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Postsecondary Mathematics Placement Processes: A case study at a regional university

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POSTSECONDARY MATHEMATICS PLACEMENT PROCESSES:

A CASE STUDY AT A REGIONAL UNIVERSITY

by

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ABSTRACT

The purpose of the study was to explore the effectiveness of the mathematics placement process for incoming freshman at a public university. Effectiveness is defined as the percentage of students who successfully complete the mathematics course they were placed into, Precalculus, College Algebra, or Intensive College Algebra. The specific university in this research study was the University of North Florida (UNF). The placement process at UNF included students' ACT, SAT, or FCPT scores, their mathematics placement exam scores (MPE), and whether or not students followed the placement recommendation (FPR). Students' ACT, SAT, or FCPT scores were grouped into a single variable of placement levels (PL). Logistic regression analysis was the multivariate method used to analyze the data. In addition, a psychometric analysis of the data obtained by using the mathematics placement exam was also conducted.

The results of the analyses indicated that measures of association were found between students' MPE scores, PL, and FPR. However, the results did not support that the three variables are strong predictors of students' success in Precalculus, College Algebra, or Intensive College Algebra. Students' MPE scores were found to be significant in every logistic regression analyses that was conducted. In contrast, students' PL was not found to be significant in any of the logistic regression analyses. The results of the psychometric analyses supported the reliability and validity of the data obtained from using the UNF mathematics placement exam as part of the placement process.

The findings contribute to the knowledge base of assessing mathematics placement procedures in higher education. The findings suggest that placement procedures should be

assessed and modified, as needed, on a regular basis to better meet the needs of the university, its faculty, and its students. This is the responsibility of the university's administrators, advisors, and faculty.

Chapter I: Introduction

The ability of the United States to compete in the global economy is recently being questioned (Chen, 2009; Gordon, 2007; Kelly & Prescott, 2007; Long, 2007; Scott, Tolson, & Huang, 2009). A well-educated workforce is necessary for future success. As recently as 40 years ago, the United States was the country with the highest proportion of adults having college degrees (Rhodes, 2006). In 2006, the international ranking of the United States fell to seventh place. Of even greater concern is the decline of science, technology, engineering, and mathematics (STEM) graduates.

In 2007, the National Academies of Medicine, Engineering, and Science published the book *Rising Above the Gathering Storm*. In this book, the authors described the importance of STEM in the global economy and the decrease in college graduates in those fields (Scott et al., 2009). In addition, the Electronics Industries Alliance and the Council on Competitiveness each published reports that suggested the United States is at risk of "losing out in the economic competition of the 21^{st} century" (Gordon, 2007, p. 31). For decades, the United States had been considered the global leader in technological development. The innovations that resulted from the research and development during World War II and afterwards were largely due to the strength of the United States in mathematics and science education (Thiel, Peterman, & Brown, 2008).

Two principal international comparisons of younger students are the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). The TIMSS tests are given to students in 4^{th} grade, 8^{th} grade, and at the end of secondary school. The results of the TIMSS tests are reported as four levels of mathematics proficiency, low, intermediate, high, and advanced. In 2007, 31% of 8th graders reached the high TIMSS international mathematics benchmark; only 6% of 8th graders reached the advanced mathematics benchmark (Gonzales et al., 2008). PISA is sponsored by the Organization for Economic Cooperation and Development (Koretz, 2009). PISA tests are given to students at 15 years of age to assess their literacy in mathematics, science, and reading; one of these three literacies is studied in depth every 3 years (Baldi, Jin, Skemer, Green, & Herget, 2007). PISA results are reported at six proficiency levels of mathematics literacy; level 6 is the highest level of proficiency. In 2009, 27% of 15-year-olds in the United States scored above proficiency level 4; 23% scored below proficiency level 2 (Fleischman, Hopstock, Pelczar, & Shelley, 2010). "The consistent finding has been that American secondary school students perform less well in mathematics than their peers in many other countries that might be considered either similar or competitors" (Koretz, 2009, p. 43).

The National Assessment of Educational Progress (NAEP) is part of the U.S. Department of Education. This organization has kept records of students' academic performance for more than 35 years (Gordon, 2007). Tests are administered regularly to elementary and secondary students across the nation in the subject areas of mathematics, science, reading, writing, the arts, geography, economics, civics, and U.S. history (National Center for Education Statistics [NCES], 2012). Achievement levels are set at basic, proficient, and advanced. Unfortunately, most students do not perform at the proficient level in mathematics on these assessments. In 2000, only 16% of 12th-grade students reached the proficient level in mathematics (Gordon, 2007).

Approximately 2.5 million students graduate from public high schools in the United States each year (Kirst & Bracco, 2004). For many of today's jobs, a high school education is no longer sufficient. High school seniors seem to recognize this; more than 70% of these secondary school graduates continue on at the postsecondary level (Kirst & Bracco, 2004). However, over 50% of students entering colleges and universities will be required to take remedial courses, many in several subject areas. Students are frequently placed into developmental or remedial mathematics at the postsecondary level (Gordon, 2008). Kirst and Bracco (2004) reported that 41% of students who earn more than 10 credits in higher education never complete either a two-year or four-year degree. In addition, of the college students who enter the university planning to major in math-intensive fields like science or engineering, most of these students don't actually complete a major in those areas (Scott et al., 2009; Thiel, et al., 2008).

Many colleges and universities use exams such as the Scholastic Aptitude Test (SAT), American College Testing (ACT), and Advanced Placement (AP) exams to decide on students' admission. Most colleges and universities now accept scores from both the ACT and SAT tests, and they treat these scores "interchangeably" (Atkinson & Geiser, 2009, p. 668). On the other hand, some colleges and universities expect students to complete several achievement tests in different subject areas for admission. These achievement tests are the SAT subject tests and Advanced Placement (AP) exams (Atkinson & Geiser, 2009). Students scoring well enough on these exams can be exempted from taking introductory college-level courses and can then enroll directly in more advanced college work upon entering the institution.

Some postsecondary schools simultaneously use the SAT, ACT, and AP exams as placement exams in many subject areas, such as English, college writing, and mathematics to determine students' placement into the appropriate college course for them. Research shows that colleges and universities use a number of different assessment tools in their mathematical placement procedures (Foley-Peres & Poirier, 2008; Latterell & Regal, 2003; Matthews-Lopez, 1998). Many institutions use a combination of SAT Math scores, ACT Math scores, and scores from a mathematics placement test to decide which college-level mathematics course is the most appropriate for incoming students.

Background

A review of the literature showed that colleges and universities all around the United States are striving to find the most effective means of correctly placing students into the most appropriate college-level courses. Upon admission to a college or university, students often have to take one or more placement exams to ascertain whether they are academically prepared to be successful in college-level courses (Kirst, Venezia, & Antonio, 2004). Some postsecondary institutions also use the scores from SAT, ACT, and AP exams as placement exams in many subject areas to decide students' placement into the suitable college course for them. In contrast, other colleges and universities use placement exams developed by their departmental faculty (Fraunholtz & Latterell, 2006; Latterell & Regal, 2003; Marshall & Allen, 2000). Many institutions of higher education "were not confident that their placement processes met students' needs, and few conducted research regarding the efficacy of placement processes" (Kirst et al., 2004, p. 287).

A variety of factors determine the placement of students into the most appropriate college mathematics class and the results of that placement. These factors include those aspects that may contribute to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure. The reviewed literature for the present study includes the following three categories: students' secondary education, students' college admission and mathematical placement, and students' postsecondary educational experiences.

The importance and relevance of mathematics literacy in high school graduates is becoming increasingly more evident. Conceptualizing mathematical principles taught in both algebra and geometry is necessary for students' success in science (Schiller & Muller, 2003). The prior research suggests that students' high school coursework substantially influences their readiness for college-level mathematics (Ma & McIntyre, 2005; Ma & Wilkins, 2007; Roth, Crans, Carter, Ariet, & Resnick, 2001). Students who take more mathematically intensive courses in high school are better prepared for postsecondary mathematics. In addition, Trusty and Niles (2003) found that students' secondary mathematics coursework was an indicator of whether those students entering higher education would complete their bachelor's degree.

However, many colleges and universities are finding that while students are taking more secondary mathematics courses than before, they are also increasingly placed into remedial mathematics at the postsecondary level (Gordon, 2008). A number of researchers studied placement procedures at their colleges or universities in an attempt to determine the most effective means of accurately placing students into mathematics courses. The studies' findings were not in agreement. Matthews-Lopez (1998) found that using a combination of students' high school percentile ranks (HSPR) and ACT Math scores was just as successful in correctly placing students as using their mathematics placement test scores. Latterell and Regal (2003) found that the ACT was better at placing students than the university's placement exam. In contrast, Foley-Peres and Poirier (2008) found that using placement test scores more accurately placed students than using their SAT Math scores. Other researchers reported on the development of a mathematics placement exam at their college or university and its effectiveness in appropriately placing students (Frauenholtz & Latterell, 2006; Latterell & Regal, 2003; Marshall & Allen, 2000).

The results of the prior research also suggest that many students who are placed into college algebra upon entering postsecondary education are not prepared to complete that course successfully (Gordon, 2008; Thiel et al., 2008). At many universities in the United States, college algebra is the lowest-level mathematics course in the algebra strand for which students can receive college credit. College algebra is generally a prerequisite course for students majoring in mathematics, business, engineering, and the sciences. It is critical that mathematics placement procedures at colleges and universities be as correct and efficient as possible to ensure a smooth progression for students from secondary education to postsecondary education.

Purpose of the Study

This research study explored the effectiveness of the mathematics placement process for incoming freshmen at a public university. The goal of this placement process is to correctly place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their intended major. Students who are placed incorrectly in a mathematics course face one of two possible dilemmas. Students who do not place into the required mathematics course for their chosen major must take a lower level course as a prerequisite for their required mathematics course which will fulfill their major requirements. It will take those students longer to graduate because they will be required to take additional courses in order to qualify for the mathematics course for their major. This will result in an increased financial burden for these students.

On the other hand, students who are placed in courses above their actual mathematics ability are likely to be unsuccessful in the course for which they registered. This means that they will have to repeat and take that course again; they may even have to take a remedial course. Again, those students will incur an additional financial burden because they will have to register for and pay for those repeated courses. In addition, many students may lose confidence in their ability to succeed in college-level mathematics courses. Some students might feel compelled to change their chosen major to a major that is less mathematics intensive. It is therefore imperative that mathematics placement procedures be as correct and efficient as possible.

The specific university in this research study was the University of North Florida (UNF). UNF is a midsize, public, regional university located in Jacksonville, Florida. Jacksonville is a large metropolitan city on the Atlantic Coast in northeast Florida.

Research Questions

The following research questions guided the present study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra?

Summary of Methods and Procedures

The present research study investigated the mathematics placement process at UNF. The research sample for the study was taken from the incoming freshmen of 2010 and 2011 at UNF. UNF is a midsize, public, regional university with about 16,000 students.

UNF's mission statement is:

> Mission Statement: The University of North Florida fosters the intellectual and cultural growth and civic awareness of its students, preparing them to make significant contributions to their communities in the region and beyond. At UNF, students and faculty engage together and individually in the discovery and application of knowledge. UNF faculty and staff maintain an unreserved commitment to student success within a diverse, supportive campus culture (UNF, 2011a).

UNF's vision statement is:

> Vision Statement: The University of North Florida aspires to be a preeminent public institution of higher learning that will serve the North Florida region at a level of national

> quality. The institution of choice for a diverse and talented student body, UNF will provide distinctive programs in the arts and sciences and professional fields. UNF faculty will excel in teaching and scholarship, sharing with students their passion for discovery. Students, faculty, staff, alumni, and visitors will enjoy a campus noteworthy for its communal spirit, cultural richness, and environmental beauty (UNF, 2011a).

In fall 2010, UNF had over 13,000 undergraduates. The average GPA of incoming freshmen was 3.79 (UNF, 2011b). Incoming freshmen SAT scores averaged 1204 and ACT scores averaged 24. In fall 2011, the number of undergraduates was about the same. The average GPA of incoming freshmen was 3.84. Average ACT scores had risen to 26, but the average SAT scores remained the same (UNF, 2011c). About 95% of UNF students are Florida residents; 56% of UNF students are female and 44% are male.

This study was retrospective, non-experimental, and predictive. Its purpose was to determine if freshmen students' success in their first mathematics course at UNF can be predicted by the test scores used in the placement process. In addition, the psychometric properties of the data obtained from the UNF mathematics placement exam (MPE) were assessed. A student's MPE score was one component of the UNF mathematics placement process.

This quantitative study investigated the UNF mathematics placement exam and assessed the reliability and validity of the data obtained from it to accurately place incoming freshmen into their first college mathematics course at UNF. The study also examined the relationship between test scores used in the mathematics placement process and freshmen success in their first mathematics course at UNF. These include students' SAT, ACT, FCPT, and UNF mathematics placement exam (MPE) scores. The purpose of the mathematics placement process is to determine students' eligibility to enroll in entry level courses in the algebra strand at UNF; these courses are Precalculus, College Algebra, and Intensive College Algebra. Students earning a grade of C or better are considered to have successfully completed the course. This study explored the extent to which the mathematics placement process at UNF accurately placed incoming freshmen into their first mathematics course at the university. The goal of this placement process at UNF is to place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their chosen major.

The research sample for the present study consisted of incoming freshmen who first enrolled in a mathematics course at UNF in the fall semester of 2010 or 2011 (N = 3,804). The data were obtained from the UNF Office of Institutional Research and Assessment. The data set included the student's term of matriculation, SAT, ACT, FCPT, MPE scores, student's first mathematics course, math points earned in that course, high school GPA, and high school mathematics GPA. Additionally, the student's test results from advanced placement (AP) or international baccalaureate (IB) mathematics end-of-course exams and incoming dual enrollment (DE) mathematics credit was included in the data set. Students' placement into their first college mathematics course was determined by a combination of various scores on these tests and any incoming credit from dual enrollment mathematics courses.

The focus was on those freshmen students who enrolled in Precalculus, College Algebra, and Intensive College Algebra (n = 1,839). The mathematics placement process at UNF determines a student's eligibility to enroll into one of those three courses based on the test scores. The research study investigated if the test scores used in the mathematics placement process at UNF effectively predict students' success in their first mathematics course in the algebra strand of courses, which include Precalculus, College Algebra, and Intensive College Algebra.

In addition, the psychometric properties of the data obtained from the UNF mathematics placement exam were examined. Two essential psychometric properties to be considered when using a test or assessment are reliability and validity. Johnson and Christensen (2004) defined reliability as "the consistency or stability of the test scores" (p. 132) and validity as "the accuracy of the inferences or interpretations you make from the test scores" (p. 132). The SAS 9.2 software program was used to conduct the statistical analysis in this research study.

Significance of the Research

In the nation's colleges and universities, less than 58% of incoming first-time, full-time freshmen earned their baccalaureate degree within six years (Astin & Oseguera, 2005). Postsecondary student retention has been studied for more than 40 years. Tinto (1975) was one of the first researchers to present a model for university student retention. He proposed a model which included students' non-cognitive factors as well as institutional factors. Pascarella and Terenzini (1980) developed an instrument to assess the "major dimensions" (p. 71) of Tinto's (1975) model of college student retention.

One component of the model was students' grade performance which led to their academic integration within the university. Tinto (1975) described academic integration as including a student's grade performance and intellectual development. Many other researchers have also focused on the impact of academic integration on postsecondary student retention (DeBerard, Spielmans, & Julka, 2004; Fowler & Boylan, 2010; Coll & Stewart, 2008; Kerkvliet & Nowell, 2005; Parker, 2004; Pfitzner, Brat, & Lang, 2011; Scott et al., 2009).

Pfitzner et al. (2011) found that colleges that admit students with higher SAT scores have higher retention rates. In Parker's (2004) research study, incoming university students' mathematics skills were assessed with a placement examination. Students who tested higher on these exams were more likely to stay in college and graduate in four years. DeBerard et al. (2004) found that low college freshmen GPA adversely impacted postsecondary retention. Similarly, Scott et al. (2009) found that students with a lower GPA were more likely to change from a STEM major to a non STEM major when compared to students with a higher GPA. Students who are successful academically are more likely to persist in college and earn their degree.

The present research study assessed the efficacy of the mathematics placement processes at UNF for incoming freshmen. The study adds to the existing literature on accurately placing postsecondary students into their first college-level mathematics. From a broader perspective, this research study also adds to the existing literature regarding students' transition from high school to higher education. This transition includes postsecondary admission criteria and placement policies, optimally resulting in the successful attainment of a college degree. In addition, the findings of this study inform administrators of higher education institutions who set and revise admission criteria at their college or university.

Limitations and Delimitations

The study was delimited to freshmen who enrolled in Precalculus, College Algebra, or Intensive College Algebra as their first mathematics course at UNF in the fall of 2010 or 2011. These delimitations excluded transfer students and students who did not register for a UNF mathematics course until the spring semester.

Limitations of the study include the omission of students who did not take the UNF mathematics placement exam, but these students were very few in number. All incoming freshmen were required to participate in UNF online mathematics placement testing prior to orientation. However, a few students still managed to enroll in a course without meeting this requirement.

One delimitation of the study is that only two years of data were considered in this study. Another delimitation of the present study was its singular focus on students' mathematics placement. The mathematics placement process in postsecondary education is only one of the many factors that influence students' retention and academic success. Other factors that play a role in students' retention in higher education include students' health and psychosocial factors (DeBerard et al., 2004). Other contributing factors to students' retention include students' academic and social integration to the university (Coll & Stewart, 2008; Pascarella & Terenzini, 1983). These factors were not considered in the present study.

These delimitations and limitations permit generalizations to colleges and universities that are similar to UNF and have a comparable mathematics placement process.

Definition of Terms

For purposes of this study, operational definitions are provided for the following terms.

Advanced Placement (AP) credit. Students taking Advanced Placement courses in high school can take end-of-course exams. Students scoring well enough on these exams can be exempted from taking introductory college-level courses and can then enroll directly in more advanced college work upon entering the institution. The exams were developed by the College Board and are available in more than 30 subject areas (Atkinson & Geiser, 2009).

Algebra strand. Courses that belong to the algebra strand require algebraic thinking, manipulation, and computation; at UNF the three entry-level courses in the algebra strand are Precalculus, College Algebra, and Intensive College Algebra. Precalculus topics include linear and quadratic functions and their applications; systems of equations; inequalities, polynomials, exponentials, logarithms, trigonometric functions and their inverses and their graphs; trigonometric identities, and complex numbers. College Algebra topics include linear and quadratic functions, systems of equations and inequalities, polynomials, exponentials, and logarithms. Intensive College Algebra is designed for the student who has some knowledge of Intermediate Algebra, but who is not ready for College Algebra. This course reviews key topics in Intermediate Algebra and it covers the material in College Algebra, linear functions, quadratic functions, inequalities, polynomials, exponentials, and logarithms.

American College Testing (ACT) exams. These achievement tests are curriculum-based and assess students' readiness for college (Atkinson & Geiser, 2009). The ACT Math scores range from 1 to 36. Many postsecondary institutions use these exam scores to determine students' admission and placement.

Dual Enrollment (DE) credit. Dual enrollment offers high school students the opportunity to be simultaneously enrolled in both secondary and postsecondary educational institutions. Secondary students can enroll in college courses and earn college credit while still in high school.

Effectiveness of the mathematics placement process. Effectiveness is defined as the percentage of students who completed the mathematics course with a grade of C or better.

Florida College Placement Test (FCPT). Many of the colleges and universities in the state of Florida use the ACCUPLACER test, developed by the College Board, as the Florida College Placement Test (FCPT). Test scores range from 0 to 120. The FCPT assesses students' readiness for college-level coursework in reading, writing, and mathematics.

International Baccalaureate (IB) credit. Secondary students enrolled in the International Baccalaureate program often have the opportunity to be exempted from taking introductory college-level courses by successfully completing IB coursework and passing the end-of-course tests. Successful IB students can then enroll directly in more advanced college work upon entering the university.

Placement processes. Placement processes, as defined for this study, are the policies and procedures that students must follow prior to enrolling in a college level course. After students are accepted for admission to a college or university, most higher education institutions have minimum placement criteria that students must meet before they can enroll in college-level coursework. The minimum criteria can be required in many different subject areas. Some postsecondary schools simultaneously use college entrance exams as placement exams to determine students' placement into college-level courses. Some colleges and universities develop their own placement exams. Some higher education institutions use a combination of admission exams and placement tests to determine students' placement.

Scholastic Aptitude Test (SAT). In 1996, the name evolved to simply SAT; this test measures students' general analytic ability and is used by many colleges and universities to determine students' admission and placement (Atkinson & Geiser, 2009). SAT scores range from 200 to 800.

SAS Programming Language. SAS 9.2 is a statistical software package and was used in the study for data analysis.

Students' success. The study defines students' success as completion of a course with a grade of C or better.

UNF mathematics placement exam (MPE). The MPE in the present study was a 40-question, multiple-choice test that is taken online by incoming freshmen students prior to orientation. MPE test scores range from 0 to 40. The MPE score determines students' placement into one of the entry-level mathematics courses in the algebra strand at UNF, Precalculus, College Algebra, or Intensive College Algebra.

Organization of the Research

The research study is presented in five chapters. Chapter 1 described the background of the study, the purpose of the research, the significance of the study, the research questions, and a summary of methods and procedures. Chapter 2 presents a review of the literature that includes the many factors that determine the placement of students into the most appropriate college mathematics class for them and the outcomes of that placement. These factors are those that may contribute to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure. The reviewed literature is separated into the following three categories: students' secondary education, students' college admission and mathematical placement, and students' postsecondary educational experiences.

Chapter 3 addresses the research questions of the study, an explanation of the current mathematics placement process at UNF, a description of the design of the study, a profile of the population studied, research variables, and the statistical methods used. Chapter 3 also addresses the delimitations and limitations of the research study. Chapter 4 provides a summary of the statistical analyses and findings regarding the mathematics placement process at UNF. Chapter 5 concludes the research study with a discussion of the findings including an analysis of implications for education leaders in postsecondary administration and admissions. In addition, Chapter 5 includes suggestions for future research.

Chapter II: Review of the Literature

The purpose of this chapter was to examine the prior research that encompasses the many factors that determine the placement of students into the most appropriate college mathematics class and the outcomes of that placement. These factors included those elements that may contribute to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure. The reviewed literature was accordingly separated into the following three categories: students' secondary education, students' college admission and mathematical placement, and students' postsecondary educational experiences. The research literature provided the necessary background information for developing this study's conceptual framework.

Students' Secondary Education

In this section of the chapter, students' secondary educational experiences that were relevant to the study are discussed. In particular, the focus was on how secondary mathematics curricula and students' mathematics coursework contributed to their readiness for college-level mathematics.

Freshmen come to college with diverse educational backgrounds. Still, the students all have to meet minimum admission requirements as specified by the postsecondary institution that they chose to attend. These admission requirements typically include minimum exam scores on standardized tests such as the ACT or SAT. In addition, college admission requirements often include specific secondary coursework and the student's high school GPA.

In any given year, students' educational experiences in completing these admission requirements are dissimilar for different subpopulations of students. Some students were homeschooled, and some students graduated from charter schools, magnet schools, or other alternative secondary schools. The majority of the students probably graduated from traditional high schools, but even their academic educational experiences were different. Some of those students took many Advanced Placement (AP) classes or participated in the dual enrollment (DE) program at their high school. Other students minimally met the required university admission criteria. Some students were in a secondary school that practiced block scheduling; some of these students did not take a mathematics class in their junior and senior years of high school. In addition, the most recent mathematics class that they took may not have been in the algebra strand of mathematics.

The importance and relevance of mathematics literacy in high school graduates is becoming increasingly more apparent. Conceptualizing mathematical principles taught in both algebra and geometry is necessary for students' success in science (Schiller & Muller, 2003). High school graduates who have not achieved this are not prepared for entry into medicine, engineering, and other technology-related fields (Schiller & Muller, 2003). Studying advanced mathematics in high school is positively correlated with success in college according to a U.S. Department of Education study (Burris, Heubert, & Levin, 2006). In addition, a positive association has been shown between rigorous mathematics courses and higher earning power (Burris et al., 2006). In other words, taking advanced mathematics courses can lead to educational and financial success.

Over the years, K-12 educational policies have evolved to provide opportunities for all students to achieve mathematics literacy. The National Council of Teachers of Mathematics (NCTM) developed the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and the *Principles and Standards for School Mathematics* (NCTM, 2000). These standards brought together the best practices from the literature over the past several decades in mathematics education and provide K-12 teachers with suggestions for improving mathematics education. More specifically, mathematical standards for what students should learn at every grade level are clearly defined. In addition, the *No Child Left Behind Act of 2001* changed the role of federal government in education through increased mandated testing and school accountability (Schiller & Muller, 2003). Students, teachers, administrators, and schools are being held accountable for achieving certain mathematical standards (Burris et al., 2006).

Secondary Curricula

In response, curricula have been specifically developed to teach according to the NCTM *Standards* at both the elementary and secondary levels of education. In the early 1990s, the National Science Foundation (NSF) funded the development of standards-based mathematics curricula (Davis & Shih, 2007; Harwell et al., 2007; Schoen & Hirsch, 2003). The different curricula in these research studies are presented in Table 1.

The University of Chicago School Mathematics Project curriculum (UCSMP) includes aspects of both the NSF-funded curricula and commercially developed (CD) standards-based curricula (Post et al., 2010). In contrast, CMIC, IMP, MMOW, MCC, and SIMMS curricula are noticeably different from CD curricula. They emphasize problem solving and higher order thinking skills (Harwell et al., 2007; Harwell et al., 2009; Post et al., 2010; Schoen & Hirsch, 2003). Small group and cooperative student activities are encouraged. CD curricula focus more on traditional algorithms and computational skills.

Table 1

Secondary Curricula

Curricula	Abbreviation	Authors/Developers
Contemporary Mathematics in Context: A Unified Approach[a]	CMIC[a]	Coxford et al. (1998)
Interactive Mathematics Project	IMP	Fendal, Resnick, Alper, and Fraser (1997)
Math Connections: A Secondary Mathematics Core Curriculum	MCC	Berlinghoff, Sloyer, and Hayden (2000)
Mathematics: Modeling Our World	MMOW	Garfunkel, Godbold, and Pollak (1998)
SIMMS Integrated Mathematics: A Modeling Approach Using Technology	SIMMS	Lott and Burke (1996)
The University of Chicago School Mathematics Project curriculum	UCSMP	UCSMP (1996)

[a]Also known as Core-Plus or CPMP in the literature (Harwell et al., 2007).

The University of Chicago School Mathematics Project curriculum (UCSMP) includes aspects of both the NSF-funded curricula and commercially developed (CD) standards-based curricula (Post et al., 2010). In contrast, CMIC, IMP, MMOW, MCC, and SIMMS curricula are noticeably different from CD curricula. They emphasize problem solving and higher order thinking skills (Harwell et al., 2007; Harwell et al., 2009; Post et al., 2010; Schoen & Hirsch, 2003). Small group and cooperative student activities are encouraged. CD curricula focus more on traditional algorithms and computational skills.

A number of researchers over the years have compared the mathematical achievement of secondary students in different curricula. In Table 2, I have listed the researchers along with the secondary mathematics curricula that were evaluated in their studies. The researchers were interested in comparing how different curricula impacted students' readiness for college-level mathematics courses and subsequent success in postsecondary math courses.

Table 2

Research on Secondary Curricula

Researcher(s)	Curricula	Assessment(s)
Davis and Shih (2007)	CMIC, UCSMP	College entrance exams, then mathematics placement tests
Harwell et al. (2007)	CMIC, IMP, MMOW	Stanford Achievement Test – 9th edition, New Standards Reference Examination in Mathematics
Harwell et al. (2009)	CD, CMIC, IMP, MMOW	University placement exam
Post et al. (2010)	CD, CMIC, IMP, MMOW,UCSMP	Success in college-level mathematics courses
Schoen and Hirsh (2003)	CD, CMIC	University placement test

Davis and Shih (2007) found that UCSMP students who completed four or five years of that curriculum did significantly better on both the combined algebra placement exam and the calculus readiness exam than students who had completed four years of the CMIC curriculum. In addition, students who had taken some CMIC courses and some UCSMP courses significantly outperformed students who had completed four years of the CMIC curriculum on the calculus readiness placement exam. Davis and Shih (2007) reported that these students typically took the lower level UCSMP courses before moving to the CMIC curriculum.

In contrast, the results of the research by Schoen and Hirsh (2003) revealed that the only statistically significant difference between the CMIC group and the precalculus group of students in CD curricula was in readiness for calculus. The CMIC students outperformed the precalculus students. Additionally, Schoen and Hirsh (2003) reported that prior research studies on CMIC curriculum suggested that those students have somewhat lower pencil-and-paper algebraic skills.

Similarly, Harwell et al. (2007) also found no significant differences in mathematics achievement among students taking any of three different NSF-funded curricula in their retrospective research study. Harwell et al. (2007) suggested that the “ongoing concern by some that standards-based students are not learning basic mathematical skills and are lacking important mathematical understandings” (p. 95) is unwarranted. Harwell et al. (2007) also suggested that future research should perhaps focus on students who have graduated from secondary schools using NSF-funded curricula and those students’ performance in postsecondary mathematics and related coursework.

A later study by Harwell et al. (2009) did exactly that. This research examined students’ success in their first college mathematics course. Similarly, Post et al. (2010) investigated the relationship between students’ curricula and their success in a university-level mathematics course. However, Post et al. (2010) went further than Harwell et al. (2009) in their research. Post et al. (2010) explored students’ progress through eight semesters at the university. Achievement, course-taking pattern, and persistence data were collected and analyzed. This allowed them to study the long term impact of curricula on students’ success in college-level mathematics courses (Post et al., 2010).

