EVALUATING THE IMPLEMENTATION OF

MATHEMATICS PATHWAYS

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 2019

EVALUATING THE IMPLEMENTATION OF MATHEMATICS PATHWAYS

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ACKNOWLEDGEMENTS

Completing a doctoral degree is no easy task. The years of coursework, research, reading, and writing a dissertation are taxing and cannot be done without proper support. The support that I have received has propelled me in the completion of these tasks and ultimately in the earning of my degree.

First, I would like to thank the people I work with. Thank you, Dr. Jenn Ivie and Justin Porterfield for helping me with data for this study. Thank you to Diane Trimble and Jackie Swicegood, my fellow department chairs for your unwavering support. I love our team! Thank you to my Dean, Lyn Kent. Your guidance, mentorship, and belief in me have helped to convince me that I can do this.

I could not have asked for a better, more supportive committee. To Dr. Toni Ivey, Dr. Jennifer Cribbs, and Dr. Susan Stansberry, thank you for forcing me to think outside of my perspective. This was a weakness I had identified long before my meetings with you. Your feedback was crucial in holding me accountable for being clear with the complex context of my study. I would also like to thank you for helping me clarify my methodology. I believe this study is important, and the three of you have assisted me in more ways than you could know.

To Dr. Adrienne Sanogo, your guidance, leadership, and friendship have been invaluable to me in this process. I have truly enjoyed getting to know you, and I can honestly say that your encouragement has been a driving force in the completion of this study. Your constant availability, prompt feedback, flexibility, and student-friendly demeanor made you my favorite professor and ultimately my choice to chair my committee. I consider myself truly lucky to have had you as the chair of my committee, my advisor, and my friend.

To my classmates, the relationships we built through the carpools, study groups, group texts, and supportive phone calls have meant so much to me. Thank you, Latoya, Yelly Kelly, Robin, Jordie, and especially my dissertation buddy, Tonya.

My family has played a pivotal role in the completion of this degree. To my daughters, Emily and Abigail, thank you for understanding all the times I had to go to class, write a paper, or shut myself in my office to complete this degree. Hopefully, you will look back on the commitment your mother and I have displayed while pursuing our doctoral degrees and realize the benefits it has given our family.

Lastly, to my wife, Dr. Alesha Baker, there are no words to describe how important you are to me. You cheered me on when my drive waned. You encouraged me when you knew I was struggling to write. You held me accountable when you knew I needed it. You provided an example of how to complete this degree. Watching you go

through this process both encouraged and inspired me. You are truly amazing. Even though I disagreed with you every time you said, “This is the fun part!” you continued to push me. Your belief in me is what will always matter the most. Thank you seems so inadequate.

Acknowledgements reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

Name: JOSHUA AARON BAKER

Date of Degree: DECEMBER, 2019

Title of Study: EVALUATING THE IMPLEMENTATION OF MATHEMATICS PATHWAYS

Major Field: EDUCATION

Abstract:

Developmental education has long served as a barrier between students and degree attainment (Bailey, Jeong, & Cho, 2010; Okimoto & Heck, 2015). Specifically, developmental mathematics (DM) sequences have had notoriously low success rates and students who are referred to them persist to completion of a gateway mathematics course at alarmingly low rates as only 31% of students referred to a DM mathematics course three-levels below College Algebra ever even enroll in the course (Bailey; 2009).

The purpose of the current study was to examine the implications of the implementation of corequisite developmental mathematics courses with College Algebra/Precalculus, by evaluating course success rates in multiple ways.

This study examined Midwestern Community College's (MCC) redesign of its DM policies. MCC changed its DM sequence from a three-course model to one with two courses. The redesigned two-course sequence leads to multiple gateway courses with corequisite support instead of requiring all students to take College Algebra. The researcher analyzed student success data from the two years pre- and two years post-policy implementation.

The major findings of the study include; 1) the proportion of first-time enrolling students who completed a gateway mathematics course within one fall and one spring of enrollment increased significantly, 2) the success rates of students in College Algebra/Precalculus 1 did not significantly change pre- to post-policy implementation, 3) students in the corequisite support course succeed in Precalculus 1 at the same rate as students only enrolled in the Precalculus 1 course.

The findings of this study can be used by community college mathematics faculty to advocate for the adoption of corequisite support and multiple gateway mathematics courses.

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CHAPTER I

EVALUATING THE IMPLENTATION OF MATHEMATICS PATHWAYS

INTRODUCTION TO THE STUDY

Nationwide nearly 70% of students entering community colleges are referred to developmental education (DE) courses (Bailey, Jeong, & Cho, 2010; Okimoto & Heck, 2015). These courses, while designed to promote success in college-level courses, create a barrier between a student and their goal of obtaining a degree. These barriers often prevent students from obtaining any credential from community colleges. For example, only 31% of students referred to the lowest level of developmental mathematics (DM) course, often three levels below a gateway course, complete the sequence of DM courses in three years (Bailey, 2009).

