displayed in Table 10.

Table 10

Regression of High School Grade Point Average and Traditional Delivery on Success

	B	*Std. Error*	*Exp(B)*	*Wald*	*Sig*
(Constant)	-3.53	.42	.03	72.16	<.001
High School Grade Point Average	1.18	.13	3.25	85.167	<.001
Traditional Delivery	.85	.15	2.33	32.45	<.001

Adding Traditional Delivery as a predictor variable was a significant step in the hierarchy (χ^2 *change* (1) = 32.47, $p < .001$) and accounted for 9.9% of the variability within the residuals of Success predictor (*-2 Log likelihood* = 1364.80, *Cox & Snell R Squared* = .099).

Logistic regression step three. Step three of the hierarchy added Mat-143 as a predictor in the regression of High School Grade Point Average and Traditional Delivery on Success. The model results are displayed in Table 11.

Table 11

Regression of High School Grade Point Average, Traditional Delivery, and Mat-143 on Success

	B	*Std. Error*	*Exp(B)*	*Wald*	*Sig*
(Constant)	-3.88	.44	.02	78.90	<.001
High School Grade Point Average	1.23	.13	3.43	89.66	<.001
Traditional Delivery	.90	.15	2.45	35.52	<.001
Mat-143	.43	.14	1.54	9.031	.003

Adding Mat-143 as a predictor variable was a significant step in the hierarchy (χ^2 *change* (1) = 9.25, $p = .002$) and accounted for 10.6% of the variability within the residuals of Success predictor (*-2 Log likelihood* = 1355.55, *Cox & Snell R Squared* = .106).

Logistic regression step four. Step four of the hierarchy added Mat-152 as a predictor in the regression of High School Grade Point Average, Traditional Delivery, and Mat-143 on Success. The model results are displayed in Table 12.

Table 12

Regression of High School Grade Point Average, Traditional Delivery, Mat-143, and Mat-152 on Success

	B	*Std. Error*	*Exp(B)*	*Wald*	*Sig*
(Constant)	-4.33	.46	.01	89.19	<.001
High School Grade Point Average	1.26	.13	3.54	91.63	<.001
Traditional Delivery	1.02	.16	2.78	43.18	<.001
Mat-143	.70	.16	2.01	19.72	<.001
Mat-152	.73	.18	2.08	16.95	<.001

Adding Mat-152 as a predictor variable was a significant step in the hierarchy (χ^2 *change* (1) = 17.64, *p* < .001) and accounted for 12.0% of the variability within the residuals of Success predictor (*-2 Log likelihood* = 1337.91, *Cox & Snell R Squared* = .120).

Logistic regression step five. The fifth, and final, step of the hierarchy added Hybrid Delivery as a predictor in the regression of High School Grade Point Average, Traditional Delivery, Mat-152, and Mat-143 on Success. The model results are displayed in Table 13.

Table 13

Regression of High School Grade Point Average, Traditional Delivery, Hybrid Delivery, Mat-143, and Mat-152 on Success

	B	*Std. Error*	*Exp(B)*	*Wald*	*Sig*
(Constant)	-4.71	.49	.01	92.40	<.001
High School Grade Point Average	1.29	.13	3.62	93.55	<.001
Traditional Delivery	1.31	.20	3.70	44.36	<.001
Hybrid Delivery	.65	.27	1.91	5.70	.017
Mat-143	.79	.16	2.21	23.61	<.001
Mat-152	.81	.18	2.24	19.81	<.001

Adding Hybrid Delivery as a predictor variable was a significant step in the hierarchy (χ^2 *change* (1) = 5.76, *p* = .016) and accounted for 12.4% of the variability within the residuals of Success predictor (*-2 Log likelihood* = 1332.15, *Cox & Snell R Squared* = .124). The hierarchical process was then terminated as no further iteration beyond the step five model because parameter estimates of -2 Log Likelihood changed by less than .001.

Summary of Level One models. The hierarchical regression of selected independent variables on Success yielded significant coefficients at each step of the hierarchy. The final model is described in equations (5) and (6).

$$P(Success = 1) = [e^{(-4.71+1.29*HSGPA+1.31*TraditionalD+.65*HybridD+.79*Mat143+.81*Mat152)}] / [1 + e^{(-4.71+1.29*HSGPA+1.31*TraditionalD+.65*HybridD+.79*Mat143+.81*Mat152)}] \quad (5)$$

$$Logit\left[\frac{P(Success=1)}{1-P(Success=1)}\right] = (-4.71 + 1.29 * HSGPA + 1.31 * TraditionalD + .65 * HybridD + .79 * Mat143 + .81 * Mat152 \quad (6)$$

Each coefficient within the final model is represented with a beta (*B*) value as well as exponentiated beta (*Exp(B)*). Although *B* is, generally, presented as the standard coefficient, *Exp(B)* is useful for measuring the effect of individual predictors on the criterion variable. The details for calculating *Exp(B)* from *B* can be found in equation (7).

$$Exp(B_n) = e^{B_n}/(1 + e^{B_n}) \quad (7)$$

In the case of the final model, High School Grade Point Average was calculated to be a significant predictor of success (*Exp(B)* = 3.62). This indicated that a student was 3.62 times more likely to successfully complete a first-year mathematics attempt with every 1-point increase in High School Grade Point Average. Each remaining predictor, at Level One, measured the effect of student choice. Since each variable was dummy coded, the model assumes a baseline decision of selecting Mat-171 delivered online. As such, each *Exp(B)* would indicate an odds of improvement by changing that decision. If a student were to choose Mat-143 (*Exp(B)* = 2.21), their odds of successfully completing their mathematics increased by a factor of 1.21. Similarly, if the choice were Mat-152 (*Exp(B)*=3.24), their odds of successfully completing their mathematics increased by a factor of 2.24. Furthermore, if the student were to elect to take the course delivered in a traditional (*Exp(B)* = 3.70) or hybrid (*Exp(B)* = 1.91) their odds of successfully completing their mathematics increased by a factor of 2.70 or 0.91, respectively.