Harwell et al. (2009) found that the results showed that students were “more likely to begin their university mathematics work in a more difficult mathematics course” (p. 224) if they had completed courses from a CD mathematics curriculum instead of an NSF-funded curriculum. However, they also observed that there was no relationship between a student’s secondary mathematics curriculum and the grade that student earned in the postsecondary mathematics course (Harwell et al., 2009). This finding suggested that the two types of curricula equally prepare students in terms of mathematics proficiency and success in a college-level mathematics course. However, CD curricula seemed to prepare students better for enrolling in a more difficult mathematics course than NSF-funded curricula (Harwell et al., 2009). Students who completed an NSF-funded curriculum had a tendency to enroll in a less difficult university mathematics course for their first college math course.

Similarly, the research by Post et al. (2010) revealed that there was no significant difference between students whose secondary education was in CD curricula, UCSMP curriculum, or in NSF-funded curricula when comparing students' grades, difficulty of completed courses, or number of mathematics courses completed (Post et al., 2010). However, Post et al. (2010) also suggested that students who had attended schools using NSF-funded curricula have a tougher time transitioning from high school to university-level mathematics. One reason for this might be that students in NSF-funded curricula spend less time "on developing and sustaining a variety of algorithmic procedures" (Post et al., 2010, p. 305). However, those students still learned about the traditional topics that are included on procedurally oriented college mathematics placement exams (Post et al., 2010). Post et al. (2010) concluded that CD curricula, UCSMP curriculum, and NSF-funded curricula were all found to do a comparable job of preparing high school students for college-level mathematics courses.

The research cited above compared the mathematical achievement of secondary students in different curricula. The results suggested that the different types of curricula, whether NSF-funded curricula or more traditional commercially developed standards-based curricula, did not significantly impact the mathematical achievement and college readiness of high school students (Harwell et al., 2007; Harwell et al., 2009; Post et al., 2010; Schoen & Hirsh, 2003). Other researchers focused instead on the specific mathematics courses that students complete in high school and their impact on mathematics achievement.

Secondary Coursework

Postsecondary admission requirements often include a minimum number of units of secondary mathematics coursework. Additionally, the type of high school mathematics course and its level might also be specified. For example, acceptable college preparatory mathematics coursework might be required to be at the algebra I level or above. A number of educational researchers examined the impact of different secondary coursework on students' mathematical achievement. Ma and McIntyre (2005) compared the mathematical achievement of secondary students enrolled in pure mathematics courses to the achievement of students enrolled in applied mathematics courses in their research. In a later study, Ma and Wilkins (2007) examined the extent to which students' rate of growth in mathematics achievement is influenced by the specific courses they take in middle and high school. Roth et al. (2001) also focused on how secondary students' mathematics coursework contributes to achievement. However, more specifically, they investigated how high school coursework and grades affected student performance on a college placement test. The research study conducted by Trusty and Niles (2003) went even further and explored how mathematics coursework in high school affected a student's completion of a bachelor's degree.

Ma and McIntyre (2005) found that studying pure mathematics in high school relates more strongly with students' improved mathematics achievement even after controlling for prior achievement. The results from this study indicated that emphasizing "the theoretical aspect of mathematics (as in pure mathematics), rather than the practical aspect of mathematics (as in applied mathematics), relates more strongly with student mathematics achievement" (Ma & McIntyre, 2005, pp. 844-845).

Similarly, the results of the research by Ma and Wilkins (2007) revealed that growth in students' mathematics achievement was heavily influenced by the coursework students completed. Coursework was separated into three categories: regular mathematics, standard mathematics, and advanced mathematics. Standard mathematics courses included prealgebra, algebra 1, geometry, and algebra 2. Advanced mathematics courses included precalculus, trigonometry, and calculus (Ma & Wilkins, 2007). The researchers found that standard mathematics courses had a much greater influence on growth in students' mathematics achievement than regular mathematics. In addition, Ma and Wilkins (2007) found that taking algebra 1 in the eighth grade was especially important for high-achieving students. Students' improvement after taking algebra 1 in the eighth grade "was greater than that for students who took algebra 1 in any other grade" (Ma & Wilkins, 2007, p. 251).

Advanced mathematics courses had the strongest regulating power on growth in students' mathematics achievement (Ma & Wilkins, 2007). In addition, the high-achieving students who took trigonometry in 10^{th} grade followed by calculus in 11^{th} grade "maintained the highest level of mathematics achievement across the grades and grew in achievement much faster than those who took trigonometry or calculus later" (Ma & Wilkins, 2007, p. 251). These two courses helped the highest achieving students grow even further in mathematics achievement. Ma and Wilkins (2007) suggested that both regular and standard mathematics courses didn't just serve to prepare students for more advanced mathematics courses; they strongly influenced students' growth in mathematics achievement.

The research by Roth et al. (2001) also suggested that students' coursework impacts their mathematics achievement. They analyzed transcripts of high school students who consecutively attended Florida high schools for four years to determine how mathematics courses, grades, tenth grade standardized test scores, race, and gender influenced their performance on a computerized placement test (CPT). Students enrolling in one of the state's community colleges were required to take the CPT to determine that student's placement in reading, writing, and mathematics courses. This research study focused only on student-level variables such as gender, ethnicity, course-taking, course load, grades in math and English, overall grade point average (GPA), and tenth grade standardized test score results (Roth et al., 2001). Course-taking, course load, and students' grades in math and English were used to construct math and English high school performance variables (HSP), Math HSP, and English HSP (Roth et al., 2001).

The results from the study revealed that Math HSP had the most influence on the estimated probability of passing the CPT (Roth et al., 2001). For this research study, the researchers merged four data sets obtained from the Florida Department of Education. One high school data set contained information on students' gender, ethnicity and their high school grade point average (GPA). The second data set contained information on students' secondary courses taken and the corresponding grades in those courses (Roth et al., 2001). The third data set contained the results of the Grade Ten Assessment Test (GTAT) of reading comprehension and mathematics. The final data set contained the results from the CPT subtests.

The results showed that Math HSP had a larger effect than either GPA or GTAT Math on the CPT Math subtest (Roth et al., 2001). In addition, students who had taken algebra 2 in high school achieved a CPT Math pass rate of nearly 75%, much higher than the average CPT Math pass rate of 50%. These students even included those students who earned a D in high school algebra 2. Roth et al. (2001) suggested that this finding supports making algebra 2 a high school graduation requirement. They further proposed that secondary students should continue to take more challenging mathematics courses, even at the risk of a lower GPA for those students. “Students with average grades who take challenging courses would be better prepared to do college-level work than students who achieve high grades through taking undemanding courses” (Roth et al., 2001, p. 80).

In a later study, Trusty and Niles (2003) similarly found that students’ secondary mathematics coursework was an indicator of whether those students would complete their bachelor’s degree. The results revealed that high school students who completed algebra 2 more than doubled the likelihood of completing their bachelor’s degree (a 140% increase); for students who completed trigonometry the odds increased by 137% (Trusty & Niles, 2003). Students who completed precalculus increased their likelihood of degree completion by 155%; students who completed calculus were 112% more likely to complete their bachelor’s degree.

In addition, the findings showed that slightly under half of those secondary students in this study did not complete their bachelor’s degree in the eight-year time frame of the study (Trusty & Niles, 2003). Many of these students were attending college and expecting to earn a bachelor’s degree. However, these students also had not taken more than one of the intensive mathematics courses in high school (Trusty & Niles, 2003). Trusty and Niles (2003) suggested that college-intending students should be advised to “progress as far as possible in an intensive high school math curriculum” (p. 104).

The above research investigated how high school mathematics coursework impacted students’ growth in mathematics achievement. The research results suggested that secondary coursework significantly influences students’ readiness for college-level mathematics (Ma &

McIntyre, 2005; Ma & Wilkins, 2007; Roth et al., 2001). Students who take more mathematically intensive courses in high school were more prepared for postsecondary mathematics. In addition, the findings by Trusty and Niles (2003) revealed that students' secondary mathematics coursework was an indicator of whether those students entering postsecondary education would complete their bachelor's degree. In the next section, university admission policies and students' placement in college-level mathematics courses are explored.

College Admission and Students' Mathematical Placement

In this section of Chapter 2, some of the common criteria that universities use for college admission are described. After that, the methods that different colleges and universities use to determine students' mathematics placement will be explored.

Postsecondary Admission Procedures

In the United States in the early 1900s, admission to colleges and universities was often based on written, curriculum-based examinations called the College Boards (Atkinson & Geiser, 2009). These exams were designed to assess student learning in college preparatory courses. On the other hand, the Scholastic Aptitude Test (SAT), which first made its appearance in 1926, was designed to measure students' general ability or aptitude for learning (Atkinson & Geiser, 2009). In the years after World War II, the SAT was readily accepted and used by many colleges and universities to predict which applicants were likely to perform well at the postsecondary level.

The SAT has changed considerably since that time; however, "the one constant has been the SAT's claim to gauge students' general analytic ability, as distinct from their mastery of specific subject matter, and thereby to predict performance in college" (Atkinson & Geiser, 2009, p. 666). Universities that require higher SAT scores for admission "should expect greater achievement and retention among their freshmen" (DeBerard et al., 2004, p. 73). The SAT is used in some way by nearly every selective postsecondary institution in the country as a measure of students' ability (Epstein, 2009).

In contrast to the SAT, the American College Testing (ACT) was introduced in 1959 as an achievement test (Atkinson & Geiser, 2009). The ACT was designed to be more closely aligned with high school curricula and "the consensus among the test prep services is that the ACT places less of a premium on test-taking skills and more on content mastery" (Atkinson & Geiser, 2009, p. 668). Over time, however, the ACT has become more like the SAT. Today, most colleges and universities accept scores from both the ACT and SAT tests, and they treat these scores "interchangeably" (Atkinson & Geiser, 2009, p. 668).

On the other hand, some colleges and universities require students to complete several achievement tests in different subject areas for admission. These achievement tests are the SAT subject tests and Advanced Placement (AP) exams (Atkinson & Geiser, 2009). The SAT subject tests were developed in the 1930s by the College Board and are offered in about 20 subject areas. The AP program and its exams were developed by the College Board in 1955 and they were intended to be used for college placement (Atkinson & Geiser, 2009). Students scoring well enough on these exams can be exempted from introductory college-level courses and can then enroll directly in more advanced college work upon entering the university. The AP exams are offered in more than 30 subject areas (Atkinson & Geiser, 2009).

An increasing number of postsecondary institution leaders are critical of the SAT for "inhibiting access to higher education" (Epstein, 2009, p. 9). In 1969, Bowdoin College in Maine made the SAT optional in its admission and placement standards; Bates College in Maine followed in 1984. By early 2009, more than 30 liberal arts colleges had adopted some variation of an SAT-optional policy (Epstein, 2009). The list of higher education institutions that have made the SAT optional in their admission process now includes public, private, and even technical schools such as Worcester Polytechnic Institute in Massachusetts. In 2008, Wake Forest University became the first national research university to adopt an SAT-optional policy (Epstein, 2009).

Some college administrators consider students' high school GPA in the admissions' process (Kirst, 1998). Including students' grades in the process encourages grade inflation at both the secondary and postsecondary level (Kirst, 1998). In addition, with the increase of Advanced Placement courses at the secondary level, many high schools now use adjusted grading systems in which students can achieve GPAs that exceed 4.0. Kirst (1998) suggested that using these measures "for evaluating students and predicting their success in college is becoming more and more questionable" (p. 5).

In summary, many colleges and universities used SAT, ACT and AP exams to determine students' admission to the university. However, many of those same postsecondary schools simultaneously used those admission exams as placement exams to determine students' placement into the college mathematics course that is most appropriate for them. The different procedures used by higher education institutions to determine students' placement into mathematics courses will be explored in the next section.

Mathematical Placement Procedures at Colleges and Universities

The research showed that colleges and universities used a number of different assessment tools in their mathematical placement procedures. Many colleges used SAT Math scores or ACT Math scores to determine student placement. Many universities also have their own math placement test. Some colleges used a combination of SAT Math scores, ACT Math scores, and scores from their own placement test to decide which college-level mathematics course is the most appropriate for the incoming students. However, many universities found that while students are taking more secondary mathematics courses than before, they are also more frequently placed into developmental or remedial math at the postsecondary level (Gordon, 2008). Furthermore, of the college students who enter the university planning to major in math-intensive fields like science or engineering, most of these students didn't actually complete a major in those fields (Scott et al., 2009; Thiel et al., 2008). A number of researchers investigated mathematics placement procedures at various universities.

Two research articles focused on comparing the effectiveness of different assessment tools used in students' mathematics placement. Foley-Peres and Poirier (2008) wanted to determine whether SAT Math scores or college math assessment scores were better at indicating which mathematics course incoming students should enroll in. In a similar study, Matthews-Lopez (1998) also compared different methods of students' mathematical placement to determine which was most accurate in placing students in the most appropriate university math course.

More specifically, Matthews-Lopez (1998) studied the placement procedures at Ohio University in an attempt to establish whether the math placement test should continue to be a necessary part of these procedures. The university was considering constructing a placement test of its own. However, Matthews-Lopez (1998) wanted to first consider students' mathematical placement results based on the alternative method of placement (Matthews-Lopez, 1998). The alternative method of placing students used a combination of students' ACT Math scores and their high school percentile ranks (HSPR). A regression equation was developed using these two items as independent variables. The dependent variable was a total score based on the number of items correct (Matthews-Lopez, 1998). From a population of 3,200 students who took the mathematics placement exam, a simple random sample of 200 students was taken. The university also had ACT Math scores and HSPR for these students (Matthews-Lopez, 1998) as well as the subsequent course in which they enrolled.

Matthews-Lopez (1998) found that the results of using the alternative method of mathematics placement to place students in the appropriate college math course were consistent with the results obtained from the math placement test scores. She concluded that the majority of students could be accurately placed in the appropriate university math course by using a combination of students' ACT Math scores and HSPR (Matthews-Lopez, 1998). In addition, by using the alternative method, the university would save "time, space, and staffing associated with the annual testing of (approximately) three thousand individuals" (Matthews-Lopez, 1998, p. 9).

In contrast, the results of the research by Foley-Peres and Poirier (2008) revealed that SAT Math scores "were not the best indicators of the math level course the student should select, and that the college math assessment scores may have been better indicators according to initial midterm grades" (p. 46). Their study included 188 students at a private college in New England whose placement was determined by their college mathematics placement scores (Foley-Peres & Poirier, 2008). Students were placed in one of six math levels based on the placement test score. Students generally took the placement exam online at home before arriving on campus. Data collected also included students' SAT Math scores and midterm grade in their first mathematics course (Foley-Peres & Poirier, 2008). Student counts were then categorized according to SAT Math scores and their midterm grades. In addition, math faculty were asked to fill out a questionnaire assessing students in the classroom (Foley-Peres & Poirier, 2008). Faculty observations and students' grades were analyzed to ascertain whether the SAT Math scores or college mathematics placement scores were better at determining students' placement. Foley-

Peres and Poirier (2008) concluded that the mathematics placement test was more effective at placing students in the appropriate math course.

A number of additional research studies explored the development of mathematics placement procedures. Marshall and Allen (2000) explained the development and refinement of the placement process used at a small private college. In the research article by Latterell and Regal (2003), the placement processes at a regional university were studied to determine whether the traditional mathematics placement exam was worth the expense of administration. In a later study, Frauenholtz and Latterell (2006) compared using the traditional placement test scores to using scores from a reform mathematics placement test that they developed.

In their article, Marshall and Allen (2000) explained how the placement process evolved to better meet the needs of the students. In 1995, the university began using a Math Placement Test (MPT) "developed from materials provided by the Placement Test Program of the Mathematical Association of America" (Marshall & Allen, 2000, p. 3). Prior to using the MPT, students were placed based on the number of secondary mathematics courses they completed. However, faculty had become increasingly concerned about the "disparities in the mathematical preparation of students wishing to enroll" (Marshall & Allen, 2000, p. 3) in calculus, precalculus, or college algebra.

In the fall of 1995, the university began using students' MPT and ACT scores to recommend the most appropriate mathematics course for each student (Marshall & Allen, 2000). When setting the initial cutoff criteria for calculus, precalculus, and college algebra, the "decision was made to err on the side of recommending students to start in a challenging course rather than recommending students to start in courses that were at too low a level" (Marshall & Allen, 2000, p. 3). The initial cutoff criteria did not yield good results. Many students found the recommended mathematics course too difficult to complete successfully and dropped the course (Marshall & Allen, 2000). The mathematics placement standards were then "refined using a procedure that compared data on student performance in entry-level math courses, student scores on the math placement exam, and student ACT Math scores" (Marshall & Allen, 2000, p. 25). These data were collected on an annual basis over a three-year period. The data were then analyzed and mathematics placement results for the two time periods were compared. Marshall and Allen (2000) determined that using the revised cutoff criteria for students' mathematics placement provided a high level of long-term predictive validity. Beginning in 1999, the math faculty additionally made several more refinements to the mathematics placement cutoff criteria in an effort to improve on this success (Marshall & Allen, 2000). In addition to modifying the cutoff criteria, the university expanded its drop-in peer tutoring program and adopted a reform textbook for college algebra.

The research by Latterell and Regal (2003) also included the development of a math placement exam. The University of Minnesota at Duluth had been using a purchased mathematics placement exam for many years (Latterell & Regal, 2003). Based on the courses students successfully completed in high school, postsecondary students were expected to be successful in certain college-level mathematics courses. However, in contrast to Marshall and Allen (2000), the math placement exam that the college used placed these students in lower level courses than expected (Latterell & Regal, 2003). Because of this, the mathematics department created its own mathematics placement test. The math placement test was "developed by one member of the mathematics department and aligned with course prerequisites" (Latterell & Regal, 2003, p. 156). However, all members of the math department had a voice in revising the placement exam. The test was then validated and first used in fall 2001; all incoming freshmen who attended orientation were given the mathematics placement test (Latterell & Regal, 2003).

Students were considered to be correctly placed either when they completed the mathematics course they tested into with a grade of C or better, or when they earned a grade lower than a C in a course higher than the math course they tested into (Latterell & Regal, 2003). On the other hand, students who enrolled in the course they tested into and received a grade lower than a C were considered to be incorrectly placed. Students who earned a grade of at least a C in a mathematics course higher than the one they tested into were also considered to be incorrectly placed (Latterell & Regal, 2003). In their research study, Latterell and Regal (2003) also compared the results of using either the mathematics placement exam or the ACT Math test scores to accurately place students in the most appropriate math course.

In their research, Latterell and Regal (2003) found that the ACT was better at placing students than the university's newly developed placement exam. If ACT test scores had been used for students' mathematical placement, 59% of the students would have been accurately placed. However, the newly developed test correctly placed only 49% of the students (Latterell & Regal, 2003). Latterell and Regal (2003) suggested that the placement test could perhaps be improved by modifying the cut-off scores that had been used to determine students' mathematical placement. Latterell and Regal (2003) noted that the university also considered dropping the placement exam altogether. In contrast to Matthews-Lopez (1998), however, Latterell and Regal (2003) also considered the public relations aspect of the university not offering a mathematics placement test. They inferred that it might "appear to the public that we did not care enough to administrate a placement test" (p. 161). Latterell and Regal (2003) asserted that students would be more inclined to follow recommendations based on a math placement exam than the ACT. They concluded that while administering and scoring the placement exam might not be worth the cost, the university would continue to use the mathematics placement test scores to place students in the most appropriate university math course for them (Latterell & Regal, 2003).

In a later article, Frauenholtz and Latterell (2006) described the development of a reform mathematics placement exam as an alternative to the traditional placement test developed by Latterell and Regal (2003). Traditional math curricula emphasize symbolic and algebraic manipulation skills. On the other hand, reform curricula focus on concepts using open-ended questions and real-life data. Frauenholtz and Latterell (2006) hypothesized that the traditional placement exam "is not a valid measure of students' mathematical ability" (p. 6). This motivated Frauenholtz and Latterell (2006) to develop the reform mathematics placement test. They found that the reform mathematics placement exam they developed more accurately placed students in precalculus than the traditional placement test. The reform placement test correctly placed 74% of students into precalculus whereas the traditional math placement test correctly placed 59% (Frauenholtz & Latterell, 2006). However, when placing students into college algebra, the reform mathematics placement exam correctly placed 82% of students versus 84% placed using the traditional exam. They also admitted that "many college mathematics professors will not view a reform test as an appropriate placement test into more traditional courses" (Frauenholtz & Latterell, 2006, p. 11). Frauenholtz and Latterell (2006) suggested that perhaps students' educational background would determine which placement exam would most accurately place them in the appropriate mathematics course.

One commonality in the above research is that students were not required to follow the recommended placement (Frauenholtz & Latterell, 2006; Latterell & Regal, 2003; Marshall &

Allen, 2000). Postsecondary students at Merrimack College in Massachusetts could also choose whether or not to take the recommended math course. These students were the subject of the research study by Rueda and Sokolowski (2004). In their article, they compared the grades of students who followed the placement recommendation to those students who did not take the recommended mathematics course.

Rueda and Sokolowski (2004) focused specifically on whether or not students followed the mathematics placement recommendations. This university used a mathematics placement test created by its math faculty. The exam had two versions; one version was for science and engineering majors and the second version for students majoring in liberal arts or business administration (Rueda & Sokolowski, 2004). All incoming freshmen were expected to take this test, and a course recommendation was made based on a combination of test scores and students' major. Rueda and Sokolowski (2004) collected data on all freshmen students from 1997 through 2001 who took a mathematics course in their entering fall semester. Student categories were then created based on the level of math course taken as determined by the recommendation (Rueda & Sokolowski, 2004). An additional category was made for those students who did not take the placement exam. Within each of these categories, students were counted according to whether their grade in that course was C- and above, or less than C- (Rueda & Sokolowski, 2004). The data were analyzed using the chi-square test.

Rueda and Sokolowski (2004) found that "students who took the recommended course or an easier one did much better than those who took a higher level course or did not take the placement exam" (p. 31), except for the year 2000. They reported that in the year 2000, there was no significant difference in grades when comparing students who completed a higher level course to those who took the recommended course. Rueda and Sokolowski (2004) suggested that the reason for this might be that the percentage of students enrolling in a higher level course than recommended had been steadily declining. They concluded that "a well-designed in-house placement test geared towards our curriculum is a simple and powerful tool for placing incoming students in an appropriate mathematics course" (Rueda & Sokolowski, 2004, p. 32).

In this section of the literature review, research that investigated university admission policies and students' placement in college mathematics courses was examined. Additionally, research that described the development of university placement procedures was discussed. The results suggested that many colleges and universities are struggling with how to effectively place students into the most appropriate college-level mathematics course for them. In the next section, students' postsecondary educational experiences and outcomes will be investigated.

Students' Postsecondary Educational Experiences

Freshmen entering college come with many expectations, both academic and extra-curricular. Many of them have already decided on their major program of study; some remain undecided through the first year.

Two research studies discussed the decline in science, technology, engineering, and mathematics (STEM) majors in universities. Scott et al. (2009) focused on how to predict retention of STEM majors in order to make better informed college admission decisions and more appropriately advise incoming students. In contrast, Thiel et al. (2008) examined redesigning university mathematics courses to improve students' success as STEM majors. In particular, Thiel et al. (2008) explained the redesign of college algebra at the University of Missouri at St. Louis.

Some additional research centered specifically on college algebra. Like Thiel et al. (2008), Gordon (2008) agreed that a redesign of college algebra is necessary to better meet the "actual needs of the students and of the other disciplines that require college algebra of their students" (p. 516). Many students take college algebra as a prerequisite for another math course or as a requirement for a non-mathematics major, such as business or nursing. In contrast, Herriott and Dunbar (2009) reported on the intended majors of students who actually take college algebra.

Mathematics in Higher Education

First, the research that focuses on mathematics in higher education will be explored. Thiel et al. (2008) explained that much of the prosperity of our nation is due to the "innovations that resulted from research and development during World War II and afterwards" (p. 45). They also reported "a decrease in the number of American college graduates who have the skills, especially in mathematics, to power a workforce that can keep the country at the forefront of innovation and maintain its standard of living" (Thiel et al., 2008, p. 45). These innovations were possible because the United States formerly led the world in mathematics and science education. Today, however, that is not the case. Scott et al. (2009) cited the National Science Board and reported that the United States "trails all but one of the nations surveyed in terms of proportions of STEM majors compared to all other majors" (p. 21). In addition, in the year 2000, less than 6% of this nation's 24-year olds possessed degrees in STEM disciplines. Furthermore, of the university students who enter college planning to major in science or engineering, less than half of them actually complete a major in those fields (Thiel et al., 2008). Scott et al. (2009) similarly found that "a vast majority of students are not retained in these fields and transfer to other majors" (p. 21).

Scott et al. (2009) found that pre-college characteristics could accurately place 61% of the students into either the group that remained as mathematics and science majors versus the group that switched when their GPA was less than 2.0. These characteristics included rank in high school graduating class, SAT Math, and SAT Verbal scores (Scott et al., 2009). Based on the results of the research, Scott et al. (2009) proposed some alternative options for advising incoming college students. They acknowledged that some STEM programs are already requiring a minimum SAT score. Scott et al. (2009) also suggested providing both students and parents with the retention characteristics at orientation so they would be better informed when choosing a major program of study. Finally, Scott et al. (2009) proposed that "the best policy might be routing all admitted students into a general studies like curriculum, utilizing pre-college characteristics and diagnostics to better advise them and letting them demonstrate their abilities in a given major through specific course work" (p. 23).

Likewise, Thiel et al. (2008) agreed on the difficulty of retaining STEM majors noting that "less than half of the students who plan to major in science or engineering actually complete a major in those fields" (p. 45). They conjectured that one explanation might be students' low success rates in university mathematics courses that serve as a prerequisite for higher level math and science courses. College algebra is often a prerequisite for other postsecondary courses such as precalculus, trigonometry, business statistics, business calculus, calculus, economics, chemistry, and physics (Gordon, 2008; Herriott & Dunbar, 2009; Rueda & Sokolowski, 2004). In addition, at many universities in the United States, college algebra is the lowest-level mathematics course in the algebra strand for which students can receive college credit (Herriott & Dunbar, 2009). In the next section, research focusing on college algebra will be explored.

College Algebra

The following research studies suggest possible modifications to college algebra. Thiel et al. (2008) described the redesign of the college algebra course at the University of Missouri.

Gordon (2008) also proposed redesigning college algebra, but his focus was on changing the way that college algebra is taught by faculty. Herriott and Dunbar (2009) went a step further; they suggested that postsecondary mathematics courses, including college algebra, should be customized to more closely meet students' needs according to their intended major.

At the University of Missouri at St. Louis, college algebra is a prerequisite for calculus, and calculus is required for students majoring in mathematics, science, business, and the health sciences (Thiel et al., 2008). In 2002, the college algebra success rate at this university was about 55% (Thiel et al., 2008). Success rate was defined as a grade of C- or above. In response to this problem, the Department of Mathematics and Computer Science (DMCS) set out to redesign college algebra in 2003 (Thiel et al., 2008).

Thiel et al. (2008) detailed the redesign process in their research. The DMCS had the support of the dean's office and was helped by the Roadmap to Redesign (R2R) Program (Thiel et al., 2008). They explained that R2R is a program that presents models for high-enrollment courses at the postsecondary level. The use of technology is emphasized, and faculty lecture time is greatly reduced. The reduction in lecture times was replaced by computer-lab sessions in a specially designed Math Technology Learning Center (MTLC) and students' attendance was mandatory (Thiel et al., 2008). In the MTLC sessions, students complete their assigned software-based homework problems. In addition, the MTLC provided students with a supportive learning environment because it was staffed by the course instructor, graduate teaching assistants, and peer tutors (Thiel et al., 2008). Students were also required to complete weekly quizzes and take their exams in the MTLC. Thiel et al. (2008) maintained that the final exam contained the same types of problems as before the course redesign.

The results revealed that the student success rate in college algebra increased from about 55% to more than 75% over a three-year period (Thiel et al., 2008). In addition, there was no decrease in course rigor according to students' final exam scores. Thiel et al. (2008) reported that faculty found the "emphasis on individual instruction and one-on-one interactions with students" (pp. 46-47) very rewarding. They admitted that the redesign of college algebra required considerable time and effort of the DMCS faculty over a period of two years. In addition, the MTLC required an investment of about $350,000 (Thiel et al., 2008). In addition, a substantial commitment from administrators, department chairs, and faculty is necessary to successfully redesign a course. Thiel et al. (2008) maintained that an increase in successful students in the STEM disciplines cannot be "measured in dollars" (p. 49).

In another study published that same year, Gordon (2008) also discussed redesigning college algebra. Mathematics educational reform in elementary and secondary schools has provided students with "very different experiences in mathematics and, as a result, different expectations of what and how mathematics should be taught" (Gordon, 2008, p. 517). He proposed that college algebra should not focus primarily on the development of algebraic skills. Gordon (2008) cited the Curriculum Renewal Across the First Two Years (CRAFTY), a committee of the Mathematical Association of America (MAA), which had developed guidelines for what college algebra should include. According to CRAFTY, a modern course in college algebra should be one that "emphasizes the use of algebra and functions in problem solving and modeling, provides a foundation in quantitative literacy, supplies the algebra and other mathematics needed in partner disciplines, and helps meet quantitative needs in, and outside of, academia" (Gordon, 2008, p. 517). He also cited similar proposals from the American Mathematical Association of Two-Year Colleges (AMATYC). These suggestions are in line with the NCTM's *Principles and Standards for School Mathematics* and if implemented at the postsecondary level would provide a smooth transition for students progressing from high school to college mathematics (Gordon, 2008).

