ASSESSING MULTIPLE PLACEMENT METHODS FOR COLLEGE MATHEMATICS AT A TWO-YEAR COLLEGE

by

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Dedication

I want to dedicate this dissertation to my wife, Katie, and our two children, Ella and William. Katie, only you know the distance it took to attain this accomplishment, and your support and dedication have given me the strength to persevere.

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Abstract

Students who attend two-year institutions are not always academically prepared for the level of work that is required to be successful. Two-year institutions determine students' readiness for college-level mathematics courses using one of three placement methods. However, few empirical studies have investigated which placement methods are most effective in predicting academic success. The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in the midwestern United States. Through binary logistic regression, data obtained from the academic records of 1,330 students from a Midwestern U. S. two-year institution revealed a positive statistically significant relationship between placement methods and students' academic success. Students placed using ACT/SAT mathematics score or ACCUPLACER methods, respectively, were 1.85 ($p < .05$) and 3.91 ($p < .001$) times less likely to pass their college mathematics course compared to those students who were placed using high school grade point average (GPA). Students who took pre-calculus were 1.66 times more likely to pass than students who took statistics ($p < .05$) after controlling for the sociodemographic and placement type variables in the model. Age had a positive relationship with passing ($OR = 1.05$, $p < .01$). Full-time students were 1.50 times less likely than part-time students to pass ($p < .05$). Pell Grant eligible students were 1.57 times less likely than non-Pell Grant eligible participants to pass ($p < .05$). Placing students using high school GPA may improve success in college-level mathematics courses. Higher education policymakers should consider the use of high school GPA as the central method to place students into these courses.

Chapter 1: Introduction

Over 20 million students attend college at any given time in the United States (National Center for Education Statistics [NCES], 2016). Of these students, more than one-third (i.e., eight million) are non-traditional students outside the traditional college ages of 18-24 years, and seven million are attending two-year colleges rather than four-year schools (NCES, 2016). Despite these statistics, academic success is the goal of every student who enters into higher education. Defining academic success can be challenging because the definition itself is complex and broad (York, Gibson, & Rankin, 2015). The meaning of *academic success* varies between individual students and institutions and is often associated with grades, grade point average (GPA), or degree completion (York et al., 2015).

Often, academic success is tied to a student receiving a credential of either a certificate or an associate's degree, at least for students at the two-year college level (Ma & Baum, 2016). The National Center for Education Statistics (2016) noted that approximately 20% of students who enroll at a two-year institution would achieve academic success in the form of a credential or certificate. Academic achievement varies from student to student; however, the Community College Survey of Student Engagement (CCSSE; 2014) identified some promising best practices for students and institutions. Student assessment methods used when entering college are some of the variables associated with student achievement at two-year colleges. Students entering two-year colleges are often assessed using their GPA, American College Test (ACT) scores, Scholastic Aptitude Test (SAT) scores, or standardized placement exams to determine college readiness (Jaggars, Hodara, & Stacey, 2013).

Approximately 90% of students entering a two-year college are required to take a placement exam (Jaggars et al., 2013). This requirement may be because the majority of institutions use a placement exam as a convincing tool for assessing students and their college readiness at the two-year level (Bettinger, Boatman, & Long, 2013). According to the CCSSE (2014), students who were required to take a placement exam were 1.5 times more likely to score in a range that required them to enroll in developmental mathematics and/or English remedial courses based on their placement test scores. Advocates of remedial courses indicate that these courses assist students in gaining the necessary skills to excel and function at the college level (Papay, Murnane, & Willett, 2016). Hodara and Xu (2016) provided further support for the use of remedial courses in higher education. The authors stated that remedial courses serve as a way to eliminate students who are not college-ready, and give colleges a way to keep certain courses or programs more selective. However, proponents of these remedial courses argue that remediation may serve as a way to bolster enrollment in course departments such as English and mathematics because these are often the courses needed by students in remediation (Bettinger et al., 2013).

A significant portion of two-year college students enrolling in a remedial course can be problematic for many reasons. Students who enter into a two-year college are often seeking quick training for employable skills in either a short-term certificate, associate's degree, or four-year university transfer (Clotfelter, Ladd, Muschkin, & Vigdor, 2015). If students are unable to receive the immediate training needed for employable skills because they tested into remedial courses, the possibility exists that they may drop out of the institution due to financial reasons. Student discontinuation may be due to the stress and financial burden of having to take another course, which also may be more than a two-year college student can handle (Clotfelter et al., 2015). Crisp and Delgado (2014) suggested that many of the students who attend a two-year college have other life challenges that contribute to their decisions to withdraw, such as a low salary or full-time employment as well as first-generation or single parent status. These challenges may, in turn, result in the student's lack of confidence and support system to overcome the remedial courses' challenges. Moreover, when a student is placed in a remedial course, it sends a clear message to the student that they are not college ready (Clotfelter et al., 2015). Baxter, Bates, and Al-Bataineh (2017) supported this claim by noting that students who test into lower-level remedial courses had lower levels of self-efficacy. Low levels of self-efficacy could be part of the reason why 40% of students fail to complete the remedial courses at two-year colleges (Bill & Melinda Gates Foundation, 2016).

Xu and Dadgar (2018) questioned the effectiveness of remedial mathematics courses as students who are required to take multiple levels of remedial mathematics courses have extremely low completion rates. Despite the number of extensive research studies conducted on the effectiveness of remedial coursework, student performance in subsequent courses is still unknown (Boatman & Long, 2017). Boatman and Long (2017) showed that a gap still exists in the literature regarding which students should be placed in remediation, as well as what qualifies a student needing remedial courses over another student. For example, a student may require remediation at one institution but be deemed remediation-free at another institution (Fulton, 2012).

This study examined student grades in specific mathematics courses (i.e., statistics, college algebra, pre-calculus) to determine the placement method utilized upon entry to a two-year college. GPA, ACT/SAT mathematics score, or remedial courses via a standardized placement test were used in the study as assessment methods to determine college placement. In the current study, the standardized placement tests used were the ACCUPLACER and the COMPASS placement test. The COMPASS placement test is no longer available as it was phased out at the end of 2015, but was available at the time of the study (Fain, 2015). The researcher sought to fill the gap in the literature by assessing three different placement methods to determine the best method for student achievement in mathematics.

The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in the midwestern United States. The objectives of this study were (1) to obtain student records related to placement methods at a two-year institution, and (2) to conduct data analyses of student records to determine the most effective placement method for college-level mathematics courses.

Chapter 1 provides an overview of the background and contextualization of the issue by explicitly identifying what is known about the topic and questions that have not been previously addressed in the literature. Next, the problem statement, purpose statement, an overview of the conceptual framework, and the research questions and hypotheses of this study are presented. Also discussed in this chapter are explicit assumptions, delimitations, and limitations that are confined to the study as well as the study's significance in the current field of research. Definition of terms and variables are outlined which include definitions of the independent, dependent, and sociodemographic variables. Chapter 1 concludes with an overview of the organization of the chapter as well as a chapter summary.

Background and Contextualization of the Issue

The students who attend two-year colleges may not be academically prepared for the rigors of academic and college work (Bahr, 2013). Therefore, it is the responsibility of the administrators of such institutions to determine the academic preparedness of the students (Scott-Clayton, Crosta, & Belfield, 2014). All two-year institutions can assess a student's college readiness using the placement assessment method they so choose; however, most institutions choose a single placement test (Scott-Clayton et al., 2014). Other forms of placement assessment methods exist—including the use of high school GPA and ACT/SAT score.

High school GPA placement. Although GPA is still an easily understood quantitative value, it can be taken to represent a broader measure of a student's ability to succeed (Noble & Sawyer, 2013). The GPA serves as a measure of a student's ability to succeed because it assesses overall success in the previous tier of education, as opposed to simple test readiness (Noble & Sawyer, 2013). Additionally, GPA provides a measurement over time that may be a strong predictor of college success (Noble & Sawyer, 2013). Noble and Sawyer (2013) suggested that one possible explanation for GPA being a strong predictor of success is that it is both a single easily assessed quantitative value and it is also representative of a long-term process that comprises a student's entire high school career. Therefore, a measurement such as high school GPA is a tool that institutions can use to measure student effort and psychological energy over a longer duration (Scott-Clayton et al., 2014). The use of GPA may be more broadly reflective of the input factors for a student entering college because high school GPA represents a cumulative result of student experiences, skills, and effort in the previous level of study (Noble & Sawyer, 2013; Scott-Clayton et al., 2014).

American College Test/Scholastic Aptitude Test placement. The ACT and SAT are standardized aptitude tests that many students take before attending college. The tests are designed to measure academic aptitude and predict performance in college education (Coyle, Purcell, Snyder, & Richmond, 2014). Radunzel and Noble (2012) noted that the ACT and SAT provide an accurate measure of a student's readiness for college and college-level coursework. Moreover, these tests are believed to have predictive validity towards college success by many colleges and universities as ACT or SAT scores are used by many admission committees as a selection criterion (Wao et al., 2016).

Standardized placement test. Placement testing at two-year institutions typically consists of a student taking a computer-based placement test to determine his or her college readiness. The student's test score is then compared to the institution's minimum score to determine whether or not the student is ready to enroll in a particular college-level course (Primary Research Group, Inc., 2014). The placement test at most institutions is the ACCUPLACER exam, which measures the academic aptitude in English and mathematics for new incoming students (Primary Research Group, Inc., 2014). Over 92% of two-year institutions assess college readiness using a traditional standardized placement test with the student's score as the sole factor in determining his or her enrollment in a college-level or a remedial course (Scott-Clayton et al., 2014).

One of the common themes in addressing the needs of students at two-year institutions is identifying which students are academically prepared for college-level courses (Bettinger et al., 2013). Correct placement benefits students and colleges; however, misplacement (i.e., students enrolled in the wrong courses for their knowledge and ability levels) negatively affects students and institutions (Bettinger et al., 2013). If a student is placed in the wrong course, he or she wastes time and money on an unnecessary course (i.e., under-placement) or is likely to struggle with a course beyond his or her ability to complete (i.e., over-placement; Bettinger et al., 2013). Similarly, if the student is incorrectly matched to his or her skill and knowledge, the institution wastes the instructor's time as well as takes a course seat from another student (Bettinger et al., 2013).

Standardized testing misplaces a significant number of students entering two-year schools (Jaggars et al., 2013). A study conducted by Jaggars et al. (2013) found that 29% of students placed in a remedial English course may have been under-placed and also could have earned a grade of "B" or better in a college-level English course. In comparison, only 5% of students were over-placed in a college-level English course. Additionally, Jaggars et al. (2013) noted that as many as 18% of students who were placed in a remedial mathematics course were under-placed and could have earned a grade of "B" or better in a college-level mathematics course in comparison to 6% of students being over-placed in a college-level mathematics course. This discrepancy is even more pronounced due to the fact that under-placement is a significantly greater waste of resources to students, including time and money. Student under-placement represents a potential danger to overall success because students placed in remedial classes are substantially less likely to complete a degree (Jaggars et al., 2013).

Remedial education. Remedial or developmental courses are college courses that do not typically count as college-level work toward a degree or credential. These courses are designed to help prepare students who are not college-ready with foundational knowledge for college-level courses (Okimoto & Heck, 2015). That is, remedial courses are designed to reteach material that students should have learned in high school and represent a base of knowledge that is necessary for completing actual college content. For example, depending on the institution, any math-related course below college-level algebra, pre-calculus, or statistics is often considered remedial (Okimoto & Heck, 2015). Additionally, a lack of mathematics competency and a sociological fear of mathematics have characterized American college students, especially at the community college level (Okimoto & Heck, 2015). Accordingly, almost 60% of community college students need some form of remedial mathematics course (Bill & Melinda Gates Foundation, 2016).

Students who achieve higher ACT/SAT scores may be more likely to achieve their educational goals (Coyle et al., 2014; Wao et al., 2017). Studies which have found ACT/SAT scores to be strong predictors of college success have primarily been conducted at universities and with four-year university students, which is a different setting and population from the current study (Coyle et al., 2014; Wao et al., 2017). Additionally, high school GPA appears to be a relatively good predictor of college success for four-year university students (Hodara & Lewis, 2017; Mau, 2016). Even so, there has been a shortage of research related to two-year institutions examining ACT/SAT scores and high school GPA as predictors for college success. Conversely, the majority of research related to standardized placement exams has occurred at the two-year college level (Logue, Watanabe-Rose, & Douglas, 2016; Okimoto & Heck, 2015). However, the majority of the research showed that a placement test is not a strong predictor of college success (Bettinger et al., 2013; Jaggars et al., 2013).

Problem Statement

Most two-year colleges continue to use one of three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, or a standardized placement test) as a predictor of appropriate college-level mathematics placement (Bettinger et al., 2013). However, colleges vary in the placement method used and students are measured differently depending on the institution that they attend. Moreover, there have been limited empirical studies examining all three placement assessment methods at a single institution to determine the single best method for mathematics college success. Jaggars et al. (2013) noted that in mathematics standardized entry placement exams (e.g., ACT or SAT), up to 18% of students are incorrectly placed in remedial courses. Misplacement has serious practical consequences for students because placement in a remedial course may significantly lessen the chances of graduation (Bettinger et al., 2013). Therefore, placing students in remedial courses who do not need them interferes with their success by adding one or more unnecessary courses (Morest, 2013). The addition of extra courses slows a student's progression through college, making degree completion more difficult (Morest, 2013).

Purpose Statement

The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in the midwestern United States.

Overview of Conceptual Framework and Methodology

The conceptual framework for the study is the Inputs-Environment-Outputs (I-E-O) model pioneered by Astin (1970a, 1970b, 1993). Astin (1970a, 1970b) originally developed the I-E-O model in 1970, which is a model of educational outcomes that conceptualizes students' educational experiences as the result of a combination of inputs and environmental factors. Astin (1970a, 1970b, 1993) suggested that what constitutes an input or environmental factor is determined by if the variable comes from a student's background and prior experiences (i.e., input) or a student's actual educational experience and context (i.e., environment). Astin (1993) further expanded his I-E-O model in 1993 with his book *What Matters in College*? In the newest iteration, Astin’s (1993) model evolved by examining student outcomes and how the college environment may affect them. For example, the study examined the use of student peer interaction and, more specifically, the aspects of race and gender. Additionally, Astin (1993) examined the use of faculty interactions with students and the impact of these interactions on student outcomes (e.g., grades, performance).

The I-E-O model was an appropriate conceptual framework for this study because it characterizes how input variables (e.g., sociodemographic information) can be used to predict or explain academic success and how environmental factors (e.g., assessments, specific courses) affect the outcome of academic success in the study. Educational outcomes (e.g., student grades) represent the output variables for use in this study. The inputs that are selected and measured in this study are divided into two variable groups, namely sociodemographic variables and placement assessment variables. For the purposes of this study, student demographic variables, including race, ethnicity, gender, age, veteran status, marital status, full-time enrollment status, and financial aid status, were selected as the inputs of the I-E-O model. These inputs were strategically selected based on a review of the literature. Also, students' sociodemographic information was readily accessible from their institutional records and served as input variables. Furthermore, using demographic variables such as race, ethnicity, gender, sex, enrollment status, veteran status, and financial aid status in the I-E-O model assisted in examining if certain sociodemographic groups were more or less likely to be successful in college-level mathematics courses.

Methodology. The study involved a quantitative research design that was used to answer the research questions and achieve the intended purpose. A quantitative design was most appropriate for the study for multiple reasons. First, a quantitative design model provided statistical strength for the study due to the availability of a large sample size. Neuman (2013) noted that quantitative studies can create significant statistical power which increases as the sample size grows. Furthermore, Creswell and Creswell (2017) indicated that a quantitative study could be used for gathering data that allows for predictions to be made, which also provided support for the use of this design. Additionally, a quantitative study design works well in examining the relationships among variables (Hoy & Adams, 2016).

The study utilized a non-experimental correlation design methodology. A non-experimental research design is one in which the researcher observes what occurs naturally without interfering (Creswell & Creswell, 2017). One strength of a correlational research design is that it can determine if a relationship exists between two variables which use large amounts of data (Hoy & Adams, 2016). Despite this strength, correlational designs also have weaknesses. Specifically, when utilizing non-experimental correlation designs, causation between variables is not established (Field, 2013). For example, when two variables have a strong correlation, a cause and effect between the relationships of the variables cannot be assumed (Babbie, 2014). Field (2013) noted that non-experimental correlation is an appropriate research design when the purpose of the research is to identify if a relationship exists between two variables. For these reasons, the non-experimental correlational design was considered the best methodological design to answer the research questions and achieve the study's intended purpose. Furthermore, the researcher utilized secondary data analysis in that student records (i.e., secondary data) collected by a two-year institution set were analyzed as part of the research design. Secondary data analysis is described by Johnston (2014) as an "analysis of data that was [*sic*] collected by someone else for another primary purpose" (p. 619).

Data analyses included the use of several statistical tests. Frequency and descriptive analyses were used to describe the data, screen for outliers, and check assumptions. To answer the research questions, the researcher performed a chi-square test of independence, a correlation analysis, and a hierarchical logistic regression analysis. Additionally, the researcher performed separate logistic regression analyses for each placement method. Following the guidelines provided by Schutts (2016), the researcher conducted a receiver operating characteristic (ROC) curve analysis as a post hoc procedure for significant predictors that were continuous.

Research Questions and Hypotheses

The study was guided by the following theory-based central research question: Which placement method (high school GPA, ACT/SAT mathematics score, or standardized placement exam) is the best predictor for success in college-level mathematics? From this central question, the following four specific research sub-questions were posed:

RQ1: What is the relationship between the placement methods and academic success in college-level mathematics at a midwestern two-year institution?

H_0: There is no relationship between placement methods and academic success.

H_1: There is a relationship between placement methods and academic success.

RQ2: After controlling for sociodemographic variables, how do placement methods influence academic success in college-level mathematics at a midwestern two-year institution?

H_0: Placement methods do not influence one's academic success.

H_1: Placement methods influence one's academic success.

RQ3: What influence does the mathematics course taken (statistics, college algebra, or pre-calculus) have on the academic success in college-level mathematics at a midwestern two-year institution?

H_0: Course taken does not influence the prediction model.

H_1: Course taken influences the prediction model.

RQ4: How do the models compare when disaggregated by placement method?

H_0**:** There is no statistical difference in models when disaggregated by placement method.

H_1**:** There is a statistical difference in models when disaggregated by placement method.

Assumptions of the Study

Simon (2011) suggested that identifying and thoroughly explaining assumptions are the key components in a research study as there may be assumptions that are unique to that specific study. For this study, the researcher made the following assumptions:

1. Historical data from the school's records are reasonably accurate, given the importance of such records to the school's operation.
2. All study variables were available for both the fall and spring semesters for various categories of students. These study variables included ACT/SAT scores, high school GPA, placement examination scores, remedial courses in which students were placed, and final course grades for pre-algebra, statistics, and calculus.
3. Instructors entered the correct grades for students when assigning final course grades and that no miscalculation occurred. The researcher posited that if a data entry error occurred, then the student would have noticed that the incorrect grade was posted to their transcript and would have appealed the grade.

Delimitations and Limitations of the Study

Simon (2011) suggested that researchers can control delimitations within a research study. Delimitations can be thought of as choices that the researcher made that need to be identified or mentioned in the study (Simon, 2011). Limitations are often defined as factors that the researcher cannot control within a research study as well as shortcomings or conditions that may influence or limit the results of the study (Simon, 2011).

Delimitations. The following section identifies the delimitations present in the current study.

1. The study was delimited to a single two-year college in the midwestern United States. This delimitation was as a result of practical factors including the fact that the college utilized the three placement methods, and the researcher collected relevant data on incoming students.
2. The study was delimited to the sample size and the duration of the study, which was limited to two academic semesters (fall and spring). The sample size was limited to the use of secondary data at a single higher education institution.
3. The study was delimited to include only students who were placed by one of the three placement assessment methods into a college-level mathematics course.
4. A further delimitation of the study was that institutions differ in their minimum placement assessment scores. An ACT/SAT score, standardized placement test score, or high school GPA at one institution may place a student in a remedial course, while at another institution that same score may place the student in a college-level mathematics course.

Limitations. The following section outlines the limitations specific to the generalization of the study.

1. The study was limited in that two-year colleges may use different standards and may also have a different constituent student body from four-year schools, limiting the scope of the results to two-year institutions.
2. The study was limited to the sociodemographic variables collected by the institution as a part of their student records. Similarly, the use of a secondary dataset may be a

limitation of the study. That is, information on a specific student group may not be collected by the institution, resulting in that group's non-representation in the study.

3. A further limitation of the study relates to specific course sections and the effects of teachers on the students' grades. Although this study will not examine multilevel modeling, future studies may explore the effect of teachers on success in college mathematics courses.
4. The study was limited in that the option for mathematics placement is also limited to three variables. It is possible that another placement variable existed that would prove to be a better predictor of mathematics success. However, the majority of two-year institutions employ one of the three variables used in this study for mathematics course placement (Jaggars et al., 2013).
5. The study was limited in that secondary data was used throughout the study. Specifically, the shortcomings of using secondary data is that the data may be inaccurate or outdated, which could invalidate the study (Williams & Shepherd, 2017).
6. A further limitation of the study was that the student's major was not used as a variable in the study. Therefore, the effects of a major on a student's academic success in a college-level mathematic course is unknown.
7. The study was limited by the high number of dual-enrollment students in the study. Specifically, the large number of dual-enrollment students in the study may be disproportionally higher than at other institutions.
8. Finally, the study was limited in that only academic success in college-level mathematics courses was explored. The study was not longitudinal, and therefore did

not examine student success in other classes after being passing a college-level mathematics course. However, given that mathematics is a barrier that many students must overcome in the path toward degree attainment, the study is of significance toward a larger issue at two-year institutions (Burdman et al., 2018).

Significance of the Study

The significance of the study is that it seeks to add to the existing literature in the field. Limited empirical studies have examined all three placement assessment variables to determine the single best method for mathematics college success. Scholars (e.g., Hodara & Lewis, 2017; Jaggars et al., 2013; Scott-Clayton et al., 2014; Wao et al., 2017) have examined the use of standardized placement test scores, high school GPA, and ACT/SAT scores as a single method of placement, and have demonstrated support for and/or against the specific placement method. However, there are no known studies that have examined all three placement variables at one institution to determine the best assessment method for academic success. Furthermore, this study will fill a gap in the literature related to the significance of student sociodemographic characteristics on the placement approaches used by two-year institutions. Most empirical studies (e.g., Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods, Park, Hu, & Betrand Jones, 2018) have not taken into consideration specific student sociodemographic characteristics (e.g., race, ethnicity, age, gender, veteran status, and Pell Grant eligibility) when exploring the experiences of students in remedial mathematics courses.