With the construction of this final model, there was evidence of a statistically significant, positive relationship between a student's high school grade point average and their performance in a first attempt at a college level mathematics course. Furthermore, this positive relationship led to the development of a model using High School Grade Point Average, among other independent, Level One predictors that applies a probability of student success in their course of choice. A further discussion of the implications of these findings can be found in Chapter 5.

Level Two Analyses

Research question two addressed the possibility of an ecological fallacy regarding the use of High School Grade Point Average as a predictor for student success in a first-year mathematics course. Such a question necessitated an analysis at a second level; the high school that issued the graduating credential for each student record. According to Heck et al. (2012) these analyses, typically occur in several stages.

1) Identification of multilevel modeling as appropriate.
2) Review of level one models incorporating a random intercept coefficient.
3) Examination of the slope coefficients of the level one model for variability between groups.
4) Selection of additional predictors at level two that explain variability beyond the treatment of a random intercept coefficient.
5) Selection of additional predictors at level two that explain variability within the slope

coefficients of the level one model.

6) Final model selection.

The following Level Two analyses will follow this hierarchy.

Appropriateness of multilevel modeling. An unconditional model was constructed regressing a random intercept coefficient on Success. The results of this model is displayed in Table 14.

Table 14

The Unconditional Model

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	.589	.11	.64	51.79	<.001

The unconditional model was significant. The fit of the constant was comparable to the percentage of students successfully completing first-year mathematics (*Exp(B)* = .64). Such a finding indicated that treatment of the intercept as a random effect across Level Two groups explained significant variability when predicting student success. The precise amount of explained variability can be calculated using the Intraclass Correlation Coefficient (*ICC*) (Heck, et al., 2012). The *ICC* was calculated using the formula described in equation (8).

$$ICC = \sigma^2{}_{Between} / (\sigma^2{}_{Between} + 3.29_{Within}) \qquad (8)$$

Table 15 displays the necessary coefficients for the *ICC* computation.

Table 15

The Unconditional Model Random Effects

Random Effect	Estimate	*Std. Error*	*Wald*	*Sig*
Var*(Constant)*	.32	.15	2.07	.038

These results indicated that 8.76% of the variability in Success can be explained by between group effects at Level Two (*ICC* = .0876). Given these results, further model building, using

Level Two effects, was appropriate.

The Level One Model revisited. Given the appropriateness of level two analysis, the final Level One Model needed to be re-calculated to account for changes in coefficients, test statistics, and significance levels. The results of these calculations are displayed in Tables 16 and 17.

Table 16

Level One Model with Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-5.08	.64	.006	-7.94	<.001
High School Grade Point Average	1.38	.16	3.96	8.69	<.001
Traditional Delivery	1.26	.23	3.54	5.51	<.001
Hybrid Delivery	.60	.28	1.83	2.16	.031
Mat-143	.86	.20	2.36	4.39	<.001
Mat-152	.79	.17	2.20	4.74	<.001

Table 17

Level One Model with Random Intercept: Random Effects

Random Effect	Estimate	*Std. Error*	*Wald*	*Sig*
Var*(Constant)*	.43	.20	2.14	.032

The Level One Model with Random Intercept included is a significant model and all coefficients retained statistically significance after accounting for random intercept effects. There were some notable differences, particularly in the estimates of the *B* coefficients. There are two possible explanations for these differences. The first is a change in parameter estimates necessitated by the use of multilevel modeling. Due to the relative newness of multilevel techniques, parameter estimates cannot produce results to support direct model fit statistics such as log likelihoods. As further research into multilevel modeling continues, further estimation options may be available (Heck, et al., 2012). The second is the addition of random intercept effects to the Level One

Model. Regardless of the coefficient differences, the predictor variables used at Level One continued to serve as significant explanations for variability in Success at Level Two. This adjusted model served as a baseline for all proceeding Level Two analyses.

Variability between groups for Level One predictors. One potential explanatory source of variability between groups for Success could have been within the slopes of Level One predictors between high schools. Of the five significant predictor variables used in the baseline Level Two model, the one most appropriate for this analysis was High School Grade Point Average. The consequences of variability between groups at High School Grade Point Average could provide evidence of certain schools being more or less equitable in the distribution of High School Grade Point Average to graduating seniors. Tables 18 and 19 detail the results of a regression of level one predictors on Success with a random intercept effect of High School Grade Point Average.

Table 18

Level Two Model with High School Grade Point Average Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-5.01	.63	.007	-8.00	<.001
High School Grade Point Average	1.36	.16	3.89	8.72	<.001
Traditional Delivery	1.26	.23	3.53	5.50	<.001
Hybrid Delivery	.59	.28	1.80	2.11	.035
Mat-143	.86	.20	2.36	4.41	<.001
Mat-152	.79	.17	2.20	4.75	<.001

Table 19

Level Two Model with High School Grade Point Average Random Intercept: Random Effects

Random Effect	Estimate	*Std. Error*	*Wald*	*Sig*
Var*(Constant)*	.23	.40	.57	.57
High School Grade Point Average	.02	.04	.53	.60

The Level Two Model with High School Grade Point Average Random Intercept was not significant (z = .53, p = .60). The lack of significant parameter estimates for this model indicated there is no significant variability in the slope of High School Grade Point Average between high schools.

The remaining Level One predictor variables are indicative of student choice regarding their first attempt at a college mathematics. As such, any attempt to explain between group variability for those predictor variables are beyond the scope of this study.

Selection of Level Two predictor variables. During phase two of the data collection process, each public, North Carolina, high school that issued a graduating credential for a student in the sample was scrutinized for data collection across several Level Two variables. The methods applied to this study required significant aggregation and analysis of predictor variables. For this type of aggregation, multicollinearity is commonplace and can adversely impact the results of analyses (Midi, Sarkar & Rana, 2013). In an attempt to reduce the likelihood of errors driven by strongly correlated predictors, each of the Level Two variables were categorized according to themes that most appropriately described groups where variables contributed similar information regarding the quality of the high school in question. The four themes were: Service Population Characteristics; Academic Performance Characteristics; Faculty Characteristics; and Classroom Characteristics. Variable assignment by category can be found in Table 20.