Gordon (2008) acknowledged that in recent years many teaching mathematicians have expounded on problems they have with students' success in traditional college algebra. To put things in perspective historically, Gordon (2008) explained that university students after World War II were an elite group "who had mastered a high level of proficiency in traditional high school mathematics, particularly algebraic manipulation" (p. 519). In contrast, more recent college students have taken high school courses that emphasized problem solving and conceptual understanding. The routine use of graphing calculators is encouraged and there is a smaller emphasis on algebraic manipulation (Gordon, 2008). Gordon (2008) noted that while students are taking more secondary mathematics courses than before, they are also more frequently placed into developmental or remedial math at the postsecondary level. Gordon (2008) argued that today's elementary and secondary students are being taught mathematics in a non-traditional way, but universities are still expecting students to be proficient in traditional mathematics.

Gordon (2008) proposed that students should be knowledgeable with the broad spectrum of various functions that model data, such as linear, power, exponential, and logarithmic functions. In addition, mathematics students should know the behavioral characteristics of each family of functions, their graphs, and the corresponding domain of the functions that model given data (Gordon, 2008). If the course content of college algebra changes, then the pedagogy must also change.

In contrast, the research by Herriott and Dunbar (2009) centered on which students enroll in college algebra. In particular, they studied enrollment patterns at the University of Nebraska at Lincoln (UNL) to determine which postsecondary students actually take college algebra. Many institutions consider college algebra the lowest level mathematics course for which students can receive college credit (Herriott & Dunbar, 2009). Most American colleges and universities require college algebra as a prerequisite course for calculus. One goal in their research was to determine how many college algebra students at UNL actually go on to take calculus (Herriott & Dunbar, 2009). UNL offers the typical Calculus I, II, III sequence, but also offers Calculus for Management and the Social Sciences. At UNL, in the spring and fall semesters of 1996, 1,458 students enrolled in college algebra (Herriott & Dunbar, 2009). Herriott and Dunbar (2009) found that of these students, more than 20% repeated that course. They also found that 32% went on to take Calculus for Management and the Social Sciences and 11% enrolled in Calculus I. Herriott and Dunbar (2009) concluded that this suggests that college algebra is "not primarily a feeder for calculus" (p. 76).

The results prompted Herriott and Dunbar (2009) to investigate the majors of the students who take college algebra. For this, they collected data on students who enrolled in college algebra in the 1996 fall semester and the 1997 spring semester. These students declared a total of 75 different majors (Herriott & Dunbar, 2009). They found that 43% of the students declared majors in business and economics; 31% intended to major in life and health sciences; 9% declared majors in mathematically intensive subjects such as physics, chemistry, engineering, computer science, actuarial science and math; 9% intended to major in social sciences; 6% declared majors in education; and 2% intended to major in the humanities (Herriott & Dunbar, 2009). Additionally, Herriott and Dunbar (2009) collected data on 914 students with declared majors from five public universities in Illinois; similarly, they wanted to find out what percentage of college algebra students had a mathematically intensive major. They found that

13.3% of these students had declared majors in mathematically intensive subjects, 41.2% had intended majors in business and economics, 18.4% declared majors in life and health sciences, 13.6% intended to major in social sciences, 8.2% declared majors in education, and 5.3% intended to major in humanities (Herriott & Dunbar, 2009).

Herriott and Dunbar (2009) noted that the primary goal of college algebra courses is to prepare students for calculus. However, many students who complete college algebra will never take calculus. They suggested that students with nonmathematical majors will be better served by a different college-level math course that includes quantitative literacy and reasoning (Herriott & Dunbar, 2009). In addition, Herriott and Dunbar (2009) suggested that a more rigorous course of college algebra which leads into trigonometry should be provided for students with intended majors in physical sciences, engineering, and mathematics. Finally, for students majoring in managerial, social, and life sciences, Herriott and Dunbar (2009) proposed that college algebra should focus on developing students' skills in mathematical reasoning, graphical analysis, and analyzing "functional relationships among quantifiable variables" (p. 84).

In this section of the literature review, some research that examined students' postsecondary educational experiences was explored. The results of the prior research suggested that many students are not prepared to successfully complete college algebra when they enter the university. Thiel et al. (2008) and Gordon (2008) both proposed redesigning college algebra, but in different ways. Thiel et al. (2008) suggested reducing lecture time and increasing student time on task. In contrast, Gordon (2008) suggested that faculty adopt a method of teaching that more closely matches students' secondary education experiences. The commonality in these two studies was the researchers' focus on increasing students' success rates in college algebra. On the other hand, Herriott and Dunbar (2009) suggested that postsecondary mathematics courses, including college algebra, should be redesigned. They suggested that courses be customized to more closely meet students' needs according to their intended major.

In the previous three sections of this chapter, the prior research that explored the many factors that determine students' mathematics placement at the postsecondary level and the outcome of that placement was reviewed. These factors included those elements that may have contributed to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure. In the following section, the conceptual framework for the present study will be defined.

Conceptual Framework

In order to develop the conceptual framework for this study, it was essential to begin by considering what empirical evidence suggests is the path that students take in their academic progression from secondary to postsecondary education. This progression begins while students are still in high school. Students who have completed secondary mathematics coursework that is challenging enough to appropriately prepare them for the rigor of college mathematics will find themselves on an ideal path. Some of these students will have successfully completed AP or IB courses. In addition, some students will have already completed postsecondary level coursework through the DE program at their high school. The coursework that students complete while in high school determine their college readiness.

The students' next step in the academic progression from secondary to postsecondary education is the college admissions and placement process. Many colleges and universities use SAT, ACT and AP exams to determine students' admission to the university. Some postsecondary institutions also consider students' secondary GPA in the college admission process.

Many universities simultaneously use the SAT and ACT admission exams as placement exams to determine students' placement into the college mathematics course that is most appropriate for them. Other colleges determine students' mathematical placement by requiring students to take a separate placement exam to more accurately assess their ability to be successful in mathematics at the college level. The mathematics placement process should then appropriately place these students into the prerequisite mathematics course for their intended major. Ideally, students will then follow that placement recommendation, successfully complete that course, and continue to progress smoothly through their postsecondary studies. This path is conceptualized in Figure 1.

The optimal result of students' postsecondary studies is completion of their undergraduate degree. Postsecondary student retention has been a topic of educational research for more than 40 years. Tinto (1975) proposed a retention model which included students' non-cognitive factors as well as institutional factors. Pascarella and Terenzini (1980) developed an instrument to assess the Tinto's (1975) model of university student retention.

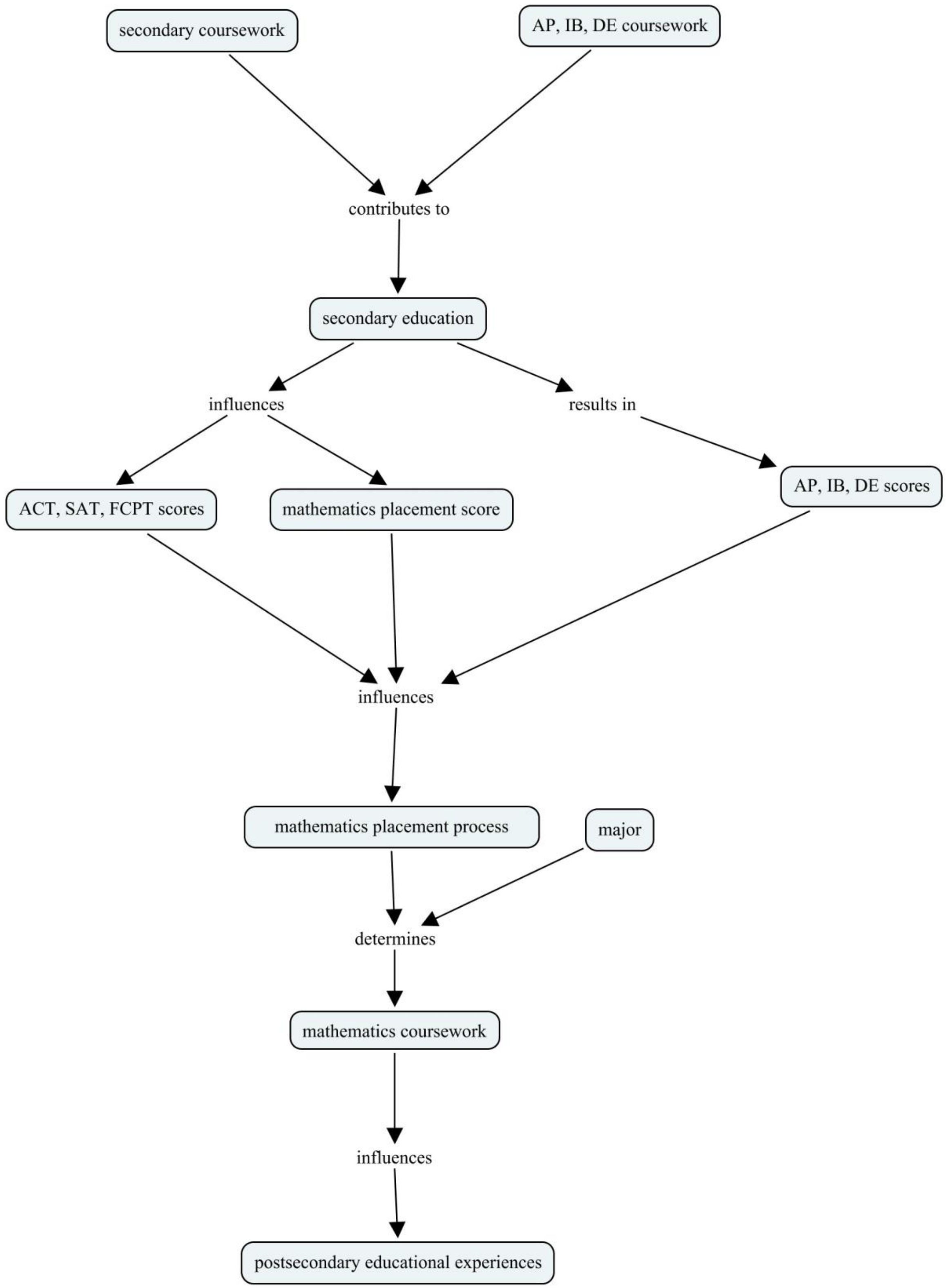

Figure 1. Conceptual framework of the path for students in their academic progression from secondary through postsecondary education.

One element of Tinto's (1975) retention model was students' grade performance which led to their academic integration within the college. Tinto (1975) defined academic integration as including both students' grade performance and their intellectual development. Other researchers have also studied the impact of academic integration on postsecondary student retention (Coll & Stewart, 2008; DeBerard et al., 2004; Fowler & Boylan, 2010; Kerkvliet & Nowell, 2005; Parker, 2004; Pfitzner et al., 2011; Scott et al., 2009). Students who are successful academically are more likely to persist in college and earn their degree. Degree completion by all students is the goal of postsecondary administrators for their institutions. DeBerard et al. (2004) emphasized that "each student that leaves before degree completion costs the college or university thousands of dollars in unrealized tuition, fees, and alumni contributions" (p. 66).

It is optimal that all students have a smooth progression throughout their school years. This progression is even more important as students move forward from one level of education to another. The mathematics placement processes in higher education should be designed to provide for a smooth transition for students from secondary to postsecondary mathematics coursework. Focusing on this transition from secondary education to postsecondary education for students will help structure and focus the study.

Summary

It is important that mathematics placement procedures in higher education be as correct and efficient as possible. Incoming freshmen who do not place into the required mathematics course for their chosen major will have to enroll in a lower level course as a prerequisite for their required mathematics course to fulfill their major requirements. These students will likely delay their graduation because they will be required to take additional courses before they can place into the mathematics course required for their major.

However, incoming freshmen who are placed in courses above their actual mathematics' ability will likely be unsuccessful in completing the course they enrolled in. They will have to repeat and take that course again. Additionally, many students may lose confidence in their ability to succeed in college-level mathematics courses. Some students might even feel obliged to change their chosen major to a major that is less mathematics intensive.

This chapter explored the literature that examines many factors that determine the students' mathematical placement and the outcomes of that placement process at the postsecondary level. These factors are those that may contribute to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure.

The research on students' secondary education centered on factors that influence students' readiness for college-level mathematics. High school math coursework was found to directly impact students' math proficiency (Ma & McIntyre, 2003; Ma & Wilkins, 2007; Roth et al., 2001). Mathematics literacy among high school graduates is becoming increasingly more important as our society becomes ever more technology-oriented (Schiller & Muller, 2003; Thiel et al., 2008). Completing advanced mathematics courses at the secondary level starts a student on the road to educational and financial success (Burris et al., 2006).

For those students headed to higher education, postsecondary admission and mathematical placement procedures contributed to students' choices in their coursework and their major program of study. The research discussed in the second section of the chapter focused on accurately placing students in a university-level mathematics course. It is imperative that colleges and universities correctly place students in the most appropriate mathematics course in which they will be successful. Inaccurate placement interferes with a smooth transition from high school to college mathematics coursework.

In the third section, the research on students' postsecondary educational experiences centered on the coursework that is necessary for students' continued increase in mathematics proficiency. Students' mathematics proficiency was found to be directly related to their quantitative literacy, data analysis, reasoning, critical thinking, and problem-solving skills.

Finally, the conceptual framework shows the path students follow in their progression from secondary through postsecondary education for the study. It is imperative that students advance without difficulty from one grade to another. It is even more important that there is a smooth transition for students from one level of education to another. The mathematics placement process is the juncture for students from secondary to postsecondary mathematics coursework. This study's conceptual framework encompasses this progression from secondary education to postsecondary education.

In summary, students' mathematics literacy is an increasingly important factor in their educational and financial success. Elementary and secondary educators have an obligation to provide students with the tools they need to achieve reading, writing, and mathematics literacy at the 12^{th}-grade level. Colleges and universities, similarly, are mandated to provide students with the tools they need for continued academic growth in postsecondary education. It is imperative for students to continue achieving at every level of education, elementary, secondary, and postsecondary education. Inaccurate mathematics placement impedes this smooth progression for students. The study detailed in Chapter 3 addressed this issue and focused specifically on the mathematics placement process at UNF.

Chapter III: Methodology

The present research study explored the effectiveness of the mathematics placement process at UNF for incoming freshmen. The goal of this process at UNF is to correctly place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their intended major. This study examined whether the placement procedures accurately place incoming freshmen into their first mathematics course at the university. This chapter includes the research questions, an explanation of the current mathematics placement process at UNF, a description of the design of the study, a profile of the population studied, research variables, and the statistical methods used. This chapter also addresses ethical considerations and the delimitations and limitations of the study.

Secondary students who plan on attending college must often complete a variety of assessments as part the postsecondary admissions and placement process (Venezia & Kirst, 2005). Many colleges and universities use SAT, ACT, and AP exams to determine students' admission. Some postsecondary institutions also consider students' secondary coursework and high school GPA in the college admission process. Many universities simultaneously use the SAT and ACT admission exams as placement exams to determine students' placement into the college mathematics course that is most appropriate for them.

In the present study, the Carnegie Classification framework was used to compare mathematics placement procedures at similar postsecondary institutions. The framework is often used by researchers in educational studies to describe commonalities and differences in postsecondary schools in the United States. The Carnegie Commission on Higher Education first developed classifications of colleges and universities in 1970 (Carnegie Foundation for the

Advancement of Teaching, 2010). The first classification framework consisted of five categories: Doctoral-Granting Institutions, Comprehensive Colleges, Liberal Art Colleges, All Two-Year Colleges and Institutes, and Professional Schools and Other Specialized Institutions (McCormick & Zhao, 2005). The framework was updated in 1976, 1987, 1994, 2000, 2005, and 2010 (Carnegie Foundation for the Advancement of Teaching, 2010).

Currently, the Carnegie Classification framework consists of the following six categories: Basic (the traditional Carnegie Classification Framework), Undergraduate Instructional Program, Graduate Instructional Program, Enrollment Profile, Undergraduate Profile, and Size and Setting (Carnegie Foundation for the Advancement of Teaching, 2010). In its 2010 Basic classification, 171 public postsecondary institutions at the level 4-year and above are listed in this category with the UNF.

The mathematics placement procedures at these colleges and universities were investigated by conducting an online query. Each university's website was explored in an attempt to discover what factors were considered in students' mathematics placement. It was difficult to discern the exact mathematics placement process at some of these universities. For example, all students might be required to take a mathematics placement test at some colleges; at other institutions, the test might be required only of students with lower SAT Math or ACT Math scores. At some universities, it is the student's choice; a high score on the mathematics placement test can be used to challenge the initial mathematics placement as determined by SAT Math or ACT Math scores. However, at some university websites, the three test scores are listed as integral to the mathematics placement process, without clarifying exactly how the scores are used. The investigation into mathematics placement procedures at the 171 colleges and universities in the Carnegie 2010 Basic classification yielded the following results. Sixty-seven universities use a specific mathematics placement exam to determine students' placement into their first college-level mathematics course. Eighty-one colleges use SAT Math scores or ACT Math scores to help determine student placement in university mathematics courses. Seventy-eight of the institutions use a combination of SAT Math scores, ACT Math scores, and scores from a mathematics placement test to decide which college-level mathematics course is the most appropriate for incoming students. UNF follows this practice in its mathematics placement process and was, thus, an appropriate setting for the present research study.

The following research questions guided the study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra? Effectiveness was defined as the percentage of students who successfully complete the mathematics course they were placed into by the UNF placement process.

Current Mathematics Placement Process at UNF

UNF is a midsize, public, regional university located in Jacksonville, Florida. Jacksonville is a large metropolitan city in northeast Florida with a population of approximately 850,000.

Freshmen come to UNF with diverse educational backgrounds. Still, they all have to meet the same university admission requirements. Students whose first semester at UNF was either summer or fall of 2010 had, at a minimum, the following high school educational background: four units of English, four units of mathematics at the algebra I level or above, three units of natural science, three units of social science, two units of foreign language, and two units of academic electives (UNF, 2010a).

Freshmen students who are admitted to UNF are generally advised during orientation to register for an English class, a mathematics class, and two other courses for their first semester. Sometimes the two other courses are from the social sciences, humanities, or natural sciences; at other times they are courses related to the student's particular major (UNF, 2010b). All students are required to take at least two mathematics courses to graduate from UNF, regardless of their major.

The UNF mathematics placement process is typically completed at freshmen orientation, which is mandatory for all incoming freshmen. Students are advised to take the appropriate mathematics course based on their intended major, a combination of their ACT, SAT, FCPT, or UNF mathematics placement exam scores, and any incoming credit from Advanced Placement (AP), International Baccalaureate (IB), or dual enrollment (DE). Students register that same day for their fall mathematics class based on the advice they receive. The objective of this placement process at UNF is to accurately place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their chosen major.

Entry-level mathematics courses at UNF include algebraic and non-algebraic courses. Finite Mathematics (MGF1106), Explorations in Mathematics (MGF1107), Statistics for Health and Social Sciences (STA2014), and Mathematics for Elementary Teachers (MGF1113) are the four non-algebraic entry-level courses. Each of these courses is a 3 credit hour course. Precalculus, College Algebra, and Intensive College Algebra are the three entry-level mathematics courses in the algebra strand offered at UNF. Precalculus (MAC1147) is a 4 credit hour course that includes both college algebra and trigonometry. College Algebra (MAC1105) and Intensive College Algebra (MAC1101) cover the same topics; however, College Algebra is 3 credit hours and Intensive College Algebra is 4 credit hours. In Intensive College Algebra, the material can be covered at a slower pace. Therefore, that course is generally recommended for students with lower test scores.

The mathematics class for which students are advised to register is largely based on the student's major. This information is presented in Table 3. Some majors require Precalculus (MAC1147), College Algebra (MAC1105) or Intensive College Algebra (MAC1101), or Statistics for Health and Social Sciences (STA2014). Additionally, some majors require both MAC1105 and STA2014. These students may be advised to take either MAC1105 or STA2014 in their first semester at UNF. Majors in elementary education or special education are advised to register for Mathematics for Elementary Teachers (MGF1113). Students whose major does not require a specific mathematics course can register for any entry-level general education mathematics course including Finite Mathematics (MGF1106) and Explorations in Mathematics (MGF1107).

However, these advising recommendations also depend on the student's placement into those required courses. For example, an engineering major would have Precalculus (MAC1147) listed as a prerequisite course. An incoming student who does not meet the minimum requirements for placement into that course would be required to successfully complete a lower level mathematics course prior to registering for Precalculus.

Table 3

Mathematics by Majors

MGF1106 MGF1107 STA2014	MAC1147	MAC1101 MAC1105
Anthropology	Biology[a]	Economics
All Art majors	Chemistry	Business majors
Communications[a]	Mathematics	Information Systems
Criminal Justice[a]	Statistics	Information Science
English	Computer Science	Health Science[a]
International Studies	Building Construction	Community Health[a]
Music	Engineering	Health Administration[a]
Jazz	Athletic Training[a]	Nutrition[a]
History	Math Education	Sport Management
Philosophy	Science Education	Community Sport
Political Science	Physics	Exercise Science[a]
Psychology[a]		Nursing[a]
Sociology[a]		Information Technology
Spanish		
French		
Education[b]		

Note. MGF1106 = Finite Mathematics. MGF1107 = Explorations in Mathematics. STA2014 = Statistics for Health and Social Sciences. MAC1147 = Precalculus. MAC1101 = Intensive College Algebra. MAC1105 = College Algebra.
[a]Major requires STA2014 as a prerequisite course.
[b]Major recommends MGF1113 (Mathematics for Elementary School Teachers).

All incoming freshmen are required to participate in UNF online mathematics placement testing prior to orientation. The UNF mathematics placement process determines students' eligibility to take one of three entry-level mathematics courses in the algebra strand offered at UNF. These three courses are Precalculus (MAC1147), College Algebra (MAC1105), or Intensive College Algebra (MAC1101).

Many other postsecondary institutions also use SAT Math scores or ACT Math scores to help determine student placement in university mathematics courses. The validity of the ACT has been compared to students' high school grades in predicting eventual students' success in college (ACT, Inc., 2008). It was found that if a university expects that its admission criteria reflect students' academic proficiency in college or their ultimate level of degree attainment, ACT scores are better predictors than high school grades. However, if an institution is attempting to predict students' first-year college grade point average (GPA) or their persistence to the second college year, ACT scores and high school grades predict this about equally (ACT, Inc., 2008). But, if a college wants its admission criteria to reflect students' final university GPA, high school grades are actually better predictors than ACT scores. Donovan and Wheland (2008) conducted a study to investigate students' placement into developmental mathematics. They found that a "fairly strong" (Donovan & Wheland, 2008, p. 10) relationship existed between students' ACT mathematics scores and success in Intermediate Algebra. Intermediate Algebra is a prerequisite course for College Algebra at UNF. Similarly, Bettinger and Long (2009) explored college remediation for underprepared students in their research study. They found that higher ACT scores are related to the impact of mathematics remediation on college retention and degree completion.

Similarly, the College Board found that the best combination of predictors of students' first year university grade point average (GPA) is both their high school GPA and SAT scores (Kobrin, Patterson, Shaw, Mattern, & Barbuti, 2008). The SAT has three sections, a critical reading test, a writing test, and a mathematics test. The writing test was the strongest predictor of the three SAT sections in predicting students' first year college GPA (Kobrin et al., 2008). The College Board encourages colleges and universities to use both SAT scores and high school GPA when making admissions decisions for their institution. Moses et al. (2011) investigated the relationship between students' mathematics readiness, personality, and retention in engineering courses. They found that a significant correlation existed between students' SAT mathematics score and retention.

The College Board also developed a computer-adaptive placement testing system called ACCUPLACER (Mattern & Packman, 2009). Many of the colleges and universities in the state of Florida use the ACCUPLACER as the Florida College Placement Test (FCPT). The FCPT assesses students' reading comprehension and writing skills. In addition, the FCPT evaluates students' skills in arithmetic and elementary algebra to help determine their readiness for college-level mathematics. Mattern and Packman (2009) found a substantial relationship between these placement test scores and students' course success in their research study. James (2006) explored the effectiveness of the ACCUPLACER in placing students in postsecondary developmental courses. They found the ACCUPLACER to be a "good predictor of student success in developmental mathematics courses" (James, 2006, p. 7).

On the other hand, Marwick (2002) explored alternative methods of mathematics placement in her research study. She recommended that placement policies should include "multiple measures of academic preparedness to place students in the mathematics curriculum" (Marwick, 2002, p. 48). Hughes and Scott-Clayton (2011) reviewed assessment in community colleges and found that the ACCUPLACER scores appear to be reasonably valid predictors of students' grades in college-level coursework. However, they also found that the use of the test scores in placement do not improve student outcomes. The evidence suggested that multiple measures should be used for both student assessment and placement to improve student outcomes (Hughes & Scott-Clayton, 2011).

The MPE was part of the UNF mathematics placement process in the present study; students' scores on the MPE determine eligibility in the algebra strand of mathematics courses taught at UNF. The present study assessed the psychometric properties of the data obtained from using the MPE. The two most important properties to consider when using an instrument are reliability and validity (Johnson & Christensen, 2004). Reliability "refers to the consistency of the information obtained" (Wallen & Fraenkel, 2000, p. 86). Reliability is a necessary characteristic of a test; however, evidence of the reliability of a test "is not sufficient evidence that the test is serving the purpose for which it was designed" (Wiersma & Jurs, 1990, p. 256). The second important property to consider when using an instrument is the validity of the data obtained from using that instrument. Validity "refers to the extent to which an instrument gives us the information we want" (Wallen & Fraenkel, 2000, p. 86). Messick (1990) emphasized that determining the validity of the data obtained from an instrument is an "evaluative judgment" of the degree to which evidence supports "the adequacy and appropriateness of interpretations and actions based on test scores" (p. 5).

The current UNF mathematics placement exam was developed by Faiz Al-Rubaee, an associate professor of mathematics at the university, in conjunction with other department faculty. The MPE in the present study was a 40-question, multiple-choice test that was taken online by incoming freshmen students prior to orientation. Participants were given one hour to complete the exam. The test was taken through Blackboard. Blackboard is a software tool used by many educational institutions to facilitate teacher-student communication and enhance student learning. Each of the 40 items had six versions; when students take the MPE, Blackboard randomly creates each student's version of the test. This means that there were 6^{40} or 1.34×10^{31} versions of the UNF MPE. The questions on the exam covered concepts and topics from both elementary and intermediate algebra. Most items were considered to be of medium difficulty by the developers of the test, but a few items were considered to be more difficult because the MPE determines students' eligibility for both algebra and precalculus courses at UNF.

The UNF mathematics placement exam was scored using the Blackboard software tool. The cut scores to determine placement into the three entry-level mathematics courses in the algebra strand offered at UNF were set by Dr. Al-Rubaee in consultation with other UNF mathematics faculty and mathematics faculty from the Florida State College of Jacksonville (FSCJ). The UNF mathematics placement exam had never been rigorously assessed for the reliability or validity of the data obtained from it to accurately place students' into their first mathematics course at UNF. This research study assessed the psychometric properties of the data obtained from using the MPE.

UNF has developed minimum mathematics criteria for its incoming freshmen based on their ACT, SAT, FCPT, and MPE scores. Students whose first semester at UNF was either summer or fall of 2010 or summer or fall of 2011 were subject to these criteria to determine their mathematics placement. This information is presented in Table 4.

Students with scores of at least 600 on the SAT Math or 26 on the ACT Math were eligible to enroll in Precalculus (MAC1147), regardless of their MPE score. Students with scores of at least 580 on the SAT Math or 24 on the ACT Math were able to register for College Algebra (MAC1105), regardless of their MPE score. Students with scores of at least 550 on the SAT Math or 23 on the ACT Math were eligible to enroll in Intensive College Algebra (MAC1101), regardless of their MPE score. Students who had not met these minimum criteria, but had scored at least 440 on the SAT Math or 19 on the ACT Math, had their eligibility determined by their MPE score. Students scoring at least 31 on the UNF MPE were considered to be eligible for Precalculus (MAC1147). A score of 25 to 30 qualified incoming freshmen to register for College Algebra (MAC1105). Students scoring 15 to 24 on the MPE were considered to be eligible for Intensive College Algebra (MAC1101).

Table 4

Required Minimum Scores for Math Course Eligibility

Mathematics Course	SAT/ACT	UNF MPE	FCPT
STA2014 MGF1106 MGF1107 MGF1113	440/19		85
MAC1101	440/19 and MPE score or 550/23	15	85
MAC1105	440/19 and MPE score or 580/24	25	85
MAC1147	440/19 and MPE score or 600/26	31	85

Note. STA2014 = Statistics for Health and Social Sciences. MGF1106 = Finite Mathematics. MGF1107 = Explorations in Mathematics. MGF1113 = Mathematics for Elementary School Teachers. MAC1101 = Intensive College Algebra. MAC1105 = College Algebra. MAC1147 = Precalculus.

Students who had not scored at least 440 on the SAT Math or 19 on the ACT Math were required to take the FCPT. At UNF, students scoring at least 85 on the FCPT qualified into the first college-level mathematics course required for their major. Students who scored below an 85 were placed in one of two remedial mathematics courses taught by FSCJ. These students were not required to take the UNF mathematics placement exam; they were placed in the appropriate mathematics course strictly according to their FCPT score.