Developmental Education (DE), also referred to as remedial education, has been a necessity since the first American university, Harvard, was established in 1636 (Boylan, 1988; Boylan & White, 1987). Harvard's original purpose was to prepare young men to be in the clergy. All of the courses required reading, writing, and speaking Latin. Many of the entering students lacked these skills. To address their students' lack of Latin skills, Harvard created courses to teach students the Latin skills before students were allowed to enroll in courses for credit. These courses represented the first remedial education program. Harvard has since evolved into the Ivy League institution it is now and neither prepares young men for the clergy nor offers any remedial courses.

The University of Wisconsin (UW), established in 1848, began the first remedial education program resembling the ones employed today at many universities and nearly every community college, although the program was not referred to as either developmental or remedial (Boylan & White, 1987). In 1848, UW began a college preparation department teaching basic reading, writing, and arithmetic. College preparation departments and programs spread across the nation to where 80% of higher education institutions employed them by 1889 (Brier, 1984). At this time, enrollment in college-level courses required the completion of the remedial education courses and programs.

Today some states, like Texas (Hagedron & Kuzetsova, 2016), still have the same requirement commonly referred to as an Adult Basic Education (ABE) requirement. To meet the ABE requirement, students must show 8th-grade level proficiency in reading, writing, and mathematics. Students who cannot demonstrate 8th-grade proficiency are not allowed to enroll until they pass courses that are two or three levels below college-level courses. Many times, the courses required are not offered at the university or college, meaning the students must complete the ABE requirement elsewhere. After meeting the ABE requirement, students can then enroll in college-level courses which do not require DE courses as prerequisites. These students will still need to complete gateway courses, such as Freshman Composition and many times College Algebra, after completing the rest of their DE courses. Other states, like the one included in this study, are open-access meaning that anyone can enroll in college-level courses which do not require the completion of DE courses as prerequisites. While some states have policies requiring students to complete DE courses within a certain number of credit hours taken, others allow students to delay their DE coursework.

When Joliet Junior College, America's first junior college, opened in 1901 developmental education was the only goal (Cohen & Brawer, 2003; Larimer, 1977; Smith, 1980; Vaughan, 1982). Students would spend two years at Joliet before entering a traditional four-year institution. Attending Joliet meant students required at least six years to complete a baccalaureate degree. This model changed as two pieces of legislation passed in California from 1907 to 1917. Coupled with the Morrill Act of 1862, also known as the Land Grant Act, the legislation led to the opening of junior and community colleges resembling modern-day institutions (Cohen & Brawer, 2003; Larimer, 1977; Smith, 1980; Vaughan, 1982). These institutions offered both DE and credit courses. States across the nation passed similar legislation leading to the opening of many junior colleges (Cohen & Brawer, 2003).

Developmental Education (DE) has evolved into one of the major functions of community colleges. Many four-year institutions still have some form of DE courses. Most four-year institutions do not offer more than one or two levels below gateway math. These institutions refer students needing more DE courses to community colleges. Additionally, four-year institutions which do not offer DE courses also refer students requiring these courses to community colleges.

In open-access institutions, there can be as many as three DM courses, each serving as the prerequisite for the next, which students must pass, with a C or better, to enroll in a gateway course. Over time, College Algebra became the sole gateway course for most, and in some cases all, students regardless of major. The use of DM sequences which lead to College

Algebra for most, or all, students creates barriers between students and degree attainment (Bailey, 2009).

Statement of the Problem

By using corequisite DM courses, institutions are allowing more students to enroll in gateway courses, even though the institution's placement policies deem them not qualified for enrollment in these courses (Vandal, 2014). While enrolled, the corequisite course serves as a support course for the gateway course. However, institutions do not employ corequisite courses uniformly, and they are a relatively new innovation in higher education institutions that offer them. Because of this, there is little formal research examining their effectiveness. The entities promoting these courses do report success data they have collected and analyzed on their websites, but little quantitative research appears in peer-reviewed journals (Campbell & Cintron, 2018; Kashyap & Mathew, 2017; Royer & Baker, 2018). Campbell and Cintron (2018) used pilot corequisite courses and found them to be effective in increasing the percentage of students completing gateway mathematics courses. Kashyap and Mathew (2017) analyzed the success rates of students placed in either a prerequisite DM course, a corequisite DM course, or in the gateway Quantitative Reasoning course alone. Royer and Baker (2018) also analyzed the success of corequisite courses with Quantitative Reasoning courses. All three studies reported the success of corequisite models, but one used small pilot courses and two used Quantitative Reasoning courses. Therefore, the purpose of the current study was to examine the implications of the implementation of corequisite developmental mathematics courses with College Algebra/Precalculus, by evaluating course success rates in multiple ways.

