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DO CO-REQUISITE REMEDIAL MATH CLASSES WORK? A STUDY OF REMEDIATION AT MTC.

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DO CO-REQUISITE REMEDIAL MATH CLASSES WORK? A STUDY OF REMEDIATION AT MTC.

A Thesis

By

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Submitted in partial fulfillment of the requirements for the degree of

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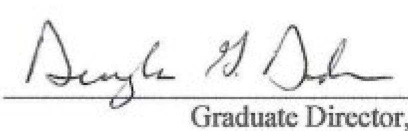 8/5/2019

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The thesis entitled '**DO CO-REQUISITE REMEDIAL MATH CLASSES WORK? A STUDY OF REMEDIATION AT MTC.**' presented by **CHRISTOPHER K. LEIMBACH**, a candidate for the degree of **Master of Science in Mathematical Sciences,** has been approved and is worthy of acceptance.

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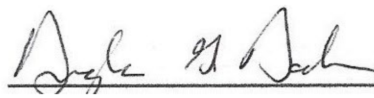

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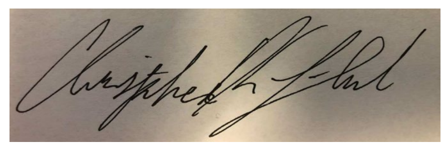

Student

ABSTRACT

As post-secondary institutions look to reform remediation in mathematics, the concept of co-requisite remediation has been widely discussed. This is especially important for community colleges and other open access institutions who receive a large percentage of students that are not yet ready for the college level material. This study observed two years of students at Marion Technical College who received remediation in one of two styles: pre-requisite and co-requisite remediation. This study looked at a STEM course and Non-STEM course. Using logistic regression the study sought to predict the success of students using the remediation style received among other demographic and academic variables. Results were mostly inconclusive, however there is evidence that students who received co-requisite remediation performed as well or better than students who received pre-requisite remediation, supporting theories that it is more efficient for students to receive co-requisite remediation in a college course rather than work on pre-requisite courses that are not at the college level before enrolling in a college course.

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CHAPTER 1: Introduction

Introductory Paragraph

The purpose of this chapter is to provide the reader a thorough introduction to this study. This chapter will include the necessary background for the study before continuing to stating the problem at hand. Further information will then be given about the purpose and significance of the study, including the research questions this study seeks to answer. The study's hypothesis and theoretical framework are then offered, finishing with the scope, limitations, and assumptions this study makes.

Background of the problem

There is a great focus on progress efficiency in higher education, whether you are a student trying to graduate, an institution seeking funding and status, or a governmental agency trying to best steward the tax dollars with which they oversee. For a student, repeating a course can set their graduation behind by a semester causing the student to spend more time and money for their degree. Institutions that are government funded based on completion of certificates/ degrees are financially motivated to improve efficient paths from enrollment to graduation. However, even without the motivation of finances, institutions that wish to attract the top talent need to show an ability to get that talent to their goals. Regardless of the motivation, there is pressure to improve the efficiency in which we produce quality certificate holders, degree holders, or degree for transfer students. Recent data indicates that only 24% of students attending a public two-year institution graduated in 3 years. (McFarland et al., 2018)

In 2010, President Obama set a goal for the United States of America to once again lead the world in producing college graduates by 2020. Included in this goal was a goal for community colleges to produce 5 million degrees and certificates. (White House, 2011) Additionally, over 30 states (including Ohio) have moved toward outcome based funding rather than enrollment based funding, creating a financial motivation for colleges to increase graduation rates without decreasing quality (Quinton, 2016).

The added intensity to add more college graduates is contrasted by the fact that research shows that a major barrier for success in higher education is the college level mathematics course. In community colleges, completing a college level mathematics course increased the likelihood that the student would graduate by 11.5% and increased the likelihood of transfer by 22.7% (Moore & Shulock, 2009). However, according to the American Association of Community Colleges (AACC), 67% of community college students are placed in at least one developmental Math and/or English course. Further, only 50% of the students in public two-year institutions complete all of the remedial math requirements. This is partially because there could be as many as five levels of mathematics remediation (CCCSE, 2016). Therefore, a focus has been placed on how mathematics is currently being taught and how it can be improved.

The system that requires remediation to be completed before a college level mathematics course can be completed is known as the pre-requisite model. This is the model that was first introduced in the 1960s to help students who were deemed underprepared for college academics. (CCCSE, 2016) The flaw in this model, is that students placed in the lowest level of remediation would need at least six semesters of mathematics (five remedial and one college level course) to fulfill the mathematics requirement of their two-year degree. This means a typical student that takes a course every fall and spring will need at least 3 years of mathematics before earning their degree. Adding summer courses, the student could finish in the summer following their second spring. As stated earlier, however, 50% of these students will not complete their remedial math semesters, leaving the student without a degree and possible student loan debt.

An alternative model has recently been explored in Ohio known as the co-requisite model. This new model has been an emphasis in the Ohio Department of Higher Education with the Mathematics Bridges to Success initiative and Co-requisite Remediation was a major focal point of the Ohio Mathematical Association of Two Year Colleges Annual Conference in March 2019. This model of remediation involves taking a remedial math class concurrently with the college level class. This "just in time" remediation style aims to build the necessary foundational knowledge just before it would be needed in the college level course. This would allow students who need remediation to receive the help they need and also enroll in the college level course all in one semester.

A logistic hurdle to co-requisite remediation is how to place students appropriately. The current placement system generally involves a single placement test of some sort taken before the student's first semester. This one measure test proved to be inadequate in properly determining success in college. Many students are unprepared for this test and/or they are unsure how to properly prepare. Further, this test only measured the students' abilities at the time of the test, rather than a comprehensive view of the students' abilities. (CCCSE, 2016)

A study done by Davidson County Community College (North Carolina) in 2013 showed that high school performance was significantly more predictive of success than a single measure test. (CCCSE, 2016) They designed a hierarchy of measurements that placed high school GPA and math courses in high school as the first criteria, ACT/SAT score next, previous college credits, and then a placement test, virtually relegating the single measure test as a last resort. The study showed 65% of students placed using the high school GPA were successful in the college course, compared to 48% of students who placed with other metrics.

Statement of the problem

Despite the early success co-requisite remediation has had in New York (Louge, 2018), California (Rodriguez, O., Mejia, M.C. & Johnson, H., 2018), and in a limited amount of time in Ohio, some are hesitant to make the switch to a full-scale co-requisite model without any pre-requisite courses. One particular hurdle to overcome is the idea that this will be harmful to the students and that they will be unable to succeed in a college level class right away. As always, the students' success should be the goal of any academic institution.

Purpose of the Study

Currently, Marion Technical College provides a pre-requisite pathway and a co-requisite pathway for mathematics completion. This study will examine the success rates of students in the college level mathematics class based on whether they took a pre-requisite or co-requisite remediation. Additionally, the study will examine the success rates of these two remediation groups in the context of a STEM and non-STEM pathway.

A secondary purpose of the study is to examine other factors, such as academic and demographic variables, which are outside of remediation that may also predict success rates. The study will seek to determine which variables are significant predictors of success. These variables, both quantitative and qualitative, have been gathered from the Institutional Research department of MTC.

This study will largely utilize logistical regression to predict success or failure in the college level course. The population is limited to on campus classes and excludes any high school students seeking dual credit. The population for the STEM course will be students enrolled in MTH1245 College Algebra beginning in the fall semester of 2017 through spring of 2019. The population for the non-STEM course will be any students enrolled in MTH1240 Statistics beginning in the fall semester of 2017 through spring of 2019. The academic variables collected for this study include: cumulative high school GPA, composite ACT score, math ACT score, and college level course grade as a letter grade (A, B, C, etc.) and as a point designation (A=4, B=3, etc.). Demographic variables include: years since high school graduation, age of the student, gender, Pell Award Eligibility, high school attended, and whether the student is considered a non-traditional student.

Definition of Terms

College Algebra – A course as defined by the Ohio Department of Higher Education Transfer Module that meets the criteria for TMM 001 – College Algebra

Co-Requisite Remediation – A style of remediation that is taken concurrently with a college level course in an effort to deliver just in time remediation

Non-traditional Student – defined for the purposes of this study any student that is at least one of the following: Minority (as defined by OBR/ODHE), 25 years of age or older, enrolled in a non-degree seeking program, Pell Grant eligible

Pre-requisite Remediation – The traditional model of remediation requiring students to pass at least one remedial course before enrolling in a college level course

Statistics – A course as defined by the Ohio Department of Higher Education Transfer Module that meets the criteria for TMM 010 - Introductory Statistics

STEM – abbreviation for Science Technology Engineering and Mathematics

Success – defined for the purposes of this study as earning a final grade of A, B, or C in the college level course

Significance of the Study

This study will be performed at a public, open access, two-year institution. As such, there is no artificial floor for the participants' abilities. Additionally, since students were unaware that a study on the data would be performed, there is no performance bias. Furthermore, the makeup of the college classes at MTC are such that students are not segregated based on remedial status, meaning it is possible (and likely) that students from the pre-requisite, co-requisite, and neither groups could all take the college level course together, diminishing some of the bias associated with the professor, time of day, or location.