Students whose majors did not require a course in the algebra strand could take one of the other general education mathematics courses offered at UNF. Some majors required STA2014; other majors had no specific mathematics requirement. In that case, students were advised to take MGF1106, MGF1107, or STA2014. Any student who scored at least a 440 on their SAT

Math or at least a 19 on their ACT Math could register for any of those three courses regardless of their MPE score.

This UNF mathematics placement process is generally completed at freshmen orientation, which is mandatory for all incoming freshmen. Students are advised to take the appropriate mathematics course based on their intended major, their test scores, and any incoming credit from AP, IB, or DE. More specifically, the UNF mathematics placement process determines students' eligibility into one of three entry-level mathematics courses in the algebra strand offered at UNF, Precalculus, College Algebra, and Intensive College Algebra.

This study focused on students' outcomes in the three entry-level mathematics courses in the algebra strand offered at UNF. These three courses are Precalculus, College Algebra, and Intensive College Algebra.

Design of the Study

This quantitative, retrospective research study explored the effectiveness of the mathematics placement process at UNF for incoming freshmen. The study examined whether freshmen students' success in their first mathematics course at UNF can be predicted by the test scores used in the placement process. The study investigated the relationship between the test scores used in the mathematics placement process and freshmen success in their first mathematics course at UNF. The placement process included students' SAT, ACT, FCPT, and UNF mathematics placement exam scores. The specific courses under consideration in the present study were Precalculus, College Algebra, and Intensive College Algebra. Students earning a grade of C or better were considered to have successfully completed the course.

Logistic regression was the statistical technique employed in the present research study. Multiple regression analysis is the general statistical method used to explain the relationship between a single continuous dependent variable and several independent variables (Hair, Black, Babin, Anderson, & Tatham, 2006). When the dependent variable is dichotomous, logistic regression is the appropriate technique (Neter, Kutner, Nachtsheim, & Wasserman, 1996). In the present study, the dependent variable was defined as either success or non-success. Students' success is defined as completion of a mathematics course with a grade of C or better.

This study explored the extent to which the mathematics placement process at UNF accurately places incoming freshmen into their first mathematics course at the university. In addition, the psychometric properties of the data obtained from using the MPE, which is part of the UNF mathematics placement process, were assessed. The reliability and validity of the data obtained from the UNF mathematics placement exam (MPE) was examined. This research was quantitative and nonexperimental.

Research Population and Data Source

The data source for the study was the freshmen students of 2010 and 2011 at UNF. The population consisted of incoming freshmen who first enrolled in a mathematics course at UNF in either the fall semester of 2010 or 2011 (N = 3,804). The data were obtained from the UNF Office of Institutional Research and Assessment. The data set included the student's term of matriculation, SAT, ACT, FCPT, MPE scores, student's first mathematics course and the earned grade in that course. The data set also contained the student's high school GPA and high school mathematics GPA. Additionally, the student's test results from AP or IB mathematics end-of-course exams and incoming DE mathematics credit were included in the data set. Students' placement into their first college mathematics course was determined by a combination of various scores on these tests and any incoming credit from dual enrollment mathematics courses.

The focus of the present study was on participants' success in the algebra strand of courses, which include Precalculus, College Algebra, and Intensive College Algebra. Students whose majors did not require a course in the algebra strand could take one of the other general education mathematics courses offered at UNF. These students were not subject to the outcomes of the placement process and were excluded from the data set. The study focused on freshmen students who enrolled in Precalculus, College Algebra, and Intensive College Algebra in 2010 and 2011 (n = 1,839). The sample was divided into subgroups according to the three courses. The mathematics placement process at UNF determines a student's eligibility to enroll into one of those three courses based on the test scores. The study investigated if the test scores used in the mathematics placement process at UNF effectively predicted students' success in their first mathematics course in the algebra strand of courses, which include Precalculus, College Algebra, and Intensive College Algebra.

Research Variables

The independent variables in this study included students' high school mathematics GPA (MGPA), their MPE score, and two dummy variables. The UNF mathematics placement exam scores range from 0 to 40; the student's raw MPE score was used in the analyses.

One of the two independent dummy variables was constructed using students' SAT, ACT, and FCPT scores. An incoming freshmen student's scores on these exams is one of the determining factors for mathematical placement at UNF. Students' SAT, ACT, and FCPT scores are used either with or without the MPE to determine mathematics placement. Most students do not take the FCPT; additionally, many students take the SAT or the ACT, but not both. However, any of the test scores by itself can meet the UNF minimum criteria for mathematics placement and can determine a student's eligibility to enroll in one of the three entry-level courses in the algebra strand offered at UNF. Because students' SAT, ACT, and FCPT scores are used either with or without the MPE to determine mathematics placement into these courses, the SAT, ACT, and FCPT scores were first grouped into one of five ranked levels of placement (PL). This information is presented in Table 5.

The three higher rankings classified students according to which mathematics course in the algebra strand they place into. This was regardless of their UNF MPE score. Students in level 2, however, placed into one of these courses based solely on their MPE score. Students scoring at least 31 on the MPE were considered to be eligible for Precalculus. A score of 25 or higher qualified incoming freshmen to register for College Algebra. Students scoring at least 15 on the MPE were considered to be eligible for Intensive College Algebra. Students in level 1 would not be eligible to enroll into any of the entry-level mathematics courses in the algebra strand at UNF.

Table 5

Placement Levels

Level	SAT/ACT scores	FCPT score
5	600 or higher/26 or higher	85 or higher
4	580 to 590/24 to 25	85 or higher
3	550 to 570/23	85 or higher
2	440 to 540/19 to 22	85 or higher
1	Less than 440/less than 19	Less than 85

The second dummy independent variable in this study was an additional constructed variable based on whether or not the student followed the placement recommendation (FPR). The variable FPR was assigned a 1 if students enrolled in the recommended course or a lower course than the course recommended; FPR was given a value of 0 if they took a course higher than the recommended course. The study investigated if the test scores used in the mathematics placement process at UNF effectively predicted students' success in their first mathematics course in the algebra strand of courses, which include Precalculus, College Algebra, and Intensive College Algebra.

Two final independent variables that were considered are incoming students' high school grade point average (GPA) and their mathematics grade point average (MGPA). At the time of the present study, the UNF mathematics placement process did not consider students' GPA or MGPA. However, previous research strongly suggests that students' secondary mathematics coursework significantly influences students' readiness for college-level mathematics (Ma & McIntyre, 2005; Ma & Wilkins, 2007; Roth et al., 2001). Because of this, the variable was considered separately from the placement process variables. The study examined whether students' secondary GPA or MGPA is a better predictor than the UNF mathematics placement process in accurately placing incoming freshmen into their first mathematics course at the university.

The dependent variable in this study was a constructed categorical variable based on the student's earned grade in Precalculus, College Algebra, and Intensive College Algebra. That course had to be taken in the fall semester after matriculation. These grades were grouped into two categories of either A, B, C, or D, F, W. At UNF, students must complete at least two general education mathematics courses with a grade of C or better to fulfill the minimum graduation requirement in mathematics. Students earning a C or better were assigned a 1 for success; students earning less than a C were assigned a 0 for students' non-success or failure to complete the course with a passing grade. Students earning a grade of A, B, or C were considered to have successfully completed the course.

Data Analyses

The study investigated if the test scores used in the mathematics placement process at UNF effectively predicted students' success in their first mathematics course in the algebra strand of courses. In addition, the psychometric properties of using the data obtained from the MPE were examined.

Two essential psychometric properties to consider when using an instrument are reliability and its validity. A test is considered to be reliable if its scores "remain relatively consistent over repeated administration of the same test or alternate test forms" (Crocker & Algina, 1986, p. 105). To assess the reliability of the data obtained from using the MPE, an item analysis was conducted. The item scores were obtained through the UNF Center for Instruction and Research Technology. Item analysis includes determining item difficulty, item discrimination, and item-test correlation (Crocker & Algina, 1986; Wiersma & Jurs, 1990). Wiersma and Jurs (1990) explained that test questions "that have undergone item analysis and have been found to be positively discriminating will increase the test's reliability" (p. 264). In addition, coefficient alpha was used to assess the internal consistency reliability of the MPE. Johnson and Christensen (2004) explained that Cronbach's alpha, also known as coefficient alpha, gives the degree to which the items on the test are interrelated. Coefficient alpha estimates test-score reliability (Ebel & Frisbie, 1986). In addition, three members of the faculty of the UNF Department of Mathematics and Statistics were asked to verify the equivalency of the six versions of each question of the MPE.

The second important property to consider when using an instrument is the validity of the data obtained from using that instrument. Ebel and Frisbie (1986) explained that validity has two aspects, “what is measured and how precisely it is measured” (p. 89). The present study includes assessment of the content validity of the MPE. Content validity “is concerned with the extent to which the test is representative of a defined body of content consisting of topics and processes” (Wiersma & Jurs, 1990, p. 184). Messick (1980) explained that content validity encompasses content relevance and content coverage; content validity “refers to the relevance and representativeness of the task content used in test construction” (p. 1015). Six faculty members of the Department of Mathematics and Statistics at UNF and two faculty members from Jacksonville University were asked to verify the content validity of the exam. In addition, the instrument was analyzed to determine if test scores differentiate between groups known to differ. The SAS 9.2 programming language was used to assess the psychometric properties of the data obtained from the UNF mathematics placement exam.

In addition, descriptive statistics were computed for each of the test scores used in the UNF mathematics placement process, the constructed variable placement level (PL), high school grade point average (GPA), and high school mathematics grade point average (MGPA). These descriptive statistics provided an overview of the characteristics of the data used in the study.

Students were separated into three subgroups according to the three courses, Precalculus, College Algebra, and Intensive College Algebra. These three courses are the primary focus of this study. For each of these courses, the data were used to construct a graph showing the relationship between the mathematics placement level rankings (PL) and the proportion of students who successfully completed the course. Similar graphs were constructed to show the relationship between students' MPE score and the proportion of students who completed the course with a grade of C or better.

Binary logistic regression was selected as the method for analyzing the effectiveness of the UNF mathematics placement process in predicting students' success in their first mathematics course in the algebra strand of courses. The dependent variable in this study was a categorical variable based on the student's success or non-success in completing Precalculus, College Algebra, or Intensive College Algebra. Logistic regression is the appropriate statistical technique to use when the dependent variable is dichotomous (Allison, 2012). The independent variables in this study included the student's MPE score, placement level (PL), and whether or not the student followed the placement recommendation (FPR).

A final independent variable that was also included is incoming student's high school mathematics grade point average (MGPA). Currently, students' MGPA is not considered in the UNF mathematics placement process. Because of this, the variable was considered separately from the placement process variables. The study investigated whether students' high school mathematics GPA is a better predictor than the UNF mathematics placement process in accurately placing incoming freshmen into their first postsecondary mathematics course.

A fourth subgroup consisted of students who registered for higher level mathematics courses. It was expected that these students qualified for the higher level courses based on their incoming credit from AP, IB, or DE. Because these incoming freshmen were part of the freshmen orientation process at UNF, they were required to participate in UNF online mathematics placement testing prior to orientation; their SAT, ACT, FCPT, and MPE scores had been recorded. It was also expected that these students' MPE scores would be higher than those students who do not enter UNF with AP, IB, or DE credit for algebraic mathematics courses.

This information was used to assess the validity of the data obtained from the MPE. The study investigated whether these students' previous mathematical experience or the UNF mathematics placement process was a better predictor of accurately placing these incoming freshmen into their first mathematics course at the university.

Quantitative multivariate analysis was employed in this retrospective study. Logistic regression was the specific multivariate method that was used. The data were analyzed used the SAS version 9.2 programming language.

Institutional Review Board Approval

The student data were obtained from the UNF Office of Institutional Research and Assessment. Students' names and identification numbers were eliminated from the data set to guarantee student anonymity. To assess the psychometric properties of the data obtained from using the UNF mathematics placement exam, the MPE item scores were obtained through the UNF Center for Instruction and Research Technology. All data obtained were stored on UNF's secure server. Waiver of Institutional Review Board (IRB) review was requested and granted. The IRB approval memorandum is included in Appendix A.

Limitations and Delimitations

The study was delimited to freshmen who enrolled in Precalculus, College Algebra, or Intensive College Algebra as their first mathematics course at UNF in the fall of 2010 or 2011. These delimitations excluded transfer students and students who did not enroll in a UNF mathematics course until the spring semester.

Limitations of the study included the omission of students who did not take the MPE, but these students were few in number. All incoming freshmen were required to participate in UNF online mathematics placement testing prior to orientation. However, some students have managed to register for a course without meeting this requirement.

One delimitation of the study is that only two years of data were considered in this study. Another delimitation of the present study was its singular focus on students' mathematics placement. The mathematics placement process in postsecondary education is only one of the many factors that influence students' retention and academic success. Other factors that play a role in students' retention in higher education include students' health and psychosocial factors (DeBerard et al., 2004). Other contributing factors to students' retention include students' academic and social integration to the university (Coll & Stewart, 2008; Pascarella & Terenzini, 1983). These factors were not considered in the present study.

These delimitations and limitations restrict generalizations to postsecondary institutions that are similar to UNF and have a comparable mathematics placement process.

Summary

This chapter presented the research questions and explained the current mathematics placement process at UNF. The design of the research study was outlined, including a description of the population, research variables, and the statistical methods employed. Logistic regression was the multivariate method used to answer the research questions. This chapter also addressed the delimitations and limitations of the study. In Chapter 4, the results of the data analyses are presented.

Chapter IV: Data Analyses

The present study investigated the effectiveness of the mathematics placement process at UNF for incoming freshmen. The placement process is generally completed at freshmen orientation, which is mandatory for all incoming freshmen. Students are advised to take the appropriate mathematics course based on their intended major, a combination of their ACT, SAT, FCPT, or UNF mathematics placement exam scores, Advanced Placement (AP) test scores, International Baccalaureate (IB) test scores, or incoming credit from dual enrollment (DE) in college level mathematics courses. Students register that same day for their fall mathematics class based on the advice they receive. The objective of this placement process at UNF is to accurately place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their chosen major.

The following questions guided the present research study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra? Effectiveness is defined as the percentage of students who successfully complete the mathematics course they were placed into by the UNF placement process. Precalculus, College Algebra, and Intensive College Algebra are the three entry level mathematics courses in the algebra strand offered at UNF.

This chapter begins with descriptive statistics of the data used in the study. The data source for the study was the freshmen students of 2010 and 2011 at UNF. The population consisted of incoming freshmen who first enrolled in a mathematics course at UNF in either the fall semester of 2010 or 2011. The second section contains an explanation of the statistical analyses conducted to address the research questions. Logistic regression analysis was the specific multivariate data analysis technique used to examine the data. The results of the data analyses are summarized in the concluding section of this chapter.

Descriptive Statistics

The data source for the present study was the 2010 and 2011 incoming freshmen at the UNF. More specifically, the population consisted of incoming freshmen who first enrolled in a mathematics course at UNF in either the fall semester of 2010 or 2011 (N = 3,804). The data were obtained from the UNF Office of Institutional Research and Assessment. The data set included the student's term of matriculation; ACT, SAT, FCPT, MPE scores; student's first mathematics course; math points earned in that course; high school GPA; and high school mathematics GPA (MGPA). Additionally, the student's test results from AP or IB mathematics end-of-course exams and incoming DE mathematics credit were included in the data set. Students' placement into their first college mathematics course was determined by a combination of various scores on these tests and any incoming credit from dual enrollment mathematics courses.

First the data set was divided into two disjoint subsets, 2010 freshmen students (n = 2,010) and 2011 (n = 1,794) freshmen students. Means and standard deviations were computed for students' ACT, SAT, FCPT, and MPE scores. In addition, means and standard deviations were calculated for students' high school GPA and MGPA.

The mean and standard deviation for the constructed variable placement level (PL) was also calculated. This variable was constructed using students' ACT, SAT, and FCPT scores. An incoming freshmen student's scores on these exams is one of the determining factors for mathematical placement at UNF. Students' ACT, SAT, and FCPT scores are used either with or without the MPE to determine mathematics placement. Most students do not take the FCPT; additionally, many students take the ACT or the SAT, but not both. However, any of the test scores by itself can meet the UNF minimum criteria for mathematics placement and can determine a student's eligibility to enroll in one of the three entry-level courses in the algebra strand offered at UNF. These three courses are Precalculus, College Algebra, or Intensive College Algebra. Because students' ACT, SAT, and FCPT scores are used either with or without the MPE to determine mathematics placement into these courses, the ACT, SAT, and FCPT scores were grouped into one of five ranked levels of placement (PL). This information was presented in Table 5.

The three higher rankings of PL classified students according to which mathematics course they placed into, Precalculus, College Algebra, or Intensive College Algebra. This was regardless of their UNF MPE score. Students in placement level 2, however, placed into Precalculus, College Algebra, or Intensive College Algebra based solely on their MPE score. Students in placement level 1 were not eligible to enroll into any of the entry-level mathematics courses in the algebra strand at UNF. The mean and standard deviation for this constructed variable placement level (PL) were also calculated. The means and standard deviations for the variables ACT, SAT, FCPT, MPE, GPA, MGPA, and PL are presented in Table 6.

Some of the statistics in Table 6 are of particular interest. Students' average SAT scores (M = 575.34) and MPE scores (M = 23.85) would place them into MAC1101, Intensive College Algebra. MAC1101 is the lowest level college course in the algebra strand offered at UNF. Students scoring at least a 24 on their ACT (M = 24.02) test would place into MAC1105, or regular College Algebra. Very few students took the FCPT; the mean score on that exam would not qualify students to take any entry level course in the algebra strand at UNF. It was also interesting that the difference between the average student GPA and the mathematics GPA is more than 0.80, with the MGPA being the lower value. Students in 2011 had higher mean values in every category than in 2010.

Table 6

Population Means and Standard Deviations

	Total			2010			2011		
	N=3,804			*n*=2,010			*n*=1,794		
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
ACT	1,873	24.02	2.62	1,001	23.47	2.59	872	24.66	2.51
SAT	1,932	575.34	62.32	1,009	573.68	59.82	923	577.15	64.94
FCPT	32	72.75	17.40	25	70.00	16.74	7	82.57	17.29
MPE	3,384	23.82	6.92	1,746	23.32	6.90	1,638	24.37	6.91
GPA	3,804	3.67	0.49	2,010	3.65	0.52	1,794	3.70	0.47
MGPA	2,871	2.82	0.61	1,517	2.77	0.62	1,354	2.87	0.59
PL	3,804	3.50	1.25	2,010	3.38	1.26	1,794	3.64	1.22

Frequency counts at each placement level are presented in Table 7. Students with ACT, SAT, or FCPT scores that place them into the highest placement level category are eligible to enroll in Precalculus, regardless of their UNF MPE score. Similarly, students in placement level 4 are considered to be ready for College Algebra; students in level 3 can register for Intensive College Algebra. Students placing into placement level 1 are not eligible to enroll into any of the three entry-level mathematics courses in the algebra strand at UNF. It was interesting that 63% of 2010 students and 73% of 2011 students were considered to be eligible for college level algebra courses by placing into the top three placement levels. These three levels determine students' placement based on their ACT, SAT, or FCPT scores; their MPE scores are not considered in their mathematics placement. In contrast, mathematics placement for students placing into placement level 2 is determined solely by their UNF mathematics placement exam scores.

Table 7

Population Placement Levels

Placement level	Total *N*=3,804 *n* (%)	2010 *n*=2,010 *n* (%)	2011 *n*=1,794 *n* (%)
5	1226 (32.2)	574 (28.6)	652 (36.3)
4	696 (18.3)	371 (18.5)	325 (18.1)
3	656 (17.3)	318 (15.8)	338 (18.8)
2	1209 (31.8)	733 (36.5)	476 (26.5)
1	17 (0.5)	14 (0.7)	3 (0.2)

Frequency counts for minimum qualifying mathematics placement exam scores are presented in Table 8. Students scoring at least 31 are considered to be eligible for Precalculus, MAC1147. Students must score at least 25 to enroll in College Algebra, MAC1105. A minimum score of 15 is required for a student to register for Intensive College Algebra, MAC1101. The statistics show that 89% of 2010 students who took the UNF mathematics placement exam were considered to be eligible for college level algebra courses based on their MPE scores; in 2011 the percentage was 92%.

Table 8

Population UNF MPE Minimum Qualifying Scores

Math Course	MPE Score	Total *N*=3,384 *n* (%)	2010 *n*=1,746 *n* (%)	2011 *n*=1,638 *n* (%)
Precalculus	> 30	609 (18.0)	282 (16.2)	327 (20.0)
College Algebra	> 24	1,621 (47.9)	787 (45.1)	834 (50.9)
Intensive College Algebra	> 14	3,053 (90.2)	1,546 (88.5)	1,507 (92.0)

The data set for each year was then divided into three smaller disjoint subsets. One of the subsets included freshmen students who enrolled into one of the three entry-level courses in the algebra strand offered at UNF. These three courses are Precalculus, College Algebra, or Intensive College Algebra. The second subset consisted of students who enrolled in higher level mathematics coursework at UNF. The third group of students consisted of students who either took no mathematics courses in their freshmen fall semester, or else they enrolled in a lower level course not in the algebra strand. These three courses include Finite Mathematics, Explorations in Mathematics, and Statistics for Health and Social Sciences. These students were excluded from the present study. The following subsections address the descriptive statistics for the three courses addressed in the present study, Precalculus, College Algebra, and Intensive College Algebra.

Precalculus

Precalculus (MAC1147) is the highest level of the entry level mathematics courses offered at UNF. Means and standard deviations for the independent variables ACT, SAT, FCPT, MPE, GPA, Math GPA, and PL for the data on Precalculus students included in the study are presented in Table 9. In addition, the success rate of incoming freshmen students in Precalculus is included in Table 9.

Table 9

Precalculus Sample Means, Standard Deviations, and Success Rate

	Total			2010			2011		
	n = 454			*n* = 209			*n* = 245		
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
ACT	171	25.49	2.62	68	24.93	2.99	103	25.85	2.29
SAT	283	612.93	45.91	141	612.91	45.38	142	612.96	46.60
FCPT	0	-	-	0	-	-	0	-	-
MPE	408	28.02	5.31	183	28.12	5.25	225	27.93	5.37
GPA	454	3.73	0.52	209	3.77	0.61	245	3.70	0.44
MGPA	331	2.93	0.57	153	2.91	0.58	178	2.94	0.56
PL	454	4.35	1.03	209	4.29	1.06	245	4.40	1.00
Percent of Success	454	76.43	-	209	74.16	-	245	78.37	-

Frequency counts at each placement level are presented in Table 10. Students in placement level 5 are considered to be eligible for Precalculus based on their SAT, ACT, or FCPT scores. It was unexpected that 35% of Precalculus students enrolled in that course despite their ineligibility. These students could have scores on AP or IB exams or DE mathematics credit that would determine their mathematics placement. For example, incoming students who already have DE credit for College Algebra would be qualified to take Precalculus regardless of their placement level.

Table 10

Placement Levels for Precalculus Sample

Placement level	Total *n*=454 *n* (%)	2010 *n*=209 *n* (%)	2011 *n*=245 *n* (%)
5	295 (65.0)	129 (61.7)	166 (67.8)
4	73 (16.1)	39 (18.7)	34 (13.9)
3	35 (7.7)	14 (6.7)	21 (8.6)
2	51 (11.2)	27 (12.9)	24 (9.8)
1	0 (0.0)	0 (0.0)	0 (0.0)

Frequency counts for minimum qualifying mathematics placement exam scores are presented in Table 11. It was notable that only 36% of Precalculus students were deemed eligible to register for that course based on their MPE scores. Students' readiness for Precalculus might have been determined by their placement level; alternatively, students could have scores on AP or IB exams or DE mathematics credit that would determine their mathematics placement. During freshmen orientation, these students would generally be asked to explain their lower than expected MPE scores. Common reasons given include computer malfunction, not taking the placement exam seriously, or completing the exam under less than optimal conditions.

Table 11

UNF MPE Qualifying Scores for Precalculus Sample

Qualified for Math Course	MPE Score	Total *n*=408[a] *n* (%)	2010 *n*=183 *n* (%)	2011 *n*=225 *n* (%)
Precalculus	> 30	145 (35.5)	70 (38.3)	75 (33.3)
College Algebra	> 24	321 (78.7)	143 (78.1)	178 (79.1)
Intensive College Algebra	> 14	397 (97.3)	178 (97.3)	219 (97.3)

[a]90% of incoming freshmen Precalculus students in 2010 and 2011 had MPE scores.

College Algebra

College Algebra (MAC1105) is the entry level mathematics course that has the highest enrollment of all the courses in the algebra strand offered at UNF. Means and standard deviations for the independent variables ACT, SAT, FCPT, MPE, GPA, Math GPA, and PL for the data on College Algebra students included in the study are presented in Table 12. In addition, the success rate of incoming freshmen students in College Algebra is included in Table 12.

Table 12

College Algebra Sample Means, Standard Deviations, and Success Rate

		Total *n* = 881			2010 *n* = 438			2011 *n* = 443	
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
ACT	464	24.21	2.43	233	23.79	2.47	231	24.63	2.32
SAT	417	576.28	45.80	205	578.63	44.33	212	574.01	47.17
FCPT	2	97.50	10.61	1	90.00	-	1	105.00	-
MPE	791	25.34	5.52	384	25.20	5.32	407	25.47	5.70
GPA	881	3.63	0.43	438	3.60	0.44	443	3.65	0.41
MGPA	657	2.82	0.58	326	2.81	0.61	331	2.84	0.55
PL	881	3.59	1.16	438	3.52	1.18	443	3.66	1.13
Percent of Success	881	73.89	-	438	74.20	-	443	73.59	-

Frequency counts at each placement level are presented in Table 13. Students whose scores placed them into placement level 5 or placement level 4 (55%) were deemed to be eligible for College Algebra based on their ACT, SAT, or FCPT scores. Students in placement level 3 or placement level 2 could have their eligibility for College Algebra determined by their MPE scores. It was interesting to note that one person placed into placement level 1. Students in placement level 1 are not considered to be qualified to take any of the entry level courses in the algebra strand at UNF.

Table 13

Placement Levels for College Algebra Sample

Placement level	Total n=881 n (%)	2010 n=438 n (%)	2011 n=443 n (%)
5	258 (29.3)	124 (28.3)	134 (30.3)
4	228 (25.9)	105 (24.0)	123 (27.8)
3	172 (19.5)	82 (18.7)	90 (20.3)
2	222 (25.2)	127 (29.0)	95 (21.4)
1	1 (0.1)	0 (0.0)	1 (0.2)

Frequency counts for minimum qualifying mathematics placement exam scores are presented in Table 14. The statistics show that 63% of students who enrolled in College Algebra had scores at or above the minimum value of 25.

Table 14

UNF MPE Qualifying Scores for College Algebra Sample

Qualified for Math Course	MPE Score	Total n=791[a] n (%)	2010 n=384 n (%)	2011 n=407 n (%)
Precalculus	> 30	111 (14.0)	50 (13.0)	61 (15.0)
College Algebra	> 24	500 (63.2)	245 (63.8)	255 (62.7)
Intensive College Algebra	> 14	757 (95.7)	367 (95.6)	390 (95.8)

[a]90% of incoming freshmen College Algebra students in 2010 and 2011 had MPE scores.

Intensive College Algebra

` Intensive College Algebra (MAC1101) is the lowest level of the entry level mathematics courses in the algebra strand offered at UNF. This course covers the same concepts and topics as College Algebra; however, it is a 4 credit hour course and College Algebra is a 3 credit hour course. The extra credit hour gives instructors and students additional time to cover the material; students with the lowest MPE and placement scores are placed in this class. Means and standard deviations for the independent variables ACT, SAT, FCPT, MPE, GPA, Math GPA, and PL for the data on Intensive College Algebra students included in the study are presented in Table 15. In addition, the success rate of incoming freshmen students in Intensive College Algebra is included in Table 15.

Table 15

Intensive College Algebra Sample Means, Standard Deviations, and Success Rate

		Total *n* = 504			2010 *n* = 245			2011 *n* = 259	
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
ACT	273	22.47	1.86	141	21.78	1.68	132	23.20	1.76
SAT	232	525.07	49.93	104	524.71	37.00	128	525.39	58.52
FCPT	6	75.67	15.42	5	77.00	16.85	1	69.00	-
MPE	461	19.53	4.32	211	19.15	4.22	250	19.85	4.39
GPA	504	3.49	0.48	245	3.42	0.38	259	3.55	0.54
MGPA	393	2.67	0.53	193	2.62	0.56	200	2.72	0.50
PL	504	2.61	0.90	245	2.41	0.80	259	2.80	0.94
Percent of Success	504	60.32	-	245	54.29	-	259	66.02	-

Frequency counts at each placement level are presented in Table 16. Students in placement level 3 or higher are considered eligible to register for Intensive College Algebra regardless of their MPE score; 40% of students fall into that category. Students in placement level 2 have their readiness for Intensive College Algebra determined solely by their MPE scores. Five students were in placement level 1; students in placement level 1 are not considered to be qualified to take any of the entry level courses in the algebra strand at UNF.

Table 16

Placement Levels for Intensive College Algebra Sample

Placement level	Total *n*=504 *n* (%)	2010 *n*=245 *n* (%)	2011 *n*=259 *n* (%)
5	26 (5.2)	8 (3.3)	18 (7.0)
4	59 (11.7)	19 (7.8)	40 (15.4)
3	117 (23.2)	43 (17.6)	74 (28.6)
2	297 (58.9)	170 (69.4)	127 (49.0)
1	5 (1.0)	5 (2.0)	0 (0.0)

Frequency counts for minimum qualifying mathematics placement exam scores are presented in Table 17. It was worthy of note that 91% of students of incoming freshmen students had scores that deemed them eligible for Intensive College Algebra; the success rate is only 60%.