Table 20

Level Two Predictor Themes

Service Population Characteristics	Academic Performance Characteristics	Faculty Characteristics	Classroom Characteristics
Free and Reduced Lunch	Achievement	Beginning Faculty	Course Size
Attendance	Growth	Early Career Faculty	Technology
	Composite Performance	Late Career Faculty	
	Percentage Scoring 3 or Higher	Teacher Turnover	
	Percentage Scoring 4 or Higher	Fully Licensed Teachers	
	Percentage Scoring 5 or higher	National Board Certified	
		Faculty Holding Advanced Degrees	

After tabulation, within theme correlations were examined. Each of the correlations were used in future stages of the Level Two analysis hierarchy to identify variables for use in model calculations or possible removal. Tables 21 through 24 display the results of this examination.

Table 21

Pearson Correlations for Service Population Characteristics

Variable Name	1.	2.
1. Free and Reduced Lunch	-	
2. Attendance	-.63**	-

*indicates an association that is significant at the .05 level
**indicates an association that is significant at the .01 level

Table 22

Pearson Correlations for Academic Performance Characteristics

Variable Name	1.	2.	3.	4.	5.
1. Achievement	-				
2. Growth	.49**	-			
3. Composite Performance	.97**	.70**	-		
4. Percentage Scoring 3 or Higher	.91**	.59**	.92**	-	
5. Percentage Scoring 4 or Higher	.89**	.61**	.91**	.99**	-
6. Percentage Scoring 5 or higher	.79**	.39**	.77**	.80**	.80**

*indicates an association that is significant at the .05 level
**indicates an association that is significant at the .01 level

Table 23

Pearson Correlations for Faculty Characteristics

Variable Name	1.	2.	3.	4.	5.	6.
1. Beginning Faculty	-					
2. Early Career Faculty	-.10**	-				
3. Late Career Faculty	-.82**	-.44**	-			
4. Teacher Turnover	.65**	.00	-.61**	-		
5. Fully Licensed Teachers	-.76**	-.03	.69**	-.54**	-	

Variable Name	1.	2.	3.	4.	5.	6.
6. National Board Certified	-.45**	-.11**	.49**	-.44**	.53**	-
7. Faculty Holding Advanced Degrees	-.21**	-.23**	.35**	-.30**	.30**	.38**

*indicates an association that is significant at the .05 level
**indicates an association that is significant at the .01 level

Table 24

Pearson Correlations for Classroom Characteristics

Variable Name	1.	2.
1. Course Size	-	
2. Technology	.15	-

*indicates an association that is significant at the .05 level
**indicates an association that is significant at the .01 level

Midi et al. (2013) argued that a possible remedy to issues with multicollinearity was variable elimination. Within at least three of the four themes, there existed significant correlations between predictor variables. In accordance with Midi et al. (2013), no Level Two model would include more than one predictor variable from each theme. Removed variables were determined by lack contribution to explained variation for Success.

Variability for Level Two analyses can, potentially, occur at the intercept coefficient and / or the slope coefficient. Predictor variables, at this level, were analyzed for both the intercept and slope coefficients

Level Two variability: Intercepts. Each of the seventeen Level Two variables were examined for fixed effects explaining variability for the intercept of the Level Two baseline model displayed in Table 16. To address multicollinearity concerns, the best predictor from each theme, as observed by a two sample t-test, was selected for further analysis and possible selection for the final Level Two model. All other variables were removed. The sections that follow display the results from analyses at each theme that generated the final predictor selection.

Theme: Service Population Characteristics. After multiple iterations pairing Service Population Characteristics with the Level Two Baseline model, a regression of Level One predictor variables on Success using Free and Reduced Lunch as a fixed, Level Two effect on the intercept of the model was found to account for the most amount of within group variability within the theme. Model coefficients and tests of significance can be found in Table 25.

Table 25

Level Two Model with Free and Reduced Lunch as a Fixed Effect on the Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-4.98	.69	.01	-7.22	<.001
(Constant)$_{\text{Free and Reduced Lunch}}$	-.002	.01	.998	-.37	.71
High School Grade Point Average	1.38	.16	3.975	8.68	<.001
Traditional Delivery	1.27	.23	3.55	5.49	<.001
Hybrid Delivery	.60	.28	1.83	2.16	.031
Mat-143	.86	.20	2.37	4.43	<.001
Mat-152	.79	.17	2.20	4.76	<.001

Although Free and Reduced Lunch was found to be the best predictor for fixed intercept variability within the theme, these results were not significant (t = -.37, p = .71). Subsequent to these findings, Service Population Characteristics appear to explain no significant amount of variability in Success. A further discussion of these implications can be found in Chapter 5.

Theme: Academic Performance Characteristics. After multiple iterations pairing Academic Performance Characteristics with the Level Two Baseline model, a regression of

Level One predictor variables on Success using Percentage Scoring 3 or Higher as a fixed, Level Two effect on the intercept of the model was found to account for the most amount of within group variability within the theme. Model coefficients and tests of significance can be found in Table 26.

Table 26

Level Two Model with Percentage Scoring 3 or Higher as a Fixed Effect on the Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-5.911	.67	.003	-8.87	<.001
(Constant) Percentage Scoring 3 or Higher	.02	.01	1.02	2.324	.02
High School Grade Point Average	1.37	.16	3.93	8.49	<.001
Traditional Delivery	1.29	.23	3.62	5.65	<.001
Hybrid Delivery	.60	.28	1.83	2.16	.031
Mat-143	.87	.19	2.39	4.53	<.001
Mat-152	.78	.16	2.19	4.48	<.001

Adding Percentage Scoring 3 or Higher was found to be the best predictor for fixed intercept variability within the theme (t = 1.37, p = .02). Within the theme, there were other variables that were significant when applied to explain fixed intercept variability, however pairing of these variables with Percentage Scoring 3 or Higher reduced overall significance due to substantial multicollinearity. As such, Percentage Scoring 3 or Higher served as a proxy for the theme in further model iterations.