The practical significance of the study is that the results may inform the use of better placement assessment methods for students attend two-year institutions. The identification of one placement assessment variable as a more accurate method than another could provide the institution and students a way to accelerate through their remedial coursework. Incorrectly placing students in remedial courses may directly hurt their chances of success (Bettinger et al., 2013). In cases where students are correctly placed into a remedial course, it still represents additional cost and effort for students in a demographic group that is already disadvantaged in many ways (Morest, 2013). The costs of remediation not only affect students, but also have a significant impact on two-year institutions. Noble and Sawyer (2013) noted that the cost of providing developmental coursework was estimated to be over $1 billion nationwide. The study also has practical significance as it may provide administrators at two-year institutions with insight regarding the appropriate mathematics courses for the various placement methods. Incorrect placement in mathematics courses can result in student course failure (Ganter & Haver, 2011). Mathematics pathways that align with students' intended educational goals or plans of study may improve their overall success rates in mathematics courses at two-year institutions (Burdman et al., 2018).

Additionally, it is estimated that institutions spend up to 10% of their entire budget on remedial courses alone (Morest, 2013). The cost to colleges will continue to rise because some state institutions are now moving toward a completion-based funding model, in which such institutions receive financial compensation for moving students through developmental courses and into college-level courses (Morest, 2013). For example, Ohio was one of the first states in the country to tie funding to successful completion of remedial coursework with its state institutions being fully funded by student completion (Ohio Department of Higher Education, 2018a).

The study is also of significance because it serves to shape policy at the institutional level. If the standardized placement examination proves to be a weaker predictor than high school GPA or ACT/SAT scores, then standards for using GPA or ACT/SAT scores as the primary placement mechanism should be developed. Overall, the results of the study may prove useful to the evaluation of current educational policies. Even if GPA or ACT/SAT mathematics score does not prove to be a superior predictor of student success, the results will provide evidence to two-year institutions that the standardized placement assessment is the correct method for evaluating students in college-level mathematics courses. Overall, the study is of significance in encouraging higher education administrators to be aware of the shortcomings of current placement methods, thereby highlighting the need to develop alternative assessments regardless of whether or not the study suggests GPA or ACT/SAT scores are an appropriate replacement for - or a supplement to - existing placement testing.

Definitions of Terms

American College Test. The term represents one of the two standardized entry exams widely administered in the United States. The ACT nonprofit organization runs the test, and it is more commonly used in the Midwest or western parts of the United States (American College Testing, Inc., 2016).

Grade point average. The term describes the cumulative calculation of a student's measure of academic work and success (York et al., 2015).

Remedial courses. The term describes the college courses that do not typically count as college-level work toward a degree or credential. These courses are designed to help prepare students who are not college-ready with foundational knowledge for college-level courses (Okimoto & Heck, 2015). For this study, this term describes the mathematics courses that do not count towards college-level degree completion. Colleges may consider high school-level mathematics courses to include algebra and trigonometry (often called pre-calculus) or pre-calculus to be entry-level college courses (Okimoto & Heck, 2015). That is, these lower courses constitute remedial courses at the college level.

Scholastic Aptitude Test. The term represents one of the two standardized entry exams widely administered in the United States (Soares, 2015). The test also known as SAT I: Reasoning Test or the SAT reasoning test. The College Board administers the test, and it is the most commonly used assessment method on the Eastern and Western coasts of the United States (Soares, 2015).

STEM. This term is the acronym for science, technology, engineering, and mathematics education in various fields (Bybee, 2013).

Definitions of Variables

Information regarding the placement assessment methods used as the independent variables in the study is provided below. The definition of each variable is also presented.

American College Test mathematics score. The variable is defined as a discrete and ranges between one and 36. The score represents a student's individual best score on the mathematics portion of the ACT standardized test. These scores were drawn directly from the school's historical data for incoming students, which were submitted as a part of the student admission process.

High school GPA. The variable is defined as continuous and ranges between zero and four. However, some schools allow for GPAs above a 4.0 through special courses such as Advanced Placement (AP). This variable was measured from the school's historical data for incoming students based on the student's official high school transcript.

Scholastic Aptitude Test mathematics score. The variable is defined as discrete and ranges between 200 and 800. This variable measured a student's success on the mathematics portion of the SAT standardized test. The SAT scores were drawn directly from the school's historical data for incoming students, which were submitted as part of the student admission process.

Standardized placement exam. The variable is defined as the placement exam score, which is either the ACCUPLACER test or the COMPASS placement test. These placement exams are used to place students in the appropriate mathematics course.

The dependent variable used in this study was college success. The definition of college success is presented below.

College success. This variable was measured by assessing if the student successfully achieved at least a passing grade in a college-level mathematics course. A passing grade was defined as a "C" grade or better (e.g., A or B). Grades higher than a "C" were required for most degree programs at the participating institution. Notably, a grade of C or better was used as a measure of academic success.

Sociodemographic variables including age, race/ethnicity, veteran status, enrollment status, gender, and financial aid were included in the analyses. The definitions of these variables as conceptualized in this study are presented below.

Age. This variable is defined as the year in which a student was born as indicated on their college application.

Race. This variable is defined as the manner in which each student self-identified the race/ethnicity with which they associate. A student may self-identify an association with a White, Black, Asian, American Indian/Alaskan Native, Hispanic or Latino, Hawaiian or Pacific Islander, or an unknown race.

Veteran status. This variable is defined as the manner in which a student self-identified current military or veteran status on the student application.

Enrollment status. This variable is defined as the manner in which a student was enrolled in school (i.e., full-time, part-time).

Gender. This variable is defined as the manner in which a student self-identified as either male or female.

Financial aid. This variable represents students who identified as Pell Grant-eligible for financial aid.

To determine success in mathematics course, three courses were included in this study and are presented below with their definition.

Statistics. This dummy variable represents a college-level statistics course. This course did not count towards the mathematics requirement for students' selected plans of study.

College algebra. This dummy variable represents a college-level algebra course. This course did not count towards the mathematics requirement for students' selected plans of study.

Pre-calculus. This dummy variable represents a college-level pre-calculus course. The course did not count towards the mathematics requirement for students' selected plans of study.

Organization of the Study

The dissertation is organized into five chapters. Chapter 1 provides the introduction to the topic and research study. Specifically, Chapter 1 began with a discussion and overview on the background and contextualization of the specific problem regarding placement testing at two-year institutions (Coyle et al., 2014; Noble & Sawyer, 2013; Scott-Clayton et al., 2014). Following the contextualization and background overview, the problem statement addressed the problem with two-year institutions and their placement-testing methods. The problem statement led to the study's purpose of assessing the three placement methods (i.e., high school GPA, ACT/SAT scores, standardized placement test) used by two-year colleges in placing students in college-level mathematics courses to determine the single best mathematics placement method for college success at one institution. Chapter 1 also included an overview of the I-E-O model and the integration of the model in the study along with the study's quantitative research design and methodology. The central research questions of the study are subsequently presented along with their respective hypotheses. Additionally, the assumptions, limitations and delimitations, and significance of the research are discussed. The terms and variables used throughout the study are then defined. Lastly, the organization of the study is explained to guide the reader.

Chapter 2 includes a comprehensive literature review of the topic. The review includes a synthesis and examination of the different placement variables used at two-year colleges. Additionally, the review examines the different sociodemographic variables that are used in this study. Following the review of literature, an examination of the I-E-O model conceptual framework that guides the study is presented. Chapter 2 explores the different input, environment, and output variables used in the study. These variables are examined in relation to the existing literature along with the theoretical constructs.

Chapter 3 presents the selected methodology for the study, including the research design and data analysis techniques used to answer the research questions. This chapter also presents the data resources and data collection procedure used to obtain the data in the research. Justification is provided for the procedures and methods to fulfill the study's purpose.

Chapter 4 presents the data analysis and results from the statistical tests performed in the study. Specifically, the chapter delineates each statistical method used to answer the four research questions as well as the assumptions that were satisfied as part of the statistical analysis. The results in Chapter 4 are organized by the four research questions.

The study concludes with Chapter 5. Chapter 5 presents the major results of the study and explores the findings in relation to the research questions. Also, the results, limitations, conclusions, implications, and recommendations for future research are presented. Chapter 5 concludes with the researcher's reflections from conducting the study as well as a summary of the study's significance.

Chapter Summary

The chapter contextualized the research topic and presented an overview of the study. The problem identified is that colleges vary in the placement method used and students are measured differently depending on the college they attend. Additionally, there have been limited empirical studies that have examined all three placement assessment methods at one institution to determine the single best method for mathematics college success. The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in Midwestern United States. The researcher examined the three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement test) used at a two-year institution in the Midwestern United States. The study examined which placement assessment method is the best predictor of success in a college-level mathematics course. The three placement assessment methods used for placing students into one of three college-level mathematics courses (i.e., statistics, college algebra, or pre-calculus) were also examined. These mathematics courses were selected because they are the only entry-level mathematics courses offered at the institution.

This study is unique because few empirical studies have investigated which placement method is most effective in predicting academic success in college-level mathematics course.

To answer the research questions, data were collected from the student records (N = 1330) of incoming or returning students at a two-year college located in a Midwestern part of the United States for both the fall and spring semesters of a single academic year. The study was guided by one central research question and four specific research sub-questions. A quantitative research design was used to answer the research questions and achieve the intended purpose. Specifically, the study utilized a quantitative, non-experimental correlational research design to answer each research question and achieve the purpose. Lastly, after evaluating the data for outliers and assumptions, the researcher used correlation and logistic regression analyses to examine the variable relationships.

Chapter 2: Literature Review

The chapter seeks to examine and analyze the existing literature and the conceptual framework used to guide the study. The literature review is aligned with the research questions and purpose of the study because the literature thoroughly explores the different placement approaches used by two-year institutions and sociodemographic variables that may also influence success in college-level mathematics courses. The literature review examines and synthesizes the current literature in regard to the standardized placement test, ACT/SAT mathematics score, and high school GPA used by two-year colleges in placing students in college-level mathematics courses. To achieve a thorough review, the researcher first identifies, summarizes, and describes available literature regarding key aspects of the research topic, including the historical context of two-year colleges and students at two-year colleges, high school GPA placement, ACT/SAT score placement, and the standardized placement test. The chapter contains a thorough discussion of the different placement assessment variables used at two-year institutions along with modern considerations of placement assessment variables used at two-year institutions.

Furthermore, this chapter examines the current placement assessment policies used by two-year institutions. The chapter also includes a review of remedial education and comparisons of success rates in mathematics courses and summarizes and examines the existing literature in relation to the conceptual model used in this study. Lastly, the chapter contains a thorough discussion of the conceptual framework, including constructs of the model as well as the model's strength, weaknesses, and criticisms. The chapter concludes with a summary that encapsulates the literature review and conceptual framework model.

Placement Assessment at Two-year Institutions

The following section provides a comprehensive summary of the literature surrounding two-year institutions in higher education. Two-year institutions are typically open-access and accept most students who apply for admission. Not every student who enters a two-year college is prepared for the rigors of college-level work (Bahr, 2013). Therefore, it is the institution's responsibility to determine students who are and who are not academically prepared (Scott-Clayton et al., 2014). All two-year institutions can assess a student's college readiness using the placement assessment method they deem fit; however, most institutions choose a single placement test (Scott-Clayton et al., 2014). Other forms of placement assessment methods do exist, including the use of high school GPA and ACT/SAT scores.

Almost all two-year institutions use some form of assessment exam to assess the mathematics skills of students for college placement (Field, 2014). Two-year institutions primarily use high school GPA, ACT/SAT scores, or the standardized placement test to assess student readiness for college-level mathematics courses (Lavonier, 2016; Scott-Clayton et al., 2014; Walters, 2014). However, each institution varies in the minimum scores used to determine college readiness (Fain, 2015; Walters, 2014).

High school GPA placement as a placement determinant. The following section provides a comprehensive summary of the literature regarding high school GPA as a placement variable as well as the opportunities and challenges of such a practice. However, GPA is an easily understood quantitative value and can be taken to represent a broader measure of a student's ability to succeed (Bahr, 2013). A student's GPA is used as a measure of success because it evaluates overall success in the previous tier of education as opposed to simple test readiness (Huh & Huang, 2016). The use of GPA may be more broadly reflective of the input factors for a student entering college as a high school GPA represents a cumulative result of a student's experiences, skills, and efforts in the previous level of study (Noble & Sawyer, 2013; Scott-Clayton et al., 2014; Scott-Clayton & Stacey, 2015).

High school GPA has been used as a predictor of success in college-level mathematics and English courses in several studies (Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods et al., 2018). There were variations in how high school GPA was used in these studies; for example, the cutoff for placement into a college-level course differed in each (Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods et al., 2018). For example, Woods et al. (2018) examined if the student took a high school level mathematics course, and Hodara & Lewis (2017) examined a student's high school GPA for placement. Further, the setting for each of the studies varied as including both four-year and two-year institutions (Hodara & Lewis, 2017; Woods et al., 2018).

The central finding of the studies suggests that high school GPA is a relatively stronger predictor of college success in mathematics courses in comparison to standardized placement exam and ACT/SAT scores (Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods et al., 2018). The studies that have explored high school GPA as a placement predictor at two- and four-year institutions consisted of a variety of college-level courses, including STEM, English, and mathematics (Hodara & Lewis, 2017; Mau, 2016; Woods et al., 2018). In general, it appears that high school GPA is a stronger predictor for students who entered college within one year of graduating high school and also for students who delayed college entry (Hodara & Lewis, 2017).

The studies that examined high school GPA as a predictor of college success had a range of limitations. In general, most of the studies did not control for sociodemographic characteristics of students, veteran status, and Pell Grant eligibility. One study found that high school GPA was a positive and significant predictor for mathematics success at a two-year college; however, the sample was limited to only Black and White students (Perrakis, 2008). A further limitation of the existing literature is that none of the researchers employed all three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement exam) in their studies.

The ACT/SAT placement as a placement determinant. The following section provides a comprehensive summary of the literature relating to ACT/SAT scores as a placement variable. The ACT and SAT are standardized aptitude tests that many students take before attending college. The tests are designed to measure academic aptitude and predict performance in college education (Coyle et al., 2014). Many college and university administrators believe that ACT and SAT scores have predictive validity towards college success as many admission committees use the scores for admission criteria selection (Wao et al., 2016).

The ACT and SAT scores have been used as predictors of success in college-level mathematics and English courses in several studies (Bettinger & Long, 2005; Coyle et al., 2014; Wao et al., 2017). However, researchers varied in how they used ACT and SAT scores in their research studies. For example, the minimum score for placement into a college-level course differed in each study (Bettinger & Long, 2005; Coyle et al., 2014; Wao et al., 2017). For example, Coyle et al. (2014) examined ACT and SAT mathematics scores to determine placement, but Wao et al. (2017) examined a student's cumulative ACT and SAT scores to predict college GPA and success. Additionally, there were variations in the study settings that included both four-year and two-year institutions (Bettinger & Long, 2005; Coyle et al., 2014; Wao et al., 2017). The central finding of these studies suggests that ACT and SAT scores were valid predictors of college success in both English and college-level mathematics courses (Bettinger & Long, 2005; Coyle et al., 2014; Wao et al., 2017).

Studies that examined ACT/SAT scores as a placement predictor had a range of limitations. In general, most of the studies did not control for the sociodemographic characteristics of students, including race/ethnicity, age, gender, veteran status, and Pell Grant eligibility. Additionally, not all studies included effect size when reporting the results (Bettinger & Long, 2005). A further limitation of the existing literature is that none of the researchers employed all three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement exam) in the studies.

Standardized placement test as a placement determinant. The following section provides a comprehensive summary of the literature regarding standardized tests as a placement variable. The section addresses how standardized placement is used as a placement variable and the opportunities and challenges associated with using standardized placement as a placement variable. The placement test at most institutions is the ACCUPLACER exam, which measures the academic aptitude in English and mathematics for new incoming students (Primary Research Group, Inc., 2014). Over 92% of two-year institutions assess college readiness using a traditional standardized placement test with the student's score as the sole factor in determining enrollment in a college-level or a remedial course (Scott-Clayton et al., 2014).

Several studies have examined the use of standardized placement tests and college success (Jaggars & Bickerstaff, 2018; Martorell, McFarlin, & Xue, 2015; Ngo & Melguizo, 2016; Windham, Rehfuss, Williams, Pugh, & Tincher-Ladner, 2014). Jaggars and Bickerstaff (2018) found that 29% of students placed in a remedial English course may have been misplaced and could have earned a grade of "B" or better in college-level English. Ngo and Melguizo's

(2016) study results were consistent with Jaggars and Bickerstaff's (2018) results. In both studies, the researchers noted that placement exam might misplace students into remedial courses where they otherwise might have succeeded in a college-level course.

The central key finding of these studies suggests that misplacement is more highly associated with standardized placement tests than the ACT/SAT and high school GPA placement (Jaggars & Bickerstaff, 2018; Martorell et al., 2015; Ngo & Melguizo, 2016; Windham et al., 2014). The misplacement ranged throughout the existing literature from 5% of students who were over-placed in a college-level English course to as high as 29% of students who were under-placed into remedial English courses (Jaggars & Bickerstaff, 2018). This is a vast range, but even the lowest percentage (i.e., 5%) of misplaced students can affect student attrition rates. Scott-Clayton and Stacey (2015) found that the attrition rate of misplaced students was 8% as opposed to those students who were admitted directly into college-level courses.

The main finding of the literature review was that under-placement of students represent a potential danger to overall success, given that students placed in remedial classes are considerably less likely to succeed (Jaggars & Bickerstaff, 2018; Martorell et al., 2015; Ngo & Melguizo, 2016; Windham et al., 2014). Martorell et al. (2015) indicated that regardless of the student's placement score, the results did not hinder a student from enrolling in their selected institution. On the other hand, Scott-Clayton and Rodriguez (2015) highlighted that students who were misplaced were less likely to enroll. Given the inconsistencies in the results of these two studies, further research is needed to understand the impact of standardized placement results on college enrollment.

Additionally, these studies were all conducted at two-year institutions and had a range of limitations. In general, most of the studies did not control for sociodemographic characteristics of the students, including race/ethnicity, age, gender, veteran status, and Pell Grant eligibility. Additionally, none of the studies included effect sizes as part of their analysis. A further limitation of the existing literature is that while the studies used both the ACCUPLACER and COMPASS placement tests, none employed the use of all three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement exam).

Remedial Education

Remedial courses are designed to help prepare students who are not college-ready with the foundational knowledge for college-level courses (Okimoto & Heck, 2015). Remedial or developmental courses are college courses that typically do not count as college-level credit toward a degree or credential (Clotfelter et al., 2015). At two-year institutions, over two-thirds of students require at least one remedial course (Bahr, 2013). Moreover, almost 60% of community college students need some form of remedial mathematics courses (Bill & Melinda Gates Foundation, 2016). A lack of mathematics competency and a sociological fear of mathematics have characterized American college students, especially at the community college level (Benken, Ramirez, Li, & Wetendorf, 2015; Gore et al., 2016; Perin, 2018). As such, students placed in remedial mathematics courses at two-year colleges are less likely to achieve their academic goals than students who do not require remedial courses (Quarles & Davis, 2017).

Several studies were examined as part of the literature review in relation to the success rates of students at two-year colleges in relation to remedial course placement (Fike & Fike, 2008; Logue et al., 2016; Waycaster, 2011; Xu & Dadgar, 2018). All of the studies varied regarding how students were placed into the remedial courses (Fike & Fike, 2008; Logue et al., 2016; Waycaster, 2011; Xu & Dadgar, 2018). Logue et al.'s (2016) study suggested that passing a remedial mathematics course is not a requirement to pass a college-level mathematics course.

Additionally, the study by Xu and Dadgar (2018) indicated that a longer sequence of required remedial mathematics courses results in a decreased chance of earning a degree or certificate within four years. Conversely, Waycaster (2011) found that students who completed a remedial-level mathematics course were positively associated with fall-to-fall retention. Waycaster (2011) highlighted that students placed into remedial courses often receive extra attention and support services through advising and tutoring, which can result in higher retention rates. A study by Fike and Fike (2008) provided further support that students who enrolled in and completed at least one remedial course were more likely to complete their educational goal than peers who tested into a remedial course and did not pass the course.

The studies related to remedial education at two-year colleges had a range of limitations. Most of the studies did not take into consideration specific student sociodemographic characteristics including race/ethnicity, age, gender, veteran status, and Pell Grant eligibility to explore the experiences of students in remedial courses (Fike & Fike, 2008; Logue et al., 2016; Waycaster, 2011; Xu & Dadgar, 2018). A further limitation of these studies is that none of the researchers explored all three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement exam) in the studies.

Placement Assessment Policies

Placement policy occurs both on an institutional as well as on a state policy level (Fain, 2015). For example, Flory and Sun (2017) indicated that 23 states had tied institutional state funding and accountability to the use of one of the three placement variables that colleges use. That is, student readiness for college must be assessed using high school GPA, ACT/SAT scores, or the standardized placement test (Flory & Sun, 2017). Each institution selects the assessment method it deems most fitting when choosing its placement policy and methods (Fain, 2015; Walters, 2014).

Several states have implemented some form of multiple placement assessment measures. Notably, Connecticut, Indiana, Wisconsin, North Carolina, Texas, and California have implemented multiple measures or forms of addressing remedial coursework (Vandal, 2014). While many four-year institutions are prohibited by state legislature from delivering any form of remedial course, states have begun to assess multiple-measure testing policies (Anderson & Fulton, 2015). Although policies regarding remedial coursework differ from state to state, the practice is that states are required to address remedial education in some form, whether through multiple-placement policy legislation or via another method (Crisp & Delgado, 2014; Harnisch & Lebioda, 2016).

The rationale for the mandatory use of multiple placement assessment testing and/or the overhaul of remedial education by state legislatures stemmed from a variety of sources. For example, Mangan (2015, 2016) recommended a complete overhaul of remedial education and encouraged legislatures to enact policy change. The recommendation for remedial education action and change to national legislation groups is that specific core principles guide the new policy of remediation and placement. These core principles included non-reliance of colleges on a single measure of placement for appropriate courses, accelerated paths out of remedial coursework to college-level courses, the use of supplemental instruction or co-requisite courses for college gateway courses, and the use of co-requisite placement as a measure of student placement (Mangan, 2015). An additional factor that spurred legislatures to mandate remedial education policy changes was related to the cost for institutions to remediate students. This stems from a 13% increase in cost nationally in remedial education since 1998 (Saxon, 2017).

As states and institutions operate on tighter budgets, it is important that they have accurate information regarding who belongs in remedial courses and who does not. Additionally, Saxon and Morante (2014) suggested that current placement testing methods may be inaccurate or invalid for students testing via a standardized placement test, and this provides further reason for state-mandated placement policy and remedial education overhauls.

Connecticut state policy and legislature has implemented a form of new placement methods for students who require college remediation work (Giordano, & Hasse, 2016). In 2012, Connecticut approved Public Act 12-40—"An Act Concerning College Readiness and Completion"—that required all postsecondary institutions to provide adequate support for academically underprepared students while they are enrolled in college-level courses (Giordano & Hasse, 2016, p. 18). In Connecticut, the Public Act 12-40 was a response to data that indicated failure of a high number of students enrolled in remedial education and who were not successfully progressing to college-level courses (Giordano & Hasse, 2016). The result of the legislation for Connecticut postsecondary institutions mandated co-requisite support or supplemental instruction for college-level courses (Giordano & Hasse, 2016).