The may be used by institutions considering the implementation or scaling of co-requisite remediation as well as offer insight on proper placement of students into remedial courses. Ideally this can prompt further research into remediation and placement on a larger scale. Additionally, this study gives insight to the viability of scaling a co-requisite model for STEM or non-STEM pathways.

Primary Research Questions

This study will seek to answer the following questions.

1. Is there a significant difference in success rates across types of remediation for students in a STEM gateway math class?
2. Is there a significant difference in success rates across types of remediation for students in a non-STEM gateway math class
3. What influence do demographic predictors have on student success in a STEM class?
4. What influence do demographic predictors have on student success in a non-STEM class?
5. What influence do previous academic predictors have on student success in a STEM class?
6. What influence do previous academic predictors have on student success in a non-STEM class?

Hypotheses

Students in the co-requisite group will have a higher success rate than those in the pre-requisite group. Demographic variables included in the study are years since high school/ GED completion, age of the student, gender, Pell Award Eligibility, high school attended, and whether the student is considered a non-traditional student. Student high school attended and years since high school/GED will be significant predictors. Other demographic variables will not.

The academic predictive variables collected for this study include: cumulative high school GPA, composite ACT score, and math ACT score. All of these will be significant predictors.

Research Design

This research is an ex post facto research design. Students are not manipulated in any way. As this was truly after the fact research, neither student nor instructor were biased in any way. Predictive variables have been collected for students who were enrolled at MTC in MTH1240 Statistics and MTH1245 College Algebra in the Fall 2017 semester through the Spring 2019 semesters inclusively. Student final grades are collected for all students at the conclusion of the Spring 2019 semester. The study is designed to predict the success of the students based on the predictive variables.

As there was no student involvement in the collecting of data, all predictive variables come from MTC's Institutional Research Department. This data was provided to the institution at enrollment at the college. Final grades were collected by the institution after the course was completed.

Theoretical Framework

Education creates a path to a better life socially, economically, and personally. In the pursuit of this better life, too many are placed into developmental mathematics. 60% of those entering developmental mathematics never earn a degree (Grubb et al., 2011). The framework of this study is rooted in the assumption that removing the barrier of pre-requisite style remediation, more students will succeed. Creating a system that provides remediation at the moment it is needed while still allowing the student to work on earning college credit at the beginning of the student's college career, we reduce the number of students exiting college with less social mobility, more debt, and failure; the opposite of education's goal.

While this study does not examine the psychology of the students, it should be noted that a student's attitude and grit have been correlated with college success. Many community college students had poor experiences in K-12 schooling or have been out of schooling for some period of time (CCCSE, 2016). At best in pre-requisite remediation, it will take you two semesters of mathematics to complete the college credit. The co-requisite model gives students the opportunity to receive college credit after one semester.

Assumptions, Limitations, and Scope

Certain limitations do exist in the data, specifically missing data, small sample size, and potential predictors not available for the study. Since community colleges are open access, it is possible a student has not taken the ACT. In the case of missing data, those records will be removed before data is analyzed. The small sample size is due to the fact that only one school was observed and there is only two years of data available. Finally, because this is an ex post facto study, the study is limited to only using data points that MTC collects for all students. No questionnaires or other demographics known only to the student could be used.

The study has implications for those researching co-requisite remediation in the state of Ohio and beyond. By examining both STEM and non-STEM courses, the study seeks to educate those interested in full scale implementation across all gateway mathematics courses. Additionally, the study will provide insight to those researching new methods of placement into co-requisite remediation versus direct placement into the college level course.

Summary

The purpose of this chapter was to provide the reader a thorough introduction to this study. This chapter showed as students and institutions seek a more efficient path to success, the delivery method of developmental mathematics is under review. It is known that mathematics is a barrier for many students, so educators are looking for new solutions to help students effectively and efficiently navigate the mathematics requirements for degrees. This study will evaluate the success of students in co-requisite remediation and secondarily evaluate academic and demographic predictors of success in both STEM and non-STEM pathways.

CHAPTER II: Literature Review

Introduction

This chapter focuses on existing literature and research that contributed to the overall foundation on which this study was built. No original ideas will be introduced, rather this is a collection of works by other experts. This chapter is provided for the reader to familiarize themselves with a summary of the necessary research pertaining to the non-traditional student, the pre-requisite and co-requisite approaches, remedial education history and development, research of college level mathematics placement strategies, and the financial implications of remediation in higher learning. While this is in no way an exhaustive list of all views and research on the topics, the reader should be well-versed enough in the research that knowledge gaps of the material are minimal.

Non-Traditional Students

Community Colleges have a disproportionately large number of non-traditional students compared to four year institutions. As many as 89% of students in community colleges are considered to have at least one non-traditional trait compared to 58% and 50% at public and private four year colleges, respectively (US DOE, 2002). In this regard, the non-traditional student is the typical student that community colleges enroll.

The term “non-traditional” implies the existence of a “traditional student. In 2018, Laura Landry from Northeastern University stated traditional students are “newly out of high school, on the verge of turning 18, when they excitedly move onto the college campus”. While the simplest definition of a non-traditional student could be stated simply as a student who does not fit the definition of traditional students, researchers have generally sought to define certain characteristics that make-up the non-traditional student.

What defines a non-traditional student has not been well fleshed out in the literature. Traditionally, age has been the predominate factor in determining whether a student is traditional or non-traditional. Specifically, those who are 25 years of age or older have been deemed non-traditional, while those under the age of 25 are considered traditional (Bean & Metzer, 1985; Horn, 1996; US DOE, 2002).

While age is the most common variable used to separate traditional and non-traditional students, it is far from the only criteria used in research to classify a student as non-traditional. Many studies point back to a study conducted by the National Center for Education Statistics that defines non-traditional as any student who fits one or more of seven different criteria (Horn, 1996):

- Any student who delays enrollment into college by one year or more after high school graduation
- Any student who attends part-time for any part of the school year
- Any student who works full time
- Any student who is considered financially independent for purposes of financial aid determination
- Any student who has dependents other than a spouse (generally children, but not exclusively)
- Any single parent
- Any student who did not earn a high school diploma

Because 73% of all undergraduates can fit one or more of these criteria, the study also applied a continuum on which to base the level of "nontraditional" on to which a student falls (US DOE, 2002)

Other studies and organizations have their own definition of who is non-traditional. While not exhaustive, other common criteria for non-traditional students include students who commute (Bean & Metzer, 1985), veterans (Auguste, Packard, & Keep, 2018), and lower socio-economic status (Wladis, Conway, & Hachey, 2015). Chung and her associates found that those students who identified themselves as non-traditional tended to be "male, older, hold a previous degree, study part-time, be an international student, speak a language other than English, have longer gap year, have more children, be reliant on government financial aid, work longer hours and admit to university via methods alternative to the standard pathway" (Chung, et al., 2017).

The literature is therefore inconclusive of what a "non-traditional" student looks like. In general, older students seem to be a part of every description, however, rarely is age alone determinate. Yet, research definitively points to community colleges having a higher rate of non-traditional students that their four year counterparts.

College Remediation: A Historical Need

Approximately one year before Pierre de Fermat wrote his Last Theorem and René Descartes introduced the world to the Cartesian plane, the first post-secondary institution of the New World was founded. In 1636, the college that would eventually become Harvard University was founded in Cambridge, Massachusetts. Its original charter was to train clergy and develop the foundation of an intellectual elite in the British colonies. Enrollment at Harvard and other early institutions, such as William and

Mary and Yale, was limited to white men of privilege and operated free of government involvement for much of its first 200 years. (Arendale, 2002)

In the early advent of higher education in modern day America, there was quickly a need for some form of assistance for those men seeking admittance, stemming from the lack of quality education at the primary and secondary levels and the entrance requirements of Latin fluency and an elementary knowledge of Greek. This lead to many men seeking entrance to hire private tutors to pass the entrance exams. By the 1860's, the advancement of "developmental" education had only expanded to include pre-college preparatory academies. All of these early forms of helping underprepared students still took place outside of formal post-secondary institutions (Arendale, 2002).

The Morrill Act of 1862 and 1890 created land-grant colleges that provided a lower cost option for students. The combination of these two acts made it more possible for women, people of color, and working class individuals to attend institutions of higher education (Land-grant universities, 2017). This, in part, created a rapid increase of Americans attending college and by association, an increase in the need for academic support. (Arendale, 2002). In 1865, the University of Wisconsin, which would become a land-grant college the following year, registered over 87% of their students in the preparatory department or as "special" students (Tomlinson, 1989; University of Wisconsin, 2013). This was not an isolated incident – by the year 1889, 84% of land-grant institutions had remediation in some form (Arendale, 2002).

Other catalysts besides Acts of Congress created a need for developmental education. In the late 1860's, the American Missionary Association was instrumental in creating colleges to cater specifically for the recently freed slaves. Among the institutions founded were Howard University and what is now Hampton University (American Missionary Association, 2015). These students had almost no formal secondary education and also had the unique disadvantage of the psychological trauma from being enslaved (Arendale, 2002).