Theme: Faculty Characteristics. After multiple iterations pairing Faculty Characteristics with the Level Two Baseline model, a regression of Level One predictor variables on Success using Faculty Holding Advanced Degrees as a fixed, Level Two effect on the intercept of the model was found to account for the most amount of within group variability within the theme. Model coefficients and tests of significance can be found in Table 27.

Table 27

Level Two Model with Faculty Holding Advanced Degrees as a Fixed Effect on the Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-6.33	.82	.002	-7.74	<.001
(Constant)$_{Faculty\ Holding\ Advanced\ Degrees}$	.05	.02	1.05	2.55	.011
High School Grade Point Average	1.40	.16	4.04	8.58	<.001
Traditional Delivery	1.25	.23	3.50	5.39	<.001
Hybrid Delivery	.57	.29	1.77	2.00	.046
Mat-143	.87	.19	2.38	4.53	<.001
Mat-152	.80	.17	2.21	4.78	<.001

Adding Faculty Holding Advanced Degrees was found to be the best predictor for fixed intercept variability within the theme (t = 2.55, p = .011). Within the theme, there were other variables that were significant when applied to explain fixed intercept variability, however pairing of these variables with Faculty Holding Advanced Degrees reduced overall significance due to substantial multicollinearity. As such, Faculty Holding Advanced Degrees served as a proxy for the theme in further model iterations.

Theme: Classroom Characteristics. After multiple iterations pairing Classroom Characteristics with the Level Two Baseline model, a regression of Level One predictor variables on Success using Course Size as a fixed, Level Two effect on the intercept of the model was found to account for the most amount of within group variability within the theme. Model coefficients and tests of significance can be found in Table 28.

Table 28

Level Two Model with Course Size as a Fixed Effect on the Random Intercept

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-4.63	.99	.01	-4.66	<.001
(Constant)$_{\text{Course Size}}$	-.02	.03	.98	-.73	.464
High School Grade Point Average	1.38	.16	3.96	8.60	<.001
Traditional Delivery	1.28	.23	3.59	5.63	<.001
Hybrid Delivery	.61	.28	1.85	2.20	.028
Mat-143	.86	.20	2.38	4.39	<.001
Mat-152	.78	.17	2.19	4.75	<.001

Although Course Size was found to be the best predictor for fixed intercept variability within the theme, these results were not significant (t = -.73, p = .464). Subsequent to these findings, Classroom Characteristics appear to explain no significant amount of variability in Success. A further discussion of these implications can be found in Chapter 5.

Summary of Level Two effects on intercept variability. Exhaustive analysis of Level Two predictors compressed the number of variables to those that explained the most variability in Success across the four themes, at the intercept level: Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees. The elimination of the other 15 variables was not meant to indicate that aspects measured by the variables did not contribute to some overall explanation of the variability in student success in mathematics, moreover, the information contributed by these variables was not unique and was captured within the selected two.

Level Two variability: Slopes and intercepts. Exhaustive analyses were also performed across each theme regarding the appropriateness of using predictor variables within the theme as modifiers for the relationship between Success and High School Grade Point Average. Results of these analyses indicated similar findings to the analyses to the intercept only models. Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees were the only variables that contributed significant, individual explanation of variability for Success at either the intercept or slope levels. This evidence indicated that of the seventeen selected predictor variables for Level Two, Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees were the two characteristics that exhibited statistically significant relationships with student success in a first-year mathematics course. The final stage of Level Two model construction was to pair Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees with the Level Two Baseline Model. This pairing occurred at the fixed intercept and slope levels.

Research question three asked about the relative strengths for any identified predictor variables regarding the relationship with success in a first-year mathematics course. To address this question four unique iterations were computed regressing Level One predictors on Success applying a pairing of Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees. The first applied both Percentage Scoring 3 or Higher and Faculty Holding Advanced Degrees as fixed intercept predictors. The second, applied Faculty Holding Advanced Degrees as a fixed intercept predictor and Percentage Scoring 3 or Higher as a modifying predictor on High School Grade Point Average. The third, applied Percentage Scoring 3 or Higher as fixed intercept predictor and Faculty Holding Advanced Degrees as a modifying predictor on High School Grade Point Average. The fourth, applied Percentage Scoring 3 or Higher as a modifying predictor on High School Grade Point Average and Faculty Holding Advanced Degrees as a modifying predictor on High School Grade Point Average. It should be noted that this is not an exhaustive pairing as there are other Level One predictors in the Level Two Baseline Model. However, examining modifications on student choice variables, such as curriculum or delivery method, is beyond the scope of this study.

Each iteration was significant evidenced by examination of two sample t-tests. As such, any of the four models could have been selected as the Final Level Two Model. However, since applying variability to different aspects of the Level One predictors contained in the model, the Final Level Two Model was selected for two specific characteristics. The first was overall parameter estimate significance. The second was the interpretation of the model coefficients to align with the literature. Pursuant to these characteristics, the Final Level Two Model was a regression of Level One predictors on Success applying Percentage Scoring 3 or Higher as modifying predictor on High School Grade Point Average and Faculty Holding Advanced Degrees as a modifying predictor on High School Grade Point Average. The results of this analysis can be found in Tables 29 and 30.