Texas Senate Bill 162 required community colleges to redesign the structure and instruction of developmental education (Kosiewicz, Ngo, & Fong, 2016). Texas Senate Bill 162 allows students who tested into developmental courses to directly take a college-level course as a co-requisite course (Kosiewicz et al., 2016). Furthermore, it is a requirement of the Texas bill that community colleges assess and identify students who may benefit from the alternative delivery methods of remedial education. Lastly, under this Bill, it is also required that the institution deliver the supplemental instruction or remediation through the use of technology or modular course materials (Ngo & Melguizo, 2016).

Testing policies and remedial legislation varies across the states but carry a common theme of remedial education policy reform (Melguizo, Bos, Ngo, Mills, & Prather, 2016). The results of the state legislative mandates on remedial education and testing are still underdetermined; however, the impetus for these decisions is the same regardless of the state. Many factors contribute to the regulation of remedial education and multiple-measure testing. These factors include the financial impact that remedial education has on state funding as well as making institutions more accountable for student success and progression. Standardization of remedial coursework and testing through state legislation may be an effective strategy to improve student success in college; however, if the policy that is developed and initiated is an ineffective strategy then the mandated policy may only further worsen the remedial and testing policy (Melguizo, Bos, Ngo, Mills, & Prather, 2016).

One of the largest studies to date on this issue took place in March 2013. The North Carolina Community College System examined multiple-measure testing system-wide and put a plan of action in place at all of the state colleges. Instead of individual institutional placement policies, North Carolina implemented a mandatory placement policy for all state institutions. The policy provides little opportunity for institutions to customize their testing policy, and the implementation for all 58 state colleges was from 2013 to the fall of 2015.

In developing the new policy, the North Carolina state system decided that it was important to look at the different points a student may encounter while entering the college system. As a result, the state system established a hierarchy that colleges now use to determine students' college readiness. This hierarchical model, Multiple Measures Policy, uses the following options to determine placement:

- Option 1: A recent high school graduate who meets the specified GPA benchmark will be exempt from diagnostic placement testing and will be considered "college-ready" for gateway math and English courses.
- Option 2: A recent high school graduate does not meet the GPA benchmark, so the college will use the specified ACT or SAT subject area test scores to determine placement.
- Option 3: A recent high school graduate does not meet the GPA threshold or have college-ready ACT or SAT scores, so the college will administer the diagnostic placement test to determine placement.
- Option 4: An applicant does not have a recent high school transcript, or ACT or SAT scores, so the college will administer the diagnostic placement test to determine placement. (Multiple Measures of Placement, 2015, p. 2)

The model that the North Carolina institutions uses represents a hierarchical format of multiple-measure testing. The hierarchy first measures high school GPA to determine prerequisite satisfaction. If not, then the next measurement is the ACT/SAT score, if available (Multiple Measures of Placement, 2015). If a student does not satisfy placement with either his or her high school GPA or ACT/SAT score, then the college administers a standardized test to determine placement. North Carolina uses a predetermined GPA score and has found that it was no longer a valid predictor of student success. Specifically, a GPA at or above 2.6 is the indicator the state system uses for most of its students, and when a student's GPA falls below the 2.6 average then institutions are required to use other measures of validating placement. Additionally, for students who do not meet the GPA requirement, a supplemental course can be taken concurrently with the college-level course in order to bypass a remedial course (Multiple Measures of Placement, 2015).

All 58 institutions in the state of North Carolina are now using multiple-measure placement for all incoming students, and the data across the state have indicated a drastic improvement in the number of students requiring remediation (Multiple Measures of Placement, 2015). During the 2012–2013 school year, graduates of North Carolina maintained a remediation rate of 63%. By the 2013–2014 school year, the remediation rate dropped to 52%. As not all 58 institutions were using multiple-measure placement testing in 2013 and 2014, it was possible that the numbers were likely to increase in the 2015–2016 data (Multiple Measures of Placement, 2015).

Results from the North Carolina placement measure study provided by the Center for Community College Student Engagement (2016) indicated positive results from the implementation of multiple measures. Study results showed that students placed using the high school GPA measure successfully completed the college-level mathematics course at a 65% rate. In comparison, just 48% passed the college-level math course who were identified via one of the other placement methods. Further results from the Center for Community College Student Engagement (2016) study indicated that multiple measures also had an impact on college-level English courses. Specifically, the study indicated that 67% of students placed using high school GPA successfully completed a college-level English course when compared to only 59% of students who were placed using other placement methods. Results also suggested that 700 students who were placed in a college-level mathematics course successfully passed. These students would have been placed in a remedial course based on the previous placement policy (Center for Community College Student Engagement, 2016).

Longitudinal research on multiple-measure placement in comparison to the years of single placement test use is sparse (Multiple Measures of Placement, 2015). However, it was important to identify North Carolina's multiple-measure research, as several of its methodological components were used in the design of the current study. Notably, the high school GPA, ACT/SAT scores, and the standardized placement test used in the hierarchical placement chart were employed in the current study. Another key difference in the North Carolina study and the current study is that students were required to take supplemental support courses in addition to the college-level mathematics course, which is not a part of the current study.

Comparisons of Success Rates in Mathematics Courses

The institution a student attends determines the college mathematics course a student can take (Ganter & Haver, 2011). However, creating mathematics pathways that align with students' intended educational goals or plans of study may improve the success rates of the students who take mathematics courses (Burdman et al., 2018). An institution needs to be strategic when selecting the mathematics pathway and placement test required for their chosen career, as incorrect placement could set students up for failure in their mathematics course (Ganter & Haver, 2011). For example, many institutions use the 2007 College Algebra Guidelines, which suggests the use of college algebra as the default class for students who need a mathematics course (Ganter & Haver, 2011). However, the study by Saxe et al. (2015) suggested that college algebra may not be an appropriate course for students with majors in social science and humanities. The National Research Council (2013) published *The Mathematical Sciences in 2025,* in which they described that the educational offerings in colleges had not kept pace with the changes in student's career pathways. It was suggested that different pathways are needed for students depending on their career choice.

The report by Burdman et al. (2018) indicated that during the selection process, it is important for institutions to align their mathematics courses with the career field and program of study. In Tennessee, educators aligned mathematics courses with pathways and eventually did not require college algebra for all students (Burdman et al. 2018). Instead, students were guided to a mathematics course that aligned with their career path. According to Burdman et al. (2018), 24 states have either implemented or started the process to integrate multiple mathematics pathways which align career choice and an appropriate level of mathematics. In California, the college-level mathematics pathways are aligned for students and their chosen career field (Burdman et al., 2018). Notably, students who earned associate’s degrees often took statistics over other mathematics course options, with 44% of students having taken a non-algebra based course to fulfill their associate’s degree requirement (Burdman et al., 2018). Of the 44% of students who took a non-algebra based course, 87% took a statistics course as their preferred mathematics course. One limitation of the study by Burdman et al. (2018) was the lack of information related to effect sizes or odd ratios.

Conceptual Framework

The researcher used the I-E-O model as the conceptual framework in this study. This model provides a tool to evaluate a variety of inputs in relation to a stable environment to determine if a relationship exists in the output (Astin, 1970a, 1970b). The output of the study was college-level mathematics course grade; that is, the grade received by the student in one of three college-level mathematics courses as reported by the student information system.

The I-E-O model provided the conceptual framework used to guide the research study. Astin's (1970a, 1970b) I-E-O model includes the Inputs-Environment-Outputs (I-E-O). The I-E-O model allows for the conceptualization of students' educational outcomes as the result of a combination of inputs and environmental factors. Astin (1970a, 1970b) suggested the precise nature of what constitutes an input or environmental factor based on whether the variable comes from a student's background and prior experiences (input), or from a student's actual educational experience and context (environment). The following section examines the conceptual model origins and evolution, in addition to the model's strengths, weaknesses, and criticisms. Additionally, a thorough examination, analysis, and synthesis of the existing literature are explored in relation to the conceptual model and study.

Development. Astin (1970a, 1970b) originally developed the I-E-O model in 1970. The model was initially developed to create a unified methodology amidst the chaotic, heterogeneous attempts to study collegiate success that characterized the academic literature at the time. However, the model evolved into a methodology for systematically assessing the real effects of college. The I-E-O model is similar to a mathematical function, positing that the results (i.e., outputs) of a student's college experience depend on both initial conditions, such as sociodemographic and academic ability, and the transformative effects of social, academic, and other environmental effects. The model also has a strong emphasis on empirical measurement and the use of hard measurement rather than perceptions in understanding both environmental effects and outputs. The I-E-O model has served as the basis for other prominent educational theory, such as Tinto's theory of student attrition.

The I-E-O model was developed and created to explore and understand student characteristics along with their environmental constructs. The results of the interaction are the outputs of the qualities and attributes gained by the student as a result of the interactions (Astin, 1970a, 1970b). The model was developed in the 1970s, which was a period of intense interest in educational research due to the systematic changes that occurred during that period (Bahr, 2013). Some of the systematic changes included an influx of students from the Vietnam War using the GI Bill, an increase in political activation on college campuses, a rise in cultural awareness in students, and, most important in relation to this study, is the rise in two-year colleges in the United States (Bahr, 2013). As noted in Chapter 1, the community college and the standardized entrance test both rose to prominence around this time. The rise in community colleges resulted in a shift to new student population; a significant portion of the two-year college population was non-traditional students and students outside the traditional college age range of 18-24 years (NCES, 2016).

It was amidst this climate of research that Astin (1970a, 1970b) identified a problem with the developing body of literature. A meta-analysis by Hoyt (1965) surveyed over 1,000 studies on college achievement, yet failed to reach any meaningful conclusions (as cited in Astin, 1970a). Astin (1970a) postulated that the reason for the highly inconclusive result was because the literature was divided into a myriad of different conflicting methodologies and theoretical approaches, the results of which were often so heterogeneous that it was impossible to compare meaningfully. Although methods to predict or improve college outcomes have been widely studied, scholars have utilized different approaches that resulted in an incoherent outcome and prevented any overall conclusions from being made.

As such, the I-E-O model of student outputs was Astin's (1970b) attempt to create a conceptual framework for methodological unity, and a broad understanding of the overall processes to guide the results students achieve in their collegiate experiences. The original two-part series in which the I-E-O model was developed in an attempt to make a more coherent methodology. Additionally, the I-E-O model was more of a byproduct of the methodology. Astin (1970a) argued that the ideal methodological design for studying college outcomes was a quantitative stepwise linear regression using a multivariate longitudinal approach. Astin (1970b) also made an argument against the common practice of employing perceptions as a measure of environmental factors, noting that institutional propaganda and biases could easily color perceptions.

Although the argument that only a stepwise linear regression model was appropriate to the study of collegiate outcomes, this model contains the intuition for the overall model (Astin, 1970b). The intuitions of the stepwise model occur because the model first examines the effect of inputs on the student's experiences in college, and then examines the cumulative impact of inputs and environmental effects (i.e., the student's experiences) on outcomes. Astin's (1970b) insistence that perceptions are not an appropriate outcome measure in this context also facilitated a more empirical understanding of outcomes. Thus, from the I-E-O perspective, outcomes should be measured in terms of actual empirical variables such as college GPA or graduation rates.

The environmental effects in the I-E-O model are educational environments with which students come into contact (Astin, 1970a). For example, Astin (1970a) suggested that curriculum or courses can be viewed as part of the college environment for use in the I-E-O model. The environmental variable used in this study was the mathematics course in which students were placed. The mathematics course environment was valid for the study because it is a stable environment as described by Astin (1993).

The I-E-O model draws on this theoretical/philosophical background and applies it to the specific context of college. The three-factor I-E-O model includes the individual in the initial traits, the environmental factors resulting from the collegiate experiences in the environmental aspect, and the behavioral results of that interaction in the outcome traits (Arendale, 2014). Therefore, while important and influential in its own right, the I-E-O model also has a strong theoretical and philosophical grounded in earlier research and theory.

Evolution of the model. College performance and outcomes have become more scrutinized since the 1970s when the I-E-O model was first proposed (McGuire, 1995). The issue became especially prominent in the 1990s during what might be best described as "market mayhem" in the educational context (McGuire, 1995, p. 45). A shift in both financial and acceptance standards resulted in a closer examination of outcomes and performances by colleges. Specifically, colleges became more accessible to a significantly broader section of the population (McGuire, 1995). The accessibility of college to a wider population resulted in not only an increase in college enrollment due to significantly larger financial aid offerings, but also lowered acceptance standards by institutions in many cases. Lower acceptance standards permitted many students who did not qualify for merit aid and who would have been rejected under prior admission standards to attend college if they could pay their own way (McGuire, 1995). The acceptance of students who could pay meant that the college market was mostly flooded, not only with more students but also with more colleges seeking to recruit students under their new standards (McGuire, 1995).

The increase in the public prominence of colleges brought with it a renewed interest in the evaluation of collegiate performance and student outcomes from a particular college (Astin, 1970a). In response to the need for assessment of student outcomes, Astin and Antonio (1991) released a book titled *Assessment for Excellence*. This book represented an updated version of the I-E-O model that moved away from the original model's specific methodological focus. Instead, the book provided suggestions on how college assessment should be designed to create transparency and accountability. The updated version of the I-E-O model highlighted the importance of colleges' abilities to show how their educational approach is transformative. As the I-E-O model evolved, it illustrated the idea that the effect of the environmental factors characterized the effect of the college education itself, and that understanding outcomes relative to this are the most important part of an assessment.

In this iteration, the model retained its focus on using quantitative measurements and specifically avoided using perceptions because this could lead to an inaccurate measurement (Astin & Antonio, 1991). Instead, the updated model indicated that outcomes must be understood in the context of the environmental influences that characterize the college experience and how they have acted to shape the inputs to create those outputs (Astin & Antonio, 1991). For example, when colleges can demonstrate their environmental processes, they achieve excellent graduation rates. Additionally, acceptance of students with poor initial abilities may be a considerably better indication of school quality rather than a school that produces excellent results but also only enrolls students who excel by nature (Astin & Antonio, 1991). The practice of using graduate rates to determine the environmental factor is relevant to the study because assessing an institution from this standpoint requires an accurate measure of initial ability.

In addition to the further development of the model by its originator, the intervening years saw the evolution of the model as a basis for other educational theories. One such model is that of the peer-assisted learning model (Arendale, 2014). This model seeks to develop one of the specific environmental effects that may manifest in the college context, which is peer interaction and students assisting one another in completing their assignments or learning the material. Despite the fact that peer interaction and assistance provided by students is not always controllable by the institution, it is viewed as a part of the environmental aspect of the I-E-O model as it represents an experience during college that can have a significant effect on student learning and ultimately on student outcomes (Arendale, 2014).

Tinto's theory on student attrition is a modified version of the I-E-O model, one which shifted its focus from positive outcomes toward focusing on the specific negative outcome of dropout (Tinto, 1987). On the surface, this shift appears to be an insignificant change since examining the negation of graduation rate is functionally the same. The differences arise when looking beyond the surface level. The I-E-O model focuses on how environmental effects improve student learning and to develop student talents, while Tinto's theory focuses on the specific social and academic environmental effects that lead to dropping out; modeling dropout with a similar approach of social misfit to those used in popular theories of the causes of suicide (Nguyen, 2013). Tinto’s theory has achieved a high degree of prominence in studying dropout rates; therefore, its development from the I-E-O model can be taken as proof that the I-E-O model was built on a strong conceptual foundation (Nguyen, 2013).

The I-E-O model is grounded in the conceptualization of students' educational outcomes as the result of a combination of inputs and environmental factors (Astin, 1970a, 1970b). The model’s framework is centered on the concept of three basic constructs. These constructs are the inputs, environment, and outputs. The three-stage notion of student success in college was built on the intuition in the effective stepwise regression modeling of college success as a function of other factors (Astin, 1970a). The I-E-O model is depicted in Figure 1 below.

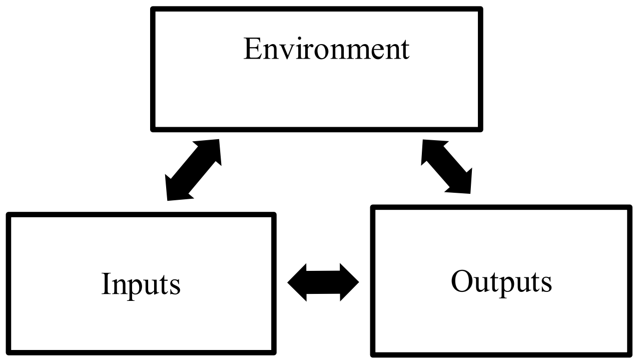

Figure 1. The I-E-O conceptual model. Adapted from "The Methodology of Research on College Impact, Part One." By A.W. Astin, 1970a, *Sociology of Education*, *43*(3), 223-254. Copyright 1970 by SAGE Journals.

Inputs. The inputs factor of the I-E-O model represents the student's background factors; that is, the conditions under which the student enters college. The inputs play an important role in determining the students' outcomes; however, the inputs are not the only factors with significant roles (Astin, 1970a). In the original stepwise regression model, the inputs were the student characteristics that were used as predictors for the first stage of the regression. Inputs can include a wide range of values with some important inputs, including sociodemographic factors like gender, race, or socioeconomic status (Astin, 1970a).

In the overall model, inputs have an important but limited role (Astin, 1970a). The limited input role is due to the college impact process presented as a stepwise series of events. The inputs are shaped and changed by interactions with other factors. Therefore, the inputs' influence on the final results should be mostly—if not entirely—mediated and moderated by the intervening relationships between two items: (1) inputs and environmental factors and (2) environmental factors and outputs (Astin, 1970b). On the other hand, under this mediation relationship, holding environmental factors constant as much as is possible should still allow inputs to be a predictor of success (Astin, 1993).

The inputs that were selected and measured in this study are divided into two variable groups, namely the sociodemographic variable and the placement assessment variables. For purposes of the study, student demographic variables including race/ethnicity, gender, age, veteran status, marital status, full-time enrollment status, and financial aid status were selected as the inputs of the I-E-O model. The inputs were strategically selected based on a review of the literature. Also, student sociodemographic information was readily accessible from records and served as input variables. Below is a description of the inputs used in the study and how they are identified in the institution's student information system. Furthermore, using demographic variables such as race/ethnicity, gender, sex, enrollment status, veteran status, and financial aid status in the I-E-O model assisted in examining if certain sociodemographic groups are more or less likely to be successful in college-level mathematics courses.

Study variables. The different variables used in the study based on the I-E-O model to capture the input, environment, and output are shown below along with their operational definition. Additionally, the rationale for the use of these specific variables in the study is explored in this section through an examination of the literature and review of other research that have utilized the variables outlined in Table 1.

Table 1

Variable Type, Names, and Definitions

Variable Type	Variable Names	Operational Definition
Input Variables (Sociodemographic Variables)	Age	Denotes the year in which a student was born as indicated on their college application.
	Gender	Students self-identify as being either male or female.
	Race/Ethnicity	Students self-identified the race/ethnicity with which they associate (e.g., White, Black, Asian, American Indian/Alaskan Native, Hispanic or Latino, Hawaiian or Pacific Islander, or unknown race).
	Veteran Status	Refers to whether or not the student self-identified as a current military or veteran on their student application.
	Enrollment Status	Denotes if a student enrolled on a full time or part-time basis.
	Financial Aid	Indicates if students are eligible for Pell Grants or not.
Environmental Variables (Mathematics Courses)	Statistics	Refers to a college-level statistics course. This course will count towards the mathematics requirement for students on selected plans of study.
	College Algebra	Refers to a college-level algebra course. The course will count towards the mathematics requirement for students on selected plans of study.
	Pre-Calculus	A college-level pre-calculus course which counts towards the mathematics requirement for students on selected plans of study.
Output Variable	Students' Grade	Refers to the grade received by the student in one of the three college-level mathematics courses as reported by the student information system.

Age was included in this study because of its potential effect on college success. The study by Shapiro et al. (2016) suggested that age had a significant effect on students completing college. Furthermore, data from the National Student Clearinghouse indicated that 49.3% of adult students aged 25 years or older failed to earn a credential at the post-secondary level in comparison to 25.9% of students aged 25 years or younger who failed to earn a credential entering a post-secondary institution (as cited in Shapiro et al., 2016). The variable of age was also suggested to be an important measure in college success from the research of Grabowksi, Rush, Ragen, Fayard, and Watkins-Lewis (2016). Grabowski et al. (2016) indicated that older students, or non-traditional students, might face additional barriers with regard to college success. Grabowski et al. (2016) also suggested that two-year institutions have a higher proportion of non-traditional students with their open admission policies and large part-time enrollment.

Based on study results by Islam and Al-Ghassani (2015), gender was also selected as an input variable in this study. Islam and Al-Ghassani (2015) suggested that course success in college-level calculus differs between male and female students. Specifically, male students were more likely to fail a college-level mathematics course than their female counterparts. Islam and Al-Ghassani (2015) also stated that male students failed the calculus course at a higher rate (28%) in comparison to female students (7%). The National Student Clearinghouse further supported gender as a strong input variable to include in the model. The Clearinghouse indicated that male students had lower completion rates and higher dropout rates than their female counterparts in two-year institutions (Shapiro et al., 2016).

Race/ethnicity was also included in the study as it has been identified as a key factor in college success. For example, White students were 15% more likely to receive an associate's degree in comparison to Black students (Bryant, 2014). Likewise, White students were 30% more likely to receive an associate's degree in comparison to Hispanic/Latino students (Bryant, 2014). A study by Ngo and Kwon (2015) provided support for race/ethnicity as an input variable in the I-E-O model as a positive correlation when using high school GPA or multiple-measures to evaluate course placement. Ngo and Kwon suggested that using prior mathematics score to determine mathematics placement could provide accessibility to African American and Latino students. Race/ethnicity was used as a variable in the current study because there is a wide gap between White students and students of other racial/ethnic backgrounds who receive degrees.

Veteran status is an important factor to add to the I-E-O model because a student who identified as a veteran is likely to also have several other sociodemographic variables that can be included in the model (Kirchner, 2015). For example, a veteran student is likely not to be a traditional-age student and is likely to be receiving some financial aid through the Serviceman's Readjustment Act of 1944 (i.e., GI Bill). Kirchner (2015) suggested that veteran students often have a difficult time transitioning from the military to the classroom. Therefore, if the support services at the institution are not available, the veteran student may be unsuccessful. Kirchner further noted that if institutions do not assist their adult and non-traditional students, they are able to provide support to their veteran students. The inclusion of veteran status in the I-E-O model is important because the number of veterans enrolled in college is expected to continue to rise in the next five years (Kirchner, 2015). Additionally, many states including Ohio mandated that state universities and state two-year institutions implement mandatory veteran services to assist veterans' transitions from the military to the classroom (Ohio Department of Higher Education, 2018b).

Enrollment status (i.e., full-time, part-time) was used in the I-E-O model for the study. Data from the National Student Clearinghouse (as cited in Shapiro et al., 2016) provided further justification for the inclusion of the enrollment status variable in this study. The data suggested that full-time enrolled students completed their education at a higher rate than their part-time counterparts. Notably, 21% of part-time students completed their education in an average of six years in comparison to 75.5% of exclusively full-time students who completed in an average of six years (Grabowksi et al., 2016).