Later, in 1890 the College Entrance Examination Board was created by several colleges including Columbia University, Cornell University, and the University of Pennsylvania. The Board was given the task of creating uniform exams to replace individual schools' entrance exams. This later grew to be the College Board that produces the SAT® and AP® exams (CEEB, 1900). This created another need for pre-college level education. In the first decade of the twenty-first century, 50% of the students entering top Ivy League schools could not meet the entrance requirements. In 1915, 350 schools reported the need for some sort of developmental education (Maxwell, 1979)

The first recorded instance of a remedial course being incorporated with college curriculum is at Harvard in 1874 with the development of Freshman English. This was originally created to bridge the growing gap between the perceived deficiencies of incoming freshman and what was required at the university level. By 1898, the course had become a standard of the University of California – Berkley (Maxwell, 1975).

The Pre-Requisite Model

Developmental Education began to expand in the 1960's through experimentation of content, pedagogy, administration and psychology. Though research into Developmental Education has continued since, the only major leap through the end of the millennium was in technological advances rather than classroom changes (Dotzler, 2003).

The most widely used method of delivering remedial education is to place students into one or more levels of remediation that must be completed in a step-by-step fashion. After a student completes all the levels of remediation, the student can then enroll in a college level course (Baily, Jeong, & Cho, 2008). This is the Pre-Requisite model. Students receive formal remedial education classes *before* they are able to enroll in a college level course.

A study of 57 colleges from Connecticut, Florida, Ohio, New Mexico, North Carolina, Pennsylvania, Texas, Virginia, and Washington, found 59% of students were referred to at least one developmental mathematics course, with 19% referred to at least three levels of remediation (Baily, Jeong, & Cho, 2008). Almost two thirds of reporting colleges had three or more levels of remediation. The study found 43.4% of students placed one level below college level math were able to complete the course, 27.3% of students requiring 2 levels of remediation were able to complete both courses, and only 16.1% of those students requiring three or more courses of remedial mathematics were able to complete the entire developmental sequence. This means nearly 40% of students entering colleges will never take a college level mathematics course.

Frustrating the issue further, a 2012 study shows that 49.5% of all students would pass the college course with a C or higher regardless of whether they tested into a remedial course. When expanding the term "passing" to include a D- or higher, this statistic rises to 63.9% of all students regardless of placement test results (Scott-Clayton, 2012). All of this matriculates to only 10% of community college students in developmental education finishing their two-year degree in three years and 35% students at four-year colleges in developmental education finishing their degree in 6 years (Whinnery & Pompelia, 2019).

Placement Strategies

Traditionally institutions have relied on a single mathematical placement test for determining whether a student is “college-ready” in mathematics. What constitutes “college-ready” varies from state to state and even institution to institution. Using the ACT as a guide, for instance, the range of acceptable mathematics scores run from 19 to 23 in varying state policies (Whinnery & Pompelia, 2019). Additionally, the single measurement approach has proved to be unreliable in placement. Judith Scott-Clayton found in a 2012 study that using multiple measures could improve accurate placing by 15%.

In 2013, Davidson County Community College (DCCC) in North Carolina implemented a state mandated Multiple Measure Policy. This policy used a hierarchy of criteria to place students. The first criteria explored was high school performance. Transcripts that were 5 years old or newer and displayed a 2.6 GPA and 4 years of mathematics in high school concluding with Algebra II or above were placed immediately in college level courses (CCCSE, 2016). Research suggests using high school data is at least as accurate as using a single measurement placement test (Whinnery & Pompelia, 2019). The second level of criteria observed ACT/SAT subject scores for recent graduates that did not meet the criteria at the first level. Thirdly, if a student was new to the college and carried college level credit with them, they were placed at the college level. Finally, in the absence of the above criteria, a diagnostic test was given to determine placement.

The DCCC study showed further showed the importance of using high school performance to predict college success. 65% of the students placed in a college level math course using the high school data from the first step in the hierarchy, earned a C or higher, whereas 48% of students placed using one of the other three placement levels earned a C or higher. The data was disaggregated across race/ethnicity and found that the trend continued (Whinnery & Pompelia, 2019).

Financial Implications of Remediation

The cost of remediation to the federal and state governments has a lack of rigorous research. Costs at the federal level for remedial education are estimated between 1 and 2 billion dollars, constituting 1-2% of the annual budget for education (Bahr, 2008 and Martinez & Bain, 2014). At the state level, the budget for remedial education consumes on average another 1-2% of state budgets for education, with as much as 10% of the budget reportedly put towards developmental education. (Martinez & Bain, 2014). These numbers are somewhat disputed because of the inconsistency in reporting. However, whatever the cost, there has been debate whether these costs should be absorbed by taxpayer monies at all. Some feel that taxpayers are paying for the studies twice- once in secondary school and again as remediation at the post-secondary level (Bahr, 2008).

While debates continue on the financial implications to the government and institutions, the students are unquestionably affected financially by remediation, beginning with those who are unable to complete the remedial education requirements. Those students who attempt and do not pass remediation lose the cost of the class without gaining the benefits of the degree. Even those who choose never to enroll because they are placed in remediation lose the potential income increase that comes with a degree. Median earnings are 18% higher for those with an associate's degree versus those with only a high school diploma, while the unemployment rate drops from 4.1% for those only with a diploma to 2.8% for those with an associate's degree (BLS, 2019).

Another cost to consider is the number of semesters of Federal Pell Grant eligibility. The Federal Pell Grant is a need-based award that does not need to be repaid (unlike a loan). The maximum number of semesters that an undergraduate student may be eligible for the grant is 12 semesters, roughly 12 years. Currently, the maximum Federal Pell Grant award amount per year is $6,095, meaning a student who uses one of their 12 semesters of eligibility in developmental mathematics could cost themselves $3,047.50 at the end of their college career (Federal Pell Grants).

Co-Requisite Remediation

The question has been raised whether remediation should continue to have a place in a post-secondary institution (Bahr, 2008 and Maxwell, 1975). Bahr goes on to answer the question that remediation is important to provide minimum skills that can lead to the transcendence in socio-economic status that is available in a free market system. There has been a plethora of research on what is wrong with remediation and comparatively little on how to fix it. The most promising research is in the recreation of how remediation is delivered.

Co-requisite remediation is a form of remediation that places students simultaneously in a college level course and a remediation course. In co-requisite remediation, students receive remediation just in time to use it in the college level course

(Complete College America). This approach has been shown to increase the number of students enrolling in and completing the college level course (CCRC, 2014)

In Ohio, Co-requisite Remediation operates in one of three forms – the Paired Course model, the 101 Plus Model, and The Technology Mediated Model. The paired course model has remedial students enroll in a separate remedial course taken in the same semester as the college level course in which they are also enrolled. This allows for some form of institutional flexibility. The remedial course can then be administered by the same instructor or a different instructor, the remedial course and the college course can run on the same day (generally back-to-back) or on separate days, and the college course can be a heterogeneous mix of remedial and non-remedial students or can run with remedial students and non-remedial students in separate college level sections (ODHE, 2018).

The most common implementation of the 101 Plus model (also known as the extended time model) is to offer a college level course with a "Plus" option. For example students could sign up for MATH1500 Statistics or MATH1501 Statistics Plus. In this model, the class times (and credit hours) are extended in the "Plus" course to offer additional support during the class. In the previous example, if MATH1500 is a 3 credit hour course, MATH1501 could be 4 or 5 credit hours (ODHE, 2018).

The Technology Mediated Model (also known as the Emporium Model) relies on technology to provide the additional support of the "just in time" remediation. In this model, the college level course is unaltered and those needing remediation receive it outside of the traditional classroom, either at home or in a lab type setting. This generally requires some form of software that is integrated with the college level course to accurately provide remediation at the appropriate time (ODHE, 2018).

Some challenges with implementation include, but are not limited to: limited buy in from faculty, advisors and students; scheduling and logistic issues; limited preparation; and change fatigue. These issues are not isolated, having been reported in California (Birrell & Pinter-Lucke), Tennessee (Belfield, Jenkins, & Lahr, 2016), and Texas (Daugherty, et. al). Despite these challenges, research in all three mentioned states showed improvement in completion rates at the college mathematics level.

Summary

This chapter focused on existing literature and research that contributed to the overall foundation on which this study was built. This chapter is provided for the reader to familiarize themselves with a summary of the necessary research pertaining to the non-traditional student, the pre-requisite and co-requisite approaches explained, remedial education history and development, research of college level mathematics placement strategies, and the financial implications of remediation in higher learning.

CHAPTER 3: Methodology

Introductory Paragraph

The purpose of the methodology chapter is to give an experienced investigator enough information to replicate the study. A research design is used to structure the research and to provide a narrative on how all of the major parts of the research project work together to address the central research questions in the study. This chapter will describe, in detail, the setting, participants, procedures, and a description of how the data was collected and will be analyzed.

The primary purpose of this study is to determine if there a significant difference in success rates across types of remediation for students in a gateway math class. This will be studied in a STEM gateway course and a non-STEM gateway course. Secondary research questions this study will investigate are the effects of academic and demographic predictors have on student success in these classes. This is an ex post facto study and the students were unaware of the study.