In recent years, several foundations, think-tanks, and education associations have promoted two initiatives whose aim is to increase the number of students who obtain credit for gateway courses within the first year of enrollment (“History,” 2019; “Project Information,” 2019; “The Blueprint,” 2019). One of those is a math pathways movement. Math pathways refers to institutions identifying math concepts and skills needed for individual majors, or clusters of majors, and offering gateway courses more appropriate for the students who have declared that major. For example, the Mathematics Association of America (MAA) advocates for treating quantitative literacy as a necessary goal of undergraduate education (Kashyap & Mathew, 2017), and thus a gateway course.

Another initiative promoted is corequisite DE courses. Corequisite courses are unique in that they are taken concurrently with gateway courses. Instead of a student enrolling in a DM course as a prerequisite for a gateway course, they will enroll in the gateway course and the corequisite in the same semester. For instance, a student enrolls in College Algebra and a corequisite course, concurrently. The corequisite course provides “just in time” support for the learning in the College Algebra course. Corequisite courses vary widely across institutions and between different gateway mathematics courses (Campbell & Cintron, 2018; Kashyap & Mathew, 2017; Logue, Watanbe, & Douglas, 2016; New America, 2016; Royer & Baker, 2018). When institutions use corequisite courses, students can earn credit for gateway courses faster and have support directly related to their gateway course instead of taking a course one semester, gaining skills, then having to wait until the next semester to employ those skills (Vandal, 2014).

More than thirty states are signing on to initiatives to develop math pathways and corequisite courses (“Dana Center Mathematics Pathways: UT Dana Center,” 2019; Vandal, 2014). The same entities promoting these initiatives often fund them. The funding organizations are reporting success on these initiatives. These reports, however, are not conducted using formal research methods and are not reported in peer-reviewed journals. While this does not mean the reports are false or misleading, they leave room for formal examination.

The community college included in the current study is the largest community college in its state. This Midwestern state is open-access, and the state governing board agreed to partner with The Dana Center create math pathways and corequisite DM courses. The goal from the state governing board is for 75% of first-time enrolling students to be placed in such a way that they can take gateway courses in the first year of enrollment. The community college included in the current study undertook a redesign of their DM course sequence and gateway math courses to meet the state's goal (College Website). This redesign was and still is called the Mathways Project.

During the initial year of planning the Mathways Project, the math faculty chose two courses: (1) Precalculus 1, previously called College Algebra, and (2) Quantitative Reasoning, previously called Math for Critical Thinking, as the gateway courses. At the time these were the only two gateway courses guaranteed to transfer to in-state four-year institutions. Math faculty formed two teams, one for each gateway course, and began the work of closely examining the course learning objectives, core content, and skills required for success in those courses. Early in planning, the Precalculus (PC) and Quantitative Reasoning (QR) teams both decided to use the Math Foundations sequence, formerly known as Basic Math and Beginning Algebra, as the prerequisite for enrollment into the gateway and the corequisite. It was at this time the Mathways Project team also decided to name the corequisite courses Essentials for either PC or QR. After the one academic year of planning and training for part-time instructors, the community college implemented the Mathways Project at full scale. In the first fall semester, there were over 7,000 students enrolled in courses affected by the Mathways Project. The current study examines the implications of the new DM sequence and corequisite courses.

Research Questions

To understand the implications of community colleges implementing corequisite courses, this study will attempt to answer the following three questions:

1. Are there differences in the proportion of first-time enrolling students who pass their gateway mathematics before and after the implementation of multiple gateway and corequisite developmental courses?
2. Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?
3. Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?

Limitations and Delimitations

All research has limitations, and every researcher must make decisions on how to limit their scope. Limitations are identifiable potential weaknesses in the study, and delimitations are used to focus a research study (Creswell, 2017). Researchers must identify limitations imposed on their research which are out of their control. Researchers use delimitations to narrow the focus of their study.

One delimitation present is the selection of a topic of research. The current study will be delimited to students enrolling in a multi-campus midwestern community college. The researcher also chose to eliminate students enrolled in concurrent courses, which include only high school students, online sections, or gateway courses not paired with a corequisite course.

To answer RQ1, the researcher limited the data by only including students who are enrolling for the first time in the fall semester of each academic year included in the analysis. The implementation of corequisite courses coincided with the implementation of a second gateway mathematics course, Quantitative Reasoning (QR). The QR course also has a corequisite course. To investigate RQ 2 and 3, the researcher excluded students enrolled in QR as a delimitation. The researcher also used section-level success rates instead of individual student grades for the analysis of RQ 2 and 3.

Two notable limitations of the study are the structure the institution used for implementing corequisite DM courses and the adjunct instructors used to teach some of the corequisite courses. The institution included in the current study chose to use a three-credit-hour format for the corequisite course. The corequisite format is a limitation because other institutions are not implementing corequisite DM courses in the same format. While the full-time faculty stayed the same of the timeframe of the study, adjunct instructors were not the same. The institution included in the study hires from the same pool of adjuncts each semester, but the set assigned to the corequisite courses is not always the same.