Bryant's (2014) study also supported the use of financial aid eligibility as an input variable because financial aid eligibility indicates that students from low-income families are statistically more at risk of not receiving a post-secondary credential or degree. As such, only 35% of students from low-income families will earn a post-secondary degree when compared to 72% of students from high-income families (Bryant, 2014).

The second measurable input group in the current study was the student's placement assessment. In this study, students were placed in the college-level mathematics course through one of three methods, namely high school GPA, ACT/SAT mathematics score, or standardized placement examination. The I-E-O model facilitates the exploration of whether high school GPA, standardized placement tests, or ACT/SAT mathematics score are the best predictor for success in college-level mathematics. The input variables of high school GPA, ACT/SAT mathematics score, and standardized placement tests were selected as placement assessment factors because this information was collected in the student information system at the participating institution and facilitated a convenience sample. Moreover, the participating institution required that all students be assessed using one of three placement assessments methods. The placement assessment variables were also selected for use in this study because Astin (1993) explained that input variables are items that occur before the student enters the college environment. High school GPA, ACT/SAT mathematics score, and the placement test are items that occurred before the students take their first college course. The placement assessment methods are listed below along with justifications of why they were used in the study.

Placement Assessment

The justification for using high school GPA and ACT mathematics score as input variables in the study were supported by Westrick, Le, Robbins, Radunzel, and Schmidt (2015). Westrick et al. (2015) sampled 189,612 students from 50 institutions and examined both ACT mathematics score and high school GPA in correlation with first-year academic performance. The results indicated that the ACT mathematics score and high school GPA were correlated with a student's academic performance in their first year. However, the study was less successful at measuring retention from the first-year to second-year students. The results indicated that ACT scores and high school GPA were weaker predictors of college success and retention for second or third-year students than first-year students alone. For this study, the research by Westrick et al. (2015) was valuable because the aim of the current study was not to examine any other factor beyond the college-level mathematics course and student's success in that course.

Stewart, Lim, and Kim (2015) also supported the use of high school GPA and ACT mathematics score as input variables in their study on college persistence factors. The study explored if a relationship existed between college persistence and ACT mathematics score as well as high school GPA and first-semester college GPA using a sample of 3,213 students. Data analysis was done using a factorial analysis of variance and multiple regression analysis. Pearson's product-moment correlation was also used to examine the relationships between variables of high school GPA, ACT mathematics score, college GPA, and persistence. Study results suggested that high school GPA was a strong predictor of a student's college success in their first year. Stewart et al. (2015) were not able to correlate college persistence to high school GPA or ACT mathematics scores. As previously stated, the study explored success in college-level mathematics course and not students’ overall persistence within the institution.

The standardized placement exam was the third placement assessment method for the mathematics course and was used as an input variable in this study. Students who did not qualify for placement in college mathematics courses using high school GPA or ACT/SAT mathematics score were assessed using a standardized placement exam by the institution in the study. Using standardized placement exams was justified as it is common practice at two-year institutions as over 92% of two-year institutions assess college readiness using a traditional placement test (Scott-Clayton et al., 2014).

Environment. The environment is the central factor of the I-E-O model. The environment represents the process, which acts upon inputs to transform them into outputs. In the collegiate context, the environmental factors fall into many categories that can include academic effects, social effects, and financial effects, among others (Arendale, 2014; Astin, 1970a). The actual learning experiences in college are part of the environment construct. It is through the specific environment that a college creates the effects of its education and how it should be assessed (Astin & Antonio, 1991).

Astin (1970a) identified seven applicable environmental classifications for the I-E-O model. These classifications include faculty, curriculum, financial aid, major or program of study, peer group, and participation in academic or extracurricular activities. Astin (1993) further described the environment in the I-E-O model by stating “the environment refers to the student's actual experiences during the educational program" (p. 18). The environment can include any experience that may impact the student and, in turn, impact the measured outcome.

Astin (1993) noted that the environmental factor in the I-E-O model must be a stable factor when applied in the research study. He suggested that curriculum or courses can be used as part of the stable college environment for use in the I-E-O model. The environmental variable used in this study was the mathematics course in which students were placed. From the input variable of the placement assessment, the students were placed into one of three college-level mathematics courses namely statistics (MATH-130), college algebra (MATH-140), or pre-calculus (MATH-150). The mathematics course environment was valid for the study because it is a stable environment as described by Astin (1993). The environmental variables and a brief description of each are provided below.

Outputs. The revised version of the I-E-O model emphasized that the outputs themselves are not necessarily a good measure of a college's quality when considered in a vacuum (Astin & Antonio, 1991). Instead, outputs should be contextualized to their corresponding inputs and used in a manner to create a depiction of the school's overall ability to foster student talent. The outputs are likely not predicted directly by the inputs in a linear fashion, but instead the relationship is one of moderation or mediation; however, the environment should be held constant as much as possible. For example, using a specific school where the overall student experience is somewhat comparable outside of how input factors create different environmental factors; it should be possible to correlate inputs with outputs within a single specific context. The nature of the environmental factors and the differences across colleges suggest that the precise relationship between inputs and outputs is context specific rather than a single overall relationship that can be universally applied.

The outputs represent the outcomes of a student's collegiate experience. Astin (1970b) stated that these outputs should be measured in quantitative forms. Astin further suggested using graduation rates and student GPA, or grades, rather than potentially biased student perceptions of their education. For purposes of this study, the output measure used was the student's grade in the mathematics course.

The use of students' mathematics course grade as the output in the study was justified with support from Astin (1993). Astin (1993) noted that the output variables should be the end result or posttest. Astin (1993) also stated that appropriate output variables could include items such as GPA, degree completion, or course performance. In this study, course performance was used as the output variable. The output variable was used to measure how the input variables and environmental factors may connect with student's mathematics course performance, which in the study was the course grade.

Applications of the I-E-O Model by Other Researchers

The following section provides a comprehensive summary of the empirical research related to the I-E-O model and the variables used as part of the I-E-O model in this study. The alignment among all of these studies was the use of the I-E-O model in a higher education setting (Chevan, Reinking, & Iversen, 2017; Franklin, Debb, & Colson, 2017; Grineski et al., 2018; Hahler & Orr, 2015; Parker, Kilgo, Sheets, & Pascarella, 2016). Further, the setting for each of the studies varied to include both four-year and two-year institutions.

The studies varied in how they applied the I-E-O model and the outcomes they sought. Additionally, each study differed in the variables they focused on for the *I* (Inputs), *E* (Environment) and *O* (Output). Specifically, the sociodemographic variables of each study were uniquely different and only applicable to the study presented.

The application and outcome of these studies were similar to the current study. The study by Chevan et al. (2017) is highlighted because it has several components that are similar to the current study. Notably, the study examined high school GPA in their I-E-O model and explored the extent to which high school GPA, along with other inputs, had an impact on the completion of a student's degree. Also, the two studies are similar in the use of high school GPA to explore the impact on student college success. A study by Parker et al. (2016) applies to the current study because it used several of the same inputs used in the current study, including gender, GPA, and race/ethnicity, to determine if a relationship exists between the output (i.e., college-level GPA).

The use of sociodemographic variables varied throughout the empirical review of the literature; however, several studies were highlighted because they applied to the current study. Grineski et al. (2018) used a variety of sociodemographic variables that are applied in the current study including age, gender, sex as part of the study. Franklin et al.'s (2017) study applies to the current study because it used several of the same sociodemographic input variables, including gender and age, as part of their study. Additionally, the study by Franklin et al. (2017) is directly relatable to the current study as academic achievement is tied directly to the college mathematics course. Hahler and Orr's (2015) study provided further support of the I-E-O model to measure academic aptitude in this study because they used both high school GPA and a standardized test such as the ACT/SAT mathematics score as a valid input variable for the I-E-O model and ties it directly to student success.

These studies had a range of limitations. In general, most of the studies ranged widely in the student sociodemographic characteristics used, and none of the studies included the veteran status and Pell Grant eligibility variables. A further limitation of the studies that have used the I-E-O model is that none of them employed all three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement exam) in their study.

Relationship of the I-E-O model to the problem. Astin's (1970a, 1970b) I-E-O model provides an appropriate guiding model to address the research problem. The I-E-O model was the appropriate framework that allowed for the critical examination of the placement assessment methods in relation to the college mathematics courses. The I-E-O model facilitated the critical examination of the relationship between placement methods used at a two-year institution and success in a college-level mathematics course. Thus, using Astin's I-E-O model as the guiding framework facilitated the identification of the placement assessment variables in relation to the environmental factors (i.e., mathematics courses) to determine the output (i.e., course success). Also, the model allowed for the critical examination of each of the variables in relation to the study. The I-E-O model was appropriate to guide the study because the study utilized specified inputs (i.e., independent variables) along with the constant environmental variables to produce the desired output (i.e., dependent variable). Finally, the use of the I-E-O model in this study allowed for the examination of data to explore if specific variables have more or less of an impact on success in a college-level mathematics course.

Justification of the Model

The relevance of the I-E-O model to the study is that it characterizes how input variables (e.g., sociodemographic information) can be used to predict or explain academic success, as well as how environmental factors such as types of assessments and specific courses affect the outcome of student academic success in the study. The application of the I-E-O model in the study is represented in Figure 2 below.

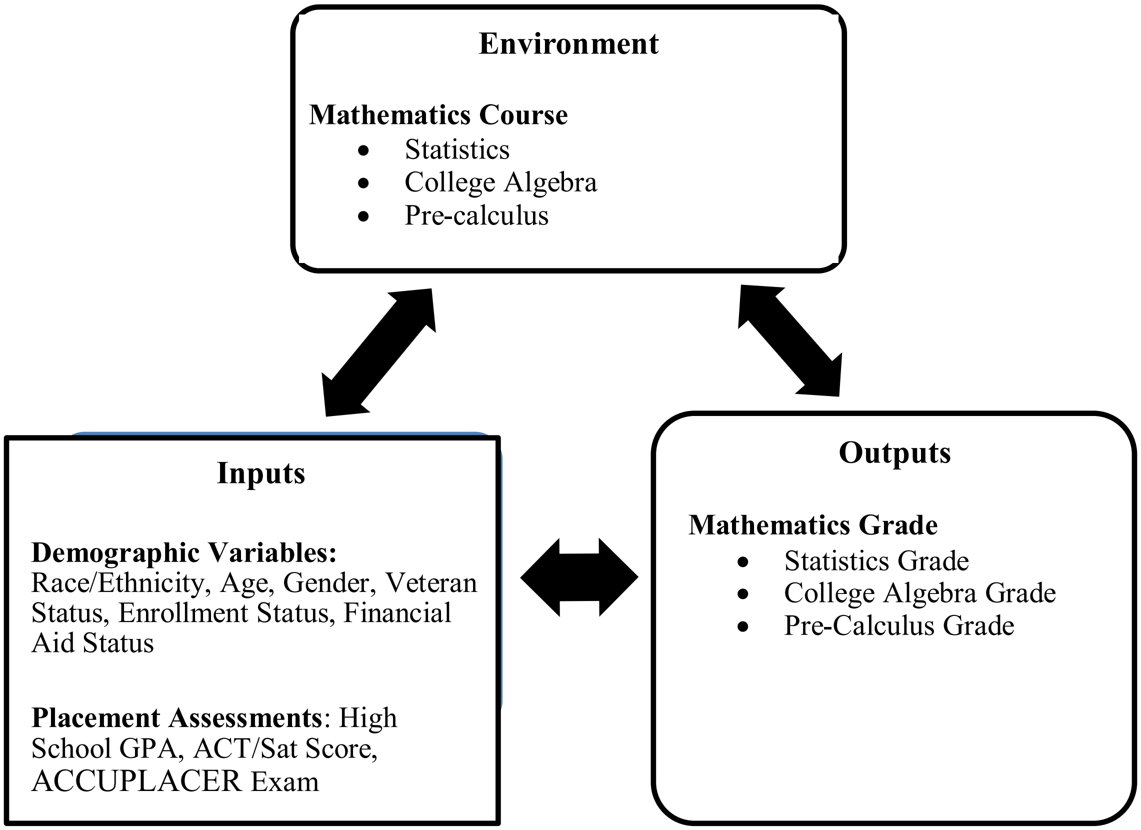

Figure 2. Application of the I-E-O model.

Figure 2 illustrates that each of the variable types—input, environment, and output—are all affected by each other. If a change occurs with any of the variables in the I-E-O model, it can affect the other variables. For example, an input of age and/or a student being admitted via his or her high school GPA can affect an environment of the mathematics course such as pre-calculus, which in turn can affect the output, or the grade in the pre-calculus course.

Alignment with the study. The purpose of the study was to assess the three placement methods used by two-year colleges in placing students in college-level mathematics courses. The researcher asked research questions to identify and examine all three placement assessments types (i.e., the standardized placement test, ACT/SAT mathematics score, high school GPA) to determine the single best mathematics placement method for college success at one institution.

As such, the I-E-O model served as the foundation for the development of research methodology in which the study was designed.

Strengths. One argument in favor of the I-E-O model and the methods of assessment it implicates is its efficacy. For example, Skenes and Honig (2004) found that an I-E-O-inspired pretest/posttest longitudinal model of assessment for a professional master's degree program was excellent for demonstrating the program's ability to create the desired behavioral changes in its students. Rather than merely assessing the program based on its final scores, the authors argued that it could be described as successful. Such success was attributed to the fact that throughout the program the participants exhibited significant attitudinal changes in the desired direction on eight out of 12 assessment scales. Students' attitudinal changes represented a simple, effective demonstration of the reason this form of assessment tool is ideal; understanding how the specific inputs were changed in the desired direction says much more about the program's success than its final results would in a vacuum.

Another advantage that the model offers is its flexibility. Moving beyond a more specialized model based on the assumptions of any specific context, the I-E-O model attempts to characterize the college experience with maximum generality while still affording an understanding of how to focus on specifics if one chooses (Astin, 1970a, 1970b). This strength has allowed the I-E-O model to be expanded to create the other specific theories discussed above, such as Tinto’s theory of student attrition (Tinto, 1987) or the peer-assisted learning model (Arendale, 2014). Such flexibility means that the I-E-O model can be applied to almost any academic context and then adjusted to model the specific interactions present in that context. The I-E-O model does not merely seek to understand results, but instead aims to contextualize those results and thoroughly explain them, creating a type of theoretical weighting system (Astin, 1970a, 1970b).

Weaknesses. Perhaps the most persuasive argument in opposing the use of the I-E-O model is its stricter criteria for assessment, which insists upon actual, empirical evidence of not only outcomes but also environmental processes, is impractical (Astin, 1970b). As noted by Brown (2017), the idea of the type of accountability offered by an I-E-O based analysis of a college's performance is attractive; however, enacting such a precise and comprehensive regimen of assessment consumes a significant amount of staff and faculty time. Therefore, one must ask if the actual results of applying an I-E-O based assessment system is worth the investment of time that might have been spent on actually improving practice.

Criticisms. Yorke (2004) has been a critic of the I-E-O model and has argued the model's generalizability. The generalizability of the model is not so much a weakness in the validity of the overall model as it is a weakness in its application (Yorke, 2004). Because the model is very general and non-specific, it must be developed considerably for any individual application (Yorke, 2004). The considerable development of the I-E-O model is perhaps an unfortunate necessity, but it does hinder the model's utility because the model itself is something of a black box that must be unraveled and understood over and over again. Reference to the I-E-O model as *a black box* is fitting since the environmental factors acting on any given college student population are in part defined by the college; even if it were possible to create a general version of the model, it would likely be prohibitively complex which extends to the inputs

(Yorke, 2004). Inputs are often limited to the specific input factors that are easily measured, although they could conceivably include an almost infinite number of factors.

Considering the arguments for and against the I-E-O model, the arguments in favor of the model are both more convincing and relevant to the present study. The main criticisms of the model are based on the difficulty of implementing it, either practically or theoretically (Brown, 2017; Yorke, 2004). These arguments are undoubtedly valid, but they only apply in a context where an institution or researcher is attempting to specify the model. For the study, the model instead provides context; it is enough to know that the black box function of environmental effects exists to transform inputs into outputs and that holding the environmental effects as constant as possible should allow a stronger set of inputs to better predict outputs. In this respect, the flexibility of the model is a substantial advantage as it means that the I-E-O model applies in the specific context of this study (Arendale, 2014). Furthermore, the model's overall efficacy and validity are such that using the model to frame the analysis should make it stronger and more complete (McGuire, 1995).

Chapter Summary

The primary issue highlighted in this chapter relates to the fact that two-year institutions accept the majority of the students that apply and that not all of the students are prepared for the rigors of college-level courses. Additionally, there is no consistency among two-year institutions in the placement method used to determine the placement of a student (Scott-Clayton et al., 2014). Specifically, institutions primarily use one of three placement methods (i.e., high school GPA, ACT/SAT scores, standardized placement exams) to assess student readiness for college-level mathematics courses (Lavonier, 2016; Scott-Clayton et al., 2014; Walters, 2014). Despite the implications associated with the use and outcomes of these placement methods, few empirical studies have investigated which placement method is most effective in predicting academic success.

Throughout Chapter 2, empirical studies that explored each placement assessment method and variable used in this study were reviewed and synthesized. There was some variability in how high school GPA was used as a predictor of success in college-level mathematics and English courses. The key finding of the studies that examined the use of high school GPA as a predictor of success in college-level courses was that in comparison to standardized placement exam and ACT/SAT scores, high school GPA is a relatively stronger predictor of success in college-level mathematics courses (Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods et al., 2018). As part of the literature review, several studies that assessed the association between standardized placement test and college success were also reviewed (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2016; Martorell et al., 2015; Windham et al., 2014). The key finding of these studies exposed that misplacement is more likely when a standardized test is used (e.g., ACCUPLACER, ACT/SAT test) compared to a student's high school GPA.

Furthermore, under-placement of students represents a potential danger to passing college-level courses. The literature review also explored how institutions utilized their placement assessment policies and opportunities and challenges associated with the various policies. Several states have implemented some form of multiple placement assessment measures policy, which have had a fair amount of variability. Although policies on remedial coursework vary from state to state, there was a common theme of remedial education policy reform.

Aligned with the problem that colleges vary in the placement method used in addition to the fact that students are measured differently depending on the college they attend as outlined in the topical literature section, the purpose of the current study was to assess the three placement methods (i.e., high school GPA, ACT/SAT score, standardized placement test) used by two-year colleges in placing students in college-level mathematics courses to determine the single best mathematics placement method for college success at one institution. Astin's (1970a, 1970b) Inputs-Environment-Outputs (I-E-O) model was used to guide this study. Included in this chapter was an extensive review of the reasons the I-E-O model was selected for use in this study as well as a literature review of how the model was used in prior studies. The following chapter provides a detailed discussion of the methodology that was used in this study.

Chapter 3: Procedures and Methods

The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in Midwestern United States. Student records (N = 1,330) for a single academic year were used to determine which of the three placement methods (i.e., high school GPA, ACT/SAT mathematics score, standardized placement test) is most effective in determining success in college-level mathematics courses. This chapter examines the methodology used to answer the overarching research question: *Which of the placement variables is the best predictor for success in college-level mathematics?* From this central question, four specific research questions are posed:

RQ1: What is the relationship between the placement methods (high school GPA, ACT/SAT mathematics score, or standardized placement exam) and academic success in college-level mathematics at a Midwestern two-year institution?

H_0: There is no relationship between placement methods and academic success.

H_1: There is a relationship between placement methods and academic success.

RQ2: After controlling for sociodemographic variables, what influences do placement methods have when it comes to academic success in college-level mathematics at a Midwestern two-year institution?

H_0: Placement methods do not influence one's academic success.

H_1: Placement methods influence one's academic success.

RQ3: What influence does the mathematics course taken (statistics, college algebra, or pre-calculus) have on the academic success in college-level mathematics at a Midwestern two-year institution?

H_0: Course taken does not influence the prediction model.

H_1**:** Course taken influences the prediction model.

RQ4: How do the models compare when disaggregated by placement method?

H_0**:** There is no statistical difference in models when disaggregated by placement method.

H_1**:** There is a statistical difference in models when disaggregated by placement method.

Chapter 3 identifies and describes the quantitative methodology used to obtain and analyze the data to answer the research questions. The researcher provides justification of the methodology used as well as an identification and discussion of the site selection, subjects, subjects' selection method, data sources, ethical issues, instrumentation, data collection, researcher positionality, credibility techniques, and data analysis procedures used in the study. The chapter concludes with a summary of the data analysis techniques used in the study with the support of empirical research.

Research Design

The philosophical paradigm of postpositivism is at the foundation of the research design. Postpositivism research asserts that ideas can be broken down into variables and then made into research questions and tested (Creswell & Creswell, 2017). Postpositivism research is often associated with quantitative studies because the variables used in postpositivism research are reduced to numeric measures which can then be used to verify the theory (Creswell & Creswell, 2017).

The quantitative design is generally used to examine the relationship between variables, and its primary goal is to analyze and represent the relationship mathematically through statistical analysis. Quantitative design is most commonly used in scientific research problems (Creswell & Creswell, 2017). Quantitative approaches generally utilize a theory that is exemplified by one or more hypotheses that are tested so that conclusions can be drawn regarding the theory (Rovai, Baker, & Ponton, 2014). A key feature of quantitative designs centers on the collection and analysis of numerical data from a relatively large sample using surveys to allow for study results to be generalizable to a larger population (Blaikie, 2010). Quantitative study design was selected as the methodology for this study for a multitude of reasons. An advantage of using a quantitative approach is that it validates relationships between variables and allows for a generalization that contributes to theory (Creswell & Creswell, 2017). An additional strength of quantitative research is that personal bias is reduced because the researcher is removed as part of the data collection process (Creswell & Creswell, 2017).

Although quantitative methods have multiple strengths, they are not without weaknesses. Williams and Shepherd (2017) identified the shortcomings of quantitative data collection and interpretation using secondary data and noted that the use of outdated data and non-applicable population samples are potential weaknesses. However, neither of these weaknesses was applicable in the current research study. The institution uses the secondary data used in this study for the creation of a variety of reports that rely on data accuracy, and the population used in this study is similar to the population norm. However, in instances where the population sample of this study was different, it was noted accordingly.

With the strengths and weakness in mind, a quantitative approach was the most appropriate design for this research study. The statistical strength of using a quantitative methodological approach was a key factor for selecting the quantitative research design because of its large sample size (Neuman, 2013). Additionally, limiting the researchers’ personal bias were all factors in the selection of the quantitative research design.

The study also utilized a non-experimental correlation design methodology. A non-experimental research design refers to research in which the researcher observes what occurs naturally without interfering (Creswell & Creswell, 2017). The use of correlational design allows the researcher to statistically analyze the relationships between two or more variables (Field, 2013). For example, a positive correlation exists when one variable increases and the other variable increases as well. The strength of using a correlational design is that it allows the researcher to collect large amounts of data that identifies explicitly if a relationship exists between two variables (Creswell & Creswell, 2017). One strength of the correlation research design is the ability to determine if a relationship exists between two variables when large amounts of data are used (Hoy & Adams, 2016). Correlational designs have few weaknesses. Non-experimental correlation designs do not allow for causation between variables to be determined (Field, 2013). For example, when two variables are positively correlated, a cause and effect between the relationships of the variables cannot be assumed (Babbie, 2014). However, Creswell and Creswell (2017) noted that non-experimental correlation is an appropriate research study when the purpose of the research is to establish if a relationship between two variables exists.