Setting and Participants

This study was performed at Marion Technical College. All students were enrolled in MTH1240 Statistics (non-STEM) or MTH1245 College Algebra (STEM) between Fall 2017 and Spring 2019 Semesters. This is a total of 5 semesters for Statistics and 4 semesters for College Algebra because there was not a College Algebra class offered in the Summer semester of 2018. A total of 310 students took Statistics for the first time during this time period and 39 students took College Algebra during this time. All students were general undergraduate students seeking a degree or certificate.

All data was collected from the institution for three reasons. Firstly, this study was done after the fact, and I did not have access to all the previous students. Additionally, requesting data from the institution itself is minimizes self-reporting bias. Finally, collecting the data in this manner helped with confidentiality.

Marion Technical College (MTC) is a two-year, state-assisted technical college located in Marion, OH on a 180 acre campus shared with The Ohio State University at Marion. MTC was founded in 1970 and offers over 60 majors, transfer programs, associate degrees and certificate programs. MTC was one of 3 institutions to earn grants from the Ohio Department of Education's Bridges to Success initiative in 2016 for establishing and implementing more streamlined mathematics pathways and co-requisite remediation. This helped Marion Technical College become one of the first institutions to fully scale co-requisite remediation for each gateway math course offered.

Instrumentation

No data was collected directly from students. The material and Final Exams for both MTH1240 Statistics and MTH1245 College Algebra have had different instructors, but the material and examinations remained the same for all semesters. All data was collected by the College itself.

Procedure

All data was received from the institution in CSV/ Microsoft Excel spreadsheets via three different secure emails. All data was "cleaned" in Excel prior to any processing or analysis in R. Thereafter the data was stored on a password protected computer and network in a locked office on the campus itself. No hard copies were produced and no data was stored in any other capacity for this study. Additionally all names have been stripped from all saved copies of the data to protect student confidentiality.

This data included any student who had enrolled in a math class from Fall 2014 to present. This was done to capture any prerequisite classes each student took before the study's timeframe. The data was filtered to include only students who had enrolled in Statistics and/or College Algebra from Fall 2017 to Spring 2019. These 376 rows were filtered further to include each student's first attempt at a course, removing 30 rows of data. Each student was then identified as a Co-Requisite student, Pre-Requisite student, or neither. Anyone taking the class without remediation was removed, leaving 203 unique students. There were a total of 175 Statistic students (87 Co-requisite students, 88 Pre-requisite students) and a total of 28 College Algebra students (6 Co-Requisite students, 22 Prerequisite students).

Student ages ranged from 18 to 55. This age was based on their age at the start of the course. No student under 18 when the course began was included in the study. Students faced no greater harm than everyday life because of this study. The proposal for this study was submitted and approved by the Shawnee State University Review Board (Appendix A).

Data Processing and Analysis

All students were enrolled in either MTH1240 Statistics or MTH1245 College Algebra between Fall 2017 and Spring 2019 at Marion Technical Institute. Students were not manipulated in any way and all data collection occurred only through the natural data collection of MTC. The purpose of this study is to predict the a successful outcome (A, B, or C) in the college gateway courses (the dependent variable) based on academic and demographic data (the independent variables), specifically the effect of the type of remediation each student participates in will be studied.

Since the main research question involves a binary pass/fail component, logistic regression will be used. Using the free statistical software, R, a backwards elimination technique will be used to find the variables that are significant for the study. Using only these significant variables, logistic regression will find the probability of success or failure. Before any data is used in R, all personal identifying information will be removed (student ID, name, date of birth, etc.).

Summary

The purpose of this chapter was to give an experienced investigator enough information to replicate the study. A research design is used to structure the research and to provide a narrative on how all of the major parts of the research project work together to address the central research questions in the study. This chapter described, in detail, the setting, participants, procedures, and a description of how the data was collected and will be analyzed. The following chapter will use the methods described here.

CHAPTER 4: Results

Introduction

This chapter discusses the results of the research. This study examined the success rates of students in the college level mathematics class based on whether they took a pre-requisite or co-requisite remediation. Additionally, the study will examine the success rates of these two remediation groups in the context of a STEM and non-STEM pathway. A secondary purpose of the study is to examine other factors, such as academic and demographic variables, which are outside of remediation that may also predict success rates. The study will seek to determine which variables are significant predictors of success.

The research questions for this study are

1. Is there a significant difference in success rates across types of remediation for students in a STEM gateway math class?
2. What influence do demographic predictors have on student success in a STEM class?
3. What influence do academic predictors have on student success in a STEM class?
4. Is there a significant difference in success rates across types of remediation for students in a non-STEM gateway math class
5. What influence do demographic predictors have on student success in a non-STEM class?
6. What influence do previous academic predictors have on student success in a non-STEM class?

Originally, I had wanted to use high school attended as a demographic predictor, however, this created a large number of dummy variables that rendered it useless. Instead the 2018 report card overall grade given by the Ohio Department of Education (Ohio Department of Education) for each high school was recorded and used to group high schools together by grade. Grades follow an A, B, C, D, F model and a category N was added for those students who earned a GED, were home schooled, attended a high school that is not given a grade by the state (i.e. vocational schools), or if the student attended out of state. There were no students from an "A" high school in the study and there were no students from an "F" high school in College Algebra. In each test, School B is used as the primary grade.

Study Participants

The first set of participants are students who took MTH1245 College Algebra at Marion Technical College between the Fall 2017 semester and Spring 2019 semester and received some form of remediation. The two subsets of students are broken down into a subset of students who received co-requisite remediation while enrolled in the course and a subset of students who received pre-requisite remediation, remediation in some semester before enrolling in the class. This set of students are observed for research questions 1-3.

The second set of participants are students who took MTH1240 Statistics at Marion Technical College between the Fall 2017 semester and Spring 2019 semester and received some form of remediation. The two subsets of students are broken down into a subset of students who received co-requisite remediation while enrolled in the course and a subset of students who received pre-requisite remediation, remediation in some semester before enrolling in the class. This set of students are observed for research questions 4-6.

Descriptive Statistics

There are a total of 28 students in the College Algebra set of the study. Table 1 shows the mean and standard deviation for each quantitative variable collected. The first three columns show the Co-Requisite students and the final three columns show the Pre-Requisite students.

Table 1. Descriptive Statistics of Quantitative Variables MTH1245 College Algebra

College Algebra	Co-Requisite Students			Pre-Requisite Students		
Quantitative Variable	Mean	Standard Deviation	N	Mean	Standard Deviation	N
ACTCOMPOSITE	19.75	2.06	4	20.93	3.60	15
ACTMATH	18.50	3.00	4	19.79	3.17	15
AGE	25.83	11.16	6	21.55	3.51	22
HSGPA	3.20	0.74	6	3.03	0.05	21
YearsSinceHSGrad	7.50	11.38	6	3.36	3.54	22

There were a total of 19 males in the study (2 co-requisite, 17 pre-requisite) and 9 females (4, Co-Requisite, 5 Pre-Requisite students).

There were 175 students in the Statistics set of the study. Table 2 shows the mean and standard deviation for each quantitative variable collected. The first three columns show the Co-Requisite students and the final three columns show the Pre-Requisite students. There were a total of 28 males in the study (14 Co-Requisite students, 14 Pre-

Requisite students) and 147 females (73 Co-Requisite students, 74 Co-Requisite students).

Table 2. Descriptive Statistics of Quantitative Variables MTH1240 Statistics

Statistics	Co-Requisite Students			Pre-Requisite Students		
Quantitative Variable	Mean	Standard Deviation	N	Mean	Standard Deviation	N
ACTCOMPOSITE	19.46	2.59	65	19.81	3.08	74
ACTMATH	18.07	2.52	54	18.83	3.51	72
AGE	27.76	9.16	87	25.72	8.28	88
HSGPA	2.61	0.61	69	2.91	0.60	71
YearsSinceHSGrad	8.31	8.20	87	6.53	7.78	88

Research Question 1

Research Hypothesis: Co-Requisite students will have more success than Pre-Requisite students in College Algebra.

Table 3. Counts of College Algebra Success by Remediation Type

	Success		
Remediation Type	Yes	No	Total
Pre-Requisite	19	3	22
Co-Requisite	4	2	6
Total	23	5	28

A logistic regression model was used to determine if placement in a Co-Requisite class was predictive of success in the college gateway course. The open source statistical software, R, was used to find whether Co-Requisite placement was significant and backwards elimination was used to see if including Co-Requisite as a dependent variable improved the accuracy of the model.