Table 29

Final Level Two Model

	B	*Std. Error*	*Exp(B)*	*t*	*Sig*
(Constant)	-5.04	.63	.006	-8.00	<.001
High School Grade Point Average	.86	.22	2.36	3.96	<.001
High School Grade Point Average*Faculty Holding Advanced Degrees	.01	.005	1.01	2.10	.04
High School Grade Point Average*Percentage Scoring 3 or Higher	.004	.002	1.00	2.05	.04
Traditional Delivery	1.27	.23	3.57	5.53	<.001
Hybrid Delivery	.57	.28	1.77	2.00	.05
Mat-143	.87	.19	2.39	4.59	<.001
Mat-152	.79	.17	2.20	4.78	<.001

Table 30

Final Level Two Model: Random Effects

Random Effect	Estimate	*Std. Error*	*Wald*	*Sig*
Var*(Constant)*	.34	.018	1.91	.05

The Final Level Two Model contained several features in explaining variability in student success. First, treatment of the intercept as a random effect on Success was significant, indicating, much like the initial phase of the Level Two analysis, that there is variability that can be explained by applying Level Two Predictors (z = 1.91, p = .05). The Final Level Two Model is further described in equations (9) and (10).

$$P(Success = 1) = \left[e^{(-5.04+.86*HSGPA+.01(HSGPA*ADVD)+.004(HSGPA*MATH3)+1.27*TraditionalD+.57*HybridD+.87*Mat143+.79*Mat152)}\right] / \left[1 + e^{(-5.04+.86*HSGPA+.01(HSGPA*ADVD)+.004(HSGPA*MATH3)+1.27*TraditionalD+.57*HybridD+.87*Mat143+.79*Mat152)}\right] \quad (9)$$

$$Logit\left[\frac{P(Success=1)}{1-P(Success=1)}\right] = -5.04 + .86 * HSGPA + .01(HSGPA * ADVD) + .004(HSGPA * MAT3) + 1.27 * TraditionalD + .57 * HybridD + .87 * Mat143 + .79 * Mat152 \quad (10)$$

Second, student choice in curriculum and course delivery, at Level One, continued to be significant predictors of student success. Model construction, at this final stage, still assumed a baseline choice of Mat-171 delivered in an online environment. As such, *Exp(B)* coefficients were interpreted as the odds of student success by the choice of curriculum or delivery method over the baseline. In the case of Mat-143, if a student were to choose Mat-143 in an online setting they were 2.39 times more likely to be successful than a student choosing Mat-171 (*Exp(B)* = 2.39). If the student were to choose Mat-152 they were 2.20 times more likely to be successful than a student choosing Mat-171. If the student were to choose a traditional delivery of the mathematics curriculum, they were 5.53 times more likely to be successful that a student taking the delivery online (*Exp(B)* = 5.53) and if they chose hybrid, 2.00 times more likely to be successful than in an online delivery (*Exp(B)* = 2.00).

Third, the main source of variability from Level Two predictors came as interaction effects with High School Grade Point Average. Each of these interactions indicated that the use of High School Grade Point Average as a predictor for success in mathematics could be modified by using characteristics of the high school granting the graduating credential for each student. In short, the effect of High School Grade Point Average on the probability of successfully completing a mathematics attempt is not the same across high schools. In the case of Percentage Scoring 3 or Higher, students with higher high school grade point averages benefit from high schools that report more students scoring higher than a three on their Math 1 End of Course Exam (t = 2.05, p = .04). Turning to Faculty with Advanced Degrees, students with higher high school grade point averages benefit from graduating from high schools with a larger proportion of the faculty holding advanced degrees (t = 2.10, p = .04).

Summary

Data analysis at both Level One and Level Two yielded significant results leading to several conclusions regarding the research questions posed by this study. Each research question has been restated below.

1) Is there a statistically significant, positive relationship between a student's high school grade point average and their success in a first attempt at a college level mathematics course?
2) What characteristics of high school quality have a statistically significant relationship with average student success in a first attempt at a college level mathematics course?
3) What are the relative strengths of high school quality and high school grade point average as predictors of average student success in a first attempt at a college level mathematics course?

Although briefly summarized here, a further discussion of the implications of these findings can be found in Chapter 5.

Research question one. Association matrices were employed to examine relationships between predictor variables at Level One and the criterion variable Success. Results of these findings led to the development of a Level One Model that indicated High School Grade Point Average was a statistically significant predictor of success, which aligns with the body of literature cited in Chapter 2. In addition to High School Grade Point Average, student choice was also scrutinized and indicated that the curriculum and delivery method of the course selected were also significant predictors of student success in a first-year mathematics course.

Research question two. To address a possible ecological fallacy in predicting student success, analyses were run to indicate a necessity for inclusion of Level Two predictors. Once indicated, exhaustive analyses of Level Two predictor variables indicated two predictors that explained statistically significant variability in student success: Percentage Scoring 3 or higher and Faculty Holding Advanced Degrees. This variable explanation could have occurred at either the slope or intercept level of the multilevel model. Although significant at all permutations, the model most appropriate for further scrutiny examined interaction effects of these two selected variables and High School Grade Point Average.

Research question three. Once the Final Level Two Model was constructed, each of the interactions between Level Two predictors and High School Grade Point Average were scrutinized for relative strengths against the main Level One effects. The presence of interaction effects indicated that the effect of High School Grade Point Average on Success is different for students graduating from individual high schools. These differing effects were, mainly, identified through the selection of Percentage Scoring 3 or higher and Faculty Holding Advanced Degrees. Each interaction effect was represented as the product of the effect and High School Grade Point Average. Regarding Percentage Scoring 3 or higher, students graduating from high schools where a larger percentage of the student population scored a 3 or higher on the math one exam were more likely to be successful in college mathematics. Although the effect size appears relatively small (*Exp(B)* = 1.01) the scaling of the interaction effect with High School Grade Point Average changes the prediction for overall success substantially. Turning to Faculty Holding Advanced Degrees, students graduating from high schools where a larger percentage of the faculty have obtained advanced degrees were more likely to be successful in college mathematics. Similar to the coefficient for Percentage Scoring 3 or Higher, the relatively small effect size (*Exp(B)* = 1.004) is not indicative small contributions to Success, but is due to the scaling of the interaction term.

Chapter 5

Conclusions and Recommendations

This chapter will summarize the study through several lenses. First, this chapter will address the research questions that guided the study. Second, a detailed discussion of the results will align the findings with the scholarly literature presented in Chapter 2 with a particular focus on themes evident from data analysis. Third, implications regarding areas for further research and practical applications to stakeholders in the research will be presented. Finally, the full study will be summarized with final conclusions.