Site Selection

The site selected for the study was a two-year technical and community college with four campuses located in the Midwestern United States; all four campuses were used in the study. The institution has an annual enrollment of approximately 3,500 students and accreditation by the Higher Learning Commission. The institution offers 33 associate's degree programs and 18 certificate programs with the most popular associate's degree program being nursing. The institution is an open-admission college and students seeking admission must meet one of four requirements. These requirements are that the student (1) graduated high school, (2) completed homeschooling at the secondary level, (3) passed the General Education Development Test (GED), or (4) if requirements one through three are not met, then the student must be 18 years or older.

The researcher gained access to the data and the site because of employment at the institution. To gain access to the data, the researcher contacted the President of the college to request permission. A face-to-face meeting with the President of the college was initially scheduled to request permission and access to the data primarily due to the fact that the researcher is employed by the institution. After obtaining approval from the President, an email was sent to the institution's Institutional Research and Effectiveness director to formally request tentative permission pending University of West Florida (UWF) Institutional Review Board (IRB) approval.

The site was selected because the researcher has been employed by the institution for over 12 years. As such, the researcher has access to secondary data that may not be readily available to others. Also, the researcher has insider and historical knowledge that would not otherwise be available to an external individual conducting the study. The researcher is also aware of failed policies and procedures and has witnessed the struggles of students, staff, and faculty who have solely used the standardized placement test. Furthermore, the insider status of the researcher facilitated institutional cooperation.

The site is typical of most two-year institutions in several areas. First, the two-year college is a public institution, and the vast majority of two-year institutions are public institutions. There are over 1,100 two-year colleges in the United States; of those, 980 are public institutions (American Association of Community Colleges [AACC], 2018). Additionally, the average annual tuition at two-year institutions is $3,570 per full-time student (AACC, 2018). At the current site, the average annual tuition and fees for a full-time student is $4,200, which is slightly higher than the national average.

Population

The population included all students who took an entry college-level mathematics (i.e., statistics, college algebra, or pre-calculus) course in the Fall 2017 and the Spring 2018 semesters. The population for this study was students at a two-year college. The two-year institution had a total student enrollment of 3,429 from which a sample of 1,131 was utilized. The subjects for the study were from one college across four campuses. Data were obtained from the student records system stored on the institution's student information system. The sociodemographic information used in the study including race/ethnicity, age, gender, and veteran status were obtained from the student's application to the college. The sociodemographic variables of enrollment status and financial aid were stored in the student records database, which was a part of the institution's student information system.

At the current site, an average of 75% of new students entering the institution sit at least one remedial course. Students take an average of 8.26 credits per semester, with full-time enrollment considered to be 12 credits per semester. The demographics of this population were as follows. Students' age ranged from 14 to 71 years at the study institution. The enrollment of younger students is as a result of a state mandate requiring all state institutions to allow high school-aged students in the seventh to 12th grade to be eligible to take college-level courses if they meet the state minimum requirements. However, at the study institution, the students' average age was 24 years. Students aged 21 years accounted for the largest group (47%) within the student population in comparison to those aged greater than 51 (2.24%).

The racial and ethnic composition of the campus was 72.4% White, 9.71% Black, 1.45% Asian, 0.47% American Indian/Alaskan Native, 1.75% Hispanic or Latino, 0.27% Hawaiian or other Pacific Islander, 3.92% two or more races, and 13% unknown. Furthermore, females accounted for 67% of the student enrollment. The gender ratio was also roughly analogous to that of all two-year institutions, with females making up approximately 60% of enrollment in both cases. Four percent of the overall student enrollment at the institution was veterans, which is in line with the national average of veteran enrollment at a two-year college of 4% (ACC, 2018).

The sociodemographic diversity of the site was also not typical in comparison to the national average. The majority of students (47%) who attend a two-year college nationally are White; however, at the selected institution 72% of students self-identified as White. Nationally, Hispanic/Latinos account for the second largest (24%) race/ethnicity of students that attend a two-year college, in comparison to approximately 2% of the entire student population at the current site. Black students accounted for the second-highest racial group at the current site at approximately 9%, which is close to the national average of 13% for two-year colleges (AACC, 2018).

Lastly, approximately 57% of students at the current institution received some form of financial aid assistance. This percentage is in line with the national average of students receiving financial aid at a two-year college at 58% (AACC, 2018). In general, the subjects may not be identical to the broader two-year college population in the United States, but they characterize a broad, relatively representative sample, especially within the specific context of a Midwest two-year institution in the United States.

Sample

The sample included all students who were placed into one of three college-level mathematics courses (i.e., statistics, college algebra, or pre-calculus) during the Fall 2017 and Spring 2018 semesters (*N* = 1131). The record for one of the students was deleted because the student did not have valid data for the dependent variable. This deletion reduced the final dataset to 1,130 cases. The majority of the sample were females (65%) and included various racial/ethnic groups. Notably, the subjects self-identified as White (68%), Black (7%), Asians (2%), Hispanic (1%), while the remaining subjects identified their race as American Indian, two or more races, or unknown. This sample was drawn from the population because all new students were assessed using the college's placement testing policy; as such, there was no need to randomize the sample. The sample consisted of students who placed in a college-level mathematics course by taking the standardized placement test, ACT/SAT mathematics score, or high school GPA in the semester that the study started. All new incoming students were included in the research study. The institution's placement policy required that all incoming students be assessed using high school GPA, ACT/SAT mathematics score, or the standardized placement test as outlined in Table 2.

Size and power. A power analysis was conducted using G*Power (Version 3.1) to determine the appropriate sample size given established benchmarks for alpha, power, and effect size. The researcher adopted Tabachnick and Fidell's (2007) suggestion for power (.80), alpha (.05), and a moderate effect size. A minimum sample of 588 was needed to meet these guidelines. If the researcher desires to have a higher degree of power (.95), a minimum sample of 988 records was required. Given the number of anticipated records in the archival dataset, power estimates of .80 and .95 are both satisfied in this study.

Sampling Method

Data used for the study were collected from students as part of their academic records by a two-year college. In this case, the data used in the study were student records from a single two-year college in the Midwest. Student data for an entire academic year were selected to achieve a larger sample size for this study. The variables selected for placement were identified concerning the institution's placement assessment policy. The sampling included subjects who were placed using high school GPA, ACT/SAT mathematics score, or the standardized placement exam. The sample consisted of subjects who were enrolled in three mathematics courses. The three mathematics courses used in this study were selected because they are used as part of the entry-level mathematics sequence at the institution. All students in these courses were enrolled based on one of the three placement methods. Although the institution has other mathematics courses, the three courses used as part of the study are the only ones that students are directly placed into based on the admissions approaches and assessments.

For the study, the variables are identified in the I-E-O model as the Inputs, Environment, and Output and were used to determine the best placement assessment method for predicting college-level mathematics success for students. Because the study used only secondary data, describing the study design as an observation of a specific group is valid. The observational design for the study was the group/population of any student who took one of the three placement assessment methods (i.e., high school GPA, ACT/SAT mathematics score, or standardized placement), to place into one of three college-level mathematics courses (i.e., college algebra, statistics, and pre-calculus).

Table 2

Assessment Placement Chart

Options	Placement Measures	Descriptions
Option A	HSGPA	Unweighted HSGPA (high school grade point average) ≥ 3.0. HSGPA must include at least three units of high school-level mathematics for placement into college-level gateway mathematics course and for any course that has a prerequisite for mathematics proficiency.
Option B	ACT/SAT Score	Sufficient score on the ACT or SAT. SAT Mathematics = 500 or ACT Mathematics = 22
Option C	College Placement Test	Sufficient score on test, such as COMPASS or ACCUPLACER. These test scores must be no more than five years old at the time of enrollment in the college.

Note. HSGPA = High School Grade Point Average; ACT score = American College Testing scores; SAT scores = Scholastic Aptitude Test scores.

Ethical Issues/Permissions

The researcher received approval from the UWF IRB and permission to access the secondary data set from the institution under study (Appendix A). The researcher followed the IRB-approved research plan as outlined by the UWF throughout this study. The researcher completed the Collaborative Institutional Training Initiative Program course for Social and Behavioral Conduct of Research (Appendix B). The researcher adhered to only the UWF-approved research protocols throughout the study. The data were stored by the researcher on a password-protected computer throughout the duration of the study. The computer was stored by the researcher in a locked office for the duration of the study. Lastly, the researcher objectively analyzed the data and the results reported without any known bias (Babbie, 2014).

Confidentiality of data. Because the study used only secondary data, there were minimal risks to study subjects. To avoid any possible ethical issues related to the use of student records, student names were not used in the study. Randomly assigned numbers were used in the study instead of student's names to protect their identity. Additionally, the data were stored on a password-protected laptop that was securely located in a locked office to prevent any possible data breach. Finally, accessing the secondary data on a separate secured drive required the use of a username and password, thereby contributing to the protection of the data. The researcher did not have access to the names of any of the students who were used in the research study.

Beneficence. The researcher assessed and monitored the study for any associated risks to protect the subjects. There were no identified risks to the subjects, primarily because the study employed the use of a secondary dataset and the identity of the students was not accessible or made available to the researcher at any point in the study. There were also no anticipated benefits of study participation. However, the results may inform the use of better placement assessment methods for students who plan to attend two-year institutions. Additionally, using the results from the data, the study has a practical policy application if the results support a specific placement method as a stronger predictor for college-level mathematics courses; that is, such a result can allow for a variety of different policy changes at the two-year institution level.

Consent. The researcher first obtained approval from the participating institution to access and examine their secondary data for this study. The participating institution does not have an IRB approval board. As a result, the approval was received from the Vice-President of Institutional Research and Effectiveness at the institution (Appendix C). No consent was required for participating individuals because no identifying information was provided to the researcher. The Institutional Research and Effectiveness department removed all identifying information before the researcher received these data. The identifying information that was removed included the student's name, date of birth, and ID number.

Data Sources

The data source used in this study was student records from a two-year Midwestern college. Secondary data were used to assess placement methods used to place students in college-level mathematics courses. Johnston (2014) described secondary data as "data that was collected by someone else for another primary purpose" (p. 619). An advantage of using secondary data is that it is a time-saving and cost-effective way of conducting research because the researcher does not have to collect the data since it was collected by another external source (Williams & Shepherd, 2017). A further advantage of using secondary data is that the variables used in the study may have a pre-established level of reliability and validity; thus the researcher did not need to re-examine the data for validity in this study (Neuman, 2013).

Conversely, a clear disadvantage of using secondary data is that the results can be inaccurate if the data is outdated which may result in a flawed the study (Williams & Shepherd, 2017). However, this was not an applicable disadvantage in this study because the data were used for a variety of other reporting purposes that rely on the accuracy of the data, including state and federal subsidy. An additional disadvantage of using secondary data relates to a lack of representation of the sample used in the secondary data in comparison to that of the larger population or norm, thereby limiting the transferability and generalizability of results to other studies. However, this limitation does not apply to this research study because the population sample is similar to the population norm. In cases where the population sample differed from the norm, it was noted accordingly.

The institution used the Ellucian Colleague database to store the secondary data. The student information system contained the academic records and sociodemographic variables for all students who attend the institution. The student information system is a secure password-protected database that can only be accessed by connecting to the institution's server, with the use of a valid username and password.

Description of Research Protocols/Instrumentation

There was no instrumentation related to the study since it used only secondary data. The secondary data was collected directly from an institutional database and therefore not dependent upon a particular methodology or instrument. The participating institution collected the data as a part of the student academic record.

Data Collection Procedure

The researcher did not engage in any primary data collection because the institution collected this data from their students. The student information was collected at various points and times by varying institutional staff employed at the college. For example, the student's sociodemographic information was entered at the time of application. Such information included students' self-identified race/ethnicity, age, gender, and veteran status at the time of application. This information was then securely uploaded to the college's student information system.

Other demographic variables such as enrollment status and financial aid status were also securely stored on the student information system by the Office of Financial Aid. The number of credits students enroll in determined their enrollment status. Lastly, the researcher received the data with the use of randomly generated numbers to represent each student. No student identifiers were present in the data that were used in the research study.

The mathematics grades that were used in the study were also stored in the institution's student information system. The student's course grades were housed and collected in Moodle. Moodle is a learning management system (LMS) that must be used by all faculty members as part of the faculty's teaching contract. The LMS calculates the assignments and provides a final grade for the course, which is then imported into the student database. The ability of Moodle to calculate student's grades ensures that no grade miscalculations occur between instructors.

Before receipt of the secondary data, all identifying student information was removed from the data set by the institutions' Institutional Research and Effectiveness department. Specifically, students' name, identification number, and social security number were all removed before the researcher received any data. Student records used in this study were randomly assigned numbers instead of student's names to protect their identity. After the removal of the student identifying information, the file was then given to the researcher on a USB drive which was subsequently saved on a password-protected computer. Once the file was saved to the password-protected computer, the USB drive was returned to the institutions' Institutional Research and Effectiveness department.

The data collection period lasted approximately two weeks during the Fall 2018 semester. During the first week, the researcher met with the representative from the Institutional Research and Effectiveness department. During the meeting, a discussion was had regarding the data required to meet the needs of the researcher. Approximately one week later, the data were available to the researcher for review. All identifying student information had been removed by the Institutional Research and Effectiveness department before the researcher receiving the data. The data were provided to the researcher in an Excel® spreadsheet, after which it was uploaded directly to the researcher's secured password-protected laptop.

During collection. During the study, the secondary data were stored on a laptop that could only be accessed using a secure password. The laptop was stored in a locked office during the data analysis phase of the study to prevent any possible data breach. Additional protection of the data required the use of a username and password to access the data on a separate external drive. The dataset was then uploaded and analyzed using the Statistical Package for the Social Science (SPSS) version 25 (International Business Machines Corporation [IBM], 2017). Once uploaded into SPSS, the dataset was removed from the researcher's hard drive.

After collection. After the data were analyzed, the data file was saved on the same password-protected computer on which the data file was initially saved. The data will be saved on this computer for approximately two years to facilitate future presentation and publications. After that, the secondary data was permanently removed from the researcher's hard drive.

Researcher Positionality

The researcher has been employed by the two-year institution for the last 12 years. The researcher has witnessed the effectiveness of the placement test and is aware of how students typically perform in college classes after taking the test from observation. Additionally, the researcher is a first-generation student and works in an open-access institution where access to education is a priority. Although the researcher is invested in the institution, it is essential to separate any subjectivity from the research to increase the study's integrity. It follows that, from an outsider's perspective, it may be viewed that the researcher may have an unclear perception of the situation because he is closely connected to the institution.

However, several essential steps were taken to avoid clouding of the researcher's perceptions including removing identifying student information and using summative data. Not knowing any of the students added a layer of protection from any positionality throughout the data analysis process. Lastly, using only summative data helped in ensuring that any researcher biases remain neutral and objective to the integrity of the research. In general, the anonymity of quantitative data and the empirical nature of the data themselves provided a reliable safeguard against bias because the data essentially speak for themselves.

Research Validity

The study can be duplicated at other institutions. However, the researcher does not assume by default that the results can be applied to other student populations and institutions. The study took place at a small- to medium-sized two-year technical and community college in the Midwestern United States. The collection of demographic data helped in ensuring the external validity of the study. Demographic data were used as control variables in determining if the differences observed in student's success in college-level mathematics courses were the results of student's high school GPA, ACT/SAT mathematics score, or the standardized placement test, and not from any sampling bias. The demographic characteristics of the study sample helped to determine if the results apply to other populations based on whether or not other populations share the same characteristics.

If replication of the study is desired, an area of concern for external validity is that the institution is located in one of the few states in the country that is 100% funded through student completion. The provision of 100% funding through student completion has resulted in some student success initiatives throughout the state to increase student completion rates. The results of these student success initiatives have helped increase student retention throughout many of the state institutions, which is essential for any future researcher looking to duplicate the study.

On the other hand, internal validity constitutes how well a study represents what it seeks to measure wholly and accurately (Merriam & Tisdell, 2015). The use of secondary data and objectively measured variables significantly boosted the internal validity of the study because it ensured that the data collected were measuring what it intended to with virtually no doubt. However, one exception is the distant concern of data entry errors in student grades by teachers or staff in the system (i.e., Moodle**).** In this regard, there is one important threat to internal validity; that is, the standardized placement test that the institution uses has only been in use for three years. Before moving to the ACCUPLACER testing, the college used the ACT COMPASS placement testing for over 10 years. The institution, like all other institutions that previously used the ACT COMPASS placement testing, was forced to either move to ACCUPLACER or another testing service due to the ACT COMPASS being discontinued in December of 2015 (Fain, 2015). The participating institution in this study had only three years' worth of historical data that provided a history of student performance on the new ACCUPLACER placement test, while the old ACT COMPASS placement test had over a decade's worth of student performances to analyze. Nonetheless, ACCUPLACER is still a widely used and accepted test for this purpose, thereby reducing the impact of the threat to internal validity.

Variables

The variables used in the study were coded accordingly in Table 3. All of the variables used in this study were identified previously in Chapter 2 and supported by a review of the current literature and research that utilized the variables.

Table 3

Variable Codes

Variable Names	Coding
Age	Continuous variable
Gender	1= Female 0 = Male
Race/Ethnicity	1 = White 0 = Other
Veteran Status	1 = Yes 0 = No
Enrollment Status	1 = Full time 0 = Part time
Financial Aid	1 = Yes 0 = No
Mathematics Course*	1 = Math-130 (Statistics) 2 = Math-140 (College Algebra) 3 = Math-150 (Pre-calculus)
Students' Grade	Grade was dichotomized into pass and fail. 1 = Pass 0 = Fail
Placement Assessment Method*	1 = High school GPA 2 = ACT/SAT mathematics score 3 = ACCUPLACER/COMPASS Exam

Note. ACT = American College Test; SAT = Scholastic Aptitude Test;
* indicates that the original nominal level variable was broken into three dummy coded variables.

Data Analyses Techniques

Data for the study were analyzed using the Statistical Package for the Social Science (SPSS) version 25 (IBM, 2017). Univariate descriptive analyses and multivariate analyses were conducted. A series of descriptive analyses were used to understand the student population in the study. Descriptive statistical analyses included frequency and proportion distribution, dispersion, measures of central tendency (i.e., mean, median, and mode), and variability. These descriptive analyses facilitated the identification of outliers, missing values, and other common data errors. The researcher ensured every record had an ID number and that the data fields were labeled in the appropriate format (e.g., string, numeric).

The researcher then performed frequency analyses on all study variables to determine the presence of missing data in the dataset. One subject did not have data for the dependent variable and was therefore deleted from the dataset. As a result of being deleted from the dataset, this student was excluded from the data analysis as the researcher had no way of making contact with the student to obtain the missing information (Field, 2013). Having no evidence to the contrary, the researcher assumed the single record with missing outcome data was missing at random. This deletion reduced the final dataset to 1,130 cases. None of the other respondents had missing data. The researcher next examined the age variable for evidence of extreme scores (i.e., outliers) using a box and whisker plot and z-scores. Field's (2013) benchmark values guided the expected frequencies of z-scores in these data.

Value labels were created for each of the variables used in the study such as sociodemographic characteristics. For example, the label for student veteran was "Military Status," and it was denoted as 0 = *no* and 1 = *yes*. Another example, is the label Pell Grant Eligible Flag was created for students who were Pell Grant eligible in the study and it was denoted as 0 = *no* and 1 = *yes*.

Additionally, descriptive statistics were conducted to describe the percentage of specific sociodemographic variables used in the study. This function was also conducted if some variables were more prevalent for students who were successful in the college-level mathematics courses. Lastly, student demographic variables were used as control variables to validate if the differences observed were the results of the high school GPA, ACT/SAT mathematics score, or placement test and not from any sampling bias.

Multivariate analyses were the second level of data analyses used in the study. A multivariate analysis is generally conducted when the researcher is attempting to analyze multiple variables and examine if one variable is more predictive of the outcome (Gravetter & Wallnau, 2016). In the study, the placement assessment variables were examined to determine if one of the variables was more predictive of success in the college-level mathematics course (i.e., outcome). Binary logistic regression was employed as the multivariate analysis to answer the research questions. Binary logistic regression is typically used when a researcher is attempting to predict a specified probability, which justifies its use in the study; that is, binary logistic regression was appropriate for use in this study because the study aimed to examine and predict which placement assessment method is best for success in a college-level mathematics course (Evans, 2013). Multiple assumptions had to be met for binary logistic regression before data analyses in SPSS. Lastly, to answer the final research question, the researcher utilized the split file command in SPSS (Field, 2013). Split file analysis is used in cases where there is a need to have a separate output for subsets of cases (Evans, 2013). In this study, the split variable was the placement method. By splitting the data on that variable, the researcher was able to generate separate regression models for comparison purposes.

Assumption 1. An assumption of binary logistic regression is that the dependent variable must be binary and the predictors are either binary or continuous. To test this assumption, the frequency distribution for both the dependent and independent variables were run to verify the level of measurement (Field, 2013). To meet this assumption, both the independent and dependent variables of this study were recoded as dichotomous.

Assumption 2. The second assumption is that the study must have an independence of observations and the dependent variable should have mutually exclusive and exhaustive categories. The independent variables can be continuous or categorical variables (Field, 2013). The assumption was tested by running a frequency analysis on the ID variable to validate that no ID number in the data set was listed more than once, suggesting that the subjects were independent (i.e., independence of observations) and not from a repeated measures design.

Assumption 3. The final assumption that needed to be met was the linearity of the logit. Specifically, there must be a linear relationship between the continuous predictors and the log transformation of the dependent variable (Field, 2013). This assumption was tested by examining the interaction term of each variable and its log transformation, which should not be statistically significant at the p >.05 level.

Assumption 4. The final assumption that was assessed in this study was the absence of multicollinearity among the predictor variables. To determine if there was multicollinearity among all the predictor variables in the study, a correlation matrix was generated. Using a benchmark of ≥ .80 for intercorrelations between the predictor variables as per Field's (2013) guideline, no multicollinearity was detected among the variables because none of the values exceeded 0.60.

Chapter Summary

Chapter 3 presented an outline of the methodology used in this study. The study employed a non-experimental correlation design and used secondary data analysis. The design was appropriate to achieve the study's purpose, which was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in Midwestern United States. The study was grounded in a postpositivism perspective that employed Astin's (1970a, 1970b) I-E-O model to frame the research design. The study was designed to answer the overarching central research question: Which of the placement variables (high school GPA, ACT/SAT mathematics score, or standardized placement exam) is the best predictor for success in college-level mathematics?

The researcher used SPSS (IBM, 2017) to perform descriptive, bivariate, and multivariate statistical analyses during the data analyses process. Descriptive statistical analyses included frequency and proportion distribution, dispersion, measures of central tendency (i.e., mean, median, and mode), and variability. Binary logistic regression analysis was used to predict which placement method was the best predictor of college success in a mathematics course at a single institution across four campuses.