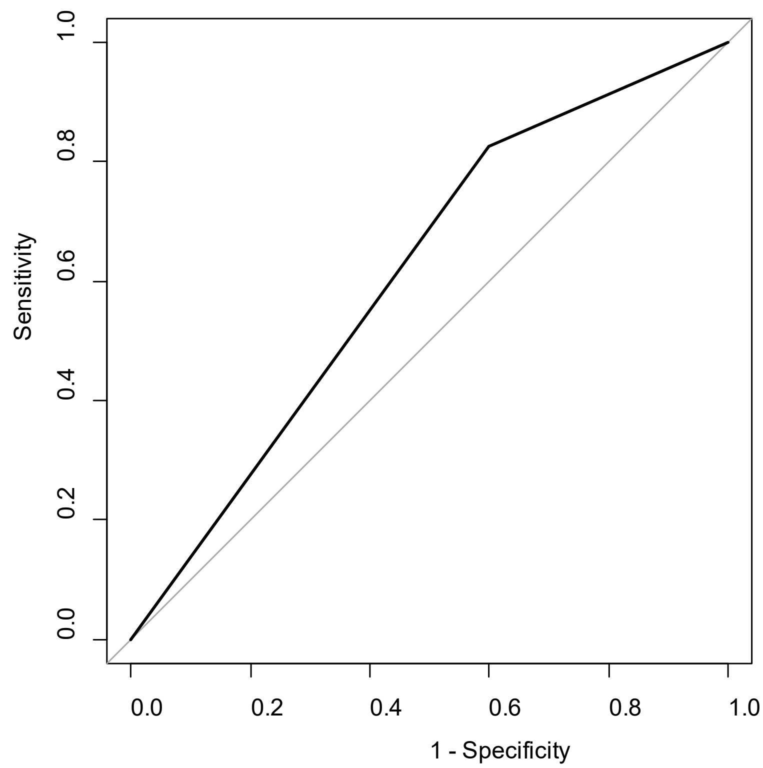
Analysis of the model showed that the model was statistically reliable, $\chi^2(2, N = 28) = 9.5, p =< .01$. The variance success rate is small, McFadden's rho = .0423, df=2. Prediction success was high, predicting 82.14% (23/28) of cases correctly with sensitivity of 100% and specificity of 0%. Table 4 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for the Co-Requisite variable. According to the Wald criterion, Co-Requisite Remediation was not statistically significant.

Table 4. Logistic Regression analysis of Success as a function of the Co-Requisite variable for Statistics.

Variables	**B**	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
Co-Requisite	-1.15	-1.08	0.32	0.28	0.04	2.98
(Constant)	1.85	2.97	6.33	0.00	2.16	26.96

A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 1. For the set of predictors, the area under the curve was found to be 0.613.

Graph 1. College Algebra Co-Requisite ROC



Overall, including the Co-Requisite variable in the model was not significant. However, the results do suggest that students performed similarly in the college course regardless of which type of remediation they received. This is a rare case where finding inconclusive results is a positive. Overall, these results are from a very small sample size, but offer encouraging results.

Research Question 2

Research Hypothesis: Student demographic variables are predictive of student success in College Algebra.

The purpose of research question 2 is to determine if demographic predictors determine student success in College Algebra. As stated before, Success was defined as receiving an A, B, or C in the course. Any other result (including withdrawing from the course) was considered to not be successful. In this model, we have one binomial dependent variable (Success) and 6 independent variables (years since high school/ GED completion, age of the student, gender, Pell Award Eligibility, high school report card, and whether the student is considered a non-traditional student).

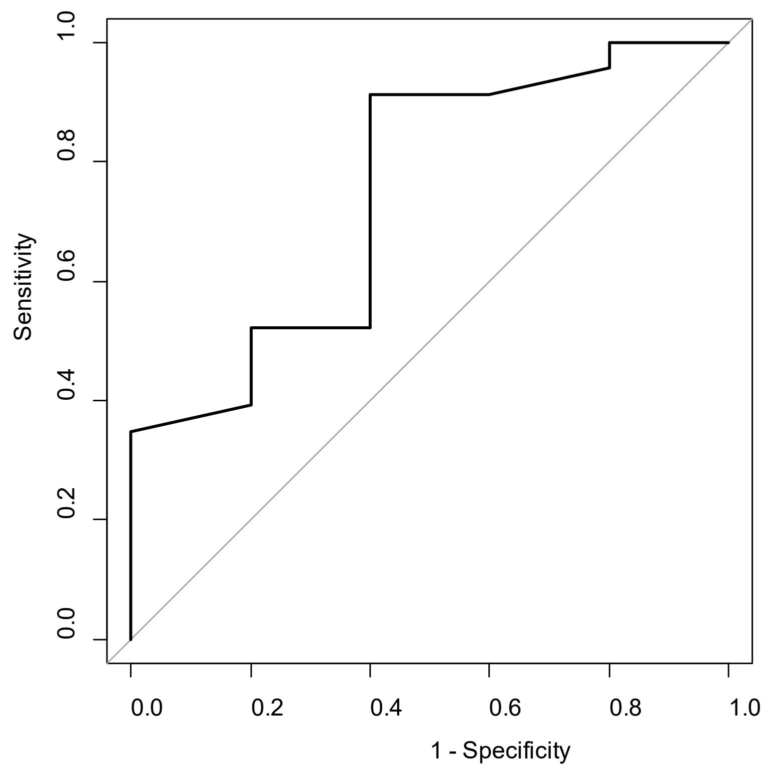
A test of the full model (all demographic variables) against a constant only model was not statistically reliable, $\chi^2(8, N = 28) = 3.4, p = .91$, indicating that the predictors did not successfully distinguish between students who succeeded and those who did not. The variance is success rate is small, McFadden's rho = .1415, df=9. Prediction success was relatively high, predicting 82.14% (23/28) of cases correctly with sensitivity of 100% and specificity of 0%. Table 5 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each predictor. According to the Wald criterion, none of the variables were statistically significant.

Table 5. Logistic Regression analysis of Success as a function of demographic variables for College Algebra.

Variables	B	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
High School C	1.70	1.00	5.49	0.32	0.15	219.00
High School D	0.45	0.242	1.57	0.81	0.03	73.40
High School N	18.35	0.00	9.34×10^7	1.00	0.00	∞
Age	1.03	0.73	2.80	0.47	0.23	84.70
Years After HS	-0.92	-0.67	0.40	0.51	0.01	4.55
Male	0.99	0.80	2.70	0.43	0.22	38.20
PELL	-15.64	-0.00	0.00	1.00	0.00	∞
Non-Traditional	16.14	0.00	1.02×10^7	1.00	0.00	∞
(Constant)	-19.70	-0.75	0.00	0.454	0.00	∞

A backward elimination logistic regression analysis was performed. The full model (all dependent variables) had an AIC = 40.56 and the most statistically significant model was the intercept (Constant) only model with an AIC = 28.28. A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 2. For the set of predictors, the area under the curve was found to be 0.75.

Graph 2. College Algebra Demographic ROC



Research Question 3

Research Hypothesis: Student academic variables are predictive of student success in College Algebra.

The purpose of research question 3 is to determine if academic predictors determine student success in College Algebra. As stated before, Success was defined as receiving an A, B, or C in the course. Any other result (including withdrawing from the course) was considered to not be successful. In this model, we have one binomial dependent variable (Success) and 3 independent variables (cumulative high school GPA, composite ACT score, and math ACT score). Any students with missing data were removed from the study before the analysis began. Logistic regression was performed with a full model including all the demographic dependent variables. Then backward elimination was used to eliminate variables that were not significant to the model until a reduced model manifested with the most statistical significance.

A test of the full model (all academic variables) against a constant only model was not statistically reliable, $\chi^2(4, N = 17) = 2.5, p = .65$, indicating that the predictors did not successfully distinguish between students who succeeded and those who did not. The variance is success rate is moderately small, McFadden's rho = .378, df=4. Prediction success was relatively high, predicting 82.35% (14/17) of cases correctly with sensitivity of 92.86% and specificity of 33.33%. Table 6 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each predictor. According to the Wald criterion, none of the variables were statistically significant.

Table 6. Logistic Regression analysis of Success as a function of academic variables for College Algebra.

Variables	B	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
HS GPA	4.77	-1.28	118.06	0.189	1.32	6.03×10^6
ACTCOMPOSITE	0.29	1.31	1.34	0.535	0.59	5.26
ACTMATH	0.46	0.62	1.58	0.555	0.41	11.33
(Constant)	-26.20	0.59	0.00	0.201	0.00	0.21

A backward elimination logistic regression analysis was performed. The results ($\chi^2(3, N = 17) = 3.3, p = .35$) show that a model that excluded *ACTMATH* was more significant than the full model and more significant than an intercept only model.

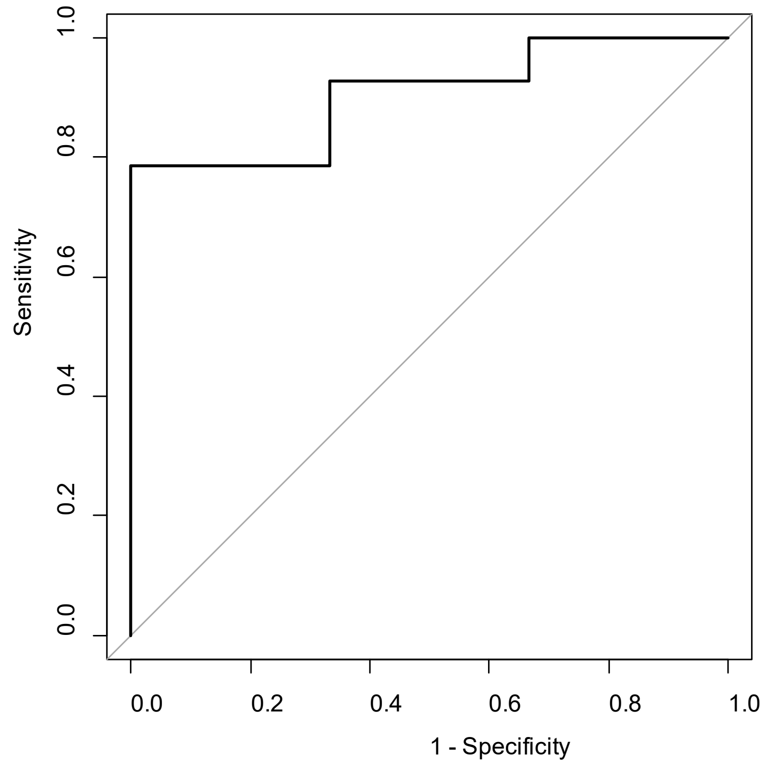
However this model was still not a statistically reliable model, nor did any significant variables appear. Table 7 shows the logistic regression analysis for the reduced model.