Table 17

UNF MPE Qualifying Scores for Intensive College Algebra Sample

Qualified for Math Course	MPE Score	Total *n*=461[a] *n* (%)	2010 *n*=211 *n* (%)	2011 *n*=250 *n* (%)
Precalculus	> 30	9 (2.0)	1 (0.5)	8 (3.2)
College Algebra	> 24	31 (6.7)	10 (4.7)	21 (8.4)
Intensive College Algebra	> 14	421 (91.3)	187 (88.6)	234 (93.6)

[a]91% of incoming freshmen Intensive College Algebra students in 2010 and 2011 had MPE scores.

The next section provides an explanation of the statistical analyses conducted to address the questions in the present study. Logistic regression analysis was the multivariate statistical method used for the data analyses.

Data Analyses Addressing the Effectiveness of the Placement Process

How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra?

Effectiveness is defined as the percentage of students who successfully complete the mathematics course they were placed into by the UNF placement process. Precalculus, College Algebra, and Intensive College Algebra are the three entry level mathematics courses in the algebra strand offered at UNF.

Exploratory Analyses

Logistic regression analysis was the statistical technique employed to address one of the research questions of the present study: How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra? SAS version 9.2 was the software used to perform the statistical analyses.

The dependent variable in the regression equation is success. This binary, categorical variable was given a value of 1 if the student completed their class with a grade of C or better; otherwise success was given a value of 0. The independent variables in this study were mathematics placement exam (MPE) scores, placement level (PL), and followed placement recommendation (FPR). MPE is a metric variable; it is the student's raw score on the UNF mathematics placement exam. The MPE is a 40-question, multiple-choice test that is taken online by incoming freshmen students prior to orientation; the scores range from 0 to 40. PL is a categorical variable constructed using students' SAT, ACT, and FCPT scores. Students' SAT, ACT, and FCPT scores are used either with or without the MPE to determine mathematics placement. Because students' SAT, ACT, and FCPT scores are used either with or without the MPE to determine mathematics placement into these courses, the SAT, ACT, and FCPT scores were first grouped into one of five ranked levels of placement (PL). This information is presented in Table 5.

The final independent variable constructed for the present study is FPR; this variable is coded according to whether or not students followed the placement recommendation. Students' placement into their first college mathematics course was determined by a combination of MPE scores, students' placement level (PL), students' test results from AP or IB mathematics end-of-course exams, and any incoming credit from DE mathematics courses. Students enrolling into the mathematics course they were placed into, or taking a class lower than the course they placed into, were deemed to have followed the placement recommendation. For these students, FPR was given a value of 1. If students enrolled in a class above the mathematics course they were placed into, FPR was given a value of 0. For example, suppose a student placed into College Algebra (MAC1105). If that student enrolled in College Algebra, or Intensive College Algebra (MAC1101), FPR would be given a value of 1. If, however, that student registered for Precalculus (MAC1147), FPR would be given a value of 0.

The research population for the present study was the freshmen students of 2010 and 2011 at UNF. The population consisted of incoming freshmen who first enrolled in a mathematics course at UNF in either the fall semester of 2010 or 2011 (N = 3,804). To address the research questions, three subgroups of the population were analyzed. Students enrolling in Precalculus (n = 454), College Algebra (n = 881), and Intensive College Algebra (n = 504) in either the fall semester of 2010 or 2011 comprised the three subsamples for the logistic regression analyses. For each of these subgroups, the data were first used to construct a bar chart showing the relationship between the mathematics placement level rankings (PL) and the proportion of students who successfully completed the course. These bar charts are presented in Figures 2, 3, and 4.

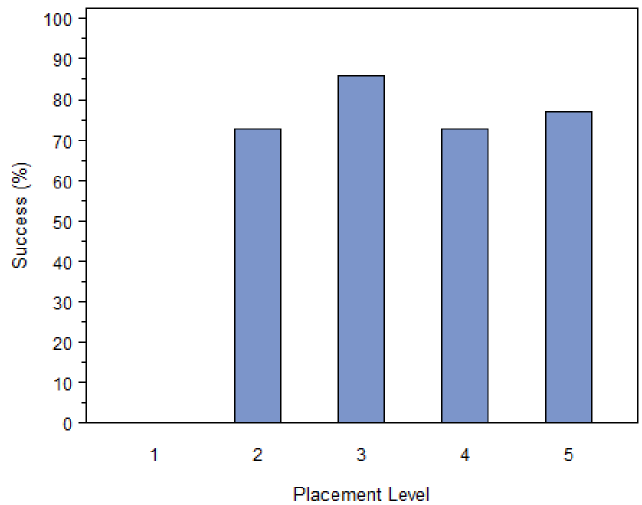

Figure 2. Bar Chart of students' percentage of success by their placement level in Precalculus.

The bar chart in Figure 2 does not provide evidence of a relationship between placement level and students' success in Precalculus. Placement level 5 is the level that determines students' eligibility for Precalculus; students with a placement level of 3 had the highest percentage of success. Students with placement levels of 2, 4, and 5 appear to have about the same success rate.

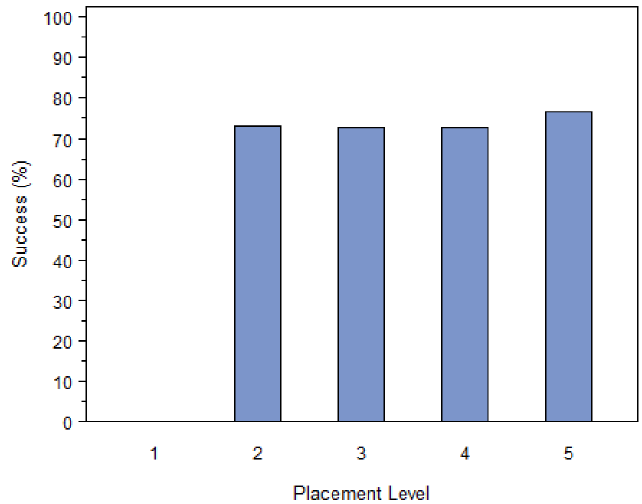

Figure 3. Bar chart of students' percentage of success by their placement level in College Algebra.

Students' eligibility for College Algebra is determined by placement level 4; the bar chart in Figure 3 shows that placement level is not related to students' success in this course. Regardless of students' placement level, their success rate is nearly the same.

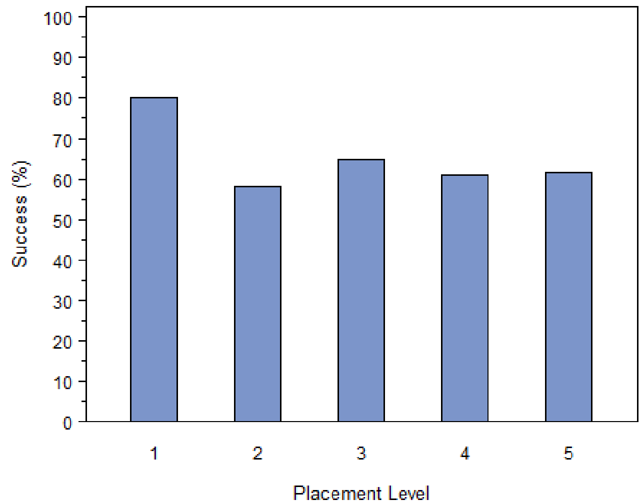

Figure 4. Bar chart of students' percentage of success by their placement level in Intensive College Algebra.

Placement level 3 is the level that determines students' eligibility for Intensive College Algebra. Similar to the bar charts for Precalculus and College Algebra, the bar chart in Figure 4 also shows that there is not a significant relationship between students' placement level and their rate of success. It was surprising that none of the bar charts for any of the three mathematics courses showed evidence of a relationship between students' placement level and their success in the course.

Graphs were constructed to show the relationship between students' MPE scores and the proportion of students who completed the course with a grade of C or better. These graphs are presented in Figures 5, 6, and 7.

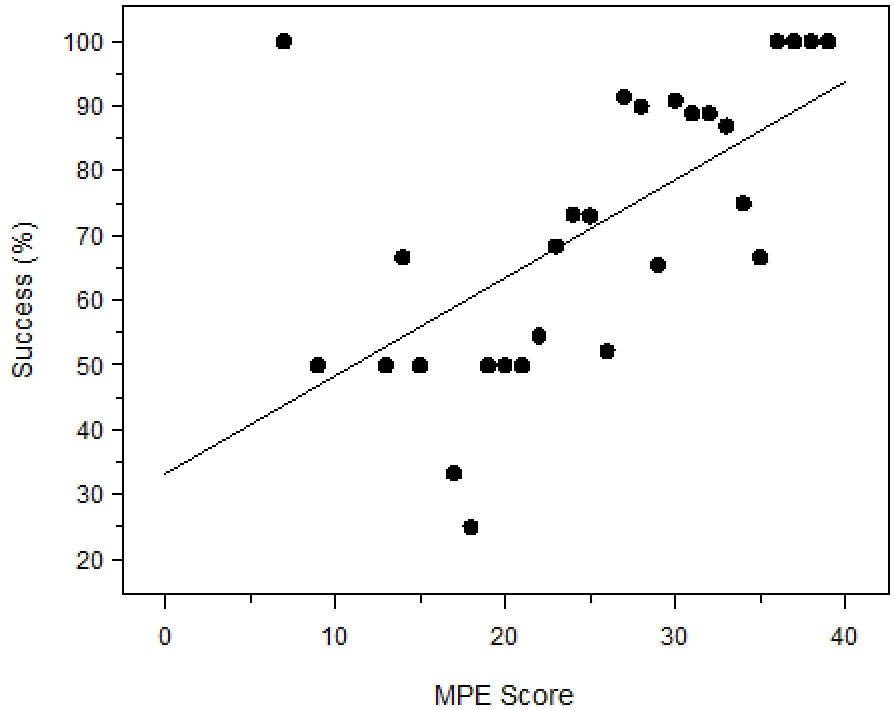

Figure 5. Graph of students' percentage of success by their mathematics placement score in Precalculus.

The graph in Figure 5 shows a generally positive relationship exists between students' MPE score and their success rate in Precalculus. Eligible students for Precalculus need to have an MPE score greater than or equal to 31.

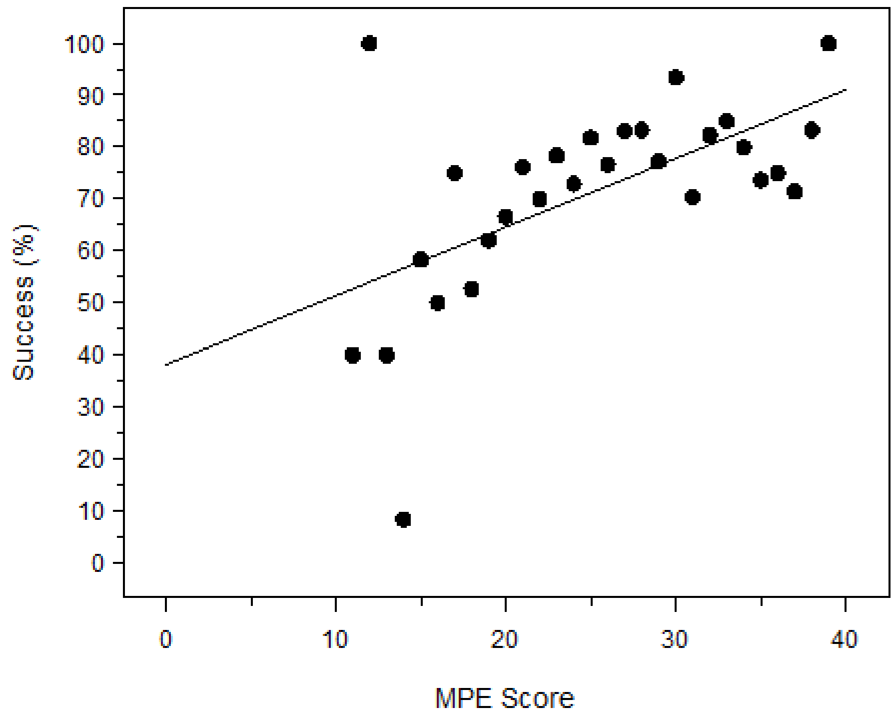

Figure 6. Graph of students' percentage of success by their placement level in College Algebra.

The graph for College Algebra in Figure 6 provides even stronger evidence of a positive relationship between students' MPE score and their rate of success. The minimum MPE score to determine students' eligibility for College Algebra is 25.

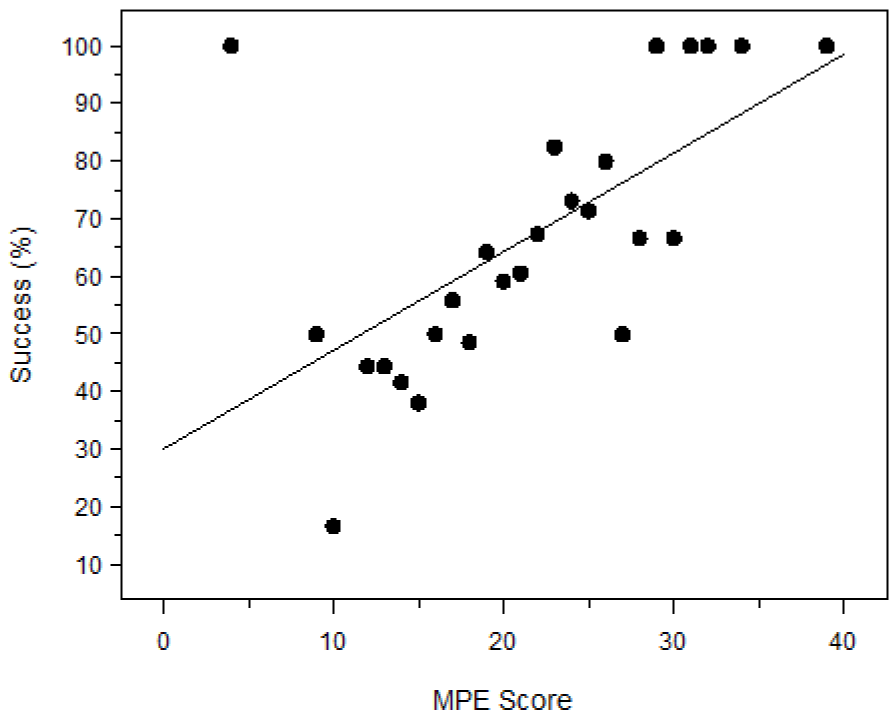

Figure 7. Graph of students' percentage of success by their mathematics placement score in Intensive College Algebra.

Similar to the graphs for the other two courses, the graph for Intensive College in Figure 7 shows a positive relationship between students' MPE score and their success rate. Students need a minimum score of 15 to qualify for Intensive College Algebra. In summary, the graphs in Figures 5, 6, and 7 verified a positive relationship between students' MPE scores and their success in each of the three courses, Precalculus, College Algebra, and Intensive College Algebra.

Frequency data and chi-square tests of homogeneity and measures of association were conducted to investigate the relationship between students' success and whether or not they followed the placement recommendation (FPR) for each of the three courses. The phi coefficient was also calculated; the phi index of association can be used to measure the strength of association in a two way contingency table (Huck, 2008). Phi values range from -1 to +1.

Values close to -1 and +1 indicate a very strong relationship; values near 0 indicate a very weak relationship. Phi values of .10, .30, and .50 represent small, medium, and large effect sizes (Green & Salkind, 2008; Huck, 2008). The results of the analyses are presented in Table 18. The results of the chi-square tests indicate that there is not a significant association between FPR and students' success in Precalculus or Intensive College Algebra. However, the results showed that there appeared to be a very small association between FPR and students' success in College Algebra ($p < .05$, phi = .06).

Table 18

Relationship between Students' Success and FPR

	Followed Placement Recommendation (FPR)		
	No	Yes	
Math Course	n (%)	n (%)	Chi-square test
Precalculus, n = 454	66 (14.5)	388 (85.5)	χ^2 [df = 1] = 0.64, $p > .05$
College Algebra, n = 881	260 (29.5)	621 (70.5)	χ^2 [df = 1] = 4.16, $p < .05$
Intensive College Algebra, n = 504	53 (10.5)	451 (89.5)	χ^2 [df = 1] = 1.39, $p > .05$

Frequency tables and chi-square tests were also used to further explore the relationship between students' success and placement level (PL) for each of the three courses. The results of the analyses are presented in Table 19. The results suggested that there is not a significant association between students' placement level and their success in any of the three courses.

Table 19

Relationship between Students' Success and their Placement Level

Math Course	PL = 5 Success n (%)	PL = 4 Success n (%)	PL = 3 Success n (%)	PL = 2 Success n (%)	PL = 1 Success n (%)	Chi-square test
Precalculus, n = 454	227 (50.0)	53 (11.7)	30 (6.6)	37 (8.2)	0 (0)	χ^2 [df = 3] = 2.74, *p* > .05
College Algebra, n = 881	198 (22.5)	166 (18.8)	125 (14.2)	162 (18.4)	0 (0)	χ^2 [df = 4] = 4.29, *p* > .05
Intensive College Algebra, n = 504	16 (3.2)	36 (7.1)	76 (15.1)	172 (34.1)	4 (0.8)	χ^2 [df = 4] = 2.61, *p* > .05

Students' MPE scores were then grouped into four categories: scores greater than or equal to 31; scores greater than or equal to 25, but less than 31; scores greater than or equal to 15, but less than 25; and scores less than 15. Students whose scores are greater than or equal to 31 are eligible for Precalculus, students with scores greater than or equal to 25 are eligible for College Algebra, and students with scores greater than or equal to 15 are eligible for Intensive College Algebra. Frequency data and chi-square tests of homogeneity and measures of association were conducted to investigate the relationship between students' success and MPE scores for each of the three courses. Cramer's V was also calculated to determine the strength of association; Cramer's V is used to measure effect size when contingency tables have more than two rows or columns (Huck, 2008). Values of .10, .30, and .50, respectively, represent small, medium, and large effect sizes (Green & Salkind, 2008; Huck, 2008). The results are presented in Table 20. The results of the analyses indicated that there is a small to medium association between students' MPE scores and their success in Precalculus, College Algebra, and Intensive College Algebra ($p < .05$; Cramer's V = .27, .28, and .16, respectively).

Table 20 *Relationship between Students' Success and MPE*

Math Course	MPE <15 Success n (%)	14 < MPE < 25 Success n (%)	24 < MPE < 31 Success n (%)	MPE > 30 Success n (%)	Chi-square test
Precalculus, n = 408	6 (1.5)	44 (10.8)	139 (34.1)	127 (31.1)	χ^2 [df = 3] = 28.7, $p < .05$
College Algebra, n = 791	9 (1.1)	175 (22.1)	320 (40.5)	86 (10.9)	χ^2 [df = 3] = 59.8, $p < .05$
Intensive College Algebra, n = 461	16 (3.5)	234 (50.8)	16 (3.5)	8 (1.7)	χ^2 [df = 3] = 11.2, $p < .05$

To further investigate the relationship between MPE scores and students' success in each of the three courses, the MPE scores were then divided into only two categories for each course. For Precalculus students, the scores were separated into scores that were greater than or equal to 31 and scores that were less than 31. The two groupings for College Algebra students' scores consisted of scores that were less than or equal to 25 and scores that were less than 25. For Intensive College Algebra students, the scores were separated into scores that were greater than or equal to 15 and scores that were less than 15. Frequency tables and chi-square tests of homogeneity and measures of association were used to investigate the relationship between students' success and MPE scores for each of the three courses. The phi coefficient was also calculated to measure the strength of association. The results of the analyses are presented in Table 21. The analyses again verified that there is a small association between students' MPE scores and their success in Precalculus, College Algebra, and Intensive College Algebra ($p < .05$; phi = .18, .20, .12, respectively).

It is noteworthy to compare the success rates of students based on their eligibility as determined by their MPE scores. Students' whose MPE scores deemed them eligible for Precalculus have a success rate of 87.6%; ineligible students' success rate is 71.9%. In College

Algebra, the success rate for eligible students is 81.2% versus a 63.2% success rate for ineligible students. For Intensive College Algebra students, eligible students have a success rate of 61.3%; ineligible students' success rate is 40.0%.

Table 21

Relationship Between Students' Success and Course Eligibility as determined by MPE Score

Math Course	Successful, eligible n (%)	Unsuccessful, eligible n (%)	Successful, ineligible n (%)	Unsuccessful, ineligible n (%)	Chi-square test
Precalculus, n = 408	127 (87.6)	18 (12.4)	189 (71.9)	74 (28.1)	X^2 [df = 1] = 13.2, $p < .05$
College Algebra, n = 791	406 (81.2)	94 (18.8)	184 (63.2)	107 (36.8)	X^2 [df = 1] = 31.3 $p < .05$
Intensive College Algebra, n = 461	258 (61.3)	163 (38.7)	16 (40.0)	24 (60.0)	X^2 [df = 1] = 6.9, $p < .05$

However, the frequency tables also indicated some anomalies about the mathematics placement categories in the three courses. For example, students who are considered eligible for Precalculus would have to be in the highest mathematics placement category; their MPE scores would be greater than or equal to 31. Out of the successful Precalculus students who had MPE scores (*n* = 316), 40% had scores greater than or equal to 31 and 60% did not. Additionally, College Algebra students who were considered ineligible for that course (*n* = 291), according to their MPE scores, had a higher rate of success at 63% than non-success.

The next section of this chapter will focus on the statistical analyses that further attempt to answer the research question: How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra? Logistic regression analysis was the specific method used in the present study.

Logistic Regression Analyses

A three-predictor logistic model was fitted to the data to explore the relationship between the likelihood of students' success and their mathematics placement score, placement level, and whether or not they followed the mathematics placement level in each of the three courses, Precalculus, College Algebra, and Intensive College Algebra. The general logistic regression equation for the present study was:

Predicted logit of (success) = $\alpha + \beta_1$*MPE + β_2*PL + β_3*FPR

The dependent variable success is coded 1 if students successfully completed Precalculus, College Algebra, or Intensive College Algebra; success is coded 0 if students earned a grade less than C. The independent variable MPE is students' raw score on the UNF mathematics placement exam; PL is the mathematics placement level the students placed into based on ACT, SAT, or FCPT scores. The variable FPR is coded 1 if students followed the placement recommendation; it is coded 0 if students enrolled in a course above their mathematics placement eligibility. The Greek letter *alpha* is the *Y*-intercept and the *beta* values are the unstandardized regression coefficients.

Students enrolling in Precalculus (n = 454), College Algebra (n = 881), and Intensive College Algebra (n = 504) in either the fall semester of 2010 or 2011 comprised the three subsamples for the study. The percentage of students who were successful in Precalculus was 76.43%; the success rate for College Algebra students was 73.89%. In Intensive College Algebra, 60.32% of students were successful. The percentage of Precalculus, College Algebra, and Intensive College Algebra students who completed the UNF mathematics placement exam was 89.87%, 89.78%, and 91.47%, respectively. For the independent variable PL, all incoming students in the data set had ACT, SAT, or FCPT scores; 100% of students had a mathematics placement level. For the variable FPR, the percentage of Precalculus students who followed the placement recommendation was 85.46%; only 70.49% of College Algebra students followed the placement recommendation. In Intensive College Algebra, 89.48% of students followed the placement recommendation.

Precalculus results. The results of the logistic regression analysis predicting success in MAC1147 in 2010 and 2011 based on MPE, PL, and FPR are presented in Table 22. A statistical significance level of $p < .05$ was used for all analyses. Students who did not complete the UNF mathematics placement exam were excluded from the analysis. Three different chi-square statistics, the Likelihood ratio test, the Score test, and the Wald statistic are generally used to evaluate the overall logistic model (Cohen, Cohen, West, & Aiken, 2003; Peng, Lee, & Ingersoll, 2002). The results of these three tests confirmed that the logistic model was more effective than the intercept-only model; at least one of the independent variables in the regression equation was not equal to zero ($p < .01$). The logistic regression equation for MAC1147 (n = 408) was:

Predicted logit of (success) = -2.4192 + 0.1342*MPE + 0.1982*PL – 0.9880*FPR

Table 22

Logistic Regression Predicting Success in Precalculus in 2010 and 2011

Predictor	β	S.E. β	Wald χ^2	*df*	*p*	e^{β} (odds ratio)	95.0% C.I. for e^{β} Lower	Upper
Intercept	-2.4192	0.8305	8.4854	1	.0036			
MPE	0.1342	0.0242	30.8717	1	<.0001	1.144	1.091	1.199
PL	0.1982	0.1267	2.4451	1	.1179	1.219	0.951	1.563
FPR	-0.9880	0.4307	5.2622	1	.0218	0.372	0.160	0.866

Test	χ^2	*df*	*p*
Overall model evaluation			
Likelihood ratio test	36.7333	3	<.0001
Score test	38.4776	3	<.0001
Wald test	32.2169	3	<.0001
Goodness-of-fit test			
Hosmer-Lemeshow	10.3606	8	0.2406

The Wald chi-square test assesses the significance of each of the independent variables in the regression model (Allison, 2012; Hair et al., 2006). The results showed that the independent variables MPE and FPR were statistically significant ($p < .05$) in predicting students' success in Precalculus in 2010 and 2011. The coefficients or *beta* values in a logistic regression equation can be used to estimate odds ratios for the independent variables (Allison, 2012; Cody & Smith, 2006; Menard, 2010).

Odds ratios are generally used as measures of effect size in logistic regression analysis. Odds ratios "reveal the strength of the independent variable's contribution to the outcome" (Stoltzfus, 2011, p. 1103). The odds of an event "is the ratio of the expected number of times that an event will occur to the expected number of times it will not occur" (Allison, 2012, p. 15). Researchers are often more familiar with probability values that range from 0 to 1; a probability value of 0 indicates an event is certain not to occur. In contrast, a probability of 1 means that the occurrence of the event is certain. On the other hand, odds ratios can be, and often are, larger than 1. The relationship between odds and probabilities is relatively easy to explain. If p is the probability of an event occurring and O is the odds of the event occurring, then $O = p/(1-p)$ and $p = O/(1+O)$ (Allison, 2012).

For the present study, the odds ratio can be defined as the odds of students' success in completing the mathematics course with a grade of C or better versus students' non-success in the course. The odds ratios are given by e^{β} in Table 19. The odds ratio for MPE means for each one unit increase in students' MPE score, there is a 14% increase in the predicted odds of students' success in Precalculus (OR = 1.144, $p < .01$); the odds of success is multiplied by 1.144. For the binary variable FPR, the odds ratio indicated that for students who follow the placement recommendation, the odds of success is multiplied by 0.372 as compared to students who do not follow the placement recommendation (OR = 0.372, $p < .05$); the predicted odds of students' success decreases when they followed the placement recommendation. The variable PL was not found to be statistically significant in predicting students' success (OR = 1.219, $p > .05$). The confidence interval provided additional evidence to support that the variable PL is not statistically significant; when the 95.0% confidence interval includes the numeric value 1, this corresponds to no significant effect (Allison, 2012; Cohen et al., 2003).

The Hosmer-Lemeshow statistic is the test that was used to evaluate the goodness-of-fit of the logistic model. The Hosmer-Lemeshow statistic is a Pearson chi-square statistic (Cohen et al. 2003; Peng & So, 2002). This test examined whether the logistic regression function is appropriate for the observed data (Cohen et al., 2003). The results indicated that the logistic regression model was fit to the data well ($p > .05$).

A number of different measures were used to assess the logistic model for association and predictive accuracy. The coefficient of determination, R^2, is commonly used to assess predictive power in least squares linear regression (Allison, 2012; Menard, 2010). In logistic regression analysis, a generalized R^2 can be used; it is based on the log-likelihood quantity being maximized (Menard, 2010). The generalized R^2 has comparability across different logistic regression models for the same data and in the same model across different data sets (Menard, 2010). Higher values of R^2 indicate a better prediction of the dependent variable. Values of .10, .30, and .50 are generally used to represent small, medium, and large coefficients of determination (Green & Salkind, 2008). For the Precalculus students, $R^2 = .09$; this indicated that the logistic regression equation is not a good predictor of students' success in this course. In addition, the *c* statistic was used and a classification table was constructed to report the validity of the predicted probabilities; this information is presented in Table 23. The *c* statistic is a measure of association and "represents the proportion of student pairs with different observed outcomes for which the model correctly predicts a higher probability for observations with the event outcome than the probability for nonevent observations" (Peng et al., 2002, p. 8). For the Precalculus students, *c* = .712; this means that for 71.2% of all pairs of students, one successful and the other not, the model correctly assigned a higher probability to successful students. The classification table showed that with the probability cutoff of 0.50, the model correctly predicted 77.0% of successful Precalculus students.

Table 23

The Observed and Predicted Frequencies for Students' Success in Precalculus

	Predicted		
Observed	Yes	No	% Correct
Yes	307	9	97.2
No	85	7	7.6
Overall % correct			77.0

Cutoff of 0.50; Sensitivity = 307/(307+9)% = 97.2%; Specificity = 7/(85+7)% = 7.6%; False positive = 85/(307+85)% = 21.7%; False negative = 9/(9+7)% = 56.3%; Predictor variables are MPE, PL, and FPR.