Chapter 3 also included a detailed overview of the quantitative research design that was used to answer the research questions and achieve the intended research purpose. The research design included a justification and a summary of the site selection, population, sample, sampling method, ethical issues, data sources, data collection procedures, researcher positionality, credibility techniques, and data analysis techniques. The researcher also provided an overview of the strengths and weakness of the study's quantitative research design with supporting literature. The following chapter will discuss the analysis of the data used in the study.

Chapter 4: Results and Analysis

Chapter 4 outlines and discusses the data analysis techniques used in the study and the results of statistical tests performed. The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in the Midwestern United States. This study was guided by one overarching research question: Which of the placement variables is the best predictor for success in college-level mathematics? To inform this central question, the researcher explored four specific theory-based research questions. These specific questions evolved from the purpose and problem statement of this study.

RQ1: What is the relationship between the placement methods (high school GPA, ACT/SAT mathematics score, or standardized placement exam) and academic success in college-level mathematics at a Midwestern two-year institution?

H_0: There is no relationship between placement methods and academic success.

H_1: There is a relationship between placement methods and academic success.

RQ2: After controlling for sociodemographic variables, what influences do placement methods have when it comes to academic success in college-level mathematics at a Midwestern two-year institution?

H_0: Placement methods do not influence one's academic success.

H_1: Placement methods influence one's academic success.

RQ3: What influence does the mathematics course taken (statistics, college algebra, or pre-calculus) have on academic success in college-level mathematics at a Midwestern two-year institution?

H_0: Course taken does not influence the prediction model.

***H_1*:** Course taken influences the prediction model.

RQ4: How do the models compare when disaggregated by placement method?

***H_0*:** There is no statistical difference in models when disaggregated by placement method.

***H_1*:** There is a statistical difference in models when disaggregated by placement method.

To answer the research questions, the researcher used a non-experimental correlational design. The data analyzed were archival records collected from one institution's student database (i.e., secondary data). Before conducting the analyses, the researcher screened the data for anomalies and influential cases (i.e., outliers) and ensured that these data met the necessary assumptions. After evaluating the data for outliers and assumptions, the researcher examined the variable relationships using correlation and logistic regression analyses.

This chapter is organized according to the research questions. The chapter begins with a description of the subjects and the baseline prevalence of the outcome. Next, the data screening methods used to evaluate influential cases and test assumptions are discussed in addition to the results from the correlation and logistic regression analyses. These sections include the results and their relationship to existing literature and previous studies. Additionally, the chapter includes a discussion on the unexpected data and concludes with a summary of the study results and a preview of the final chapter.

Description of the Subjects

The study sample included students enrolled at a two-year technical or community college in the Midwest region of the United States. The sample comprised of records from 1,130 students enrolled in the Fall 2017 and Spring 2018 semesters. Table 4 presents the sociodemographic characteristics of the sample. The subjects had a mean age of 21 years (*SD* =

6.58). Most of the subjects were female (65.5%, *n* = 740) and self-identified as White (68.5%, *n* = 774). More than three-quarters (78.2%; *n* = 884) of the subjects were enrolled part-time (i.e., taking less than 12 semester hours). Nearly two-thirds (65.2%, *n* = 737) of the subjects were placed into their respective mathematics course using their high school GPA. The baseline prevalence of passing the mathematics class that the subject was enrolled in was 73.7% (*n* = 833).

Table 4

Sociodemographic Characteristics of the Sample, N = 1,130

Characteristics	*n*	%
Race/Ethnicity		
White (reference category)	774	68.5
Non-White	356	31.5
Gender		
Male (reference category)	390	34.5
Female	740	65.5
Military Status		
No (reference category)	1102	97.5
Yes	28	2.5
Pell Grant Eligible Flag		
No (reference category)	837	74.1
Yes	293	25.9
Full or Part Time		
Part time (reference category)	884	78.2
Full time	246	21.8
Placement Method		
High School GPA (reference category)	737	65.2
ACT/SAT	72	6.4
ACCUPLACER Exam	321	28.4
Mathematics Course Taken		
Statistics (reference category)	418	37.0
College Algebra	321	28.4
Pre-calculus	391	34.6
Mathematics Course Grade		
Fail (code = 0)	297	26.3
Pass (code = 1)	833	73.7

Note: Dichotomous variable reference category = 0; comparison category = 1. Multinomial variable reference category is omitted and reflected as dummy variable for comparison.

Data Preparation

The researcher prepared and analyzed the data using SPSS version 25 (IBM, 2017). First, the researcher screened the data for influential cases (i.e., outliers) and anomalies. One respondent did not have valid data for the dependent variable. Little's (1988) MCAR test using expectation maximization was performed to determine if data were missing at random. Non-significant results indicated that these data were missing at random, $\chi^2 = 9.955$, $df = 13$, $p = 0.698$. The record was deleted from the dataset. This deletion reduced the final dataset to 1,130 cases. Next, the researcher examined the underlying distributions of the predictor variables. The race/ethnicity variable was highly skewed. To control for the skewness, the researcher dichotomized the race/ethnicity variable into White versus Non-White. Outlier analysis was conducted on the age variable using box and whisker plots and z-scores. A z-score greater than 2.58 was present in 1.6% of the records. A z-score of 3.29 was present in 2.2% of the records, further suggesting there were extreme outliers in the age variable. Because the researcher had previously explored the age variable for potential data entry errors for which none were found, it was concluded that the variation in the age variable represented a real skew in the student demographics. The researcher decided not to remove the outlier for the age variable because they reflected real age differences among students and would result in a reduction in the overall sample size. The box and whisker plot of the age variable is presented in Figure 3.

Two of the predictor variables (ACT/SAT mathematics score and ACCUPLACER Exam) were multinomial and required dummy coding to conform to the assumptions of logistic regression. For the placement method variable, the researcher followed Field's (2013) procedure and created three dummy variables in each record to account for the method used by the institution. For example, placement occurred using *high school GPA*, the student would receive a “1” in the high school GPA dummy variable, and a score of “0” in the dummy variables for ACT/SAT mathematics score and ACCUPLACER Exam. The same procedure for creating and coding dummy variables was repeated for the mathematics course taken. The researcher created three dummy variables called statistics, college algebra, and pre-calculus.

Before running the analyses, the researcher tested the formal assumptions of binary logistic regression as previously described. The four assumptions tested were: (1) the level of measurement in the independent and dependent variables, (2) independence of observations, (3) linearity of the logit, and (4) absence of multicollinearity. The dependent variable (i.e., mathematics course grade) was measured dichotomously using a pass/fail rating. After dummy coding, all the predictors used in this study were either binary or continuous. No student had more than one record in the dataset, providing support to the assumption of the independence of observations.

The assumption of linearity of the logit assumed that a linear relationship exists between any continuous predictors and the log transformation of the dependent variable. The researcher followed Field’s (2013) procedure for testing the assumption. This assumption was violated in these data for the age variable. The most likely reason for the violation of this assumption is due to the presence of outliers in the data. Figure 3 below displays the box and whisker plot and documents that there were numerous cases in these data that were more than two standard deviations beyond the median score for age. The researcher decided not to remove the outliers in the age variable because they reflected real age differences and would result in a reduction of the overall sample size. Such a reduction in sample size could have had negative implications on the overall power of the statistical tests.

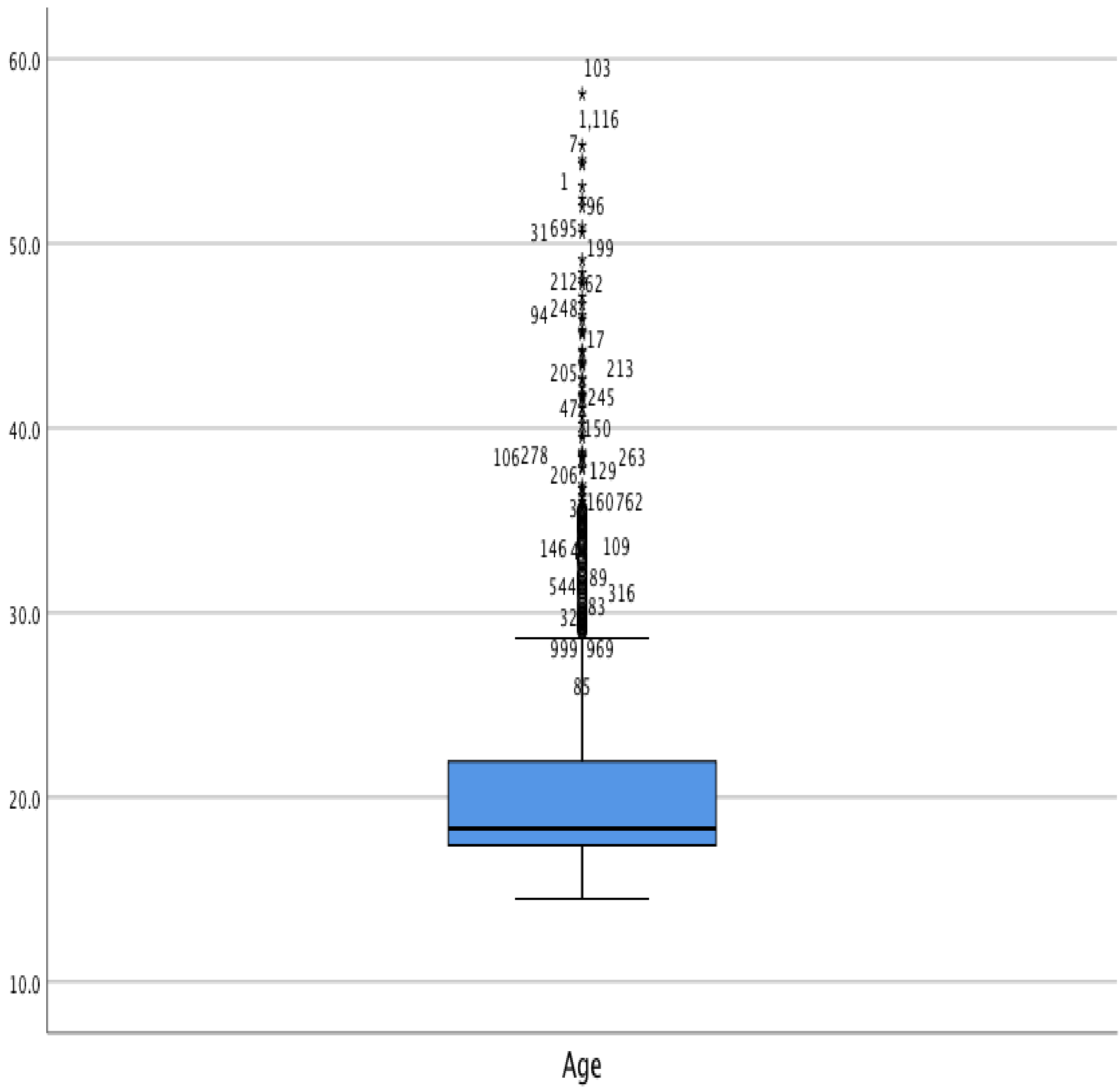

Figure 3. Box and whisker plot for the age variable.

The researcher then created a correlation matrix of all predictor variables to validate that multicollinearity was not an issue (see Table 5). The absence of multicollinearity was verified as no intercorrelation exceeded Field's (2013) benchmark of .80. The absence of multicollinearity validates that no intercorrelation exceeded .80.

Table 5

Correlations among Predictor Variables in the Study

Characteristics	1	2	3	4	5	6	7	8
1. Non-White	.							
2. Female	-.03	.						
3. Military Status	-.18	-.14	.					
4. Pell Grant Eligible Flag	-.07	.14	.08	.				
5. Full Time Enrolled	-.13	-.01	.10	.23	.			
6. Age	-.14	.12	.14	.42	.01	.		
7. Placement Method	-.15	.03	.10	.39	.02	.57	.	
8. Mathematics Course Taken	.17	-.14	-.10	.36	-.19	-.35	-.33	.

Notes: $p < .05$ for all rs > |.06|

Presentation and Analysis of Results

This study sought to examine which of the placement methods (i.e., high school GPA, ACT/SAT mathematics score, ACCUPLACER Exam) was the best predictor for success in college-level mathematics. The researcher developed four research questions specific to the topic and consistent with the conceptual framework of the study. The results of the analyses are presented in the following sub-sections and organized by research question.

Research Question 1. To answer RQ1, the researcher performed a chi-square test of independence and correlation analysis between placement method and mathematics grade (i.e., success). A statistically significant positive association existed between placement method and success, χ^2 (n = 1,130) = 101.82, $p < .001$, Cramer's $V = .30$, denoting a small to moderate effect size (Field, 2013). For students placed using their high school GPA, the majority (82.9%) were successful in their respective mathematics course. A smaller percentage (69.4%) of students placed using ACT/SAT mathematics score experienced success in their mathematics course. Slightly more than one-half (53.3%) of students placed using the ACCUPLACER Exam experienced success. Results suggest that the null hypothesis (H_0) can be rejected. In these data, there is a relationship between placement method and academic success. Students placed using their high school GPA experienced far greater success than those placed using the ACCUPLACER Exam. This finding is in alignment with the existing literature in that high school GPA is a valid predictor for placement (Noble & Sawyer, 2013; Scott-Clayton et al., 2014, Scott-Clayton & Stacey, 2015). Furthermore, the study is in alignment with the existing literature in that standardized placement test such as ACCUPLACER or COMPASS are poor predictors of success in a college-level course (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2016).

Research Question 2. To answer RQ2, the researcher ran a hierarchical logistic regression. First, the sociodemographic variables were entered into the model. The researcher examined the chi-square test, Nagelkerke's pseudo R^2 statistic, and the overall classification accuracy. Collectively, these values allowed the researcher to assess model fit. The predictors and effect sizes were interpreted if the resulting chi-square test was statistically significant at the .95% confidence level and the model accuracy reflected a value higher than 73.7% (i.e., the baseline prevalence of the outcome in these data).

Next, the researcher entered the placement method variables. The placement method consisted of two dummy variables representing ACT/SAT mathematics score and the ACCUPLACER Exam. The dummy variable for the high school GPA was omitted because it was the reference category and was accounted for in the constant of the model. High school GPA was chosen as the reference category because it was the most frequently occurring placement method in the data set (Field, 2013). The model improvement was determined based on several change statistics, namely the $\Delta\ \chi^2$ statistic, $\Delta\ R^2$ statistic and the Δ accuracy statistic. The resulting model (Model 2, Table 6) documented the effect of placement method on the prediction of mathematics success after controlling for sociodemographic factors. Table 6 presents the results of the regression analyses. When odds ratios (ORs) were less than 1.0, the researcher interpreted the inverse of the odds ratio (1/*OR*) as "odds *less likely*."

The sociodemographic model (Model 1, Table 6) was a better fit to the data than the null model ($\chi^2 = 62.369$, $df = 6$, $p < .001$). The sociodemographic factors accounted for 7.9% of the variance in course grade. The overall accuracy of Model 1 was 73.0%, which was worse than the baseline prevalence of 73.7% in the null model. Among the six independent variables used in the model, two were statistically significant predictors of passing the mathematics class. The most significant sociodemographic predictor was *Pell Grant Eligible flag* (Wald $z = 24.499$, $p < .001$, $OR = .438$). The other significant predictor was *enrollment level* (Wald $z = 6.403$, $p = .011$, $OR = .659$). The remaining sociodemographic variables did not predict mathematics success. When controlling for the variables in the model, full-time enrollment status and having a Pell Grant eligible flag both decreased the odds of passing the college mathematics course (1/*OR*s between 1.52 and 2.28). Military status, although slightly higher than the threshold for statistical significance ($p = .067$), had a meaningful effect size despite having lower odds of mathematics success ($1/OR = 2.28$)

The model that controlled for sociodemographic factors and then included placement method (Model 2) was an improvement over the sociodemographic only model (Model 1, $\Delta\chi^2 = 62.928$, $\Delta df = 2$, $p < .001$). The sociodemographic factors and placement method collectively accounted for 15.3% of the variance in course grade ($\Delta R^2 = 7.4\%$). The overall accuracy for Model 2 was 74.1% (Δ accuracy = 1.1%). Being placed into a college-level mathematics course using the ACT/SAT mathematics score method decreased the odds of passing the course compared to being placed using the high school GPA method (Wald's $z = 6.124$, $p = .013$, $OR =$

.497). Likewise, being placed in a college-level mathematics course using the ACCUPLACER Exam method decreased the odds of passing the course in comparison to being placed using the high school GPA method (Wald's z = 61.831, p < .001, OR = .232). The full results of the regression analyses are presented in Table 6.

Table 6

Binary Logistic Regression of Mathematics Course using Sociodemographic Factors and Placement Method

	Model 1			*Model 2*		
Variable	*b*	*OR*	*p*	*b*	*OR*	*p*
Non-White (reference = White)	.007	(1.01)		-.001	(1.00)	
Female (reference = Male)	-.018	(1.02)		-.142	(1.15)	
Military Status (reference = No)	-.745	(2.10)		-.680	(1.97)	
Pell Grant Eligible Flag (reference = No)	-.825	(2.28)	***	-.530	(1.70)	**
Full Time Enrolled (reference = Part Time)	-.417	(1.52)	*	-.488	(0.00)	**
Age	-.017	(1.07)		.030	(1.03)	*
Placement Method (reference = HS GPA)						
ACT/SAT				-.699	(2.01)	*
ACCUPLACER Exam				-1.463	(4.31)	***
Constant	1.780			1.327		
χ^2	62.370		***	125.300		***
$\Delta\ \chi^2$	62.370			62.930		***
Nagelkerke R^2	.070			.150		
Δ Nagelkerke R^2	.070			.080		
Accuracy (P_0 = 73.7%)	73.000			74.100		
Δ Accuracy	-0.700			1.100		

Notes. n = 1,130. *OR* = Odds Ratio. Values presented in parentheses are inverse odds ratios (1/*OR*). P_0 = Baseline prevalence of the outcome "mathematics success" (null model). *p < .05, **p < .01, ***p < .001

The two previously significant sociodemographic variables remained statistically significant predictors in Model 2. Military status became less significant (p=.104). Age became statistically significant (p=.022), and also decreased the odds of success. Full-time enrollment status, having a Pell Grant eligible flag and being placed using either the ACT/SAT mathematics score method or the ACCUPLACER Exam method decreased the odds of success. More specifically:

- For each one-year increase in an individual's age, the odds of success decreased by 1.04.
- Students with full-time enrollment were 1.63 times less likely than part-time students to be successful.
- Students with a Pell Grant eligible flag were 1.70 times less likely than non-Pell Grant eligible flag students to be successful.
- Students placed using their ACT/SAT mathematics exam score were 2.01 times less likely to be successful than students placed using their high school GPA.
- Students placed using the ACCUPLACER Exam score were 4.31 times less likely to be successful than students placed using their high school GPA.

Results suggest that the null hypothesis (H_0) can be rejected for RQ2. Further alignment with the existing literature is that students who were receiving financial aid had a higher risk of being unsuccessful than students who were not receiving aid (Bryant, 2014). The results of the study suggested that students who were Pell Grant eligible for financial aid were statistically more at risk of not passing the class than their peers who were not Pell Grant eligible. The variable of age in the study was also in alignment with the existing literature whereby older students were less likely to be successful than their younger counterparts (Shapiro et al., 2016).

Research Question 3. To answer RQ3, the researcher continued to build on the emerging logistic model. Model 2 was used as the baseline model for comparison, and the same model fit statistics were evaluated as before. The researcher began by entering the variables associated with the mathematics course taken. The mathematics course taken consisted of two dummy variables representing college algebra and pre-calculus. The dummy variable for the statistics variable was omitted because it was the reference category and was accounted for in the constant of the model. Statistics was chosen as the reference category because it was the most frequently occurring course taken in the data set (Field, 2013). As before, the model improvement was determined based on several change statistics, namely, the $\Delta \chi^2$ statistic, ΔR^2 statistic, and the Δ accuracy statistic. The resulting model (Model 3, Table 7) documented the effect of mathematics course taken on the prediction of mathematics success after controlling for sociodemographic factors and placement method. Table 7 presents the results of the regression analyses.

The full model (Model 3) was a better fit to the data than Model 2 ($\Delta \chi^2 = 14.61$, $\Delta df = 2$, $p = .001$). The combination of sociodemographic, placement method, and mathematics courses taken variables accounted for 17.0% of the variance in course grade ($\Delta R^2 = 2.0\%$). The new model accuracy was 74.1% (Δ Accuracy = 0.0%).

The mathematics course taken was a significant predictor of mathematics course grade after controlling for sociodemographic and placement method variables. Taking pre-calculus increased the odds of passing the course compared to statistics, or reference category (Wald's $z = 5.888$, $p = .015$, $OR = 1.655$). There was essentially no difference in the odds for students taking college algebra compared to statistics (Wald's $z = 2.938$, $p = .086$, $OR = .749$).

The three previously significant sociodemographic variables and the dummy variables for the placement method remained statistically significant predictors in Model 3. Age decreased the odds of success. In his dissertation, Schutts (2016) recommended conducting a receiver operating characteristic curve (i.e., ROC curve analysis as a post hoc procedure for significant predictors that are continuous). The ROC curve results indicated that a cut score of 19 years and below best differentiated between the success and non-success groups (*AUC* = .673, 95% CI [.639, .706], *SE* = .017, $p < .001$, Youden's *J* = 1.334). Full-time enrollment status, having a Pell Grant eligible flag and being placed using either the ACT/SAT mathematics score method or the ACCUPLACER Exam method decreased the odds of success. More specifically:

- For each 1-year increase in one's age, the odds of success decrease by 1.04. Furthermore, the odds for success were disproportionately better for students who were 19 years or younger compared to those who were 20 years or older.
- Students with full-time enrollment were 1.50 times less likely than part-time students to be successful.
- Students with a Pell Grant eligible flag were 1.57 times less likely than non-Pell Grant eligible students to be successful.
- Students placed using their ACT/SAT mathematics exam score were 1.85 times less likely to be successful than students placed using their high school GPA.
- Students placed using the ACCUPLACER Exam score were 3.91 times less likely to be successful than students placed using their high school GPA.
- Students enrolled in pre-calculus were 1.65 times more likely to be successful than students enrolled in statistics after controlling for all of the sociodemographic and placement type variables in the model.

Table 7

Binary Logistic Regression of Mathematics Course Grade Using Sociodemographic Factors, Placement Method, and Mathematics Course Taken

	Model 2			*Model 3*		
Variable	*b*	*OR*	*p*	*b*	*OR*	*p*
Non-White (reference = White)	-.001	(1.00)		-.087	(1.09)	
Female (reference = Male)	-.142	(1.15)		-.060	(1.06)	
Military Status (reference = No)	-.680	(1.97)		-.723	(2.06)	
Pell Grant Eligible Flag (reference = No)	-.530	(1.70)	**	-.453	(1.57)	**
Full Time Enrolled (reference = Part Time)	-.488	(0.00)	**	-.405	(1.50)	*
Age	.030	1.03	*	.035	1.035	**
Placement Method (reference = HS GPA)						
ACT/SAT	-.699	(2.01)	*	-.615	(1.85)	*
ACCUPLACER Exam	-1.463	(4.31)	***	-1.361	(3.91)	***
Mathematics Course Taken (reference = Statistics)						
College algebra				-.290	(1.34)	
Pre-calculus				.504	1.655	*
Constant	1.327			1.070		
χ^2	125.300		***	139.910		***
$\Delta\ \chi^2$				14.610		**
Nagelkerke R^2	.150			.170		
Δ Nagelkerke R^2				.020		
Accuracy (P_0 = 73.7%)	74.100			74.100		
Δ Accuracy				0.000		

Notes. n = 1,130. *OR* = Odds Ratio. Values presented in parentheses are inverse odds ratios (1/*OR*). P_0 = Baseline prevalence of the outcome "mathematics success" (null model). *$p < .05$, **$p < .01$, ***$p < .001$

Results suggest that the null hypothesis (H_0) can be rejected for RQ3. Alignment with the existing literature was consistent in that older students were less likely to be successful than their younger counterparts (Shapiro et al., 2016). Additionally, students who received financial aid had a higher risk of being unsuccessful than students who did not receive aid (Bryant, 2014).