Research Questions

This research was guided by three specific questions that were addressed through data collection and analysis:

1) Is there a statistically significant, positive relationship between students' high school grade point average and success in a first attempt at a college level mathematics course?
2) What characteristics of high school quality have a significant relationship with student success in a first attempt at a college level mathematics course?
3) What are the relative strengths of high school quality and high school grade point average as predictors of student success in a first attempt at a college level mathematics course?

Regarding research question one, a statistically significant, positive relationship was identified between high school grade point average and success in a first attempt at a college level mathematics course. This aligned with hypotheses originally posed at the start of this study.

Turning to research question two, two specific characteristics of *high school quality* were identified as having a significant relationship with first year mathematics success: the percentage of students achieving a score of three or higher on the Math 1 End of Course Examination and the percentage of *high school faculty* that have obtained an advanced degree. These findings were hypothesized, to an extent. Contrary to what was hypothesized, classroom characteristics, student access to technology, and, perhaps most surprising, service area economic indicators exhibited no significant relationship with student success in a first year mathematics course. Each of these variables were identified as possible predictors based on previous findings (Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Pike & Saupe, 2002), however, in each of these studies, predictors were analyzed at the student level. For example, socioeconomic status was gauged at the student level whereas this study aggregated the scores by using the percentage of students on free and reduced lunch as a service area indicator. The result of such an aggregation could have, potentially, filtered these impacts across the student population and weakened relationships with student success.

Finally, regarding research question three, the effect sizes of the two identified modifiers on high school grade point average were statistically significant, although small in scale due to the computation of the interaction term. With both effects indicating a positive relationship, students with higher high school grade point averages benefited from better group performance on the Math 1 End of Course Examination as well as a higher percentage of the faculty holding advanced degrees. Contrary to the original hypothesis, these effect sizes did not vary in strength as hypothesis tests for both interaction effects were statistically significant.

Discussion of the Findings

After addressing key findings aligned by the research questions posed by this study, there were three key themes evident from data analyses:

1) A student's high school grade point average, as scholarly literature would indicate, was the best individual level indicator of first year mathematics success;

2) Student choice in delivery mode and curriculum was also indicative of overall academic success; and
3) A student's high school grade point average, although valid alone as an indicator, was modified by institutional characteristics of the credential granting school.

Each of these themes will be defined in sections below. Following each definition will be an alignment with scholarly literature regarding that theme as identified in Chapter 2.

Validity of high school grade point average. High school grade point average has been long accepted as mechanism for evaluating student performance in high school. Although students may choose different courses in their pathway to graduation, recognitions for performance at commencement are largely dependent on this metric. Historically, high school grade point average has been viewed as part of the student portfolio when applying to college, accompanied by references and standardized test scores. More recently, colleges have begun to view high school grade point average as more than a metric for college acceptance, but as an indicator of performance in college specific coursework (Bracco, et al., 2014; Burdman, 2012; Collins, 2008).

Since most community colleges are open access institutions, acceptance is guaranteed for all applicants. With open access comes a potential student population with greatly differing experiences and skill sets. The remedy for such differentiation had been some application of a placement examination. However, researchers have argued that such placement examinations were poor indicators of student performance and argued for an increased emphasis on student academic experience (Belfield & Crosta, 2012). In this, high school grade point average has become a panacea for the placement problem.

Regarding the data collected for this study, high school grade point average was examined as a possible predictor for student success in a first attempt at a college mathematics course. The findings of this study indicated that when applied as a soul predictor of success in mathematics, high school grade point average explained 7.3% of the variability in student success in a mathematics course. Such a finding aligned with the findings of other researchers.

Authors for every study examined as part of the literature review for this document pointed to high school grade point average as a valid metric for success in college level coursework (Belfield & Crosta, 2012; Cyrenne & Chan, 2012; Geiser & Santelices, 2007; Kobrin et al., 2008; Kowski, 2013; Pike & Saupe, 2002; Scott-Clayton, 2012). Other authors identified high school grade point average as a valid predictor for individual course success (Goldhaber & Brewer, 2000; Kowski, 2013; Scott-Clayton, 2012). In each case, the utility of high school grade point average was adjusted by accounting for other sources of variability, at the student level, such as placement and other standardized test scores (Belfield & Crosta, 2012; Geiser & Santelices, 2007, Kobrin, et al., 2008, Pike & Saupe, 2002, Scott-Clayton, 2012) and socioeconomic status (Geiser & Santelices, 2007, Kowski, 2013). Other authors examined variability at other levels such as student expenditures at graduating high schools (Cyrenne & Chan, 2012) and faculty credentials (Goldhaber & Brewer, 2000). Such a consensus in the research community led to the establishment of policies applying high school grade point average in predictive analytics for student success. The findings of this study add to a body of research holding that high school grade point average, although modified at other levels, can and should be used in placing students in their college level coursework.

Student choice matters. The first-year mathematics curriculum has undergone significant changes as an underlying tenet of the comprehensive curriculum offered by community colleges (Geiger, 2011). As programs grow in number and become more specific regarding the skill set required to be successful, viewing the mathematics curriculum as a single course or all-encompassing set of algorithms is inappropriate. Regardless of the college or system, three different pathways have emerged under the guise a first-year mathematics; quantitative literacy, statistics, and pre-calculus. Researchers have argued that even though the curriculum for each pathway varies, all present a significant barrier to success and credential completion in college (Jaggars et al., 2015; Martinez & Bain, 2014; Rutschow & Schneider, 2011).

As the community college mathematics curriculum has grown, students have been granted the opportunity to choose their curriculum pathway and the mode in which this curriculum is delivered. The expansion of educational pedagogy beyond the traditional classroom to an online environment have afforded students even more opportunities for choice in first-year mathematics. Although this choice could, potentially, be limited by access, program of study, or institutional necessities, affording students a choice comes with possible consequences. This study identified that although each curriculum is clustered under the umbrella of first-year mathematics, the pathway selected by each student has implications in their overall success.