College algebra results. The results of the analysis predicting success in MAC1105 in 2010 and 2011 are presented in Table 24. Students who did not complete the UNF mathematics placement exam were excluded from the analysis. The results of the Likelihood ratio test, the Score test, and the Wald test all indicated that the logistic model was more effective than the null model ($p < .01$). The logistic regression equation for MAC1105 (n = 791) was:

$$\text{Predicted logit of (success)} = -1.8365 + 0.0981*\text{MPE} + 0.0904*\text{PL} + 0.2409*\text{FPR}$$

Table 24

Logistic Regression Predicting Success in College Algebra in 2010 and 2011

Predictor	β	S.E. β	Wald χ^2	*df*	*p*	e^{β} (odds ratio)	95.0% C.I. for e^{β} Lower	Upper
Intercept	-1.8365	0.4918	13.9457	1	.0002			
MPE	0.0981	0.0159	38.2367	1	<.0001	1.103	1.069	1.138
PL	0.0904	0.0870	1.0806	1	.2986	1.095	0.923	1.298
FPR	0.2409	0.2145	1.2614	1	.2614	1.272	0.836	1.937

Test	χ^2	*df*	*p*
Overall model evaluation			
Likelihood ratio test	48.3141	3	<.0001
Score test	48.3278	3	<.0001
Wald test	44.8392	3	<.0001
Goodness-of-fit test			
Hosmer-Lemeshow	22.3283	8	0.0043

The results indicated that MPE was the only independent variable that was statistically significant ($p < .01$) in predicting students' success in College Algebra in 2010 and 2011. The odds ratio for MPE indicated that for each unit increase in MPE scores, there is a 10% increase in the predicted odds of students' success (OR = 1.103, $p < .01$). Neither of the other two independent variables, PL or FPR, was considered significant ($p > .05$) in predicting students' success in College Algebra. To further support this conclusion, the confidence intervals for the odds ratio for PL and FPR included the numeric value of 1; this indicates that neither of these variables have a significant effect on students' success in College Algebra. In addition, the Hosmer-Lemeshow test suggested that the logistic regression model was not a good fit to the data ($p < .01$).

In assessing the model for predictive accuracy and association, R^2 and the *c* statistic were calculated for College Algebra students. The value of $R^2 = .06$ indicated that the logistic model is not a good predictor of students' success in this course. To measure association, the value of the *c* statistic was found to be $c = .643$; this means that for 64.3% of all pairs of students, one successful and the other unsuccessful, the model accurately assigned a higher probability to successful students. A classification table was produced to document the validity of the predicted probabilities; this information is presented in Table 25. The results showed that with the probability cutoff of 0.50, the model accurately predicted 75.9% of successful students in College Algebra.

Table 25

The Observed and Predicted Frequencies for Students' Success in College Algebra

	Predicted		
Observed	Yes	No	% Correct
Yes	580	10	98.3
No	181	20	10.0
Overall % correct			75.9

Cutoff of 0.50; Sensitivity = 580/(580+10)% = 98.3%; Specificity = 20/(181+20)% = 10.0%; False positive = 181/(580+181)% = 23.8%; False negative = 10/(10+20)% = 33.3%. Predictor variables are MPE, PL, and FPR.

Intensive college algebra results. The results of the logistic regression analysis predicting success in MAC1101 in 2010 and 2011 based on MPE, PL, and FPR are presented in Table 26. Students who did not complete the UNF mathematics placement exam were excluded from the analysis. The results of the Likelihood ratio test, the Score test, and the Wald test supported that the logistic model was more effective than the intercept-only model. The logistic regression equation for MAC1101 (n = 187) was:

Predicted logit of (success) = -2.3301 + 0.1229*MPE + 0.0551*PL + 0.2073*FPR

Table 26

Logistic Regression Predicting Success in Intensive College Algebra in 2010 and 2011

Predictor	β	S.E. β	Wald χ^2	*df*	*p*	e^{β} (odds ratio)	95.0% C.I. for e^{β} Lower	Upper
Intercept	-2.3301	0.5940	15.3862	1	<.0001			
MPE	0.1229	0.0271	20.5520	1	<.0001	1.131	1.072	1.192
PL	0.0551	0.1119	0.2421	1	.6227	1.057	0.848	1.316
FPR	0.2073	0.4783	0.1878	1	.6648	1.230	0.482	3.142

Test	χ^2	*df*	*p*
Overall model evaluation			
Likelihood ratio test	29.8554	3	<.0001
Score test	28.4736	3	<.0001
Wald test	26.4226	3	<.0001
Goodness-of-fit test			
Hosmer-Lemeshow	4.6173	9	0.8663

Similar to the College Algebra results, the results of the logistic regression analysis for Intensive College Algebra show that MPE was the only variable that was statistically significant ($p < .01$) in predicting students' success in 2010 and 2011. For each unit increase in MPE scores, there is a 13% increase in the predicted odds of students' success (OR = 1.131, $p < .01$). The other two independent variables, PL or FPR, were not found to be significant ($p > .05$) in predicting students' success. In addition, the confidence intervals for the odds ratio for PL and FPR included the numeric value of 1; this indicates that neither of these variables have a significant effect on students' success in Intensive College Algebra. However, in assessing the overall goodness-of-fit of the logistic regression model, the Hosmer-Lemeshow test indicated that the logistic regression model was a good fit to the data ($p > .05$).

To test the logistic regression model for association and predictive accuracy of success in Intensive College Algebra, values were found for R^2 and the *c* statistic. A value of $R^2 = .06$ indicated that the logistic regression equation is not a good predictor of students' success. The *c* statistic was calculated to be $c = .653$; this means that for 65.3% of all pairs of students, one successful and the other unsuccessful, the model correctly assigned a higher probability to successful students. A classification table was also used to examine the validity of the predicted probabilities; this information is presented in Table 27. The results indicated that with the probability cutoff of 0.50, the model correctly predicted 61.6% of successful students in Intensive College Algebra.

Table 27

The Observed and Predicted Frequencies for Students' Success in Intensive College Algebra

	Predicted		
Observed	Yes	No	% Correct
Yes	224	50	81.8
No	127	60	32.1
Overall % correct			61.6

Cutoff of 0.50; Sensitivity = 224/(224+50)% = 81.8%; Specificity = 60/(127+60)% = 32.1%; False positive = 127/(224+127)% = 36.2%; False negative = 50/(50+60)% = 45.5%. Predictor variables are MPE, PL, and FPR.

Logistic Regression Model Diagnostics

Analyses were also conducted to assess multicollinearity between the independent variables, MPE, PL, and FPR. Multicollinearity occurs when a correlation exists between one or more of the independent variables (Hair et al., 2006; Menard, 2010). The tolerance statistic is a commonly used measure of multicollinearity (Allison, 2012; Hair et al., 2006). According to Allison (2012), a tolerance value below .4 is an indication of some multicollinearity between the independent variables; Cohen et al. (2003) suggested that tolerance values of .1 or less indicate serious problems of multicollinearity. The tolerance value was calculated for each of the independent variables in each of the subgroups, Precalculus (tolerance > .82), College Algebra (tolerance > .72), and Intensive College Algebra (tolerance > .82); the indication was that there is not a strong correlation between the independent variables.

Additionally, graphs were constructed to illustrate the logistic regression model fit. Because MPE was the only independent variable that was found to be statistically significant in every analyses, the graph displayed the relationship between students' probability of success and their raw MPE scores. The value of FPR was held constant at 1; this means students followed the placement recommendation. In addition, the placement level 1 was not included in the graphing process; students in placement level 1 are not deemed eligible for any algebra or precalculus courses at UNF. The placement level for each of the data points on the graph are indicated by their own numeric value. The graphs for each of the three courses are shown in Figures 8, 9, and 10.

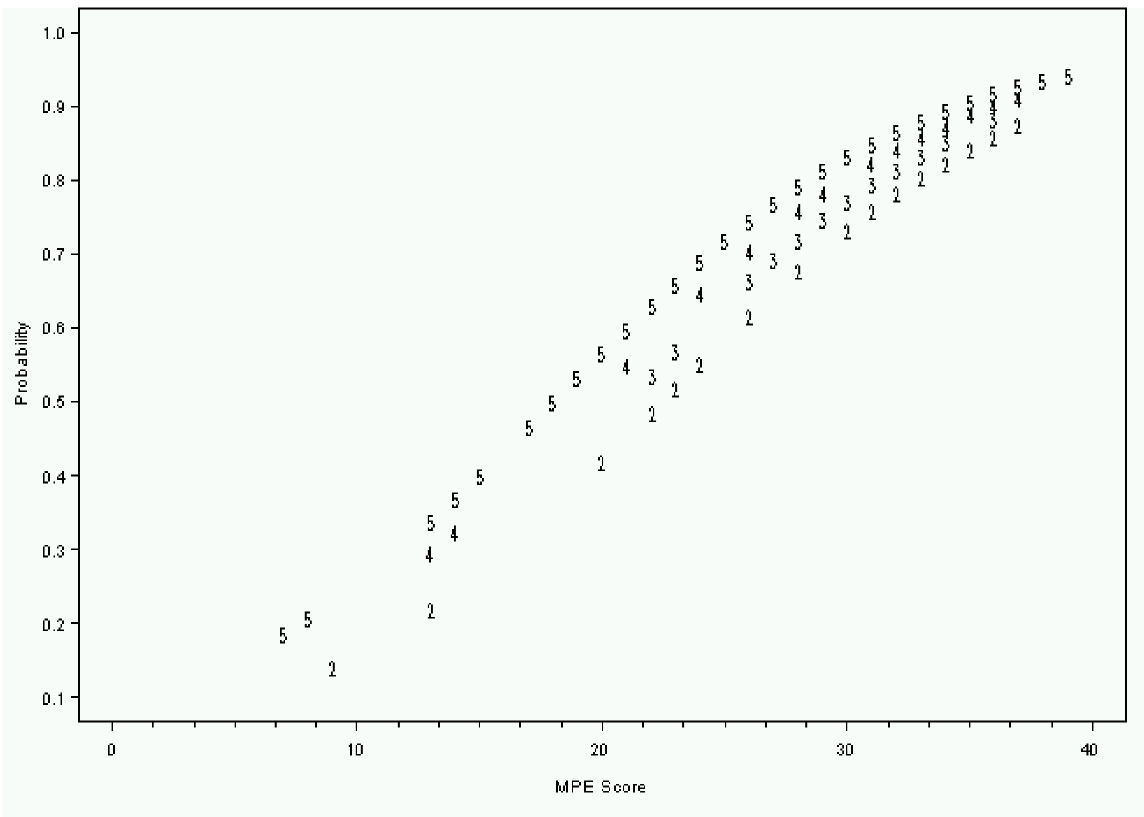

Figure 8. Graph of students' predicted probability of success by their MPE score in Precalculus; numeric values indicate placement levels. Placement levels 5, 4, and 3 qualify students for Precalculus, College Algebra, and Intensive College Algebra regardless of their MPE scores; students in Placement level 2 have their course eligibility determined by their MPE score.

The graphs indicated that the cut scores for the three entry level courses in the algebra strand offered at UNF were problematic. For example, the current cut score of 31 that determines students' eligibility to Precalculus corresponds to a probability of success of over 70%. The graph in Figure 8 showed that students' MPE scores are positively related to their probability of success. On the other hand, the small shift in the curve as placement level changes shows the small effect of placement level in the model.

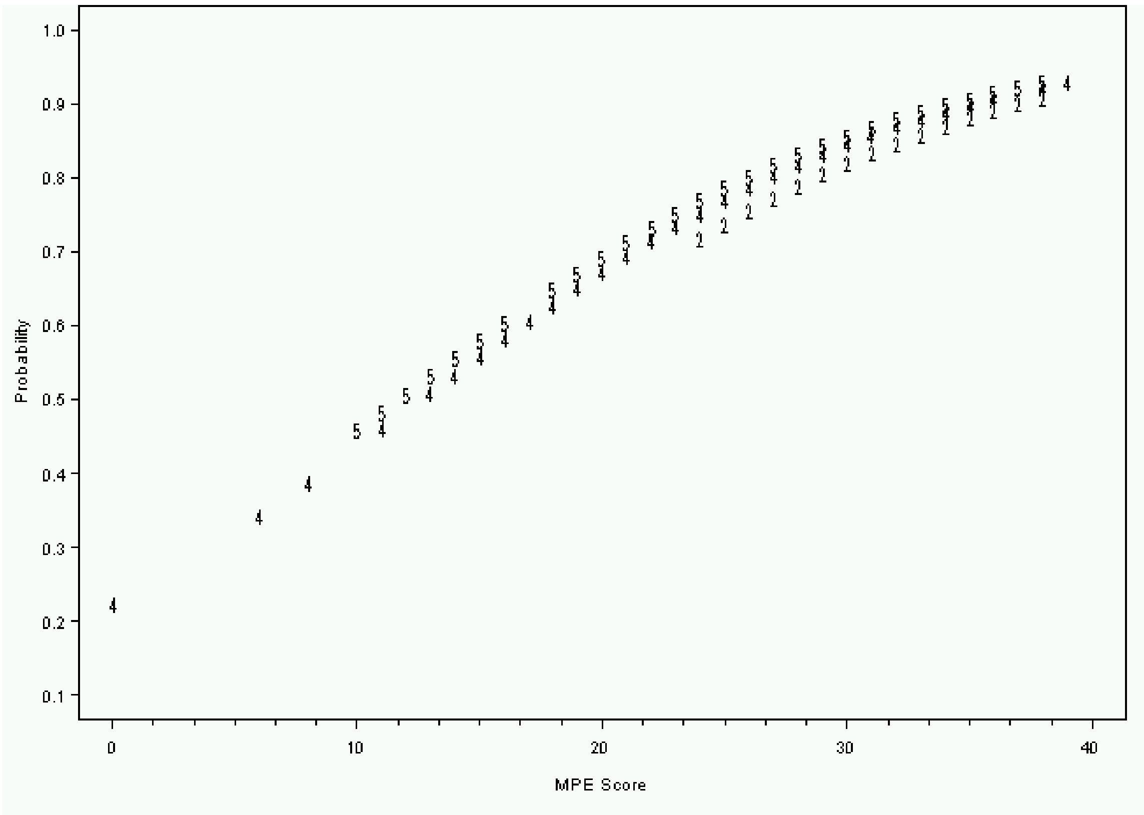

Figure 9. Graph of students' predicted probability of success by their MPE score in College Algebra; numeric values indicate placement levels. Placement levels 5, 4, and 3 qualify students for Precalculus, College Algebra, and Intensive College Algebra regardless of their MPE scores; students in Placement level 2 have their course eligibility determined by their MPE score.

It was surprising that no observations for placement level 3 appeared on the graph in Figure 9. Upon further investigation of the data, it was found that no College Algebra students who placed into placement level 3 also followed the placement recommendation; therefore, students in placement level 3 are not included in the graph. For College Algebra, the current cut score that determines students' eligibility is 25. The graph in Figure 9 indicated that students'

MPE scores are positively related to their probability of success. In contrast, the graph showed that students' placement level is not related to their probability of success.

The graph in Figure 10 shows the logistic regression model fit for Intensive College Algebra. The cut score of 15 that determines students' eligibility to Intensive College Algebra corresponds to a probability of success of just under 50%. Similar to the graph for Precalculus in Figure 8 and the graph for College Algebra in Figure 9, the graph in Figure 10 indicated that students' MPE scores are positively related to their probability of success. The variable MPE was the only independent variable found to be significant in all the logistic regression analyses conducted for determining students' success in Precalculus, College Algebra, and Intensive College Algebra.

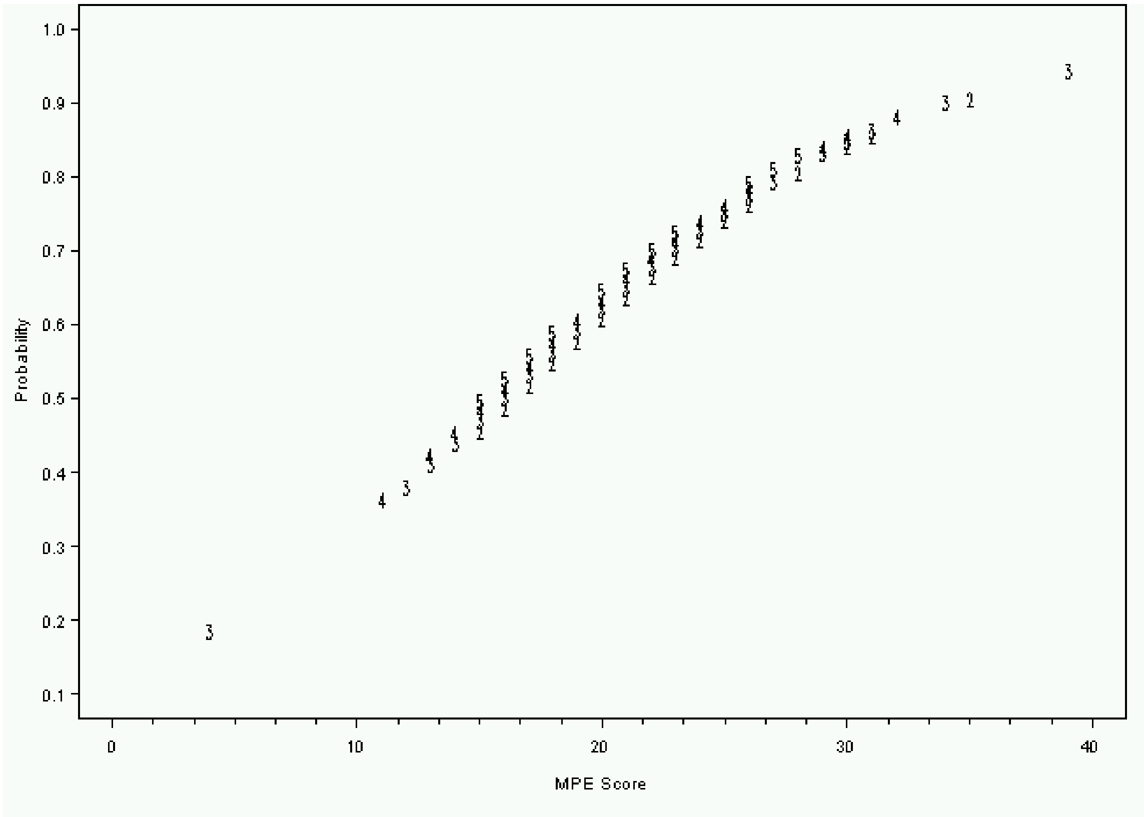

Figure 10. Graph of students' predicted probability of success by their MPE score in Intensive College Algebra, numeric values indicate placement levels. Placement levels 5, 4, and 3 qualify students for Precalculus, College Algebra, and Intensive College Algebra regardless of their MPE scores; students in Placement level 2 have their course eligibility determined by their MPE score.

Cut scores were then adjusted for each of the three courses based on the graphs and additional frequency tables were constructed. Chi-square tests of homogeneity and measures of association were used to investigate the relationship between students' and course eligibility as determined by MPE score. The phi coefficient was also calculated to measure the strength of association. The results of the analyses are presented in Table 28. The analyses verified that there is a small to medium association between students' MPE scores and their success in Precalculus and College Algebra ($p < .05$; phi = .30 and .22, respectively).

When comparing the success rates of students based on their eligibility as determined by their MPE scores with the modified cut scores, students' whose MPE scores deemed them eligible for Precalculus have a success rate of 86.4%; ineligible students' success rate is 60.0%. In addition, when the cut score categories for Precalculus were adjusted to those greater than or equal to 27 and those less than 27, the percentage of qualified Precalculus students was increased from 36% to 67%. In College Algebra, the success rate for eligible students based on the modified cut scores is 80.3% versus a 58.3% success rate for ineligible students. Cut scores for College Algebra were adjusted to those greater than or equal to 23 and those less than 23. With the new cut score of 23, the percentage of eligible College Algebra students is increased from 63% to 74%. This information is presented in Table 28.

Table 28

Relationship Between Students' Success and Course Eligibility as determined by MPE Score with Adjusted Cut Scores

Math Course	Successful, eligible n (%)	Unsuccessful, eligible n (%)	Successful, ineligible n (%)	Unsuccessful, ineligible n (%)	Chi-square test
Precalculus n = 408	235 (86.4)	37 (13.6)	81 (60.0)	55 (40.0)	X^2 [df = 1] = 37.4, $p < .05$
College Algebra n = 791	470 (80.3)	115 (19.7)	120 (58.3)	86 (41.7)	X^2 [df = 1] = 39.2, $p < .05$

Cut scores were not adjusted for Intensive College Algebra. With the standing cut scores for Intensive College Algebra (n = 461), students who are eligible have a minimum MPE score of 15. Eligible students only have a rate of success of 61% in Intensive College Algebra, but the percentage of students who are considered eligible with the present cut score is 91.3% (X^2 [df = 1] = 6.86, $p < .05$, phi = .12).

In reviewing the overall results of the logistic regression analyses, measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support that the three variables are strong predictors of students' success in those courses.

Comparison of Alternative Logistic Regression Models

Peng and So (2002) recommended fitting alternative models to the data to "gather as much information as possible before accepting a model as the best model for the data" (p. 54). Alternative logistic regression models were fit to the same data to investigate if a better model fit could be found. For each of the three mathematics courses, Precalculus, College Algebra, and Intensive College Algebra, additional regression models included those that contained a single independent variable, MPE, PL, and FPR; other models included two of the three variables, MPE and PL, MPE and FPR, and PL and FPR.

In comparing across models, comparisons were made for Akaike's Information Criterion (*AIC*), the coefficient of determination R^2, and the *c* statistic. *AIC* is calculated as: $AIC = -2 \log L + 2k$ where $-2 \log L$ is the maximized value of the logarithm of the likelihood function multiplied by -2 and k is the number of parameters (Allison, 2012). For the present study, the number of parameters is 4; the parameters are the three independent variables and the intercept. Lower values of *AIC* indicate a better fitting logistic regression model (Allison, 2012; Cohen et al., 2003). When using the coefficient of determination to compare logistic regression models, higher values of R^2 indicate a better prediction of the dependent variable (Hair et al., 2006; Menard, 2010). Peng et al. (2002) described the *c* statistic as "a basis for comparing different models fitted to the same data or the same model fitted to different data sets" (p. 8). Higher values for *c* indicate a better logistic regression model fit (Allison, 2012; Peng et al, 2002).

However, different logistic regression models can only be compared for the same data set. The first set of models that can be compared all included the independent variable MPE (n = 408). When assessing these different logistic regression models for predicting success in Precalculus, the best model that contained the independent variables in the current placement process was the regression equation that included all three of the independent variables. This model had the lowest *AIC* value, the highest R^2 value, and the highest *c* statistic. The model with the independent variable MPE and the model with the variables MPE and FPR were not a good fit to the data, according to the Hosmer-Lemeshow goodness of fit test. This information is presented in Table 29. The second set of models that can be compared contained only the independent variables PL and FPR ($n = 504$). The model that included only the variable FPR was not a good fit to the data. The remaining two models had nearly identical *AIC* values; a difference of less than 2 points in the *AIC* statistic is not considered to be meaningful. The R^2 values were less than .01 and the *c* statistic values were nearly identical.

Table 29

Comparison of Logistic Regression Models for Precalculus

Predictor Variables	Hosmer-Lemeshow Goodness of Fit	*AIC*	R^2	*c* statistic
MPE, PL, FPR ($n = 408$)	X^2 = [df = 8] = 10.36, $p > .05$	406.82	.09	.71
MPE ($n = 408$)	X^2 = [df = 9] = 17.22, $p < .05$	409.08	.07	.68
PL ($n = 454$)	X^2 = [df = 2] = 2.64, $p > .05$	499.76	< .01	.51
FPR ($n = 454$)	X^2 = [df = 0] = 0	499.15	< .01	.52
MPE, FPR ($n = 408$)	X^2 = [df = 8] = 18.43, $p < .05$	407.19	.08	.69
PL, FPR ($n = 454$)	X^2 = [df = 3] = 1.49, $p > .05$	500.80	< .01	.53
MPE, PL ($n = 408$)	X^2 = [df = 8] = 6.72, $p > .05$	410.70	.07	.69
GPA ($n = 454$)	X^2 = [df = 8] = 7.35, $p > .05$	488.24	.03	.65
MGPA ($n = 331$)	X^2 = [df = 8] = 10.75, $p > .05$	334.64	.09	.70

The assessment of College Algebra models gave mixed results; however, the difference in the results was small. The only model that was a good fit to the data and included the independent variable MPE ($n = 791$) was the model with MPE and FPR. The model that contained only the variable FPR also did not was not a good fit to the data. The model that included the variable PL and the model (*n* = 881) with the variables PL and FPR had nearly identical *AIC* values, R^2 values, and *c* statistic values. This information is presented in Table 30.

Table 30

Comparison of Logistic Regression Models for College Algebra

Predictor Variables	Hosmer-Lemeshow Goodness of Fit	*AIC*	R^2	*c* statistic
MPE, PL, FPR (*n* = 791)	X^2 = [df = 8] = 22.33, *p* < .05	856.37	.06	.64
MPE (*n* = 791)	X^2 = [df = 8] = 16.72, *p* < .05	857.24	.05	.64
PL (*n* = 881)	X^2 = [df = 3] = 3.02, *p* > .05	1014.60	< .01	.52
FPR (*n* = 881)	X^2 = [df = 0] = 0	1011.61	< .01	.54
MPE, FPR (*n* = 791)	X^2 = [df = 8] = 8.83, *p* > .05	855.44	.06	.64
PL, FPR (*n* = 881)	X^2 = [df = 3] = 4.95, *p* > .05	1013.61	< .01	.54
MPE, PL (*n* = 791)	X^2 = [df = 8] = 23.91, *p* < .05	855.63	.06	.64
GPA (*n* = 881)	X^2 = [df = 8] = 6.77, *p* > .05	878.12	.14	.75
MGPA (*n* = 657)	X^2 = [df = 8] = 5.44, *p* > .05	700.25	.09	.70

The results for Intensive College Algebra also appear to be mixed; but again, the difference in results is small. The only model that did not fit the data was the model that included only the independent variable FPR. Of the set of models that contained the independent variable MPE (*n* = 461), the model with only MPE has the lowest *AIC* value; the R^2 and the *c* statistic are the same. A difference of less than 2 points in the *AIC* statistic is not considered to be meaningful. When comparing the model that included the independent variable PL and the model that contains the variables PL and FPR (*n* = 504), the *AIC* values, R^2 values, and *c* statistic values are nearly identical. This information is presented in Table 31.

Table 31

Comparison of Logistic Regression Models for Intensive College Algebra

Predictor Variables	Hosmer-Lemeshow Goodness of Fit	*AIC*	R^2	*c* statistic
MPE, PL, FPR (*n* = 461)	X^2 = [df = 9] = 4.62, $p > .05$	600.71	.06	.65
MPE (*n* = 461)	X^2 = [df = 10] = 6.03, $p > .05$	597.27	.06	.65
PL (*n* = 504)	X^2 = [df = 3] = 2.19, $p > .05$	680.67	< .01	.52
FPR (*n* = 504)	X^2 = [df = 0] = 0	679.71	< .01	.52
MPE, FPR (*n* = 461)	X^2 = [df = 10] = 6.20, $p > .05$	598.95	.06	.65
PL, FPR (*n* = 504)	X^2 = [df = 3] = 0.82, $p > .05$	681.60	< .01	.53
MPE, PL (*n* = 461)	X^2 = [df = 9] = 4.44, $p > .05$	598.90	.06	.65
GPA (*n* = 504)	X^2 = [df = 8] = 6.68, $p > .05$	644.86	.07	.65
MGPA (*n* = 393)	X^2 = [df = 8] = 10.89, $p > .05$	507.94	.08	.65

Additional Analyses and Summary of the Logistic Regression Analyses

Finally, logistic regression analyses were used to assess how students' high school mathematics grade point average (MGPA) impacted students' success in Precalculus, College Algebra, and Intensive College Algebra. Additionally, students' high school grade point average (GPA) was also investigated as to its ability to predict students' success. Previous research results suggested that secondary coursework substantially influences students' readiness for college-level mathematics (Ma & McIntyre, 2005; Ma & Wilkins, 2007; Roth et al., 2001). Students who take more mathematically intensive courses in high school were found to be more prepared for postsecondary mathematics. In addition, Trusty and Niles (2003) found that students' secondary mathematics coursework was an indicator of whether those students entering postsecondary education would complete their bachelor's degree.

Currently, students' MGPA or GPA is not considered in the UNF mathematics placement process. Because of this, each of the two variables was considered separately from the placement process variables for each of the three courses. The significance of the independent variable MGPA or GPA was tested; logistic regression model comparisons included the Hosmer-Lemeshow goodness-of-fit test, Akaike's Information Criterion (*AIC*), the coefficient of determination R^2, and the *c* statistic.

A one-predictor logistic model was fitted to the data to explore the relationship between the likelihood of students' success in Precalculus, College Algebra, and Intensive College Algebra and students' high school GPA. In all three courses, the analyses showed that the independent variable GPA was found to be significant ($p < .01$). The results for Precalculus are presented in Table 29; the results for College Algebra are presented in Table 30. The results for Intensive College Algebra are presented in Table 31. The logistic regression results indicated that the model with students' high school GPA was appreciably better than the model that included the two independent variables, PL, and FPR ($n = 881$). The test statistics for Precalculus, College Algebra, and Intensive College Algebra show that Akaike's Information Criterion is substantially lower for every course, the coefficient of determination R^2 is higher, and the *c* statistic is higher for all three courses.

Additionally, a one-predictor logistic model was fitted to the data to investigate the relationship between the likelihood of students' success in Precalculus, College Algebra, and Intensive College Algebra and students' high school mathematics GPA. The results for Precalculus are presented in Table 29; the results for College Algebra are presented in Table 30. The results for Intensive College Algebra are presented in Table 31. In all three courses, the analyses showed that the independent variable MGPA was found to be significant ($p < .01$); however, the logistic regression results cannot be compared to the other logistic regression models because the data sets are not identical.