Definition of Terms

Adult Basic Education (ABE) refers to courses designed to help prospective college students attain 8th grade-level skills in reading, writing, and mathematics. Some states have

ABE requirements for their course, meaning students must either demonstrate 8th grade-level skills in these areas or pass ABE courses.

Corequisite Developmental Courses differ from prerequisite courses. Students in prerequisite courses must pass those courses before enrolling in the next course in the sequence. Corequisite courses allow students to enroll in gateway courses paired with the corequisite course concurrently. “Broadly defined, corequisite remediation is the delivery of academic support to academically underprepared students while they are learning gateway course content in the same subject,” (Vandal, 2014, p. 3).

Developmental Education (DE) refers to courses below college-level. DE courses, previously referred to as remedial courses, traditionally serve prerequisites to college-level courses. Reading, writing, and mathematics are all included in DE, but not all students referred to DE courses have to complete all of them.

Gateway courses are those which are generally included in general education at institutions of higher education and are also called entry-level courses. Courses which require success for degree completion are considered “gateway” courses.

Pre-policy change refers to the two academic years before the implementation of the redesigned DM and gateway courses. This includes the academic years 2015-2016 and 2016-2017 (AY16 and AY17).

Post-policy change refers to the two academic years after the implementation of the redesigned DM and gateway courses. This includes the academic years 2017-2018 and 2018-2019 (AY18 and AY19).

Success rates will be used in this study for analysis instead of pass rates. Pass rates include students who earn an A, B, C, or D in a course, while success rates are more restrictive and only include students who earn an A, B, or C. The requirement of students earning at least a C arises from a D not satisfying prerequisites for other courses.

Organization of the Study

Chapter 1 introduced the study and included the background, statement of the problem, research questions, the assumptions, limitations, and delimitations. In chapter 2, the researcher will present a review of the relevant literature. The literature review includes a history of freshman-level mathematics requirements, a history of junior and community colleges, and the evolution of developmental education. Chapter 2 ends with a review of the major shift across the nation in developmental education.

The third chapter serves as the context of the study by providing an explanation of the redesign efforts by the institution included in the current study. The fourth chapter outlines the methodology the researcher employed to investigate the research questions. Chapter 5 presents the findings of the analysis. Chapter 6 discusses the results, their implications, and the need for further research.

CHAPTER II

REVIEW OF LITERATURE

When the academic community critically examines the issues which are perpetuated by, and the reasons to move away from, a "one-size fits all" style mathematics course, it is useful to understand the historical perspective. The histories of College Algebra, Junior/Community Colleges, and Developmental Education are especially important to consider. The purpose of this study is to examine the implications of the implementation of corequisite developmental mathematics courses (DM) by evaluating course success rates and the experiences of students enrolled in a corequisite DM course. To address this purpose, the researcher sought to answer the following research questions:

1. What effect does the implementation of corequisite developmental mathematics courses have on the percentage of first-year students who pass a gateway course within one year?
2. Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?

3. Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?

This literature review is intended to serve as a historical reference for the development of the program under study, including the issues which have arisen from the predominant DM structure. The chapter contains four sections. In the first section, the focus is the development of College Algebra as the gateway course for all college students. The second section will contain the history of Junior/Community Colleges and the proliferation of Developmental Education. Third, the literature about issues in DM sequences and College Algebra as the one, and only, gateway course, as well as national trends to reform DM sequences, will be summarized. Finally, an examination of the current body of peer-reviewed literature will be summarized and critiqued.

The History of College Algebra

Institutions of higher education have not always required students to complete a college-level mathematics course for undergraduate degree completion (Tucker, 2013). The evolution of freshman-level mathematics was influenced by the military after each of the World Wars and the space race that occurred due to Russia's success with Sputnik (Furr, 1996; Rees, 1980; Tucker, 2013). The examination of this evolution began with the first colleges in America, whose purpose was to train ministers (Bisesi, 1982; Tucker, 2013). In these times curricula centered around Latin, Greek, Hebrew, and mathematics. The purpose of teaching mathematics, at that time, was primarily for training the mind instead of preparing for science and engineering. In the early 1800s, all engineers were either educated at the U. S. Military Academy or Rensselaer Polytechnic Institute

(Tucker, 2013). Growing demand for well-trained engineers began the migration of these programs to other institutions. It wasn't until 1862 that the first Ph.D. in mathematics was awarded in the US by Yale University ("History of Yale Graduate School," 2019).

In the late nineteenth century, with college enrollments decreasing, Charles Eliot, who was serving as Harvard's president, instituted an all-elective curriculum. While this led to increases in college enrollments (Hofstadler & Smith, 1961), it also led to decreases in the number of students studying mathematics. The all-elective curriculum swept across the nation to most institutions.