Table 7. Logistic Regression analysis of Success as a reduced function of academic variables for College Algebra.

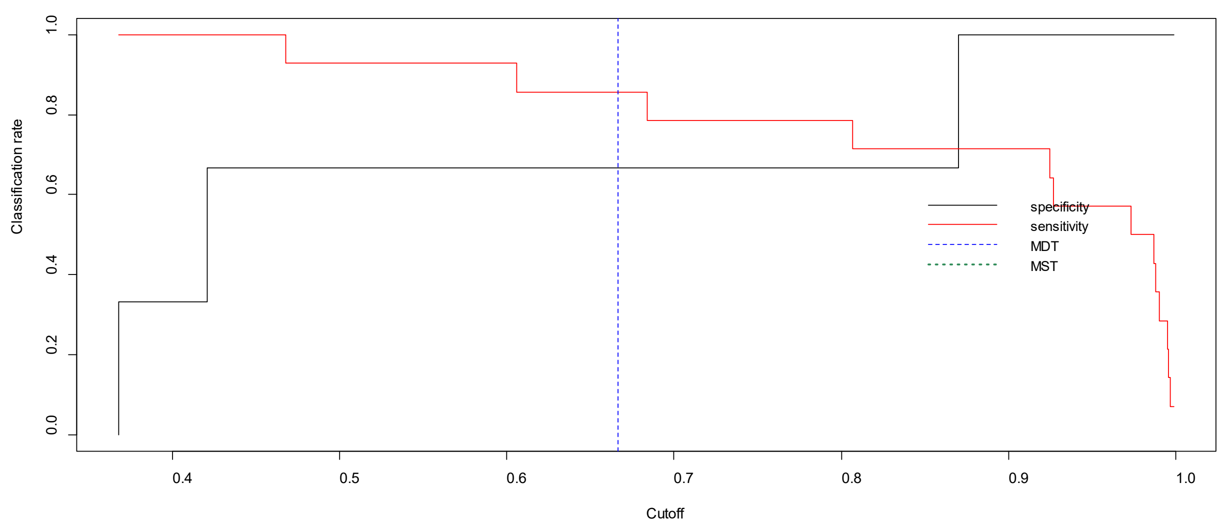
Variables	**B**	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
HS GPA	3.76	1.53	43.08	0.13	1.24	43600.00
ACTCOMPOSITE	0.49	1.33	1.63	0.19	0.97	5.78
(Constant)	-19.09	-1.51	0.00	0.13	0.00	0.38

The reduced model was used to determine cut off points to create adequate sensitivity and specificity. A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 3. For the set of predictors, the area under the curve was found to be 0.90. Graph 4 shows a plot of model sensitivity and specificity for various cutoffs. Using R and the minimized difference threshold it was found that 0.67 is the value that minimizes the absolute difference between sensitivity and specificity. The values of the sensitivity and specificity at 0.67 were 0.71 and 0.87, respectively.

Graph 3. College Algebra Academic ROC



Graph 4. College Algebra Academic Specificity and Sensitivity Graph, Reduced Model



Research Question 4

Research Hypothesis: Co-Requisite students will have more success than Pre-Requisite students in Statistics.

Table 8. Counts of Statistics Success by Remediation Type

	Success		
Remediation Type	Yes	No	Total
Pre-Requisite	54	34	88
Co-Requisite	54	33	87
Total	108	67	175

A simple logistic regression test was run to test if remediation type could predict the success in Statistics. Success was defined as receiving an A, B, or C in the course. Any other result (including withdrawing from the course) was considered to not be successful. In this model, we have one binomial dependent variable (Success) and one binomial independent variable (Remediation type). Success in the course was coded with a 1 in the data and 0 otherwise. Remediation type was coded as 1 for Co-Requisite Remediation and 0 for Pre-Requisite remediation.

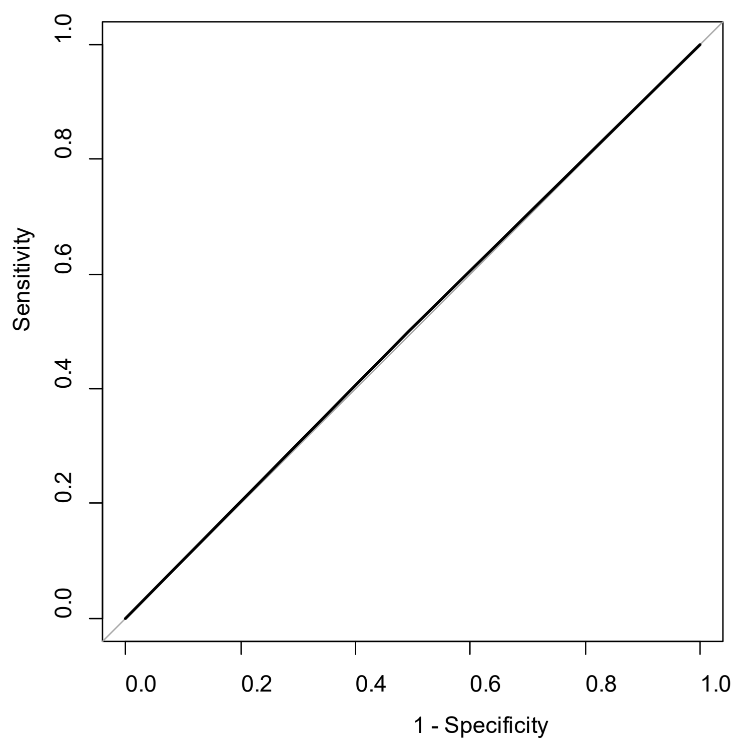
Analysis of the model showed that the model was statistically reliable, $\chi^2(2, N = 175) = 9.4, p =< .01$. The variance success rate is extremely small, McFadden's rho = 3.955E-05, df=2. Prediction success was relatively low, predicting 61.71% (108/175) of cases correctly with sensitivity of 100% and specificity of 0%. Table 9 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for the Co-Requisite variable. According to the Wald criterion, Co-Requisite Remediation was not statistically significant. The model containing Co-Requisite (AIC = 236.9) was not as significant as the Constant only model (AIC = 234.9)

Table 9. Logistic Regression analysis of Success as a function of the Co-Requisite variable for Statistics.

Variables	**B**	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
Co-Requisite	0.03	0.10	1.03	0.92	0.56	1.90
(Constant)	0.46	2.11	1.59	0.03	1.04	2.46

A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 5. For the set of predictors, the area under the curve was found to be 0.5037.

Graph 5. Statistics Co-Requisite ROC



Overall, including the Co-Requisite variable in the model was not significant. Though this study did not show that students in Co-Requisite remediation performed better than their Pre-requisite counterparts, the data shows that the success rates for the two cohorts were virtually identical.

Research Question 5

Research Hypothesis: Student demographic variables are predictive of student success in Statistics.

The purpose of research question 5 is to determine if demographic predictors determine student success in Statistics. As stated before, Success was defined as receiving an A, B, or C in the course. Any other result (including withdrawing from the course) was considered to not be successful. In this model, we have one binomial dependent variable (Success) and 6 independent variables (years since high school/ GED completion, age of the student, gender, Pell Award Eligibility, high school report card, and whether the student is considered a non-traditional student).

A test of the full model (all demographic variables) against a constant only model was statistically reliable, $\chi^2(10, N = 163) = 23.0, p < .05$, indicating that the predictors did successfully distinguish between students who succeeded and those who did not. The variance is success rate is small, McFadden's rho = .1012, df=10. Prediction success was moderate, predicting 69.94% (114/163) of cases correctly with sensitivity of 92.08% and specificity of 33.87%. Table 10 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each predictor. According to the Wald criterion, attending schools graded "D" was the only significant predictor.

Table 10. Logistic Regression analysis of Success as a function of demographic variables for Statistics.