In summary, the overall results of the logistic regression analyses indicated that measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support that the three variables are strong predictors of students' success in those courses. The independent variable MPE was consistently found to be significant in every logistic regression analysis conducted for each of the three courses ($p < .01$). The current cut scores for the mathematics placement exam seem to be problematic in correctly placing students; for example, out of the successful Precalculus students who had MPE scores, 60% had scores below the minimum score for Precalculus. The results of the research indicated that adjusting the cut scores for the UNF mathematics placement exam might more accurately predict students' success in Precalculus and College Algebra. The independent variable FPR was found to be statistically significant only for Precalculus ($p < .05$); it was not found to be statistically significant for College Algebra or Intensive College Algebra. The independent variable PL was not found to be significantly associated with students' success in any of the three courses, Precalculus, College Algebra, or Intensive College Algebra ($p > .05$). In the next section of this chapter, some psychometric properties of the UNF mathematics placement exam were investigated.

Psychometric Analyses of the UNF Mathematics Placement Exam

The second research question of the present study was: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? To answer this question, some preliminary psychometric properties of the data obtained from using the UNF mathematics placement exam were assessed using SAS 9.2 statistical software.

The MPE used in the present study was a 40-question, multiple-choice test that was taken online by incoming freshmen students prior to orientation. Students were given one hour to complete the exam. The test was taken and scored through Blackboard. Blackboard is a software tool used by many educational institutions to facilitate teacher-student communication and enhance student learning. The questions on the exam covered concepts and topics from both elementary and intermediate algebra. Most items were of medium difficulty, but a few items were more difficult because the MPE was used to determine students' eligibility for both algebra and precalculus courses at UNF. The mathematics placement exam had not been assessed for the reliability or validity of the data obtained from it to correctly place students in algebra and precalculus courses. Some of the 2011 MPE item scores (n = 959) were obtained through the UNF Center for Instruction and Research Technology.

Two essential psychometric properties to consider when using an instrument are the reliability and validity of the data obtained from it. As Johnson and Christensen (2004) explained, "Reliability refers to the consistency or stability of the test scores, and validity refers to the accuracy of the inferences or interpretations you make from the test scores" (pp. 132-133). A student's score on the MPE test was the number of items the student answered correctly. The reliability and validity of the test are dependent upon the "properties of the individual items which make up the test" (Magnusson, 1967, p. 197).

To assess the data's reliability, item scores of the UNF mathematics placement exam were analyzed. Item analysis includes determining item difficulty, item discrimination, and item-test correlation (Crocker & Algina, 1986; Wiersma & Jurs, 1990). Item difficulty is simply defined as the proportion of students who responded to the question correctly to the total number of students who completed the test (Wiersma & Jurs, 1990). The items on the MPE are multiple choice, but the exam is scored dichotomously. Questions answered correctly are given a score of 1; incorrectly answered items are given a score of 0. The item difficulty value for item *i* is generally denoted as p_i (Crocker & Algina, 1986) and takes on values from 0 to 1. Items with p_i values near 0 are too easy; items with p_i values near 1 are too difficult. Items with p_i values near 0 and 1 provide no useful discriminating information (Crocker & Algina, 1986; Rust & Golombok, 2009). Items with difficulty values near $p_i = .5$ will maximize the item variance and are preferred (Crocker & Algina, 1986; Rust & Golombok, 2009). However, Crocker & Algina (1986) recommended that the p_i value be adjusted for multiple choice items, because some students will answer the question correctly simply by guessing. They recommended that optimal item difficulty to maximize the variance is given by $p_i = .5 + .5/m$ where m is the number of possible responses per item. On the UNF mathematics placement exam, each item has 5 possible responses; the optimal item difficulty is $p_i = .5 + .5/5 = .6$. Item difficulty values and item variances were found for each of the 40 questions on the MPE. This information is presented in Table 27.

The easiest questions on the UNF mathematics placement exam are 1, 4, 11, 14, 17, 26, 28, and 30. These items are between .20 and .25 above the optimal difficulty value of $p_i = .6$ and are not balanced with the same quantity of more difficult questions. Only two of the items, 29 and 39, are between .20 and .25 below the optimal difficulty value. However, there is one question, number 33, that is considerably below the optimal difficulty value with a value of $p_i =$ .17.

Item discrimination can be calculated in a number of different ways, "with different practitioners having their own special preferences" (Rust & Golombok, 2009). The calculation of item discrimination used in this study was introduced by Kelley (1939) and is supported by

Magnusson (1967), Crocker and Algina (1986), and Wiersma and Jurs (1990). The students' MPE scores were first sorted in ascending order. These scores were then used to divide them into three categories; the students who scored in the upper 27% (n = 259) were designated the upper group; the students who scored in the lower 27% (n = 259) were designated the lower group. The remaining students' scores were not used to calculate the item discrimination value. Kelley (1939) found that separating the students' scores into these three categories is "optimal for the study of test items" (p. 24). The item discrimination index is given by $D_i = p_{upper} - p_{lower}$. The values p_{upper} and p_{lower} are the proportion of students in each group who answered the question correctly.

Ebel and Frisbie (1986) suggested the following guidelines for assessing item discrimination: items with discrimination values .40 and greater are considered to be very good items; values from .30 to .39 indicate reasonably good items; items with discrimination values from .20 to .29 are considered to be marginal items; values below .19 implies that the items are poor. These guidelines are also supported by Crocker and Algina (1986), and Wiersma and Jurs (1990). Item discrimination indices were calculated for each of the 40 test questions on the UNF mathematics placement exam. This information is presented in Table 32.

Table 32

Item Analysis for the UNF Mathematics Placement Exam

Question Number	Item Difficulty	Variance	Item Discrimination	Item-Test Correlation
1	.83	.14	.36	.40
2	.79	.17	.29	.28
3	.60	.24	.57	.46
4	.80	.16	.37	.37
5	.45	.25	.44	.34
6	.76	.18	.37	.38
7	.69	.21	.53	.45
8	.59	.24	.57	.45
9	.70	.21	.44	.40
10	.45	.25	.25	.24
11	.80	.16	.34	.36
12	.48	.25	.59	.45
13	.54	.25	.56	.42
14	.80	.16	.47	.49
15	.54	.25	.51	.40
16	.77	.18	.43	.44
17	.81	.15	.40	.42
18	.54	.25	.65	.51
19	.46	.25	.47	.35
20	.67	.22	.49	.42
21	.79	.16	.35	.35
22	.63	.23	.36	.30
23	.69	.22	.44	.40
24	.67	.22	.54	.47
25	.43	.25	.37	.29
26	.83	.14	.25	.30
27	.77	.18	.45	.43
28	.83	.14	.40	.47
29	.36	.23	.28	.23
30	.82	.15	.41	.46
31	.77	.18	.47	.49
32	.69	.22	.47	.43
33	.17	.14	.37	.40
34	.72	.20	.53	.46
35	.65	.23	.52	.43
36	.53	.25	.48	.37
37	.49	.25	.60	.48
38	.50	.25	.22	.18
39	.37	.23	.66	.53
40	.59	.24	.52	.42

Using Ebel and Frisbie's (1986) guidelines, none of the items had discrimination indices that would categorize them as poor questions. However 5 of the items had discrimination values below .30; these are questions 2, 10, 26, 29, and 38. Ebel and Frisbie (1986) suggested that questions with discrimination values between .20 and .29 are considered to be marginal and should be revised and improved. Nine of the items are considered to be good questions; 27 questions on the UNF mathematics placement exam are considered to be very good.

Item-test correlation tests how well each item correlates to the total score (Kline, 2000; Magnusson, 1967). The Pearson product moment correlation coefficient is generally used (Kline, 1998; Wiersma & Jurs, 1990). However, when the test questions are scored dichotomously, the point biserial correlation (r_{pb}) is often used (Crocker & Algina, 1986). This item-test correlation was calculated for each of the 40 questions on the MPE. This information is presented in Table 32. Five questions had correlation values below .30; these are questions 2, 10, 25, 29, and 38. Kline (2000) recommended item-test correlations of .30 or higher; Crocker & Algina (1986) suggested item-test correlation values should be above .15. Four of these 5 items were also considered to be marginal because of their low discrimination values.

The method used to measure the internal consistency reliability of the UNF mathematics placement exam was the coefficient alpha procedure. Coefficient alpha was computed to measure the internal consistency reliability of the instrument. Johnson and Christensen (2004) explained that coefficient alpha gives the degree to which the items on the test are interrelated. The coefficient alpha formula was developed to improve on an earlier technique called the split-half method developed by Charles Spearman to measure the internal consistency reliability of an instrument (Cronbach & Shavelson, 2004). The split-half method divided a test into two parts; Spearman developed a formula to estimate the correlation between the two half-tests. Kuder and Richardson improved on this method by developing a set of formulas "that attempted to cut through the confusion caused by the multiplicity of possible splits" (Cronbach & Shavelson, 2004, p. 396). One of these formulas was named K-R 20; this formula was used when test items were scored one and zero. Cronbach later developed the formula for coefficient alpha which "gave a result identical with the average coefficient that would be obtained if every possible split of a test was made and a coefficient calculated for every split" (Cronbach & Shavelson, 2004, p. 396). In addition, the formula was identical to K-R 20 when it was applied to test items scored dichotomously. Crocker and Algina (1986) explained that coefficient alpha "is not a direct estimate of the reliability coefficient but rather an estimate of the lower bound of that coefficient" (p. 142). The value of coefficient alpha for the MPE was $r_a = .86$. Cronbach and Shavelson (2004) emphasized that coefficient alpha "is now seen to fit within a much larger system of reliability analysis" (p. 416).

To assess the equivalent forms reliability of the instrument, three members of the faculty of the UNF Department of Mathematics and Statistics were asked to verify the equivalency of the six versions of each question of the MPE. A different version of each question is actually the exact same question with the numbers changed. The different versions of the UNF mathematics placement exam were found to be equivalent.

The second important property to consider when using an instrument is the validity of the data obtained from using that instrument. Messick (1990) defined validity as "an integrated evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based on test scores" (p. 5). Ebel and Frisbie (1986) explained that there are two aspects to validity; the first is "what is measured" and the second is "how precisely it is measured" (p. 89). Evidence that supports validity can be categorized as content validity, criterion validity, and construct validity; Ebel and Frisbie (1986) emphasized that these should not be considered as types of validity but as types of validity evidence. Messick (1980) explained that content validity encompasses content relevance and content coverage; criterion validity includes the predictive utility and diagnostic utility of the instrument. Construct validity "is based on an integration of any evidence that bears on the interpretation or meaning of the test scores" (Messick, 1990, p. 18). Construct validity includes both content-related evidence and criterion-related evidence (Messick, 1990). Messick (1990) emphasized that "construct validity of score meaning is the integrating force that unifies validity issues into a unitary concept" (p. 29).

Evidence for the instrument's content validity was examined. Six faculty members of the Department of Mathematics and Statistics at UNF were asked to verify the content validity of the mathematics placement exam. Additionally, the chair of the UNF Department of Mathematics and Statistics contacted faculty from Jacksonville University; they were also asked to verify the content validity of the MPE. If an instrument has content validity, the test questions "adequately represent the construct domain of interest" (Johnson & Christensen, 2004). The content validity of the exam was verified by five faculty members at UNF and the participating faculty members of Jacksonville University. The response e-mail from the faculty at Jacksonville University is presented in Appendix B. However, one UNF professor found some of the test items to be too difficult and provided some suggestions for revising the MPE to more accurately assess students' readiness for college level algebra and precalculus courses at UNF. This information is presented in Appendix C.

In addition, the instrument was analyzed to determine if exam scores differentiate between groups known to differ. Students' scores from two subsets of the data were compared; one of the subsets included freshmen students who enrolled into one of the three entry-level courses in the algebra strand offered at UNF. These three courses are Precalculus, College Algebra, or Intensive College Algebra. The second subset consisted of students who enrolled in higher level mathematics coursework at UNF. Means and standard deviations were computed for students' ACT, SAT, FCPT, and MPE scores. In addition, means and standard deviations were calculated for students' high school GPA and MGPA. This information is presented in Table 33.

The mean and standard deviation for the constructed variable placement level (PL) was also calculated and included in Table 33. This variable was constructed using students' ACT, SAT, and FCPT scores. An incoming freshmen student's scores on these exams is one of the determining factors for mathematical placement at UNF. Students' ACT, SAT, and FCPT scores are used either with or without the MPE to determine mathematics placement. Most students do not take the FCPT; additionally, many students take the ACT or the SAT, but not both. However, any of the test scores by itself can meet the UNF minimum criteria for mathematics placement and can determine a student's eligibility to enroll in one of the three entry-level courses in the algebra strand offered at UNF.

Known groups evidence validity was verified by the descriptive statistics shown in Table 33. The mean of the UNF mathematics placement exam is substantially higher for students who enrolled in higher level mathematics courses ($M = 30.18$) than for students who enrolled in UNF algebra and precalculus courses ($M = 24.38$). This pattern also holds true for students' ACT and SAT scores; the reliability and validity of the data obtained from those two assessments have been verified (ACT, Inc., 2008; Bettinger & Long, 2009; Donovan & Wheland, 2008; Kobrin et al., 2008; Moses et al., 2011).

Table 33

Comparison of Sample Means and Standard Deviations for Students in Algebra/Precalculus versus those in Higher Level Mathematics

	Algebra/ Precalculus *n*=1,833			Higher level mathematics *n*=277		
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*
ACT	908	23.93	2.55	106	25.40	2.91
SAT	931	575.28	53.86	171	638.36	56.07
FCPT	8	81.13	16.97	0	-	-
MPE	1,660	24.38	6.07	243	30.18	5.71
GPA	1,833	3.61	0.47	277	4.05	0.54
MGPA	1,381	2.81	0.57	210	3.28	0.57
PL	1,833	3.51	1.23	277	4.35	1.03

In summary, the results of the psychometric analyses of the UNF mathematics placement exam indicated that the data obtained from using the instrument is relatively reliable and valid. The results of the item analysis suggested that some of the questions might need to be revised but 77.5% of the questions fall within .20 of the optimal difficulty value of p_{i} = .60 and 87.5% of the items had good discrimination indices. In addition, 87.5% of the questions were found to have good correlation with the test ($r_{pb} > .30$). The items that should likely be improved were below recommended values in at least two of the above item analysis tests, item difficulty, item discrimination, and item-test correlation. These are questions 2 ($p_i = .79$, $D_i = .29$, $r_{pb} = .28$), 10 ($p_i = .45$, $D_i = .25$, $r_{pb} = .24$), 26 ($p_i = .83$, $D_i = .25$, $r_{pb} = .30$), 29 ($p_i = .36$, $D_i = .28$, $r_{pb} = .23$), and 38 ($p_i = .50$, $D_i = .22$, $r_{pb} = .18$). The coefficient alpha reliability statistic indicated that the scores are internally consistent ($r_a = .86$). Equivalent forms reliability of the MPE was also verified. In addition, evidence was also found to support the content validity and the known groups evidence validity of the UNF mathematics placement exam.

However, the predictive validity of the UNF mathematics placement exam scores does not seem to be supported; the ability of students' MPE scores to predict their success in those courses was not supported by the logistic regression analyses. The current cut scores seem to be problematic in accurately placing students; for example, out of the successful Precalculus students who had MPE scores, 60% had scores that deemed the students ineligible to take Precalculus. The results of the research indicated that adjusting the cut scores for the UNF mathematics placement exam might more accurately predict students' success in Precalculus and College Algebra.

Summary

This chapter presented the data analyses that were used to answer the research questions of the present study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra?

Logistic regression analysis was the statistical technique employed to analyze the data; SAS version 9.2 was the software used to perform the statistical analyses. The overall results of the logistic regression analyses indicated that measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support that the three variables are strong predictors of students' success in those courses. The independent variable MPE was found to be statistically significant in every logistic regression analyses conducted for each of the three courses ($p < .01$).

The independent variable MPE in the logistic regression analyses is the UNF mathematics placement exam; a psychometric analysis of the data obtained from using the MPE was also conducted as part of the present study. The results of the analyses supported the internal consistency reliability and equivalent forms reliability of MPE scores. In addition, evidence was found to support the instrument's content validity and known groups evidence validity. However, the predictive validity of the UNF mathematics placement exam was not supported by the results of the research; the ability of students' MPE scores to predict their success in those courses was not supported by the logistic regression analyses.

The final chapter will address the research questions and present a discussion of the findings of the study. The limitations of the study will also be discussed. The chapter will also include recommendations for educational leaders who are making and implementing placement procedures in postsecondary education. The chapter will conclude with recommendations for future research in this area.

Chapter V: Summary, Conclusions, and Recommendations

Faculty and administrators at many colleges and universities in the United States are trying to find the most effective means of correctly placing students into appropriate college-level courses. Upon admission to a higher education institution, students often have to take one or more placement exams to ascertain whether they are academically prepared to be successful in college-level courses (Kirst, et al., 2004). Some colleges and universities use the scores from SAT, ACT, and AP exams as placement exams in many subject areas to decide students' placement into entry level college courses. In contrast, other postsecondary institutions use placement exams developed by their departmental faculty (Fraunholtz & Latterell, 2006; Latterell & Regal, 2003; Marshall & Allen, 2000). Many universities "were not confident that their placement processes met students' needs, and few conducted research regarding the efficacy of placement processes" (Kirst et al., 2004, p. 287).

The importance and relevance of mathematics literacy in high school graduates is becoming increasingly more evident. At the same time, many postsecondary institutions are finding that although students are taking more mathematics courses in high school than before, they are also increasingly placed into remedial mathematics when they enter college (Gordon, 2008). In postsecondary education, college algebra is the lowest-level mathematics course in the algebra strand for which students can receive college credit. College algebra is commonly a prerequisite course for students majoring in mathematics, business, engineering, and the sciences. It is critical that mathematics placement procedures at postsecondary institutions be as correct and efficient as possible to ensure a smooth progression for students from high school to college.

The conceptual framework for the present research study focused on students' smooth transition from secondary education to postsecondary education. The mathematics placement process is the juncture for students from secondary to postsecondary mathematics coursework. This study explored the efficacy of the mathematics placement process for incoming freshmen at UNF. The aim of this placement process is to accurately place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their intended major. It is imperative that mathematics placement procedures be as correct and efficient as possible.

The following research questions guided the study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra? Effectiveness is defined as the percentage of students who successfully complete the mathematics course they were placed into by the UNF placement process. Precalculus, College Algebra, and Intensive College Algebra are the three entry level mathematics courses in the algebra strand offered at UNF.

This chapter begins with a summary of the present study, its findings, and its limitations. The research questions of the study will also be addressed. The chapter will then include the conclusions drawn from the study and recommendations based on the study's identified conclusions. The chapter will conclude with recommendations for future research and the study's conclusion.

Summary of the Study

This quantitative, retrospective research study explored the effectiveness of the mathematics placement process at UNF for incoming freshmen. The study investigated whether freshmen students' success in their first mathematics course at UNF can be predicted by the test scores used in the placement process. The study examined the relationship between the test scores used in the mathematics placement process and freshmen success in their first mathematics course at UNF. The placement process included students' SAT, ACT, FCPT, and UNF mathematics placement exam scores. The psychometric soundness of the data obtained from using the UNF MPE was also investigated. The specific courses under consideration in the present study are Precalculus, College Algebra, and Intensive College Algebra. Students earning a grade of C or better were considered to have successfully completed the course. In the following section, the findings from the statistical analyses completed on the UNF mathematics placement process will be summarized.

Findings from the Logistic Regression Analyses

The data source for the study was the freshmen students of 2010 and 2011 at UNF. The population consisted of incoming freshmen who first enrolled in a mathematics course at UNF in either the fall semester of 2010 or 2011(N = 3,804). Three subgroups of the population were analyzed; students enrolling in Precalculus (n = 454), College Algebra (n = 881), and Intensive College Algebra (n = 504) in either the fall semester of 2010 or 2011 comprised the three subsamples for the analyses.

Binary logistic regression was selected as the method for analyzing the effectiveness of the UNF mathematics placement process in predicting students' success in their first mathematics course in the algebra strand of courses. The dependent variable in this study was a binary categorical variable based on the student's success or non-success in completing Precalculus, College Algebra, or Intensive College Algebra. The independent variables in this study were students' mathematics placement exam (MPE) raw scores, placement level (PL), and whether or not students followed the placement recommendation (FPR). PL and FPR were categorical variables; MPE was a metric variable; it was the student's raw score on the UNF mathematics placement exam.

The overall results of the logistic regression analyses indicated that measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support that the three variables are strong predictors of students' success in those courses. The independent variable MPE was found to be statistically significant in every logistic regression analyses conducted for each of the three courses in the algebra strand at UNF ($p < .01$). On the other hand, the independent variable PL was not found to be statistically significant in any of the logistic regression analyses. The independent variable FPR was only found to be statistically significant in the logistic regression analysis for Precalculus ($p < .05$).

For Precalculus, the odds ratio for MPE means that for each one unit increase in students' MPE score, there is a 14% increase in the predicted odds of students' success (OR = 1.144, $p < .01$). However, the low value of $R^2 = .09$ indicated that the logistic regression equation is not a good predictor of students' success in Precalculus. The *c* statistic was also calculated as $c = .712$; this means that for 71.2% of all pairs of students, one successful and the other not, the model correctly assigned a higher probability to successful students. The classification table showed that with the probability cutoff of 0.50, the model correctly predicted 77.0% of successful Precalculus students.

The logistic regression results for College Algebra indicated that MPE was the only independent variable that was statistically significant ($p < .01$). The odds ratio for MPE indicated that for each unit increase in MPE scores, there is a 10% increase in the predicted odds of students' success (OR = 1.103, $p < .01$) in College Algebra. In addition, the Hosmer-Lemeshow test suggested that the logistic regression model was not a good fit to the data ($p < .01$). In assessing the model for predictive accuracy and association, R^2 and the *c* statistic were calculated for College Algebra students. The value of $R^2 = .06$ indicated that the logistic model is not a good predictor of students' success in this course. To measure association, the value of the *c* statistic was found to be $c = .643$; this means that for 64.3% of all pairs of students, one successful and the other unsuccessful, the model accurately assigned a higher probability to successful students. The results showed that with the probability cutoff of 0.50, the model accurately predicted 75.9% of successful students in College Algebra.

The results of the logistic regression analysis for Intensive College Algebra show that MPE was the only variable that was statistically significant ($p < .01$) in predicting students' success in 2010 and 2011. For each unit increase in MPE scores, there is a 13% increase in the predicted odds of students' success (OR = 1.131, $p < .01$). A value of $R^2 = .06$ indicated that the logistic regression equation is not a good predictor of students' success. The *c* statistic was calculated to be $c = .653$; this means that for 65.3% of all pairs of students, one successful and the other unsuccessful, the model correctly assigned a higher probability to successful students. The results indicated that with the probability cutoff of 0.50, the model correctly predicted 61.6% of successful students in Intensive College Algebra.

One of the two research questions that guided the study was how effective the mathematics placement process at UNF was in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra. Effectiveness is defined as the percentage of students who successfully complete the mathematics course they were placed into by the UNF placement process. Students enrolling in Precalculus in either the fall semester of

2010 or 2011 (n = 454) had a success rate of 76.43%; College Algebra students (n = 881) had a success rate of 73.89%. Students in Intensive College Algebra (n = 504) had a success rate of 60.32%.

Of the three independent variables in the logistic regression equation, MPE, FPR, and PL, only MPE was found to be statistically significant in every one of the analyses (p < .01). FPR was only found to be statistically significant in the logistic regression equation for Precalculus. However, none of the analyses supported that the three variables were predictors of students' success in any of the three courses in the algebra strand at UNF; the values for R^2 were all too low. These results suggest that the mathematics placement process at UNF is not very effective in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra. The analyses verified that there is a small to medium association between students' MPE scores and their success in Precalculus , College Algebra, and Intensive College Algebra (p < .05; Cramer's V = .27, .28, and .16, respectively).

Adjusting placement cut scores for the UNF mathematics placement exam might be one way to more accurately predict students' success. When the cut score categories for Precalculus were adjusted to those greater than or equal to 27 and those less than 27, students' whose MPE scores deemed them eligible for Precalculus have a success rate of 86.4%; ineligible students' success rate is 60.0%. In addition, the percentage of successful Precalculus students who had scores greater than or equal to 27 increased to 74% (χ^2 [df = 1] = 37.39, p < .01, phi = .30); the percentage of qualified Precalculus students was increased from 36% to 67%.

Cut scores for College Algebra might also be adjusted. For example, suppose that cut scores were categorized according to those greater than or equal to 23 and those less than 23. With the modified cut score of 23, the success rate for eligible students based on the modified cut scores is 80.3% versus a 58.3% success rate for ineligible students (χ^2 [*df* = 1] = 39.22, $p < .01$, phi = .22). In addition, the percentage of eligible College Algebra students using the new cut scores is increased from 63% to 74%.

In summary, the results of the logistic regression analyses showed that measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support the conclusion that the three variables are strong predictors of students' success in those courses. Overall, the results suggest that the mathematics placement process at UNF is not very effective in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra. In the next section, the findings of the psychometric analyses of the UNF mathematics placement exam will be presented.

Findings from the Psychometric Analyses

The independent variable MPE was consistently found to be significant in every logistic regression analyses conducted for each of the three courses in the algebra strand at UNF. Frequency tables and chi-square tests of homogeneity and measures of association supported that there is a significant relationship between students' MPE scores and their success in Precalculus (χ^2 [*df* = 1] = 13.23, $p < .01$, phi = .18), College Algebra (χ^2 [*df* = 1] = 31.34, $p < .01$, phi = .20), and Intensive College Algebra (χ^2 [*df* = 1] = 6.86, $p < .01$, phi = .12). The other research question addressed in the study was how reliable and valid the data obtained by the UNF mathematics placement exam were.

The reliability and validity of the data obtained from using the UNF mathematics placement exam were also assessed as part of the present research study. The MPE used in the present study was a 40-question, multiple-choice test that was taken online by incoming freshmen students prior to orientation. Students were given one hour to complete the exam. The questions on the exam covered concepts and topics from both elementary and intermediate algebra. The mathematics placement exam had not been assessed for the reliability or validity of the data obtained from it to correctly place students in UNF algebra and precalculus courses. Some of the 2011 students' MPE item scores (n = 959) were obtained through the UNF Center for Instruction and Research Technology. A student's score on the MPE test was the number of items the student answered correctly.

The results of the psychometric analyses of the UNF mathematics placement exam indicated that the data obtained from the instrument for the present study are relatively reliable and valid. The results of the item analysis indicated that some of the questions might need to be revised but 77.5% of the questions fell within .20 of the optimal difficulty value of .60 and 87.5% of the items had good discrimination indices. In addition, 87.5% of the questions were found to have good correlation with the test using the point biserial correlation ($r_{pb} > .30$). The coefficient alpha reliability coefficient was also calculated and supported that the instrument possesses internal consistency reliability ($r_a = .86$). Equivalent forms reliability of the MPE was also verified by three members of the faculty of the UNF Department of Mathematics and Statistics.

Some faculty members of the Department of Mathematics and Statistics at UNF and some faculty members from Jacksonville University were asked to verify the content validity of the mathematics placement exam. Evidence was found to support the content validity of the UNF mathematics placement exam. The response e-mail from the faculty at Jacksonville University is presented in Appendix B. However, one UNF professor found some of the test items to be too difficult and provided some suggestions for revising the MPE to more accurately assess students' readiness for college level algebra and precalculus courses at UNF. This information is presented in Appendix C.

Evidence was also found to support the known groups validity of the MPE. In the present study, the mean of the UNF mathematics placement exam is higher for students who enrolled in higher level mathematics courses (M = 30.18) than for students who enrolled in UNF algebra and precalculus courses (M = 24.38). This pattern also holds true for ACT and SAT scores; the reliability and validity of the data obtained from those two assessments have been verified (ACT, Inc., 2008; Bettinger & Long, 2009; Donovan & Wheland, 2008; Kobrin et al., 2008; Moses et al., 2011).

In conclusion, the results of the psychometric analyses supported the reliability and validity of the data obtained from using the UNF mathematics placement exam as part of the UNF mathematics placement process for placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra. The item analysis suggested that the MPE could be improved if some of the questions were revised or rewritten. However, the predictive validity of the UNF mathematics placement exam does not seem to be strongly supported; the ability of students' MPE scores to predict their success in those courses was not supported by the logistic regression analyses. The current cut scores seem to be problematic in accurately placing students; for example, out of the successful Precalculus students who had MPE scores, 60% had scores that deemed the students ineligible to take Precalculus. The results of the research indicated that adjusting the cut scores for the UNF mathematics placement exam might more accurately predict students' success in Precalculus and College Algebra.

Limitations of the Study

The present study explored the effectiveness of the mathematics placement process at the UNF for incoming freshmen. The placement process included students' SAT, ACT, FCPT, and UNF mathematics placement exam scores. The specific courses under consideration in the present study were Precalculus, College Algebra, and Intensive College Algebra.

One of the limitations of the present research study included the omission of students who did not take the UNF mathematics placement exam, but these students were few in number. All incoming freshmen were required to participate in UNF online mathematics placement testing prior to orientation. However, some students did register for a course without meeting this requirement. The percentage of Precalculus, College Algebra, and Intensive College Algebra students who completed the UNF mathematics placement exam was 89.87%, 89.78%, and 91.47%, respectively.

A delimitation of the study is that only two years of data were considered in this study. Another delimitation of the present study was its narrowness of scope; the focus was on students' mathematics placement. The mathematics placement process at postsecondary institutions is only one of the many contributing factors to students' retention and academic success. Students who are successful academically are more likely to persist in college and earn their degree. Degree completion by all students is the goal of college and university administrators for their institutions.