In 1910, Harvard again led the way with President Lawrence Lowell's system which required students to select academic majors. Expanding on Lowell's work at Harvard, Woodrow Wilson added a core curriculum at Princeton (Tucker, 2013). This core curriculum became known as general education requirements. Soon both of these requirements, declaring an academic major and core/general curriculum, were commonplace in higher education (Bisesi, 1982). Around the same time, E. B. Wilson (1913) advocated for a yearlong freshman-level mathematics course to increase rigor for freshman students. In some instances, the freshman-level course was called College Algebra. The College Algebra course served as one of the first concerted efforts to raise the mathematical rigor for freshman students. However, most institutions classified mathematics with natural sciences. This classification meant that students could elect to take science instead of a mathematics course.

John Dewey's reform, expanding mandatory education through 12^{th} grade, took hold while World War I ended (Tucker, 2013). As a result of mandatory 12^{th}-grade education, college enrollments surged by 150% from 1910-1919 to 1920-1929 (Tucker, 2013). This surge was attributed to meeting the demand for high school teachers (Tucker, 2013). During this time of expansion of education, both in common education and higher education, mathematics was still not required for many college students. In 1920, Colgate University, a private liberal art college, began to require all students to take two mathematics courses to foster logical and independent thought (Colgate Catalog, 1920; Tucker, 2013). As a result, a small movement began across the nation for some level of mathematics as a requirement for all students.

The next push for a greater emphasis on mathematics in higher education corresponded to World War II (WWII) (Furr, 1996; Rees, 1980; Tucker, 2013). In the years preceding WWII, the U.S. had experienced an influx of European mathematicians who were leaving Nazi Germany (Siegmund-Schultze, 2009). Mathematics was being shown to have a great impact on many fields in the wartime effort. Computing, analysis, ballistic computations, fluid mechanics, classical dynamics, air warfare, statistics, code-breaking, and probability were all impacted by mathematics (Rees, 1980). Shortly after WWII, mathematics was viewed by industry as being as valuable as engineering (Schoenfeld, 2004). During the post-WWII era, college enrollments surged by 50%, with over 2.2 million veterans attending college utilizing the G.I. Bill, which paid tuition and gave a housing allowance for veterans (Bound & Turner, 2002). Additionally, the areas of national security and defense led to an increased importance for the teaching of mathematics (Curry, 1942).

With these global events in mind the Mathematical Association of America (MAA), established in 1915, formed the Committee on the Undergraduate Program (CUP) to create a common freshman-level mathematics course for all natural and social sciences (“MAA History,” 2019; Tucker, 2013). MAA was formed by a collection of mathematics educators who wished to focus their research on the teaching of the subject. The CUP group formed a course called Universal Mathematics which, “consisted of one semester of functions and limits, the real number system, Cartesian coordinates, functions (with focus on exp(x) and log(x)), limits, and elements of derivatives and integrals, followed by one semester of mathematics of sets, logic, counting and probability,” (Tucker, 2013, p. 696). The course was never fully implemented due to the decision of physics programs to use calculus as the freshman-level course for its majors. Even then, Universal Mathematics courses had companion workshops for students who needed support with basic calculus formulas.

The Cold War and the successful launching of Sputnik in 1957 renewed the efforts to emphasize the study of mathematics (Furr, 1996; Rees, 1980; Tucker, 2013). Specifically, the Sputnik launching forced the general public to recognize the vital importance mathematics had in the space race and national security (Lappan, 1997). Eventually, higher education had to include the study of mathematics in general education, more specifically in the freshman year, to satisfy the growing demand for students prepared to continue studies in the natural and social sciences (Tucker, 2013) and the rising requirements of technical competence the job market required of graduates (Furr, 1996).

The CUP, as a part of MAA, was later renamed the Committee on the Undergraduate Program in Mathematics (CUPM). In 1962, CUPM surveyed college catalogs to find the extent to which colleges were offering mathematics courses (Buck, 1962). This survey found that most colleges and universities offered a wide array of courses, but that most institutions were now offering College Algebra. The report also noted that most junior colleges also offered elementary algebra and intermediate algebra as DM courses. The CUPM continued to advocate for commonality among colleges in their mathematics offerings (Duren, 1965). CUPM created a recommended General Curriculum in Mathematics for Colleges, which focused mainly on students who were mathematics majors. However, there was one recommendation which paved the way for all majors to require a common mathematics course. In the report, Duren (1965) recommended Integral and Multivariate Calculus for all, “liberal arts students, or majors in social and behavioral sciences, and business administration students” (p. 826). Furthermore, Duren, acknowledging that teaching a variety of mathematics courses for each major would be taxing on faculty, emphasized creating a common curriculum which, “will serve as many purposes as possible, and as economically as possible,” (p. 828).

By 1974, nearly two-thirds of the 142 junior/community colleges surveyed offered a general education mathematics course, but only about a quarter had the course as a requirement (Mitchell, 1974). The trend of implementing a mathematics course as a general education requirement continued until Small (2000) reported that approximately 400,000 students were enrolled in College Algebra. This enrollment gave College Algebra the highest, credit-bearing mathematics, nationwide enrollment. The course has traditionally been used to prepare students for Calculus I. However, only 32% of College Algebra students ever enroll in Business Calculus, and only 11% ever enrolled in Calculus I (Herriott & Dunbar, 2009), meaning 57% of College Algebra students are preparing for a Calculus course they will never take.