Variables	B	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
School Grade C	-0.39	-0.79	0.68	0.43	0.25	1.74
School Grade D	-1.06	-2.00	0.35	0.05	0.12	0.95
School Grade F	-17.27	-0.02	0.00	0.99	0.00	∞
School Grade N	-0.79	-1.19	0.46	0.23	0.12	1.68
Age	-0.10	-1.40	0.91	0.16	0.76	1.01
Years After HS	0.12	1.72	1.13	0.09	1.01	1.36
Male	-0.66	-1.42	0.52	0.16	0.21	1.29
Pell Award	-0.51	-0.71	0.60	0.48	0.13	2.33
Non-Traditional	1.57	1.81	4.74	0.07	0.93	28.04
(Intercept)	1.94	1.43	6.94	0.15	0.77	219.24

A backward elimination logistic regression analysis was performed. Beginning with the full set of demographic variables (AIC= 214.64), a statistically reliable model was found, $\chi^2(8, N = 163) = 21.9, p < .01$ with 4 predictors: School Grade, Age, Years After High School, and Non-Traditional students (AIC = 212.85). The variance remained small with McFadden's rho = .0910, df= 8. Prediction success dropped slightly to 66.87% (109/163) as sensitivity and specificity also dropped slightly to 90.01% and 29.03%, respectively. Table 11 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each predictor. According to the Wald criterion, Non-Traditional was the only significant predictor.

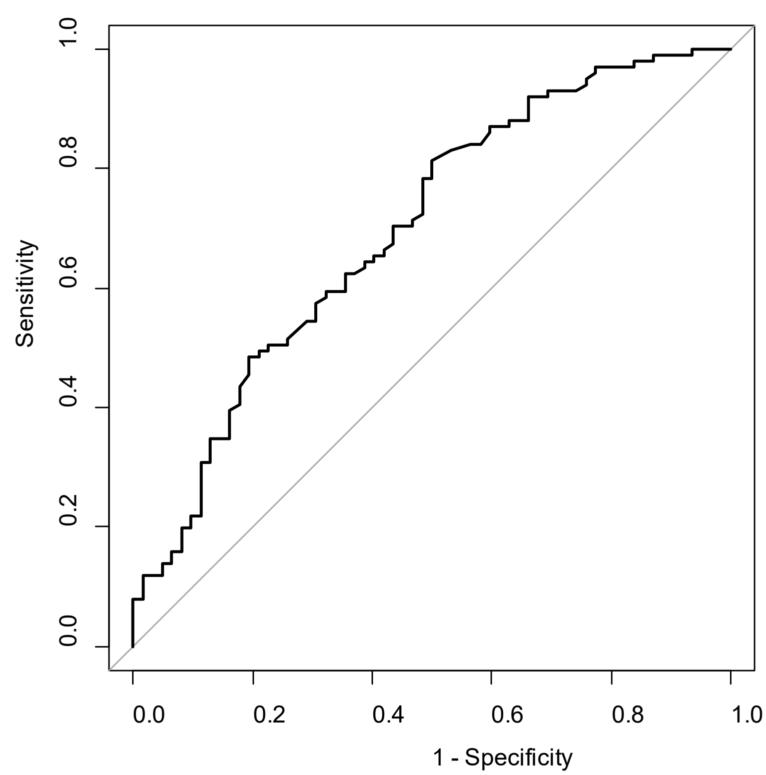
Table 11. Logistic Regression analysis of Success as a function of demographic variables for Statistics.

Variables	B	*Wald (z-ratio)*	*Odds Ratio*	*p-value*	*95% CI Lower*	*95% CI Upper*
School Grade C	-0.35	-0.72	0.70	0.47	0.26	1.79
School Grade D	-1.01	-1.94	0.36	0.05	0.12	0.99
School Grade F	-17.25	-0.02	0.00	0.99	0.00	9.22×10^{61}
School Grade N	-0.82	-1.25	0.44	0.21	0.12	1.61
Age	-0.08	-1.31	0.92	0.19	0.78	1.02
Years After HS	0.12	1.73	1.12	0.08	1.01	1.34
Non-Traditional	1.05	2.24	2.87	0.03	1.15	7.40

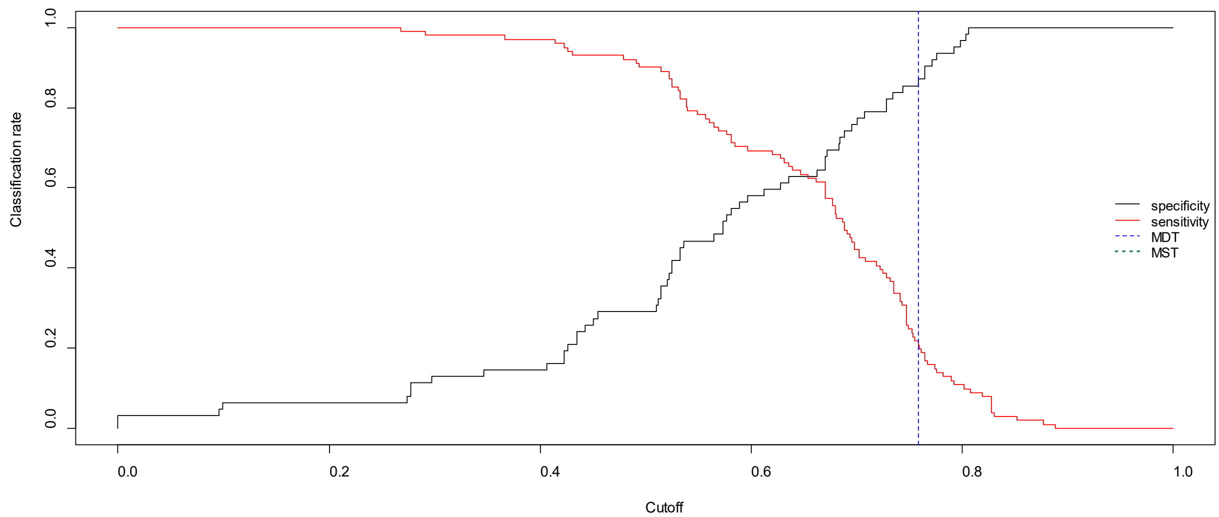
(Intercept)	1.54	1.24	4.67	0.21	0.60	118.30

Since the four-predictor model was more statistically reliable than the full model, and the percentage of accurately classified cases decreased moderately, the reduced model was used to determine cut off points to create adequate sensitivity and specificity. A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 6. For the set of predictors, the area under the curve was found to be 0.68. Graph 7 shows a plot of model sensitivity and specificity for various cutoffs. Using R and the minimized difference threshold it was found that 0.63 is the value that minimizes the absolute difference between sensitivity and specificity. The values of the sensitivity and specificity at 0.63 were 0.65 and 0.63, respectively.

Graph 6. Statistics Demographic ROC



Graph 7. Statistics Demographic Sensitivity and Specificity, Reduced Model



The coefficients in the reduced model for School Grade suggested that students from B Schools performed better than students from C Schools performed better than D Schools performed better than F schools. A chi-square test was performed to test whether these was a significant association between School Grade and Success. The test revealed there was not a significant association between School Grade and Success, $\chi^2(4) = 5.07, p = .28$. The minimum expected cell count assumption was violated, so the School Grades were recoded to B, C, D, and F+N. This test was also not statistically significant, $\chi^2(3) = 2.66, p = .45$.

Research Question 6

Research Hypothesis: Student academic variables are predictive of student success in Statistics.

The purpose of research question 6 is to determine if academic predictors determine student success in Statistics. As stated before, Success was defined as receiving an A, B, or C in the course. Any other result (including withdrawing from the course) was considered to not be successful. In this model, we have one binomial dependent variable (Success) and 3 independent variables (cumulative high school GPA, composite ACT score, and math ACT score). Any students with missing data were removed from the study before the analysis began.

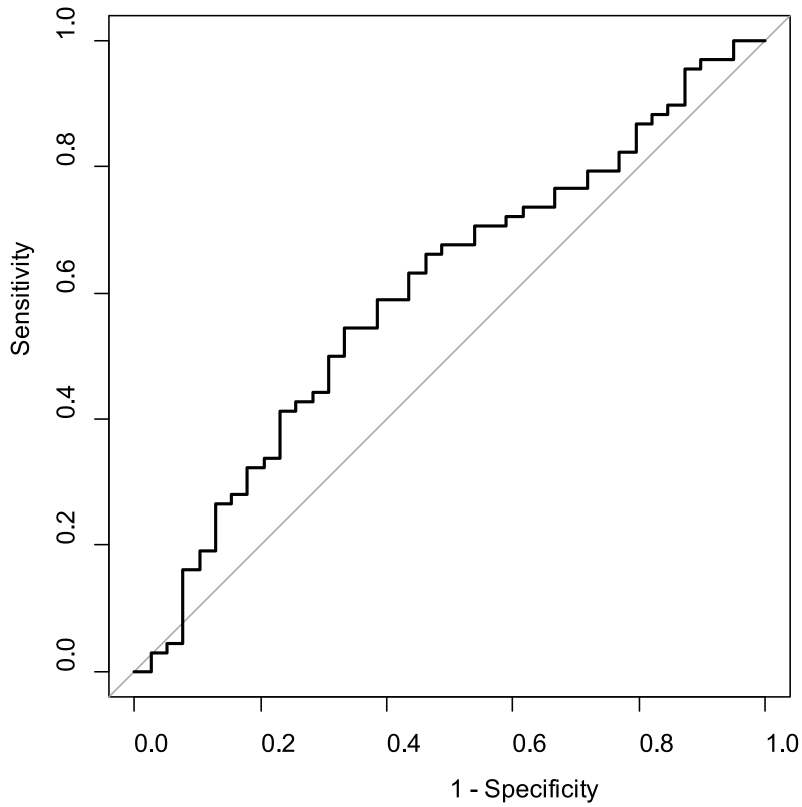
A test of the full model (all academic variables) against a constant only model was not statistically reliable, $\chi^2(4, N = 107) = 9.4, p = .052$, indicating that the predictors did not successfully distinguish between students who succeeded and those who did not. The variance is success rate is extremely small, McFadden's rho = .017, df=4. Prediction success was moderately low, predicting 64.49% (69/107) of cases correctly with sensitivity of 97.06% and specificity of 7.69%. Table 12 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each predictor. According to the Wald criterion, none of the variables were statistically significant. A backward elimination logistic regression analysis was performed on the full model (AIC= 146.06), with no model showing greater statistical significance than the intercept (Constant) only model (AIC = 142.37).