On the other hand, the results of the study found several items in opposition to the existing literature. For example, the results of the study suggested that full-time students were less likely to pass the mathematics courses in comparison to part-time students. Data from the National Student Clearinghouse suggested part-time students completed courses at a lower rate than students who are enrolled full time (Grabowksi et al., 2016).

Research Question 4. To answer RQ4 separate analyses for each placement method were conducted. The researcher used the "split data" command in SPSS and choosing *placement method* as the filter. Consistent with the approaches in RQ2 and RQ3, each analysis began by controlling for the sociodemographic variables and then modeled the effect of mathematics course taken. The overall model fit statistics were used to determine which model performed the best. Table 8 presents the results of the regression analyses.

Model 2 outperformed Model 1 for both high school GPA and ACCUPLACER Exam placement methods. The placement method that was the least accurate, yet explained the most variance in the outcome was ACT/SAT mathematics score (Nagelkerke $R^2 = .19$). The most accurate model was *high school GPA* (Accuracy = 82.9%); however, that model did not significantly contribute to the prediction beyond what was already known from the null model. The ACCUPLACER *Exam* model showed the most improvement when sociodemographic variables and the course taken were considered. Taken holistically, results are mixed for this research question. Therefore, the data suggested that the null hypothesis (H_0) can be rejected.

Table 8

Model Comparisons Based on Placement Method

	Model 1			*Model 2*		
Model Fit	*HS GPA*	*ACT/SAT*	ACCU-PLACER	*HS GPA*	*ACT/SAT*	ACCU-PLACER
χ^2	40.773	10.048	12.438	60.498	10.203	17.589
Nagelkerke R^2	.090	.190	.050	.130	.190	.070
Accuracy	82.800	66.700	55.800	82.900	68.100	58.900
P_0	82.900	69.400	53.600	82.900	69.400	53.600
N students classified	737.000	72.000	321.000	737.000	72.000	321.000

Note: N = 1,130. Model A = Sociodemographic model. Model B = Sociodemographic and course taken model. P_0 = Baseline prevalence of the outcome "mathematics success" (null model).

Conceptual framework. The results of the study were analyzed in relation to the conceptual framework. The results suggested that the I-E-O framework served as an appropriate conceptual model for the research study. Specifically, the I-E-O model allowed for the conceptualization of students' educational outcomes as the result of a combination of inputs and environmental factors. The I-E-O model characterized how input variables such as sociodemographic information were used to predict or explain academic success, and how environmental factors such as types of assessments and specific courses affect the output of student academic success in the study. As previously stated, the study explored the use of sociodemographic variables and placement assessment method (i.e., Inputs) along with the college-level mathematics courses (i.e., Environment) to determine academic success (i.e., Output). As a result, the I-E-O conceptual framework was a valid framework to use to answer the research questions in the study.

Unexpected data. The negative relationship between age and success was a curious finding. Data suggested that students who were traditional college age (i.e., 19 years and younger) were more likely to be successful in the college-level mathematics course. There are implications for recent high school graduates (i.e., 18 years of age) and current high school students taking courses via a dual enrollment system.

Disaggregating the models by placement method yielded mixed results. Each model was advantageous in some respect but underperformed in others. The researcher chose to disaggregate the models and expected a clearer picture of the optimal method to emerge; however, that was not the case with the use of this dataset. More data are needed to understand the complexity of those results further.

Chapter Summary

Chapter 4 described the subjects of the study and the methods used to test the assumptions associated with the statistical tests performed. The results of each research question were also presented and interpreted based on previous literature and the conceptual framework that guided this study. A discussion of the analysis in relation to the four research questions identified in the study was also discussed in this chapter.

For RQ1, the results identified a positive statistically significant relationship between the placement method used by the institution and the ultimate academic success of the student in their college-level mathematics course. For RQ2, study results identified a positive, statistically significant relationship between the placement method and success in college-level mathematics after controlling for sociodemographic variables. More specifically, high school GPA emerged as the best placement method. Several sociodemographic variables (e.g., age, not having a Pell Grant eligible Flag, part-time enrollment) were also positively predictive of success in combination with placement method.

For RQ3, the results indicated a positive statistically significant relationship between the mathematics course taken and academic success in college-level mathematics after continuing to control for placement method and sociodemographic factors. Comprehensively, students who took pre-calculus had higher odds of success than students who took statistics, after controlling for all of the sociodemographic and placement type variables in the model. As found previously, the placement method and some sociodemographic factors continued to remain statistically significant predictors of mathematics success.

For RQ4, the results were mixed as to the optimal method for placing students into their respective mathematics course. The high school GPA model had the highest overall classification accuracy. The ACT/SAT mathematics score model explained the most variance in the outcome. The ACCUPLACER Exam model was the most influenced by the sociodemographic variables and the course taken. Comprehensively, the results suggest that this institution should use high school GPA as its placement method and funnel students into pre-calculus for the highest likelihood of success after controlling for all of the sociodemographic and placement type variables in the model. Guiding students into the pre-calculus course would require the institution to examine their current mathematics course selection in all their plans of study. Subsequently, the institution would need to evaluate if pre-calculus was a better mathematics option for students based on their plan of study. The implications of these results are discussed in the following chapter. Attention should also be paid to students who might be first-generation or have a low socio-economic status and thus making them Pell Grant eligible, students with full-time enrollment status, and students who are more than 19 years of age as each group may need additional support resources for success.

Chapter 4 included the results and analysis in relation to the existing literature and the conceptual framework. Specifically, the results of the data align with the literature in that the standardized placement test such as ACCUPLACER or COMPASS are poor predictors of success in a college-level mathematics course (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2015). Results also indicated that full-time students were less likely to pass the mathematics courses in comparison to part-time students. This finding runs counter to data from the National Student Clearinghouse that suggested part-time students complete courses at a lower rate than students who are enrolled full-time (Shapiro et al., 2016). The next chapter presents a summary of the study, conclusions, limitations and implications, recommendations for future research, and personal reflections made by the researcher.

Chapter 5: Summary, Conclusions, Implications, and Suggestions for Future Research

Chapter 5 contains a summary of the discussion in relation to the results of the study. Specifically, the chapter is organized into three major sections with the first being a summary of the study along with the major results. Next, a section that provides overall conclusions and interpretations of the results of the study is outlined. The third section includes a discussion in relation to the implications of the study based on the existing literature, current policy, and practice. Chapter 5 concludes with an exploration of possible future research along with an examination of the limitations of the current study and the researcher's reflective comments about knowledge gained from his experience during this dissertation process.

Summary and Major Results

Most two-year colleges use one of three placement assessment methods (i.e., high school GPA, ACT/SAT scores, standardized placement test) as a predictor of appropriate college-level mathematics placement (Bettinger et al., 2013). As a result, there is a problem of variation in placement assessment methods across two-year institutions and the use of different student measures (Bettinger et al., 2013). Furthermore, depending on the placement method used by the institution, the accuracy of the placement method is questionable. Jaggars et al. (2013) best illustrated the problem and noted that in mathematics standardized entry placement exams (e.g., ACT, SAT), up to 18% of students are incorrectly placed in remedial courses.

As a result of the different placement assessment policies and methods used by two-year institutions, students are often incorrectly placed into remedial courses that they may not require. Specifically, misplacement has practical consequences for students because placement in a remedial course may significantly lessen the chances of graduation (Bettinger et al., 2013).

Additionally, misplacement can slow or prevent degree completion by adding one or more unnecessary courses (Morest, 2013).

The variation in placement methods by two-year institutions for college-level mathematics courses as well as the misplacement of students spurred the purpose of the study, which was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in midwestern United States. Records of 1,330 students during a single academic year were used to determine which of the three placement methods (i.e., high school GPA, ACT/SAT mathematics score, the standardized placement exam) is most effective in determining success in college-level mathematics courses. The research questions were:

RQ1: What is the relationship between the placement methods and academic success in college-level mathematics at a midwestern two-year institution?

H_0: There is no relationship between placement methods and academic success.

H_1: There is a relationship between placement methods and academic success.

RQ2: After controlling for sociodemographic variables, how do placement methods influence academic success in college-level mathematics at a midwestern two-year institution?

H_0: Placement methods do not influence one's academic success.

H_1: Placement methods influence one's academic success.

RQ3: What influence does the mathematics course taken (statistics, college algebra, or pre-calculus) have on academic success in college-level mathematics at a midwestern two-year institution?

H_0: Course taken does not influence the prediction model.

***H_1*:** Course taken influences the prediction model.

RQ4: How do the models compare when disaggregated by placement method?

***H_0*:** There is no statistical difference in models when disaggregated by placement method.

***H_1*:** There is a statistical difference in models when disaggregated by placement method.

In previous studies, researchers identified high school GPA as a strong placement predictor for success in a college-level mathematics course (Hodara & Lewis, 2017; Mau, 2016; Perrakis, 2008; Woods et al., 2018). Specifically, a key finding from the literature review suggested that high school GPA is the strongest predictor of college success in mathematics courses in comparison to a standardized placement exam and ACT/SAT scores (Hodara & Lewis, 2017; Jones, 2018; Mau, 2016; Perrakis, 2008; Woods et al., 2018).

The I-E-O model provided the conceptual framework used to guide the research study. The constructs of Astin's (1970a, 1970b) I-E-O model includes the Inputs-Environment-Outputs. The I-E-O model facilitated the conceptualization of students' educational outcomes as the result of a combination of inputs and environmental factors. The model was initially developed as an effort to create a unified methodology amidst the chaotic, heterogeneous attempts to study collegiate success that characterized the academic literature at the time. However, the model evolved into a methodology for systematically assessing the real effects of college.

The I-E-O model is similar to a mathematical function, positing that the results (i.e., outputs) of a student's college experience depend on the initial conditions (e.g., sociodemographics, academic ability) and the transformative effects of social, academic, and other environmental effects. The justification for the use of the I-E-O model in the study is that it characterizes how input variables (e.g., sociodemographic information) can be used to predict or explain academic success, and how environmental factors (e.g., types of assessments and specific courses) affect the outcome of student academic success. As such, the I-E-O model served as the foundation for the development of research methodology in which the study was designed.

A quantitative, non-experimental correlation design with secondary data was used to achieve the purpose of this study and to answer the research questions. The use of a correlational design allowed the researcher to statistically analyze the relationships between two or more variables (Field, 2013). The sampling method used in the study was an analysis of secondary data; as such, no primary data were collected as part of the study. Secondary data were used in this study because it is a time-saving and cost-effective way of conducting research as the researcher does not have to collect the data since it was obtained by an external source (Williams & Shepherd, 2017).

The data for this study were records of incoming or returning students at a two-year college in a midwestern region of the United States for both the fall and spring semesters of a single academic year. The sample consisted of 1,330 student records. The variables selected for placement were identified in relation to the institution's placement assessment policy. Furthermore, the mathematics courses that were identified as part of the study were selected because all three courses were used as part of the entry-level mathematics sequence at the institution.

After the data were screened for influential cases (i.e., outliers) and anomalies, they were analyzed using binary logistical regression by the researcher. In addition to running binary logistical regression, the data were analyzed in SPSS using grouping data. The data analysis revealed that high school GPA is a robust placement method for success in college-level mathematics. Secondly, the analysis revealed that the ACCUPLACER placement exam method is a poor method for placement in relation to success in a college-level mathematics course. Lastly, the analysis revealed that the ACT/SAT mathematics score placement method is a poor method for placement in relation to success in a college-level mathematics course. In summary, the rationale for the study was to determine which of the three placement methods (i.e., high school GPA, ACT/SAT mathematics score, the standardized placement test) is most effective in determining success in college-level mathematics courses.

Conclusions

In this study, three placement methods (i.e., high school GPA, ACT/SAT mathematics score, the standardized placement test) used by two-year colleges in placing students in college-level mathematics courses were examined to determine the single best mathematics placement method for college success at one institution. Based on the results of the analyses conducted in this study, several conclusions can be drawn in examining the results along with the conceptual framework and existing literature.

First, a relationship existed between the use of placement methods of high school GPA and academic success in college-level mathematics. The result indicated that the high school GPA is a strong placement method for success in college-level mathematics. Secondly, a relationship existed between the ACCUPLACER Exam placement method and academic success in a college-level mathematics course. The result suggested that the ACCUPLACER Exam placement method is a poor method for placement in relation to success in a college-level mathematics course. Lastly, an inverse relationship existed between the ACT/SAT mathematics score placement method and academic success in a college-level mathematics course. This result suggested that the ACT/SAT mathematics score placement method is a poor method for placement in relation to success in a college-level mathematics course. In conclusion, the results indicated that specific placement methods are good predictors of a student's academic success while other methods are poor predictors of academic success.

The results of this study aligned with the existing literature in that high school GPA is a valid predictor for placement (Noble & Sawyer, 2013; Scott-Clayton et al., 2014, Scott-Clayton & Stacey, 2015). The results of the study indicated that high school GPA is a valid predictor for mathematics placement. It can be concluded that high school GPA represents a cumulative result of student experiences, skills, and effort in the previous level of study (Noble & Sawyer, 2013; Scott-Clayton et al., 2014, Scott-Clayton & Stacey, 2015). The current study adds to the existing literature in that it supports the results by previous studies that high school GPA can be effectively used as a predictor for placement exams. As such, it is concluded that the use of high school GPA as a placement method for college-level mathematics course is a valid tool for institutions to use.

The results also aligned with the existing literature in that the standardized placement method proved to be a poor predictor for academic success (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2015; Scott-Clayton et al., 2014). The results of the study indicated that the standardized placement exam is not a valid predictor for mathematics placement. One plausible explanation for this finding is that the standardized placement exam only represents how the student performed on one single test. The test does not encompass a cumulative result of student experiences, skills, and effort in the previous level of study (Scott-Clayton et al., 2014).

The ACT/SAT mathematics score method was found to be statistically significant in the analysis. The results suggested an inverse relationship whereby students who were placed using ACT/SAT mathematics score were less likely to succeed in the college-level mathematics course. The finding that ACT/SAT mathematics score is inversely correlated with success in college mathematics is in opposition to the literature. Wao et al. (2017) and Coyle et al. (2014) identified that higher ACT/SAT mathematics score resulted in higher rates of success for students in college mathematics. However, Wao et al. (2017) and Coyle et al.'s (2014) studies differed from this study because their study was conducted at four-year institutions while the current study was conducted at a two-year institution. Specifically, an inverse relationship existed between ACT/SAT mathematics score and success in the mathematics course. In other words, ACT/SAT mathematics score is a good predictor of non-success in the college-level mathematics course.

Several sociodemographic variables provided insight into characteristics and profiles that influence success in the college-level mathematics course. The first is that students who were Pell Grant eligible for financial aid were statistically more at risk of not passing the class than their peers who were not Pell Grant eligible. The finding that students who received financial aid assistance had a higher risk of being unsuccessful than students who did not receive aid was consistent with the existing literature (Bryant, 2014). Existing studies suggest that students in receipt of aid have factors outside the classroom that can increase their chances of being unsuccessful (Bryant, 2014). Factors that contribute to the lack of success for students who are receiving aid include being less academically prepared to take college-level classes, socioeconomic status, and employment in addition to attending classes. The additional time constraint is one of the reasons that students who receive aid can be less successful in the classroom. Although the current study did not examine each student's life circumstances, it does support the existing literature that students who received financial assistance had a higher risk of being unsuccessful in the classroom (Bryant, 2014). As such, it can be concluded that the students who had received financial aid require additional support as they are an at-risk student population and have a lower percentage of passing their college-level mathematics course.

A further sociodemographic variable that influenced success in the college-level mathematics course in this study was that of a student's age. The study found that older students were less likely to be successful in a college-level mathematics course than their younger counterparts. This finding was consistent with the existing literature in that older students were less likely to succeed than younger students in the classroom (Shapiro et al., 2016). Such a finding could be as a result of several factors including time away from school; possible responsibilities outside of the classroom including work, children, and spouse; and overall time management availability to be able to dedicate to their current school workload (Shapiro et al., 2016). Although the current study did not examine the specifics of each student's circumstances, it does add to the existing literature in that increased age resulted in a lower percentage of passing the mathematics course (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2015; Scott-Clayton et al., 2014). Therefore, it can be concluded that the non-traditional students can require additional support as they are an at-risk student group and statistically are at a higher risk of not passing their college-level mathematics course.

Student enrollment status was another sociodemographic variable that influenced success in the college-level mathematics course. Notably, full-time students were more likely to be unsuccessful in the college-level course when compared to part-time students. The results of the study were unique in comparison to the existing literature because the current literature suggests that part-time students are less successful than full-time students (Grabowksi et al., 2016). However, in the current study, the opposite was true: part-time students were more successful than full-time students. While it can be difficult to explain why this may be the case without further statistical analysis, this does warrant further explanation. First, prior studies such as Ngo and Melguizo (2015) and Scott-Clayton et al. (2014) primarily examined college success by students achieving their credential and not at the micro level of course completion.

Further research is warranted to determine if the same pattern of success occurs at the macro level of students obtaining their college credential. Lastly, this finding can be as a result of a large number of dual enrollment students. Future research should conduct further analyses while controlling for dual enrollment students in the analysis.

After controlling for sociodemographic variables and placement methods, students who took precalculus were more likely to pass than those who took statistics. Several factors could be related to the results of higher success in pre-calculus in comparison to the other mathematics courses. The first is that the pre-calculus course is required for specific programs at the participating institution. These programs include engineering, which often requires students to have a higher level of mathematics comprehension than other programs. Furthermore, students in the engineering program employed the use of mathematics computational skills in other related courses that can lead to higher proficiency in mathematics. Therefore, the mathematics course can have a relationship with the academic program and the courses associated with that program, after controlling for sociodemographic variables and placement methods. However, further research is required to determine if the relationship between the mathematics course taken and success is due to the academic program or the course.

Interpretation of Results

The purpose of this quantitative study was to identify the placement methods that best predict student success in college-level mathematics courses at a two-year college located in the midwestern United States. Several binary logistic regression analyses using secondary data were conducted to answer the four listed research questions. The results of RQ1 identified a positive statistically significant relationship between the use of high school GPA and academic success in college-level mathematics.

The results of RQ2 identified a positive statistically significant relationship between the placement methods of high school GPA and academic success in college-level mathematics after controlling for sociodemographic variables. Additionally, the results identified a negative and statistically significant relationship between the placement method ACCUPLACER Exam and academic success in a college-level mathematics course after controlling for sociodemographic variables. Lastly, the results revealed a negative and statistically significant relationship between the placement method ACT/SAT mathematics score and academic success in a college-level mathematics course after controlling for sociodemographic variables.

The results of RQ3 identified a positive statistically significant relationship between the pre-calculus (Math 150) mathematics course taken and academic success in college-level mathematics, after controlling for sociodemographic variables and placement methods. Specifically, students who took precalculus were 1.05 times more likely to pass those who took statistics. The results of RQ4 partially supported the hypothesis with a statistically significant positive relationship identified between the use of high school GPA as a placement method and academic success in college-level mathematics when placement methods disaggregated the models. However, the results did not support a positive relationship for academic success in college-level mathematics when placement methods disaggregated the models for ACT/SAT mathematics score and ACCUPLACER Exams.

The sample size (N = 1,130) was sufficient for all four research questions and was able to meet the appropriate alpha, power, and effect size of 0.80 and 0.95 for the study (Field, 2013).

The following section identifies and explains the interpretations of the study along with the connection to the study's purpose.

The sociodemographic variables played a vital role in determining academic success. Several key demographic variables were identified in relation to success in a mathematics course. Descriptive statistics identified age, Pell grant eligibility, and enrollment status as statistically significant factors in academic success. The majority of the sociodemographic variables were in line with the existing literature that supports those variables as factors in academic success (Bryant, 2014; Shapiro et al., 2016). However, the study identified enrollment status as a significant factor in academic success, which is in opposition to the existing literature (Grabowksi et al., 2016).

Placement assessment methods can vary from institution to institution and can delay or prevent completion for students if students are not properly assessed (Scott-Clayton et al., 2014). The results of the study indicated that high school GPA is a better placement method than ACT/SAT mathematics score and the standardized placement exam. As a result, the findings of this study aligned with the existing literature in that high school GPA can be used as a successful predictor for college-level placement (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2015).

Implications

The study has implications for the existing literature, I-E-O theoretical framework, current policy, students at the two-year institution, college practitioners, and researchers. The results add to the existing literature and also support new findings that have not been identified in the existing literature. Implications for the existing literature, current policies in practice, and professional practitioners in the field are discussed in the following sections.

Implications for literature. The results of the study were examined in relation to the existing literature. Some of the results were consistent with the existing literature; specifically, in that high school GPA proved to be a valid predictor for placement (Noble & Sawyer, 2013; Scott-Clayton et al., 2014, Scott-Clayton & Stacey, 2015). Using the high school GPA placement raises the odds of passing the class by 101.2%. Study results are also in alignment with the existing literature in that standardized placement tests—such as ACCUPLACER or COMPASS—were poor predictors of success in a college-level course (Jaggars & Bickerstaff, 2018; Ngo & Melguizo, 2015). Results of the analyses indicated that students placed using the ACCUPLACER Exam score were 3.91 times less likely to be successful than students placed using their high school GPA. Another finding that was also consistent with the literature is that students in receipt of financial aid had a higher risk of being unsuccessful than students who did not receive aid (Bryant, 2014). The results of the study suggested that students who were Pell Grant eligible for financial aid were statistically more at risk of not passing the class than their peers were not Pell Grant eligible. Students with a Pell Grant eligible flag were 1.57 times less likely than non-Pell Grant eligible students to be successful. The results of the study add to the existing literature by providing support that students who are Pell Grant eligible are more likely to be unsuccessful in college-level mathematics courses than non-Pell Grant eligible students.

The variable of age in the study was also in alignment with the existing literature in that older students had less likely odds of being successful than their younger counterparts (Shapiro et al., 2016). The results of the study supported the literature in that for each one-year increase in one's age, the odds of success increased by 1.04. Furthermore, the odds for success were disproportionately better for students who were 19 years of age or younger compared to those who older than 19 years of age. The results of the study add to the existing literature by providing support that traditional-age students are more likely to be successful than non-traditional age students.