Mathematics practitioners could make an argument for a hierarchy of difficulty regarding course selection and delivery mode. The findings of the present study indicated that students in a quantitative literacy treatment of mathematics were more successful than those in statistics. Furthermore, students in quantitative literacy and statistics performed better than those in pre-calculus. The same could be argued for delivery mode, with online students being less successful than those with more face-to-face interactions with faculty. However, such an argument is unfounded in this research as these findings point purely to student success and not an examination of individual curricula or student experiences. Further research would be required to investigate such claims.

The current study does, however, indicate that students need to be well-informed as to the consequences of their decisions and what expectations are for each curriculum and delivery option. Bailey et al. (2010) and Kowski (2013) argued for an increased emphasis on the student advising process, and the findings of this research support such an emphasis. With the litany of options afforded to students, being well-informed as to the consequences of each option is key to student success.

Modifications to high school grade point average as a predictor for success. This study examined several variables, at multiple levels, as possible covariates for success in college mathematics beyond student choice and high school grade point average. Aligning with the findings of other researchers, ethnicity and gender did not account for significant variability in mathematics success beyond what had been identified through past performance and student choice (Geiser & Santelices, 2007; Pike & Saupe, 2002). However, a key piece of the current study was the potential of the quality of the high school issuing the graduation credential to modify high school grade point average as a predictor for success in mathematics. To this end, student performance in the Math 1 curriculum and employment of faculty with advanced degrees were two characteristics of high school quality that were identified as having such an effect.

Math 1 is a course offered in all North Carolina high schools as a first exposure to secondary mathematics curricula. Topics covered in this course include algebra fundamentals, geometry principles, and elementary probability topics. According to national Common Core principles, all high school graduates must have successfully completed this course to qualify for diploma conference (Common Core State Standards Initiative, n.d.). Furthermore, each high school is required to report student performance on the End of Course examination for Math 1.

Performance is reported on a standardized scale from 1 to 5, with scores of 3 or higher indicating content proficiency (North Carolina Report Cards, n.d.a). Student performance in Math 1 was selected for examination in this study as a proxy for standardized testing related to mathematics success. Unlike other standardized tests, all students are required to show proficiency in this content and, as the findings of this study indicated, modified high school grade point average as a predictor for mathematics success in college. Kobrin et al. (2008) exhibited precedent for applying standardized tests as a modifier for high school grade point average as a predictor for success, and this study aligned with those findings.

In addition to Math 1 performance, this study also identified faculty credentials as a significant modifier for high school grade point average when predicting success in mathematics. Previous studies identified faculty credentials as a valid predictor for high school level content mastery (Goldhaber & Brewer, 2000), and such an examination for college mathematics success seemed appropriate. Although there were many ways to consider faculty credentials as a variable for consideration, the attainment of an advanced degree contributed to the most amount of variable explanation. Interestingly, this variable made no account for the content area in which the advanced degree was earned, but purely indicated that one had been obtained. In short, the effect of this variable in model considerations could not be identified as advanced mathematicians teaching students in the classroom, but was more indicative of a high school culture that placed an emphasis on advanced teacher credentialing. It is, perhaps, the establishment of rigorous academic cultures at credentialing high schools that are the true culprit of modification effects identified in the current study.

Taken together, student performance in the Math 1 curriculum and employment of faculty with advanced degrees were indicative of relationships with college mathematics success at multiple levels. Such evidence led to the development of the Final Level Two Model that accounts not only for student level predictors, but also the source of prior educational experiences as interacting covariates. The implications and applications of these findings are categorized in the sections that follow.

Implications

This study exhibited that the utility of high school grade point average as a predictor for success in first-year mathematics coursework was modified through the inclusion of high school quality characteristics. These findings have many practical applications across the spectrum of stakeholders. Furthermore, as is common in studies like this one, there are more questions that have arisen through this process that are recommended for further research.

Practical applications. Individuals across the education spectrum should have an interest in the findings of this research. Among them are students, faculty, and administrators at the high school and community college levels. Furthermore, policymakers at the local, system, and legislative levels should inform policies and procedures based on the results currently presented.

Emphasis on academic culture at the secondary level. This study has shown evidence that student performance on mathematics standardized testing at the high school level significantly modifies high school grade point average as a predictor for college mathematics success. Furthermore, employing a faculty with advanced academic credentials also significantly modifies high school grade point average as a predictor. Taken together, these two characteristics point to the creation of an academic culture of excellence that through professional development opportunities, budget stewardship, and alignment with a pedagogy constructed with student success in mind has the potential to create a higher percentage of students that are successful in mathematics at the college level. As administrators at this level look for avenues to impact student success with ever retracting budgets, applying resources in these areas have been shown, through this research, to have a positive impact on student performance after graduation.

Student placement for mathematics curricula. The placement problem at community colleges has been pervasive in academic literature and on campus practice. Although certain systems have begun to identify prior student performance through the use of high school grade point average as a valid predictor for success, to decide to ignore the characteristics of the high school that issued the graduating credential would be a decision made in error. The Final Level Two Model presented in Chapter 4 predicts student success, by curriculum and delivery mode, by accounting for not only high school grade point average but also the quality of the high school issuing the graduation credential. Policies could be developed around these predictive analytics to more appropriately describe a pathway for students entering the college after graduation from a public high school.

Advising and student support at the community college. Students would benefit from The Final Level Two Model in knowing an assessment of their future performance based upon students that had already been through the proposed curriculum. If students are well informed as to the consequences of their choices regarding their likelihood for success, not only could they make choices better suited for their experiences, but they could make informed decisions regarding additional services. Such services could be tutoring or other academic support, to increase the probability of a successful performance in mathematics.

As the colleges begin to adopt new advising practices, as proposed here, having an understanding as to the student population they serve would help with staffing related to services utilized by their student population. This research provides colleges the opportunity to assess the possible performance of their student population at intake, thus greatly reducing the need for quick adjustments after a certain amount of time had passed.