Junior/Community Colleges and Developmental Education

Developmental Education (DE) for college students predates the junior and community college system. The need for DE was apparent at Harvard College from its beginning in 1636 (Boylan, 1988; Boylan & White, 1987). Latin was the language of most texts utilized by Harvard, this meant that students would have to know how to read, write, and speak in Latin. To address this issue, Harvard began teaching courses designed to increase their students' Latin skills. However, the first DE program resembling the modern approach started at the University of Wisconsin (UW) in 1849 (Boylan & White, 1987). UW began a college preparatory department which functioned like most modern DE programs teaching reading, writing, and basic arithmetic. This model of developing students into ones who could succeed in college-level courses spread to the point where 80% of higher education institutions had similar programs by 1889 (Brier, 1984). One way in which these programs were different than modern models is that students had to graduate the programs before being admitted to the college or university (Arendale, 2005).

These types of DE programs were common practice for the rest of the 19^{th} and the beginning of the 20^{th} century. A major change occurred in 1901 with the opening of America's first junior college, Joliet Junior College (Cohen & Brawer, 2003; Larimer, 1977; Smith, 1980; Vaughan, 1982). Joliet was designed to add two more years to a prospective college student's education before entering a traditional four-year institution. Joliet's original model was very different from the model in use today in which students earn actual credit hours toward a bachelor's degree and can earn an associate degree.

In 1907, California passed legislation paving the way for the modern model of junior and community colleges (Cohen & Brawer, 2003; Larimer, 1977; Smith, 1980; Vaughan, 1982). The legislation made it possible for high schools to teach post-secondary courses for college credit, but the legislation provided no funding for these activities (Vaughan, 1982). Funding wasn't available until 1917 when legislation was passed giving state and county funding to junior colleges. Earlier the Morrill Act of 1862, also known as the Land Grant Act, expanded the reach of higher education by granting land for the creation of institutions. These three events lead to the opening of many junior colleges across the nation, as many states passed legislation similar to California's (Cohen & Brawer, 2003).

The next major event was the founding of the American Association of Junior Colleges (AAJC) in 1920 (Cohen & Brawer, 2003; Smith, 1980; Vaughan, 1982; Larimer, 1977). The founding of AAJC gave the junior college a national voice for advocacy. The AAJC began the *Community and Junior College Journal* in 1930 as a forum for advancing their agenda and for the sharing of ideas (Vaughan, 1982).

In her textbook *Secondary Education* Aubrey Douglass (1927) outlined the essential functions of a junior college: 1) making higher education more accessible to the general population, 2) to give a needed adjustment in the organization of the school system, 3) to offer two years of education after a senior year to students who desire to continue their education, and 4) to supply "semi-professional training" a level greater than secondary school but lower than a university.

In 1947, the Truman Commission on Higher Education entered these essential functions into the national conversation (Gilbert & Heller, 2013). The Truman

Commission Report and the G. I. Bill lead to junior and community colleges fulfilling the first of these essential functions with open access (Vaughan, 1982). One of the hallmarks of the Truman Commission is its advocacy for increased enrollment by "ending discrimination based on race…ending discrimination based on religion…eliminating 'antifeminism'…eliminating financial barriers" (Gilbert & Heller, p. 420). Open access was achieved in the 1960s, but the financial barriers were not addressed until later. The Higher Education Act of 1965, the Higher Education Amendments in 1972, and the Basic Education Opportunity Grants of 1972 allowed students to take advantage of financial assistance to enroll (Vaughan, 1982).

> "These Pell Grants, as they are known today, in addition to the Supplemental Educational Opportunity Grants, the College Work-Study Program, and the National Direct Student Loans, have made it possible for every American who could profit from an education to have the financial resources to do so, in most cases without assuming a large financial debt," (p. 13).

With the end of WWII and the Korean War, the G.I. Bill allowed for an influx of 2.2 million veterans into the community college system (Vaughan, 1982). There was another burst of community college enrollment, a 413% increase, between 1965 and 1999 from around 1 million to about 5.3 million, with most of that coming between 1965 and 1975 when the Baby Boomers came of age (Kasper, 2003). Open access and financial aid certainly contributed to these enrollment increases. The general public had access to higher education and a way to pay for it. Increases in students needing developmental courses accompanied these increases in enrollments.