The age variable 19 years or younger supports the bivariate correlation between age and the outcome ($r = -.13$, $p < .001$). Originally, age was not significantly influential. However, when controlling for mathematics course taken, the nature of the relationship between age and passing the mathematics course changes to a positive relationship. Future research should be given to the nuances associated with the age variable and the outcome. Further exploration of the effect of dual enrollment and the relationship between course taken and age are worthy of further study.

Further research would be required to examine if students who are 19 years of age or younger are dual enrollment students. If the students are dually enrolled, the limited literature in the field suggests that dual enrollment students perform better than traditional full-time and part-time students (Wang, Chang, Phelps, & Washbon, 2015). Specifically, Wang et al. (2015) examined dual enrollment students at a two-year technical college and found that dual enrollment students attempted more credits and had stronger academic performance than students who did not participate in dual enrollment programs.

Study results also revealed several items in opposition to the existing literature. The finding that ACT/SAT mathematics score is inversely correlated with success in college mathematics is in opposition to the literature. Wao et al. (2017) and Coyle et al. (2014) both found that higher ACT/SAT mathematics score resulted in higher rates of success for students in college mathematics. However, a key difference between the Wao et al.'s (2017) and Coyle et al.'s (2014) studies is that they were with students at four-year institutions and the current study was conducted at a two-year institution. The results of the current study indicated that students who were placed using ACT/SAT mathematics score were less likely to succeed in the college-level mathematics course. The result of this study that ACT/SAT mathematics score is not a strong predictor of success in a college-level mathematics course was in opposition to the existing literature, but adds to the body of knowledge.

Another example of the results of the current study being in opposition to the existing literature is that full-time students were less likely to pass the mathematics courses in comparison to part-time students. Data from the National Student Clearinghouse suggested part-time students completed courses at a lower rate than students with full-time enrollment (Grabowksi et al., 2016). In the current study, students with full-time enrollment were 1.50 times less likely than part-time students to be successful which is in direct opposition to the current literature. Although not in alignment with the existing literature, the results of the study add to the existing literature that full-time students are more likely to be successful than part-time students. The results of this finding add new literature that is currently not in the existing literature.

Conceptual framework. The results of the study were analyzed in relation to the I-E-O conceptual framework (Astin, 1970a, 1970b). The results suggested the I-E-O framework served as an appropriate conceptual model for the research study. The I-E-O model allowed for the conceptualization of students' educational outcomes as the result of a combination of inputs and environmental factors. The I-E-O model characterized how input variables such as sociodemographic information were used to predict or explain academic success, and how environmental factors such as types of assessments and specific courses affect the outcome of student academic success in the study. As previously stated, the study explored the use of sociodemographic variables and placement assessment method (i.e., Inputs) along with the college-level mathematics courses (i.e., Environment) to determine academic success (i.e., Outputs). Based on the results of the study, the I-E-O conceptual framework was valid for use for use in this study. Therefore, the use of the I-E-O conceptual framework is a valid tool for future researchers to use to examine placement methods and environmental factors in relation to college success; that is, researchers can use the model as outlined in this study and add or remove placement methods or environmental factors to examine the output of the course grade.

Implications for current policy. The study has implications for current policy at two-year institutions and policymakers. First, the study identified a statistically significant relationship between the use of high school GPA as a placement method and academic success in college-level mathematics. Therefore, policymakers should consider the placement method used when determining placement for two-year students. For example, over 92% of two-year institutions assess college readiness using a traditional standardized placement test with the student's score as the sole factor in determining if they are to enroll in a college-level or a remedial course (Scott-Clayton et al., 2014). Based on the results of this study, it is recommended that two-year institutions consider using high school GPA as their placement method for mathematics courses instead of the standardized placement exam.

Second, the study identified a statistically significant relationship between the placement method of high school GPA and academic success in college-level mathematics courses after controlling for sociodemographic variables. Additionally, the results revealed a negative and statistically significant relationship between the ACCUPLACER Exam placement method and academic success in a college-level mathematics course after controlling for sociodemographic variables. This finding provides support that placement methods influence one's academic success. Again, these results suggested that policymakers should carefully examine their placement testing options when selecting the appropriate placement test for two-year students.

As the results of this study indicated that the standardized placement exam is a poor predictor for college success, institutions should consider eliminating standardized placement exams or moving towards high school GPA as the sole placement method for students into college-level mathematics courses.

Thirdly, a statistically significant relationship was found between the pre-calculus (Math 150) mathematics course taken and academic success in college-level mathematics. Results indicated that students enrolled in a pre-calculus course were 1.65 times more likely to be successful than students enrolled in statistics after controlling for all of the sociodemographic and placement type variables in the model, which indicates that the course taken influences the prediction model. The importance of this finding is that policymakers carefully examine which mathematics course should be taken in relation to academic programs. Policymakers and curriculum content creators should carefully examine their mathematics pathway selection in their curriculum to assess if pre-calculus may be able to satisfy the curriculum mathematics requirement.

Lastly, the results partially supported the hypothesis with a statistically significant relationship identified between the use of high school GPA as a placement method and academic success in college-level mathematics when placement methods disaggregated the models, but not for ACT/SAT mathematics score and ACCUPLACER exams. This finding was indicative that there is a difference in placement models when disaggregated by placement method. This result suggests the need for policymakers to be diligent when selecting the appropriate placement method for two-year college students. Specifically, the results of the study indicated that students placed using the ACCUPLACER Exam score were 4.31 times less likely to be successful than students placed using their high school GPA. Additionally, students placed using their ACT/SAT exam mathematics score were 2.01 times less likely to be successful in a mathematics course at the college-level than students placed using their high school GPA. This finding is important in highlighting the need for policymakers and practitioners to predominantly use high school GPA as the placement method for students.

Implications for professional practice. The results of this study also have implications for professional practice. Study results may impact higher-education practitioners and faculty at the two-year college-level. The results of the study first identified a statistically significant relationship between the use of high school GPA as a placement method and academic success in college-level mathematics. Therefore, there is a relationship between placement methods and academic success. As a result, practitioners should consider a multiple methods approach when assessing the placement methods to use for two-year college students. Specifically, practitioners in the field of higher education should consider using high school GPA as the primary method of placement for college-level mathematics courses. Furthermore, study results revealed that the use of the standardized placement exam is a poor predictor of college success and should only be considered by higher education practitioners as a last resort for placement.

The study also identified a statistically significant relationship between the placement methods of high school GPA and academic success in college-level mathematics courses after controlling for sociodemographic variables. The results also identified a negative and statistically significant relationship between the ACCUPLACER placement method and academic success in a college-level mathematics course after controlling for sociodemographic variables. These results supported the notion that placement methods influence one's academic success. Again, this suggests that two-year college practitioners carefully examine their placement testing options when selecting the appropriate placement test for two-year college students; specifically, the use of a multiple measure approach as this study had may be an appropriate model to use. Practitioners in higher education can advise students more effectively if they have information related to the student's high school GPA. For example, if a student performed well at the high school level, two-year practitioners can more effectively advise on the placement level and correct course for the student. Correct advisement and placement can accelerate degree completion and help the student avoid taking a class(es) they may not need.

A statistically significant relationship between the pre-calculus (Math 150) mathematics course taken and academic success in college-level mathematics was also found in this study, further indicating that the course taken influences the prediction model. This finding implies that practitioners should carefully examine which mathematics course should be taken in relation to academic programs. Program directors, deans, and provosts should examine the mathematics courses in their curriculum to determine if they have the correct courses in their plan of study. If the program directors, deans, and provosts find that pre-calculus is an acceptable alternative to the current mathematics course in their curriculum, then a change in curriculum or an option for students to have a course substitution for the pre-calculus course may be warranted.

The results partially supported the hypothesis with a statistically significant relationship identified between the use of high school GPA as a placement method and academic success in college-level mathematics when placement methods disaggregated the models, but not for ACT/SAT mathematics score and ACCUPLACER exams. This finding suggested that there is a difference in models when disaggregated by placement method. This result again highlights the need for two-year college practitioners to be diligent when selecting the appropriate placement method for two-year college students. Furthermore, the use of a multiple measure approach similar to this study may be an appropriate model to use. In summary, based on the results of this study, practitioners can take several specific items of action. First, practitioners in the field of higher education should consider using high school GPA as the primary method of placement into college-level mathematics courses. The use of the standardized placement exam is a poor predictor of college success and should only be considered by higher education practitioners as a last resort for placement. Second, practitioners in higher education can advise students more effectively if they are knowledgeable about the student's high school GPA. Students may be better placed in their mathematics course if practitioners use a high school GPA instead of standardized placement exams. Lastly, program directors, deans, and provosts should examine the mathematics courses in their curriculum to determine if they have the correct courses in their plan of study. If warranted, a change in the plan of study for the mathematics curriculum can occur for the pre-calculus course based on the results of this study.

Unexpected data. The negative relationship between age and success was a curious result. Data suggested that students who were traditional college age (i.e., <19 years) were more likely to be successful in the college-level mathematics course. This finding has implications for recent high school graduates who are 18 years of age and current high school students taking courses via a dual enrollment system.

Disaggregating the models by placement method yielded mixed results. Each model was advantageous in some respect but underperformed in others. The researcher chose to disaggregate the models and expected a clearer picture of the optimal method to emerge; however, that was not the case with the use of this dataset. As a result, more data are needed to understand the complexity of these results further.

Suggestions for Future Research

Multiple research studies may be explored as a result of the findings of this study. The first study that could be explored is to determine if the results are transferable to other two-year institutions. This study was limited to a two-year institution in the Midwest, and it would be important to examine if the results were unique to this study and the institution examined or if the results are transferable. A large number of students at the institution used in this study had a dual enrollment status; as such, it would be beneficial to examine if the results are different at a two-year institution with different sociodemographic populations. Future research should also explore the three placement methods at four-year institutions and determine if the results vary from two-year to four-year institutions. Because the sociodemographic characteristics of the students vary between the two types of institutions, it would be interesting to see if the results differ as well.

A future study assess using high school GPA as the placement variable. For example, the current study used the unweighted high school GPA of 3.0 and above to place students into the college-level mathematics courses. However, future studies may want to explore if increasing or decreasing the unweighted high school GPA has a statistically significant effect on academic success in a college-level mathematics course. Given the results of this study, future research should also examine the effects of various placement methods on success in other college-level courses not including mathematics. Although the study found that high school GPA was a valid predictor for success in a college-level mathematics course, the predictability of high school GPA on other courses or graduation rates were not explored. For example, are the students who successfully pass their college-level mathematics course graduating at a higher rate and earning their credentials? Longitudinal study design may be warranted to ultimately determine the effects of placement method on future courses and students' graduation.

Another study may examine academic success in additional mathematics courses that students take during their programs of study. This study only focused on academic success in the first mathematics course (statistics, college algebra, or pre-calculus) taken by students. While other mathematics courses exist at the institution, students can only be placed into statistics, college algebra, or pre-calculus due to the current placement policy. Additional research may examine how students perform in subsequent mathematics courses such as calculus to see if they are successful as well and if the placement assessment method has any impact on future coursework other than the initial mathematics course.

From a cursory review of the data, it might be assumed that all students should be funneled into pre-calculus based upon the data and success rates. However, a future study may examine the role of major and mathematics course taken in relation to academic success. Specifically, each major requires a specified mathematics course for degree completion. Additional research may determine if students in a particular major are performing better than students in another major. Specifically, a future study may explore if a student's major is what is driving the difference in success in the mathematics courses.

Studies may also examine other environmental factors such as the instructors who facilitate/teach the courses. As stated in the limitations, the effects of the instructor are not known with regards to the grade the students earned for the course. Specifically, the current study did not examine the effects of placement methods on college-level success at different levels to include the effect of teachers/instructors on student's success within the institution.

Future studies may want to explore the impact of the instructor on student success in college-level mathematics courses.

Given that the odds for success were disproportionately better for students who were 19 years of age or younger, it may be beneficial to determine if their success was related to the inclusion of dual enrollment students in this group (*N* = 101). After all, students who are 19 years or younger may be dual enrollment students or traditional students transitioning from high school. Such a study would compare the academic success of dual enrollment students to non-dual enrollment students to determine if the success rates of the two groups were equivalent. Further analysis would be required to determine the cause of any differences in success rates if discovered.

Further exploration may seek to analyze the success rates of dual enrollment students in relation to the mathematics course taken to determine if course has an effect on academic success. Specifically, from the study, it was determined that students who took pre-calculus were 1.66 times more likely to pass than those who took statistics after controlling for all of the sociodemographic and placement type variables in the model. However, future studies may want to examine this further to determine which students are taking the pre-calculus course. For instance, the students may be taking the pre-calculus course because they are higher achieving students and going on to a STEM pathway at a four-year institution. Further analysis would be required to determine why students are more successful in the pre-calculus course and whether the students taking the course are dual enrollment students.

Limitations and Reflexivity

The study's limitations were identified previously in Chapter 1 and throughout the research process. Limitations of the research include the use of a single institution, thereby limiting the generalizability of the results to other institutions that may have different sociodemographic variables. Second, this study did not have a variable for mathematics courses instructors to assess the effects of teachers on students' grades. Third, the sociodemographic characteristics of the sample were all obtained from a two-year institution. Specifically, the demographics of a four-year institution may vary from that of a two-year institution (Jaggars et al., 2013). Lastly, the study was limited because only academic success in college-level mathematics courses was examined (Burdman et al., 2018).

The researcher acknowledges the use of secondary data as a benefit because it allowed the researcher to examine a large sample of students at a two-year institution. Additionally, since the researcher was familiar with the institution the use of the secondary data was a benefit because all the identifying student information was removed from the data. The use of de-identified data was critical since the researcher was familiar with the school. A qualitative or mixed methods study would not have worked to achieve the goals set forward by the research. Specifically, a quantitative methodological approach was a key factor for selecting the quantitative research design because of the large sample size used in this study that would not have been possible with a mixed method or qualitative study (Neuman, 2013).

The researcher acknowledges that the study used a representative sample of the student body, student demographics, and, specifically, student age. In retrospect, the researcher acknowledges that removing dual enrollment students from the study would be a valid step to determine if the results were consistent with this study. Specifically, given the higher number of dual enrollment students in the study, it would be beneficial for future studies to examine this student population separately. However, the research of this study is valid because if dual enrollment students were excluded than a future research study would be needed to determine the effects of using dual enrollment students in the study.

The research study was an illuminating experience. The results of the study reaffirmed the researcher's passion for two-year institutions and the population that these institutions serve. The importance of correctly assessing students at the beginning of the college journey was also solidified for the researcher in this process. Of importance to the researcher is that the study highlighted the need for a more robust placement assessment method to be used at two-year institutions. The majority of institutions still use only one of three placement assessment methods, with the majority of institutions using a standardized placement exam. Furthermore, study results revealed that standardized placement exams are poor predictors for success in a college-level mathematics course. Therefore, institutions may have an opportunity to explore other assessment methods, specifically high school GPA because of this study.

Chapter Summary

Chapter 5 identified the study's major results, conclusions, interpretations, implications, and suggestions for future research, as well as limitations and personal reflections on the overall dissertation research process. Overall, the study examined the three placement methods (i.e., the standardized placement test, ACT/SAT mathematics score, high school GPA) used by two-year colleges in placing students in college-level mathematics courses to determine the single best mathematics placement method for college success at one institution.

The results of RQ1 identified a statistically significant relationship between the use of high school GPA and academic success in a college-level mathematics course. The results of RQ2 identified a statistically significant relationship between the placement methods of high school GPA and academic success in a college-level mathematics course after controlling for sociodemographic variables. Additionally, the results revealed a negative and statistically significant relationship between the ACCUPLACER placement method and academic success in a college-level mathematics course after controlling for sociodemographic variables. A negative and statistically significant relationship between the placement method ACT/SAT mathematics score and academic success in a college-level mathematics course was also found after controlling for sociodemographic variables. A statistically significant relationship between the mathematics course taken (Pre-calculus - Math 150) and academic success in college-level mathematics was also found for RQ3 after controlling for sociodemographic variables and placement methods. Study results partially supported the hypothesis for RQ4, with a statistically significant relationship identified between the use of high school GPA as a placement method and academic success in a college-level mathematics course when placement methods disaggregated the models, but not for ACT/SAT mathematics score and ACCUPLACER exams. As such, the implications of this study for policymakers and higher-education practitioners and faculty are to examine their institutions own placement assessment method to determine if high school GPA may be best for their institution to assess student placement.

Multiple future research studies were recommended as part of this chapter. Notably, exploration and future research to determine if the results of this study are transferable to other two-year institutions are needed. A future study could explore if the study results apply to four-year institutions and if the results vary from two-year to four-year institutions. Lastly, a future study could also explore how students perform in other college-level classes besides their college-level mathematics courses.

Study limitations were identified throughout the study. One limitation of this study was the use of a single institution, resulting in the inability to generalize the results to other institutions that may have different sociodemographic variables. An additional limitation of the study was that a variable that reflected the course instructor was not used. Therefore, the effects of the instructor on the students' grades were not assessed in this study but may have had an impact on a student's grade. Another limitation of the study was the use of subjects with similar sociodemographic characteristics from a single two-year institution. Lastly, the chapter concluded with a personal reflection on the research process and the academic and personal impact of such a process on the researcher.

Ultimately, the study sought to answer the overarching research question: Which of the placement variables is the best predictor for success in college-level mathematics? The results of the study indicated that high school GPA was statistically the strongest predictor for success in college-level mathematics. The results of the study support the existing literature that high school GPA is a better predictor for college success. Although these results are not generalizable to four-year institutions or possibly even other two-year institutions as the sociodemographic makeup of each institution is unique, the results are noteworthy and worth considering when stakeholders at two-year institutions are determining placement assessment policies and practice.

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Appendices

Appendix A: IRB Letter of Support

University of West Florida

Research and Sponsored Programs
11000 University Parkway, Bldg. 11
Pensacola, FL 32514-5750

Mr. Chad Weirick

October 31, 2018

Dear Mr. Weirick:

The Institutional Review Board (IRB) for Human Research Participants Protection has completed its review of your proposal number IRB 2018-068 titled, "Assessing Multiple Placement Methods for College Mathematics at a Two-Year College," as it relates to the protection of human participants used in research, and granted approval for you to proceed with your study on 10-29-2018. As a research investigator, please be aware of the following:

* You will immediately report to the IRB any injuries or other unanticipated problems involving risks to human participants.

* You acknowledge and accept your responsibility for protecting the rights and welfare of human research participants and for complying with all parts of 45 CFR Part 46, the UWF IRB Policy and Procedures, and the decisions of the IRB. You may view these documents on the Research and Sponsored Programs web page at http://research.uwf.edu. You acknowledge completion of the IRB ethical training requirements for researchers as attested in the IRB application.

* You will ensure that legally effective informed consent is obtained and documented. If written consent is required, the consent form must be signed by the participant or the participant's legally authorized representative. A copy is to be given to the person signing the form and a copy kept for your file.

* You will promptly report any proposed changes in previously approved human participant research activities to Research and Sponsored Programs. The proposed changes will not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the participants.

* **You are responsible for reporting progress of approved research to Research and Sponsored Programs at the end of the project period 05-[illegible]. If the data phase of your project continues beyond the approved end date, you must receive an extension approval from the IRB.**

* If using electronic communication for your study, you will first obtain approval from the authority listed on the following web page: https://uwf.edu/offices/institutional-communications/resources/broadcast-distribution-standards/.

Good luck in your research endeavors. If you have any questions or need assistance, please contact Research and Sponsored Programs at 850-474-2824 or 850-474-2609 or irb@uwf.edu.

Sincerely,

Dr. Matthew Schwartz, Assistant Vice President for Research and
Interim Assistant Vice President
Research Administration

Carla J. Thompson

Dr. Carla Thompson, Chair, IRB for
Human Research Participant Protection

UWF IRB APPROVED

Phone 850.474.2824 Fax 850.474.2802
Web research.uwf.edu
An Equal Opportunity/Equal Access/Affirmative Action Employer

Appendix B: CITI Program Coursework Requirements

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements

- **Name:** Chad Weirick (ID: 5429344)
- **Email:** cw65@students.uwf.edu
- **Institution Affiliation:** University of West Florida (ID: 2862)
- **Institution Unit:** UWF

- **Curriculum Group:** Social and Behavioral Responsible Conduct of Research
- **Course Learner Group:** Same as Curriculum Group
- **Stage:** Stage 1 - RCR
- **Description:** This course is for investigators, staff and students with an interest or focus in **Social and Behavioral** research. This course contains text, embedded case studies AND quizzes.

- **Report ID:** 18870345
- **Completion Date:** 02/29/2016
- **Expiration Date:** 02/28/2019
- **Minimum Passing:** 80
- **Reported Score*:** 83

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Research Misconduct (RCR-Basic) (ID: 16604)	02/29/16	5/5 (100%)
Data Management (RCR-Basic) (ID: 16600)	02/29/16	4/5 (80%)
Authorship (RCR-Basic) (ID: 16597)	02/29/16	5/5 (100%)
Peer Review (RCR-Basic) (ID: 16603)	02/29/16	4/5 (80%)
Mentoring (RCR-Basic) (ID: 16602)	02/29/16	5/5 (100%)
Conflicts of Interest (RCR-Basic) (ID: 16599)	02/29/16	4/5 (80%)
Collaborative Research (RCR-Basic) (ID: 16598)	02/29/16	5/5 (100%)
Research Involving Human Subjects (RCR-Basic) (ID: 13566)	02/29/16	1/5 (20%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** Chad Weirick (ID: 5429344)
- **Email:** cw65@students.uwf.edu
- **Institution Affiliation:** University of West Florida (ID: 2862)
- **Institution Unit:** UWF

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CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

Appendix C: Approval for Use of Study Location

CENTRAL OHIO TECHNICAL COLLEGE

1179 University Dr. Newark, Ohio 43055-1767
740.366.1351 800.963.9275

August 9, 2018

University of West Florida
Research and Sponsored Programs
Bldg. 11/Rm. 110
11000 University Pkwy.
Pensacola, FL 32514

RE: Letter of Support

Dear Institutional Review Board:

This is to indicate that Central Ohio Technical College (COTC) is permitting Chad Weirick, doctoral student at the University of West Florida, to use secondary data from the College in connection with his dissertation work.

Mr. Weirick's project requires data from COTC of students taking college mathematics during autumn 2017 and spring 2018 semesters. The College's Office of Institutional Research and Effectiveness has provided this data with all personally identifying data removed to ensure student anonymity. The data was provided in an Excel format to Mr. Weirick and each student record has been given a random identification number to ensure anonymity. Further, it is my understanding that the College's name will be withheld in his study and instead it will say a "two-year college in the Midwest."

Therefore, as a representative of Central Ohio Technical College, I agree that Chad Weirick's research project may be conducted at our institution.

Sincerely,

Jacqueline H. Parrill

Jacqueline H. Parrill, Ed.D.
Vice President for Institutional Planning and Human Resources

cotc.edu

Coshocton Campus
200 North Whitewoman Street
Coshocton, OH 43812
740.622.1408

Knox Campus
236 South Main Street
Mount Vernon, OH 43050
740.392.2526

Pataskala Campus
8660 East Broad Street
Reynoldsburg, OH 43068
740.755.7090