Early intervention classroom practices. Instructors at the community college level can apply these findings to better understand classroom dynamics and early intervention practices. Since students, generally, self-select sections for registration, random clustering of students has the potential to yield sections of students with greatly differing skill sets. With the findings detailed in this study, faculty can begin to assess the skill set of their classroom before the term begins. This assessment provides faculty with opportunities to make pedagogical changes to differentiate instruction for students of different levels.

Turning to individual student interventions, identification of students that are likely to struggle with the curriculum has been, typically, limited until after students have shown a lack of aptitude in course concepts through assessment. The Final Level Two Model can inform faculty as to the probability of student success long before this lack of aptitude were traditionally identified through poor performance on course assessments. Once identified, recommendations can be made to the student, counselors, advisors, or other student services personnel to create a pathway for student success.

Teacher education programs at the graduate level. The findings indicate that high school administrators should advocate for increased demand for secondary faculty having academic credentials at the graduate level. Universities offering such training and credentialing should be prepared for this increased demand. Furthermore, as these institutions prepare for such changes, they should begin to evaluate the curriculum and instruction offered to these students to prepare for high school environments that expect high performance in mathematics and mathematics related fields.

Increased funding for innovative practices. Many of the proposed applications of this research require additional financial support. Funding bodies, such as general assemblies, systems, or local boards should consider increasing the budgets of institutions attempting to apply the recommendations of this research. Additionally, institutions should pursue grants and scholarships to aide their faculty, administrators, and students in establish policies and procedures central to student success in mathematics.

Areas for further research. In as much as there are implications for practice resulting from the findings of this study, these results have also informed several promising areas for further research. Although not a comprehensive list, the sections that follow document a few possible areas for expansion based upon the findings currently presented.

Regular adjustment of model parameters. The model building process, although decorated with benchmarks, is never complete. As many of the implications for practice are executed, the parameter estimates used in Chapter 4 are likely to change value or perhaps shift to better, more predictive variables. The only way to identify when these changes are appropriate is regular re-evaluation of the data as time progresses. Drawing new samples from the service population at no less than five year intervals is paramount to the continued use of the findings of this document. Furthermore, it would be prudent to expand the sampling frame beyond the scope of a single system. A national sample of the United States two-year college system has the potential to yield different results from those presented here, however such a difference, although anticipated, would most likely be small.

Models for other content areas. One of the motivating factors for this study was the documented barrier first-year mathematics presented to student completion of a credential. Such documented barriers are not unique to mathematics. Reading comprehension, English curriculum, and the natural sciences have also been shown to impede student success in the pursuit of a college credential (Scott-Clayton, 2012). Given the similar motivations for study, one possible area that is ripe for additional inquiry is to apply similar methodologies to the ones presented in this study but applied to other content areas.

Student and classroom interventions. As colleges and systems begin to apply the recommendations of this research, there will be a need to address what interventions were successful and in what way. There could be an establishment of specific markers for student success based on the probability generated by the models presented in Chapter 4. Other areas could engage students and faculty in a more qualitative approach to success based on high school quality and secondary education experiences. In total, the findings presented in this document indicate the need for a series of works further extending the academic conversation regarding student success in college through the lens of prior learning experiences.

Ethical implications. The current study presents several applications to enhance student services, student success models, teacher education pedagogy, and advocacy for increased funding. However, users of these findings should be cautious not to overgeneralize any of this information beyond the scope of the sampling frame. Any model applications should be limited to students meeting the criteria for inclusion as part of this study. Furthermore, application beyond the curriculum specifically described in this document would be inappropriate. Finally, a cursory reading of these findings may appear to hold class or racial implications. Generalizing the findings of the current research to any social or racial group is inadvisable.

Summary

The purpose of this study was to explore relationships between student performance in high school, high school quality, and first-year mathematics success. Through careful design and planning, aligning with best practices and a review of scholarly literature, methods were designed and implemented to examine these relationships through the use of high school grade point average, metrics indicative of secondary education institutional performance, and student completion of mathematics at the community college. Exhaustive data analysis then ensued using multilevel, hierarchical logistic regression that ultimately produced a predictive model for student success using identified variables.

Although the findings presented in this dissertation research study were significant and worthy of practical application, this study has posed more questions than answers. The body of work that will result from these findings will extend the academic conversation regarding student success in first-year mathematics and inform policies at multiple levels for years to come.

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Vita

CHRISTOPHER CALEB MARSH

EDUCATION

2017 Old Dominion University — Norfolk, VA

PhD Candidate Community College Leadership

2008 Appalachian State University — Boone, NC

Master of Arts in Mathematics

2004 Appalachian State University — Boone, NC

Bachelor of Science in Statistics

2002 Caldwell Community College and Technical Institute — Boone, NC

Associate Degree in the Arts

1998 Caldwell Community College and Technical Institute — Boone, NC

General Education Development

PROFESSIONAL EXPERIENCE

2010 – Present Caldwell Community College and Technical Institute — Boone, NC

Instructor - Mathematics

- Faculty Senate President
- NIC Facilitator NCGPS

2006 – Present Appalachian State University — Boone, NC

Statistics Lecturer

2008 – 2010 South Caldwell High School — Hudson, NC

Mathematics Instructor

PUBLICATIONS & CONFERENCE PRESENTATIONS

A Snapshot of Public Education in NC (Panelist for the Education Forum)
Presented at Appalachian State University for the Reich College of Education Spring 2016

Bringing Statistics Education into the 21st Century
Presented at the North Carolina Mathematics Association of Two-Year College Teachers at Southwestern Community College 2016

College Mathematics Instructor Voices: Influencing Change in Supplemental Instruction Implementation and Participation
Presented with Dean Roughton at the Southern Association of Colleges and Schools Commission on Colleges Conference 2017

PROFESSIONAL SERVICE

Application Reader
NCSSM Durham, NC
Summer Ventures
2009 to 2017

NCCTM Math Fair
Spring 2009

Math Competition Co-Chair
South Caldwell High School
Spring 2009 -2010

Placement Test Advisor
Caldwell Community College
Fall 2006 to Spring 2008