Table 12. Logistic Regression analysis of Success as a function of academic variables for College Algebra.

Variables	**B**	***Wald (z-ratio)***	***Odds Ratio***	***p-value***	***95% CI Lower***	***95% CI Upper***
HS GPA	-1.67	-1.02	1.29	0.31	0.60	2.76
ACTCOMPOSITE	0.25	0.66	1.12	0.51	0.92	1.39
ACTMATH	0.12	1.10	0.96	0.27	0.79	1.16
(Constant)	-0.04	-0.43	0.19	0.67	0.01	4.43

A receiver operating characteristics graph (ROC), which has been shown to be a reliable technique for visualizing, organizing, and selecting classifications based on performance, is presented in Graph 8. For the set of predictors, the area under the curve was found to be 0.60.

Graph 8. Statistics Academic ROC



Conclusion

The purpose of this chapter was to discuss the results of the research. This study examined the success rates of students in the college level mathematics class based on whether they took a pre-requisite or co-requisite remediation. Additionally, the study examined the success rates of these two remediation groups in the context of a STEM and non-STEM pathway. A secondary purpose of the study is to examine other factors, such as academic and demographic variables, which are outside of remediation that may also predict success rates. The study will seek to determine which variables are significant predictors of success.

CHAPTER 5: Conclusions

Introduction

The purpose of this study was to examine the success rates of students in college level mathematics classes based on whether they took a pre-requisite or co-requisite remediation. Additionally, the study examined the success rates of these two remediation groups in the context of a STEM and non-STEM pathway. A secondary purpose of the study was to examine other factors, both academic and demographic, which are outside of remediation that may also predict success rates, to determine which variables are significant predictors of success.

This chapter is provided to summarize the study, results, and implications of the study. Although the results on the main research questions were inconclusive, there are still important takeaways that can be useful in future research and provides useful insight to educators and administrators seeking to reform their current remediation approaches and placement strategies. Each research question will be summarized and then limitations of this and future research ideas will be offered.

STEM Course: College Algebra

Research Question 1: *Is there a significant difference in success rates across types of remediation for students in a STEM gateway math class?*

Research Question 2: *What influence do demographic predictors have on student success in a STEM class?*

Research Question 3: *What influence do academic predictors have on student success in a STEM class?*

Research Questions 1 through 3 suffered from a low number of students during the time period. This resulted in no variables being a significant predictor of success. An interesting note from the data was that every student who finished the course, succeeded. The only students to not experience a "success" outcome were those who withdrew from the class or earned a "Failure No-Attendance" designated for students who stop attending without officially withdrawing from the class.

Despite the inconclusive nature of this study, it does suggest that there is no statistically significant difference between students taking pre-requisite remediation and those taking co-requisite remediation. Therefore, it may be more beneficial for a student to receive co-requisite remediation, because the student is then enrolled in a college course immediately, rather than taking (and potentially failing) a pre-requisite course before attempting a college course.

Because the population for this study included only those enrolled in College Algebra, there is no indication from this study, significant or otherwise, whether students who enter pre-requisite remediation are successful in the college level course, rather, those who did pass pre-requisite remediation were not statistically different than those who started who received co-requisite remediation. Future research could focus on overall performance from the start of a student's college career, rather than the point at which a student enters college level coursework.

Finally, because most research focuses on larger institutions, this research was performed at a small, rural, community college. Future research that wants to focus on this type of community college may want to observe multiple institutions to avoid the limitation of such small N values. That was clearly the largest limitation for this particular set of research questions. Another significant limitation of this study was the inability to collect data from the students themselves. Should this study be duplicated with improvements, I would study several cohorts of students for multiple years. Time limitations for this study made that impossible.

Non-STEM Course: Statistics

Research Question 4: *Is there a significant difference in success rates across types of remediation for students in a non-STEM gateway math class*

Although the results of this study did not show co-requisite remediation was statistically significant in predicting success in the gateway course of Statistics, the study discovered the two groups were nearly identical. 54 co-requisite students out of 87 succeeded, while 54 out of 88 pre-requisite students succeeded. Additionally, a cursory glance at the quality points (A=4, B=3, etc.) for both sets of students showed that the co-requisite students outperformed the pre-requisite students with averages of 1.874 and 1.784, respectively. Similarly to research question 1, this does seem to suggest, that it seems to be in the student's best interest to enroll in a college course with co-requisite remediation rather than using time and resources in pre-requisite remediation.

As stated earlier, the study did not follow the students' entire mathematics career at the institution, rather this is a snapshot of how students in the college level course performed. Future studies that want to expand on this study may want to look at the success of students based on their entry point at the institution versus their entry into college level mathematics. Additionally, if I were to repeat this study (and time permitted), I would have preferred to collect data from the students that could only be done with a questionnaire. Specifically, the results of this study raised questions about whether those who succeeded in the pre-requisite classes had a better persistence (also called grit) score because they had already completed a mathematics course at the institution. Another possible explanation (and possible catalyst for future research) is that the content, delivery, or other pedagogical element of the co-requisite course needs improvement.

Research Question 5: *<u>What influence do demographic predictors have on student success in a non-STEM class?</u>*

This research question was the only research question to show statistical promise. The final model showed that the high school, age, years since high school, and whether a student was a non-traditional student created the most statistically significant model. Additionally, within this model, non-traditional student status was shown to be a significant predictor of success. In fact non-traditional students outperformed traditional students with 65% of non-traditional students achieving success while only 45% of traditional students achieved success.

The inclusion of the grade of the high school a student attended in the final model also seems to show that the quality of education matters in college success. Although, this was not statistically significant, it does seem to support the idea that the higher performing high schools produce higher performing college students. It also seems to support the process by which the high schools are graded by the state.

Following the theme of limitations in this study, because there was no contact with students, there were demographic data points that could not be gathered. Variables I would have liked to have included were number of hours students worked, number of dependents, parents' education level, and whether or not a student had familial support at home (spouse, parent, partner, etc.). Also, although the N value for the Statistics students was not necessarily low, I would have liked to have had more students and/or included multiple institutions.

Research Question 6: What influence do previous academic predictors have on student success in a non-STEM class?

This research question had the lowest N of the Statistics questions because of missing data. Because MTC is an open institution, ACT scores are not required and there were multiple students with missing high school GPAs for various reasons. Although none of the variables were found to be significant, all of the variables did have lower p-values than the intercept. Literature suggested this could have provided the best indicator for success, but unfortunately this study was not able to confirm this.

The limitations of this portion of the study include those already discussed, but additional limitations existed in the form of a lack of easily query-able data. Most high school transcript data was available only in pdf form to the college making it extremely difficult for the data to be provided. Additional data I would like to include in any future iteration of this study would be highest math course taken in high school, high school GPA of math classes, and number of college prep or AP classes taken in high school.

Summary of Limitations

The limitations in this study started with a low number of observed students. Because MTC is a smaller institution, there were fewer students to observe than would be available at other institutions. This was particularly true in the College Algebra classes.

Limitations in number of students existed even within the institution. MTC has a second non-STEM gateway course: Quantitative Reasoning. This particular course was excluded because there was a pedagogical change between years one and two of the study. Because of this change Statistics alone was chosen for observation because there were no changes made during the timeframe of the study.

In the literature, three major styles of co-requisite remediation were presented. Because this study was conducted at only one institution, only one of the three styles was researched in this study. Although this made an easier comparison between co-requisite students and pre-requisite students (the purpose of this study), it does limit the scope of what co-requisite remediation could look like. A multi-institutional study could have the benefit of comparing co-requisite styles within a similar logistical regression study.

Finally, the last major limitation in this study is the inability to gather information directly from students. While this prevented any sort of bias on the students' part, it left some desirable variables out of the study. Any future studies could benefit from some of the variables mentioned earlier that could only (efficiently) be supplied by the student.

Conclusion

College level mathematics remains a significant barrier to overall student success at the post-secondary level. A major contributor to this obstacle is remediation, specifically pre-requisite remediation. As students attempt to navigate through college efficiently and institutions have become financially incentivized toward the same goal, Co-Requisite remediation has become a popular alternative to old models of one or more pre-requisite classes.

The purpose of this study was to examine the success rates of students in college level mathematics classes based on whether they took a pre-requisite or co-requisite remediation. Additionally, the study examined the success rates of these two remediation groups in the context of a STEM and non-STEM pathway. A secondary purpose of the study was to examine other factors, both academic and demographic, which are outside of remediation that may also predict success rates, to determine which variables are significant predictors of success.

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