Issues in Developmental Mathematics

Community colleges have become increasingly aware of and concerned with the success of students enrolled in developmental mathematics (DM) (Bailey, 2009; Bassett & Frost, 2010; McClenney & Dare, 2013; Merseth, 2011). Research (Bailey, Jeong, & Cho, 2010; Okimoto & Heck, 2015) reveals an alarming trend for students enrolling in community colleges across the U.S. where a staggering number, as high as 70%, of entering community college students are underprepared for college-level coursework. When these students are referred to Developmental Mathematics (DM) courses, only 30% pass the course. Furthermore, only 31% of students referred to DM course sequences complete them within three years, and only 40% ever complete the sequence at all (Bailey, Jeong, & Cho, 2010). Most sequences are three courses or less. After students complete the DM sequence, they must then enroll in a gateway course, usually College Algebra, which will satisfy their general education mathematics requirement. Many issues are affecting the completion rates for students enrolled in DM courses. Four of the main issues are placement procedures used by institutions, the percentage of incoming cohorts placed in DM, student persistence, and completion of DM coursework, and the cost associated with placing students in DM, to both the student and the institution.

Placement. Students deemed to be college ready by the institution's placement procedures and policies can enroll in any gateway course. However, students who are not deemed college-ready by their institution's placement procedures must complete developmental education (DE) courses to prove themselves ready for college-level coursework. Traditionally, high school students have been required to complete the ACT and SAT exams to determine their college-readiness. Freedle (2003), Jaschik (2015), Rattani (2016), and Santelices and Wilson (2010) reported the evidence of racial and socio-economical biases in the SAT. Freedle (2003) published a report showing that white students scored higher on easier items on the SAT while black students scored higher on the more difficult items. Santelices and Wilson's (2010) report replicated Freedle's with the same results, providing more evidence of racial and socio-economical biases in the SAT. Castro (2013) reported ACT data from a six-year longitudinal study in Illinois revealing 30% of White students who took the ACT were college-ready, meaning their composite score was 21 or better, only 3% and 8% of Black and Hispanic students did so, respectively. Many times, students ACT and SAT score are used to place into college-level or DE courses.

Colleges and universities have placement procedures for students who do not have the minimum ACT or SAT score required to enroll in college-level coursework. Many community colleges have relied on placement tests, such and COMPASS and ACCUPLACER, for their placement process (Bahr, Fagioli, Hetts, Willett, Lamoree, Newell, Sorey, & Baker, 2019; Melguizo, Koslewicz, Prather, & Bos, 2014). The tests contain questions from basic arithmetic to topics covered in traditional College Algebra courses. The use of these placement procedures means a single assessment is used to determine a student's placement into DE courses. Another issue with the use of placement tests is the lack of uniformity in cut scores employed by institutions. Cut scores are the minimum score required for each DM course in the sequence. Melguizo, et al. (2014) found institutions interpret the results differently by having a wide range of cut scores for their developmental mathematics (DM).

Percent of Entering Students in Developmental Mathematics. The National Education Longitudinal Study (NELS) collected tracking data of students from K-12 to college-level enrollment from 1988 to 2000. Bailey (2009) reported, from both the K-12 and college-level data collections, as many as 58% of students tracked from eighth grade were required to take at least one developmental course through 2000. Bailey also reported nearly one-third of first-time students enrolled in the lowest level DM course their institution offers. Additional research shows that as much as 70% of students entering community colleges require DE courses in a combination of reading, writing, and mathematics. Enrolling in the lowest level DM course means a student is either two or three courses away from completing the sequence. Furthermore, of those students who enroll in the lowest level DM course, only 31% complete the sequence of courses in three years. NELS data also shows less than 25% of students who enroll in developmental education courses complete a degree or earn a certificate within eight years.

Developmental Mathematics Course Success Rates. Once community colleges place students into DM courses, the next issue to consider is whether students are succeeding in those courses. One way DM courses can be deemed successful is if they have adequate success rates. In DE courses, students must earn at least a C to satisfy the prerequisite for the next course in the sequence or the gateway mathematics course. Reporting on success rates varies, both between institutions and between the level of course. Using data collected from institutions involved in Achieving the Dream (AtD) initiatives, Bailey, Jeong, and Cho (2010) report 40% of students placed in a DM course three levels below a gateway course do not either enroll or succeed in the course.

Ultimately, meaning only 25,015 of the 43,886 (57%) sample of students in the AtD institutions both enrolled in and succeeded in the course.

Similarly, the rates of students not enrolling in or succeeding in the next course in the sequence were similar, between 40% and 47% (Bailey, Jeong, & Cho, 2010). By the end of the second year, only 16% of the original sample had completed the gateway mathematics course. The result is more than 36,000 students did not complete the sequence of DM courses and the gateway course. Bailey et al. (2010) also reported the same statistics for students placed 2 and 1 level below the gateway course. In all, of a total sample of 144,590, nearly 96,000 students either did not enroll or succeed in their DM course sequence and the gateway course.

Student cohorts referred to the lowest level course, three courses away from the gateway course, not only suffer attrition from issues with course success, but also because of the structure of the sequence. If a student passes each class they enroll in, they will experience four decisions, regarding enrollment, through the gateway course. For example, once referred to the lowest level course, the student must decide to enroll in the course. Once they pass the course, they must decide to enroll in the next course, and so on, through the gateway course. A student who fails any course in the sequence must then decide to re-enroll in the course. For each course, a student fails; they will experience at least one more decision. Bailey, Jeong, & Cho (2010), using data from the National Education Longitudinal Study (NELS) reported only 10.1% of students placed in the lowest level DM course consecutively enrolled in and passed each course in the DM sequence and the gateway course.