These limitations and delimitations permit generalizations to colleges and universities that are similar to UNF and have a comparable mathematics placement process.

Conclusions Drawn from the Study

The conceptual framework for the present research study focused on students' smooth transition from secondary education to postsecondary education. The mathematics placement process is the juncture for students from secondary to postsecondary mathematics coursework. This study explored the effectiveness of the mathematics placement process for incoming freshmen at UNF. Five conclusions were identified through the course of conducting the research and data analyses. These conclusions are related to the research questions that guided the study: How reliable and valid are the data obtained by the UNF mathematics placement exam (MPE)? How effective is the mathematics placement process at UNF in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra?

Postsecondary Education Institutions Vary in Their Placement Processes

The mathematics placement procedures at 171 colleges and universities having the same Carnegie classification as UNF were investigated by conducting an online query. Each university's website was explored in an attempt to discover what factors were considered in students' mathematics placement. The investigation into mathematics placement procedures at the 171 colleges and universities in the Carnegie 2010 Basic classification yielded the following results. Sixty-seven universities use a specific mathematics placement exam to determine students' placement into their first college-level mathematics course. Eighty-one colleges use SAT Math scores or ACT Math scores to help determine student placement in university mathematics courses. Seventy-eight of the institutions use a combination of SAT Math scores, ACT Math scores, and scores from a mathematics placement test to decide which college-level mathematics course is the most appropriate for incoming students. It seems evident that many colleges and universities in the United States are trying to find the most effective means of correctly placing their incoming students into the most appropriate college-level courses. In summary, a variety of different assessments, and combinations of different assessments, are used for mathematics placement in postsecondary education.

Students' MPE Scores are Related to their Success

Students' MPE scores are related to their success in Precalculus, College Algebra, and Intensive College Algebra. Frequency tables and chi-square tests of homogeneity and measures of association were used to investigate the relationship between students' success and MPE scores for Precalculus, College Algebra, and Intensive College Algebra. The analyses indicated a statistically significant ($p < .01$) relationship between students' MPE scores and their success. In addition, the independent variable MPE was found to be significant ($p < .01$) in the logistic regression model for all three courses.

Data Obtained from Using the UNF MPE is Relatively Reliable and Valid

The data obtained from using the UNF mathematics placement exam in the placement process was found to be relatively reliable and valid. To assess the data's reliability, an item analysis of the UNF mathematics placement exam was conducted. The results of the psychometric analyses of the UNF mathematics placement exam indicated that the data obtained from the instrument is relatively reliable and valid. The results of the item analysis indicated that some of the questions might need to be revised but 77.5% of the questions fall within .20 of the optimal difficulty value of .60 and 87.5% of the items had good discrimination indices. In addition, 87.5% of the questions were found to have good correlation with the test using point biserial correlation ($r_{pb} > .30$).

The method used to measure the internal consistency reliability of the UNF mathematics placement exam was the coefficient alpha procedure. The reliability coefficient alpha supported that the instrument possesses internal consistency reliability (r_a = .86). Equivalent forms reliability of the MPE was also verified by three members of the faculty of the UNF Department of Mathematics and Statistics.

In addition, evidence was found to support the content validity of the UNF mathematics placement exam. Evidence was also found to support the known groups validity of the MPE. However, the predictive validity of the UNF mathematics placement exam does not seem to be supported; the ability of students' MPE scores to predict their success in those courses was not supported by the logistic regression analyses.

The UNF MPE Can Be Improved

The UNF mathematics placement exam can be improved. Five items on the UNF MPE were below recommended item analysis values in at least two of the analysis tests, item difficulty, item discrimination, and item-test correlation. These are questions 2, 10, 26, 29, and 38. In addition, questions 1, 4, 11, 14, 17, 26, 28, and 30 were found to be more than .20 above the optimal value; questions 29, 33 and 39 were found to be more than .20 below the optimal value. These results indicate which questions could be revised to improve the UNF mathematics placement exam.

The UNF Mathematics Placement Process is Not Effective

The UNF mathematics placement process investigated in the present study included three independent variables, MPE, PL, and FPR. MPE was the students' raw score on the mathematics placement exam. PL was a categorical variable calculated using students' ACT, SAT, or FCPT scores. FPR was a binary variable coded according to whether or not students followed the placement recommendation. The binary dependent variable was coded according to whether or not students succeeded in their mathematics course.

Frequency data and chi-square tests of homogeneity and measures of association were conducted to investigate the relationship between students' success and FPR for each of the three courses. The results indicated that there is not a significant association between FPR and students' success in Precalculus or Intensive College Algebra. However, the results showed that there appeared to be an association between FPR and students' success in College Algebra. A similar analysis was conducted to explore the relationship between students' success and PL for each of the three courses. The analyses appeared to show that there is not a significant association between students' placement level and their success in Precalculus, College Algebra, or Intensive College Algebra.

The results showed that the independent variables MPE ($p < .01$) and FPR ($p < .05$) were statistically significant in predicting students' success in Precalculus in 2010 and 2011. However, the results indicated that MPE was the only independent variable that was statistically significant ($p < .01$) in predicting students' success in College Algebra and Intensive College Algebra. Measures of association were found between the independent variables MPE, PL, and FPR and students' success in the Precalculus, College Algebra, or Intensive College Algebra; however, the results did not support that the three variables used in the UNF mathematics placement process are strong predictors of students' success in those courses. The UNF mathematics placement process is not effective in accurately placing incoming freshmen into Precalculus, College Algebra, and Intensive College Algebra.

This section of Chapter 5 contained the conclusions drawn from the present research study. In the following section, the suggested recommendations for mathematics placement processes in postsecondary education will be addressed.

Recommendations for Postsecondary Placement Processes

Mathematics placement in postsecondary education needs to be accurate. The literature review for the present research study suggested that many colleges and universities are struggling with how to effectively place students into the most appropriate college-level mathematics course for them. These recommendations will first address the specifics of this case study at UNF. After that the recommendations will be broadened to address mathematics placement processes in postsecondary education.

Recommendations for UNF

In this case study of the mathematics placement process at UNF, the placement process was already in place. The standard assessments for determining students' readiness for courses in the algebra strand at UNF were the ACT, SAT, and FCPT. The mathematics placement exam was developed as a supplementary assessment to these standard assessments. Students' scores on the ACT, SAT, and FCPT could qualify them as eligible for Precalculus, College Algebra, or Intensive College Algebra. However, if students' ACT, SAT, or FCPT scores were not high enough, then students' scores on the UNF mathematics placement exam (MPE) would determine their eligibility for those courses.

The first recommendation suggested by the research is that some of the items of the UNF mathematics placement exam should be revised so that every exam item is within the chosen optimal range of difficulty. If the exam remains a multiple choice exam with 5 options for each answer, the optimal difficulty for each item is p_i = .60. The optimal difficulty range for all items could then be chosen to be from .40 to .80, for example.

The second recommendation is that for each item on the UNF mathematics placement exam, item analysis should include the item difficulty value (p_i), the variance, the item discrimination index (D_i), and the item-test point biserial (r_{pb}) correlation. Questions that do not conform to the acceptable values of $.40 < p_i < .80$, or $D_i > .30$, or $r_{pb} < .30$ should be rewritten or revised. The specific items that are most in need of improvement were below recommended values in at least two of the above item analysis tests, item difficulty, item discrimination, and item-test correlation. These are questions 2, 10, 26, 29, and 38. The UNF mathematics placement exam should be evaluated regularly using item analysis.

The third recommendation suggested by the research follows closely after the second; a thorough psychometric analyses of the data obtained by the UNF mathematics placement should be conducted regularly. In the present study, the UNF mathematics placement exam was found to have equivalent forms reliability; internal consistency reliability was supported using the coefficient alpha procedure ($r_a = .86$). In addition, evidence was found to support the content validity of the UNF mathematics placement exam. Evidence was also found to support the known groups validity of the MPE. However, the predictive validity of the UNF mathematics placement exam does not seem to be supported; the ability of students' MPE scores to predict their success in those courses was not supported by the logistic regression analyses. The psychometric analyses of the utility of the UNF mathematics placement exam should be complete and comprehensive.

The fourth recommendation is that cut scores should be analyzed each year as to their effectiveness in accurately categorizing students' placement. The cut scores that UNF used for the mathematics placement exam at the time of the present study seem to be problematic. For example, students who are considered eligible for Precalculus would have to be in the highest mathematics placement category; their MPE scores would be greater than or equal to 31. Out of the successful Precalculus students who had MPE scores, only 40% had scores greater than or equal to 31; 60% had scores below 31. Additionally, College Algebra students who were considered ineligible for that course, according to their MPE scores, had a higher rate of success at 63% than non-success.

The fifth recommendation suggested by the research is that the entire mathematics placement process at UNF needs to be more closely studied. The General Education Committee of the UNF Department of Mathematics and Statistics should review the entire mathematics placement procedure at the university and work with the Academic Center for Excellence in modifying the mathematics placement process to increase its effectiveness in accurately placing incoming freshmen into precalculus and algebra courses. In the analyses, the independent variable PL in the logistic regression equation is a categorical variable constructed using students' SAT, ACT, and FCPT scores. Students' SAT, ACT, and FCPT scores are used either with or without the MPE to determine mathematics placement. However, the variable PL was not found to be significant in any of the logistic regression analyses. Many postsecondary institutions use SAT Math scores or ACT Math scores to help determine student placement in university mathematics courses. Many of the colleges and universities in the state of Florida use the ACCUPLACER as the Florida College Placement Test (FCPT). The FCPT evaluates students' skills in arithmetic and elementary algebra to help determine their readiness for college-level mathematics. The results of this study suggest that students' SAT, ACT, and FCPT scores be excluded from the UNF mathematics placement process. The independent variable PL was not found to be statistically significant in any of the logistic regression analyses. In contrast, the independent variable MPE was found to be statistically significant in every logistic regression analyses conducted for each of the three courses in the algebra strand at UNF ($p <$

.01). The results suggest that the UNF mathematics placement exam should be used to assess students' college readiness for Precalculus, College Algebra, and Intensive College Algebra.

The research results suggest that mathematics placement exams constructed by the teaching faculty are a more appropriate placement tool than students' SAT, ACT, or FCPT test scores. In the logistic regression analyses, the independent variable MPE was consistently found to be significant for each of the three courses in the algebra strand at UNF. In addition, the chi-square analyses verified that there is a significant relationship between students' MPE scores and their success in Precalculus, College Algebra, and Intensive College Algebra. The results indicate that the teaching faculty who actually teach these courses are best equipped to construct appropriate placement assessments for these courses.

If this fifth recommendation is implemented, the participation of freshmen students who complete the MPE prior to freshmen orientation will have to be increased to 100%. The UNF Academic Center for Excellence has been very proactive in working toward this goal. The percentage of students who completed the UNF mathematics placement exam in 2010 was 87%; in 2011 the percentage had increased to 91%. The UNF mathematics placement exam should be a mandatory part of the placement process without exception; it should be taken in a proctored setting prior to freshmen orientation.

The mathematics placement process at UNF might also be modified to include students' high school mathematics GPA. The current mathematics placement process does not include students' GPA or their MGPA. The logistic regression models that included GPA or MGPA could not be adequately compared to the models that included MPE, PL, and FPR because the data sets were not identical. However, results from prior research indicated that secondary coursework considerably impacts students' readiness for college-level mathematics (Ma &

McIntyre, 2005; Ma & Wilkins, 2007; Roth et al., 2001). Students who complete more mathematically intensive courses in secondary education were more prepared for college level mathematics.

The final recommendation is that mathematics placement processes at UNF should be assessed regularly. It is important that mathematics placement procedures be as accurate and efficient as possible. Every independent variable in the mathematics placement process at a postsecondary institution should be investigated as to the extent of its contribution to the prediction of the dependent variable. The placement process should then be adjusted accordingly.

Marshall and Allen (2000) found in their study that the initial cutoff criteria used at their university did not yield good results. The mathematics placement standards were then adjusted; Marshall and Allen (2000) found that using the revised cutoff criteria for students' mathematics placement provided a high level of long-term predictive validity. Since 1999, the math faculty additionally made several more refinements to the mathematics placement cutoff criteria in an effort to improve on this success (Marshall & Allen, 2000).

The above recommendations for UNF can be broadened and generalized to all mathematics placement processes used in postsecondary education.

Recommendations for Higher Education Administrators and Faculty

Educational leaders and faculty that are involved in making and implementing mathematics placement processes at their universities have a responsibility to their incoming freshmen students that the placement be as accurate as possible. A variety of factors determine the placement of students into the most appropriate college mathematics class and the results of that placement. These factors include those aspects that may contribute to a student's mathematical achievement before their actual placement, the placement process itself, and the outcome of the placement procedure.

The first recommendation that the research suggests is that mathematics placement processes should be assessed consistently at every postsecondary institution as to their effectiveness. It is important that mathematics placement procedures in higher education be as correct and efficient as possible. Efficient mathematics placement processes should accurately predict students' success. Educational leaders, administrators, policy makers, advisors, and faculty should all be involved in the mathematics placement processes at their university. DeBerard et al. (2004) emphasized that "each student that leaves before degree completion costs the college or university thousands of dollars in unrealized tuition, fees, and alumni contributions" (p. 66).

The second recommendation is that every component in the mathematics placement process at a postsecondary institution should be analyzed as to its significance in predicting students' success. If different assessment instruments are used in the placement process, they should each be investigated as to their psychometric soundness; the reliability and validity of the data obtained from each instrument should be verified. A complete item analysis should be conducted for every testing instrument used. Assessing the cutoff criteria of these measures should also be part of the analyses. The statistical analyses should be complete and comprehensive. In addition, the analyses should be conducted on a regular basis.

The final recommendation suggested by the research is that the mathematics placement processes should be revised and adjusted on a regular basis; they should evolve to meet the needs of each university and its students. It is critical that mathematics placement procedures at colleges and universities be as correct and efficient as possible to ensure a smooth progression for students from secondary education to postsecondary education. The following section will contain the recommendations for future research.

Recommendations for Future Research

The present study was an investigation into the efficacy of the current mathematics placement process that was used at UNF during the years of 2010 and 2011. Mathematics placement procedures in postsecondary education need to be effective.

These recommendations for future research are suggested for higher education institutions that use placement processes in an attempt to accurately place their incoming students into entry level college mathematics courses.

A review of the literature included a number of studies of placement procedures in higher education. Researchers studied placement procedures at their colleges or universities in an attempt to determine the most effective means of accurately placing students into mathematics courses. The studies' findings were not in agreement. Matthews-Lopez (1998) found that using a combination of students' high school percentile ranks (HSPR) and ACT Math scores was just as successful in correctly placing students as using their mathematics placement test scores. Latterell and Regal (2003) concluded that the ACT was better at placing students than the university's placement exam. In contrast, Foley-Peres and Poirier (2008) found that using placement test scores more accurately placed students than using their SAT Math scores. Kirst et al. (2004) inferred that while many universities were not confident in the accuracy of their placement processes, few of them conducted research to ascertain their effectiveness in correctly placing students.

One recommendation for future research suggested by this study is that additional research of the efficacy of mathematics placement procedures in higher education is needed.

The second recommendation is an extension of the first; educational administrators and faculty who develop and implement placement processes should regularly assess them for the reliability and validity of the data obtained from them. Necessary modifications to the mathematics placement processes should be continually made to improve their effectiveness to better meet the needs of both the students and faculty in postsecondary institutions. Effective mathematics placement processes will accurately place students in the appropriate entry level college mathematics course; these students will then successfully complete the mathematics course with a grade of C or better.

In addition, future research should include a comparison of the effectiveness of mathematics placement exams at different universities. Some universities require that their placement exams be taken in a proctored setting; other postsecondary institutions have students complete the exam online.

Another suggestion for future research would include using students' high school GPA or students' high school mathematics GPA to determine students' placement. Prior research results suggested that secondary coursework influences students' readiness for college-level mathematics (Ma & McIntyre, 2005; Ma & Wilkins, 2007; Roth et al., 2001). Students who take more mathematically intensive courses in high school were more prepared for postsecondary mathematics. In addition, Trusty and Niles (2003) found that students' secondary mathematics coursework was an indicator of whether those students entering postsecondary education would complete their bachelor's degree.

Degree completion by all students is the objective of higher education administrators. The mathematics placement process must provide for a smooth transition for students from secondary to postsecondary mathematics coursework. However, this transition is just one factor in students' progression through higher education. Kirst (1998) suggested that educational "reform policies are moving secondary and postsecondary education in disparate directions" (p. 3). DeBerard et al. (2004) found that health and psychosocial factors were related to students' retention in higher education. Students' academic and social integration to the university were also found to influence students' retention (Coll & Stewart, 2008; Pascarella & Terenzini, 1983). Additional recommendations for future research include studies that focus on the many various factors that influence students' retention and degree completion.

Conclusion

This research study explored the effectiveness of the mathematics placement process for incoming freshmen at UNF. The goal of this placement process is to correctly place students into a mathematics course in which they will be successful and which will also move them closer to their graduation with a degree in their intended major. It is important that mathematics placement procedures be as correct and efficient as possible.

Five conclusions emerged as a result of the research study and the data analyses. Three conclusions were directly related to the UNF mathematics placement exam. The MPE was found to be related to students' success. In addition, the data obtained from using the MPE as part of the UNF mathematics placement process was found to be relatively reliable and valid. However, it was also found that the MPE was not an accurate predictor of students' success. But, more importantly, the results of the research indicate how the UNF mathematics placement exam can be improved. The results of the item analysis indicated which questions on the MPE should be revised or replaced. In addition, the modification of cut scores might improve the predictive validity of the UNF mathematics placement exam.

The fourth conclusion that was drawn from the study was that the UNF mathematics placement process was not an effective predictor of students' success. The results of the study point to possible revisions to the placement process that might improve its effectiveness and predictive accuracy. These possible modifications include eliminating students' ACT, SAT, and FCPT scores from the placement process; additionally, changing the cut scores of the UNF mathematics placement exam might improve the efficacy of the UNF mathematics placement process. The placement process might also be modified to include students' high school mathematics GPA. The first four conclusions that emerged from this case study pointed to specific recommendations for improving placement procedures at UNF and the necessary future research to analyze those procedures.

The final conclusion that was identified from the present research study is that mathematics placement procedures vary widely at colleges and universities across the United States. This conclusion reinforced the premise that these recommendations can be extended to all postsecondary institutions that have a mathematics placement process that includes one or more assessment instruments. Every component in the mathematics placement process at colleges and universities should be assessed as to its significance in predicting students' success; the reliability and validity of the data obtained from each instrument should be verified. Assessing the cutoff criteria of these measures should also be part of the analyses. The statistical analyses should be complete and comprehensive. In addition, the analyses should be conducted on a regular basis. The complete mathematics placement process should be revised and adjusted on a regular basis, as needed to better meet the needs of the students and faculty.

The findings of this study contribute to the knowledge base of assessing mathematics placement procedures in higher education. It is critical that mathematics placement procedures at colleges and universities be as correct and efficient as possible to ensure a smooth progression for students from secondary education to postsecondary education. Effective mathematics placement procedures at colleges and universities are the responsibility of university administrators, advisors, and faculty; they should all be involved in the development of the mathematics placement processes at their school. These processes should be assessed and modified, if needed, on a regular basis to better meet the needs of each university, its faculty, and its students. Educational leaders and faculty have a responsibility to their incoming freshmen students that the entire mathematics placement process in higher education be as effective as possible.

APPENDIX A

Waiver of Institutional Board Review

From: O'Connor, Dawn
Sent: Monday, May 14, 2012 3:23 PM
To: Simonson, Debora
Cc: Kasten, Katherine; Paulsen, Krista; Champaigne, Kayla
Subject: RE: requesting waiver of IRB review

Hi Debbie,

I'm touching base as a follow up to your inquiry about whether your project is defined as human subject research. Based on several emails (below), as outlined, this project is not human subject research as defined in 45 CFR 46. For more information, you will find the code of federal regulations via this link: http://ohsr.od.nih.gov/guidelines/45cfr46.html. Therefore, as outlined, review and approval by UNF's IRB is not necessary. Please let us know if activities for this project change (e.g., surveying people, collecting identifiable information) such that a new determination is necessary.

UNF's IRB thanks you for being conscientious and aware of the need for human subject in research protections. Please let us know if you have questions or if we can be of assistance in some way. We wish you much luck with this project!

Best Regards,

Dawn P. O'Connor
Research Integrity Assistant Director
Office of Research and Sponsored Programs
University of North Florida
1 UNF Drive
Building 3, Suite 2501
Jacksonville, FL 32224
Tele: 904.620.2316
Fax: 904.620.2457
Web: http://www.unf.edu/research/Research_Integrity.aspx

APPENDIX B

Letter from Jacksonville University faculty regarding Content Validity of the UNF Mathematics Placement Exam

From: Nancarrow, Mike
Sent: Friday, March 01, 2013 3:24 PM
To: 'd.simonson@unf.edu'
Cc: 'Hochwald, Scott'
Subject: Content Validity of Placement UNF Examination

Dear Ms Simonson,

As you requested, Dr. Crawford and I reviewed the UNF mathematics placement examination to help you in your efforts to demonstrate the content validity of the examination. Because Jacksonville University courses do not fall under the Florida common course numbering system, our algebra course prerequisites may not exactly be the same as those at UNF. Consequently, it is somewhat difficult for us to answer your question directly because we are not sure of precisely what knowledge and skills UNF expects incoming students to have for each of the three classes you listed in your letter.

The list you see below contains our observations of what is being measured by the placement examination. If the list matches what the UNF mathematics department is trying to measure, then the instrument is valid. We suggest you discuss the list with Dr. Hochwald to make sure what he is trying to measure is listed. Because our survey of the examination is somewhat subjective, it may be possible that there are areas the department is trying to measure that we haven't listed. In that case, please contact us and we will be glad to reexamine the instrument to verify that the missing areas can be added to the list.

- constructing and using algebraic models given a verbal description
- evaluating expressions given inputs
- factoring equations and expressions
- knowledge of absolute values
- knowledge of linear functions and their graphs
- knowledge of perpendicular line properties
- knowledge of quadratics and their graphs
- knowledge of radical expressions
- knowledge of rational expressions
- long division
- manipulating fractions
- simplifying compound fractions
- simplifying expressions
- solving 2-dimensional linear systems
- solving equations containing radicals
- solving equations with rational expressions
- solving inequalities
- solving quadratics
- understanding properties of linear equations
- using order of operations

- using the rules for exponents

Best wishes,

Mike Nancarrow, Ph.D.
Chair, Institutional Review Board
Associate Professor of Mathematics
Jacksonville University
Suggestions from UNF faculty member on improving the current UNF mathematics placement exam:

APPENDIX C

Suggested revisions to the UNF mathematics placement exam from a UNF faculty member

The faculty member considered three of the forty questions to be too difficult. The faculty member also suggested that seven additional questions be replaced.

Faculty member's suggestions regarding the three questions considered to be too difficult:

The first question required students to simplify a rational expression that included variables with both positive and negative exponents. The faculty member suggested that a simpler rational expression be provided that did not include negative exponents.

The second question required students to solve a word problem that involved combining two varied strength alcohol solutions to get a single alcohol solution of the required quantity and strength. The faculty member suggested replacing the word problem with a rational expression that contained radicals. Students would be required to simplify the expression.

The third question required students to simplify a rational expression that included the sums of variables with negative exponents. The faculty member suggested replacing this question with a rational expression that included imaginary units and requiring students to simplify the expression.

Faculty member's suggestions for replacing existing questions:

The first question required students to solve an equation that contained rational expressions. The faculty member suggested that students should be required to simplify the difference of two terms containing radicals.

The second question required students to complete a long division problem with polynomial expressions. The faculty member suggested students simplify a rational expression that included radicals.

The third question required students to simplify a rational expression with polynomial terms. The faculty member suggested students simplify a rational expression with variables with exponents.

The fourth question required students to factor a four term polynomial expression. The faculty member suggested replacing the question with a problem that required students to factor the difference of two squares.

The fifth question required students to solve a word problem that included two investments. The faculty member suggested replacing it with a problem that required students to find the GCF of a polynomial with three terms.

The sixth question required students to solve a quadratic inequality. The faculty member suggested replacing it with a problem that required factoring a trinomial.

The final question required students to solve an equation with a cubic trinomial. The faculty member suggested requiring students to solve a linear equation that contained fractions.

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VITA

Debora Jean Chwierut Simonson

CURRENT POSITION

- *Instructor of Mathematics – 2006 to Present*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

EDUCATION

- *Doctor of Education in Educational Leadership*
  University of North Florida, Jacksonville, Florida
  Graduated August 2013, GPA: 3.85/4.00
  Dissertation Title: *Postsecondary placement processes: A case study at a regional university.*
  Advisors: Dr. Kathe Kasten, Dr. Donna Mohr, Dr. Warren Hodge, Dr. Daniel Dinsmore

- *Master of Science in Mathematical Sciences*
  University of North Florida, Jacksonville, Florida
  Graduated August 2003, GPA: 3.65/4.00
  Thesis Title: *Fractal image compression*
  Advisors: Dr. Scott Hochwald, Dr. Dan Dreibelbis, Dr. Peter Braza
  Outstanding Graduate Student 2003-2004

- *Bachelor of Science in Mathematics with a Minor in Computer Science*
  University of North Florida, Jacksonville, Florida
  Graduated December 1999, GPA: 3.52/4.00

- *Associate of Science in Mathematics*
  Santa Rosa Junior College, Santa Rosa, California
  Graduated May 1996, GPA: 3.83/4.00

- *Associate of Arts in General Education*
  Santa Rosa Junior College, Santa Rosa, California
  Graduated May 1996, GPA: 3.83/4.00

TEACHING EXPERIENCE

- *Instructor of Mathematics – 2006 to Present*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

- *Quest (Quality for the Ultimate Educational Success Today) Mathematics Instructor – Summer 2010, 2011, and 2012*
  University of North Florida Intercultural Center for PEACE
  Jacksonville, Florida

- *Visiting Instructor of Mathematics – 2003 to 2006*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

- *Academic Potential Program Instructor – Summer 2003*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

- *Graduate Teaching Assistant – 2001 to 2003*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

- *Academic Potential Program Recitation Instructor – Summer 2001, 2002*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

- *Teacher of Mathematics – 2000 to 2001*
  William Raines High School, Duval County Schools
  Jacksonville, Florida

- *Summer Camp Teacher – Summer 2000*
  University of North Florida Mathematics and Statistics Department
  Jacksonville, Florida

TEACHING HIGHLIGHTS

- *University of North Florida Mathematics and Statistics Department*
  Elementary Algebra, Intermediate Algebra, Intensive College Algebra, College Algebra, Finite Mathematics, Explorations in Mathematics, Explorations in Mathematics (Venture Studies), Math for Teachers 1, Math for Teachers 2, Trigonometry, Precalculus, Business Calculus, Statistics for Social Sciences, Statistics for Business.

- *William Raines High School*
  Algebra 1, Algebra 2, Geometry.

- Utilized the Academic Systems program, Blackboard, WileyPlus, MyMathLab, Enhanced WebAssign and other technological applications in the classroom.

- Experienced working with a culturally diverse student population.

- Integrated innovative teaching concepts and cooperative learning in the classroom.

COMPUTER RELATED SKILLS

- *Programming languages*
  C, Java, Maple, Mathematica, Mathcad, SAS

- *Software*
  Microsoft Word, Microsoft Excel, Microsoft Powerpoint, Scientific Workplace, SAS, SPSS, Blackboard, Dreamweaver, Enhanced WebAssign, WileyPlus, MyMathLab

PROFESSIONAL ASSOCIATIONS, ORGANIZATIONS, ACTIVITIES, AND COMMUNITY INVOLVEMENT

- University committees – Adjunct Affairs, 2007, 2008; General Education Task Force, 2010, 2011, 2012, 2013

- College committees – Doctoral Steering for COEHS, 2007, 2008, 2009

- Department committees – Procedures and Bylaws, 2007, 2008; Evaluation, 2007, 2008; General Education, 2007, 2008, 2009, 2010, 2011, 2012, 2013

- Freshman orientation and advising with the UNF Academic Center for Excellence, 2007, 2008, 2010, 2011, 2012

- Professional development workshops for St. Augustine diocesan teachers.

- Attended NCAT (National Center for Academic Transformation) conference in anticipation of redesigning the teaching of College Algebra.

- Mathematical Association of America – member since 2000

- National Council for Teachers of Mathematics – member since 2000

- *Vice- President - 1999*
  Pi Mu Epsilon National Mathematics Honor Society - Florida Eta Chapter – member since 1997

- *Editor- 1999*
  “The Identity” – Newsletter of the University of North Florida Math/Stat Club

- Pi Lambda Theta International Honor Society and Professional Association in Education – member since 2008

- Golden Key National Honor Society – member since 1996

- Alpha Gamma Sigma – California Community College Honor Scholarship Society – member since 1995

- Volunteer work involving various organizations including Mu Alpha Theta, St. Francis of Assisi Community, Cursillo of the Diocese of Savannah, Woodbine Womens Club, Babe Ruth baseball, Little League baseball, Boy Scouts of America, Girl Scouts of America, Redwood Empire Gymnastics, PAL Gymnastics, Resurrection Parish

PUBLICATIONS

- "An Interesting Arithmetic Problem," *Mathematical Mayhem*, No. 5, Volume 27, 2001 (with Dr. Jingcheng Tong)

PRESENTATIONS

- "Collinearity in Multiple Linear Regression Analysis" presented as a student paper at the Southwest Educational Research Association, February 2009