Another illustration of students progressing, or not, through a DM sequence comes from Complete College America (CCA). CCA describes the attrition of students referred to DM sequences with three levels below college-level, or gateway course work ("The Blueprint" 2019). Of those ten students, three do not enroll in the course, while two more of the remaining seven failed the course. For the five who passed, the next step is enrolling and passing the next course in the sequence. Only one and a half do so. For those students, only the last DM course stands between them and their gateway course. In the end, only one will both enroll and pass each of the courses in the DM sequence and the college-level, gateway course.

The Cost of Developmental Education. One of the end effects for students referred to DE courses is financial. The issues of placing high levels of students in DM courses, the low pass rates of those courses coupled with low persistence and high attrition, leave many community college students with no degree and, in most cases, student loan debt. The website, www.finaid.org/loans/studentloandebtclock.phtml, continually updates the total student loan debt for US citizens (2019). Currently, US citizens owe over $1.6 trillion. Avery and Turner (2012) reported 41% of all students attending two-year institutions were taking on student loans, while Ma and Baum (2016) reported 25% of full-time students at two-year institutions were using student loans

Additionally, DE has a high financial cost for community colleges. In 2008, costs were estimated to be $1.9 to $2.3 billion and another $500 million at four-year colleges (Strong American Schools, 2008). Scott-Clayton and Rodriguez (2012) found that the cost increased in just four years to an estimated $4 billion. Together the issues of the cost of DE courses, to both students and institutions, must be resolved to serve community college students better nationwide.

Redesigning Developmental Mathematics

The issues of large numbers of students entering higher education referred to DM courses, the success rates of those courses, the low persistence of students referred to DM courses, and the costs to both the student and institution have not gone unnoticed. Many institutions have implemented small scale innovations aimed toward promoting student success in DM courses. The innovations were created with guidance from existing data from research on the characteristics of successful courses and students. Small scale innovations are those innovations which are either for research purposes only or which do not reach full-scale implementation. These practices rarely make large impacts on great numbers of students for various reasons. For instance, Zientek, Yenkiner, Fong, and Griffin (2013) showed students enrolled in courses taught by full-time faculty were more likely to pass, but it is unreasonable for community colleges to hire enough full-time faculty to teach all DM courses.

Researchers from the University of Hawaii implemented DM courses redesigned to include online instruction, continuous assessment and feedback, on-demand support, and mastery learning (Okimoto & Heck, 2015). Their efforts were designed to increase student engagement using active learning components. Students in the redesigned DM courses three levels below college-level were between 3.2 and 7.2 times more likely to pass. When the analysis extended to the courses two and one levels below college-level, the results showed the students in the redesigned courses were 5.7 to 6.9 to pass the class two levels below, and 5.8 times more likely to pass the course one level below college-level. Unfortunately, this model did not reach full-scale.

Wladis, Offenholley, and George (2014) reported the results of an innovation conducted at Manhattan Community College (MCC). In this innovation, students in DM course were given a common assessment as their midterm. Students who scored less than 70% were required to complete common intervention assignments which covered material both from the midterm and leading up to the final exam. These assignments were delivered online, so the students could receive immediate feedback. Additionally, MCC created an intervention lab and increased computer and tutor availability. Students who frequently visited the intervention lab during the last eight weeks after the midterm had a significantly greater pass rate than those who did not.

One innovation which did reach full-scale implementation was at Jackson State Community College (JSCC). Bassett & Frost (2010) reported the developments of SMART Math (Survive, Master, Achieve, Review, and Transfer), which combined their three DM courses into one course with 12 modules. The other departments at JSCC then reviewed their math requirements and selected the DM competencies required to succeed in their programs. Students then enrolled in the DM courses which contained the competencies they needed for their program of study. Once a student mastered the competency, they moved to the next one, and so on. The year before implementation, JSCC DM courses had a pass rate of 42%. After the first semester of implementation, the pass rate dipped to 41%. In the four semesters after implementation, the pass rates dramatically increased to 54%, 57%, 59%, and 60%.

A Move Toward Mathways and Corequisites. The histories of the evolution of freshman-level mathematics studies, which culminates in a College Algebra for everyone approach, the connected evolutions of developmental education and junior and community colleges serve as a pretext to the issues with traditional approaches to DE. The traditional approach of sequences of DE courses, each serving as a prerequisite to the next and, ultimately, the gateway course has created a broken system which, while designed to provide students with skills to succeed in college-level courses, serves as a barrier to their success by trapping them in sequences with low completion rates. The product is a small percentage of students referred to DE courses obtaining a degree. This data does not mean there is no hope for underprepared students. Several foundations think tanks, and associations are now promoting new models designed to accelerate students through DE courses while also earning credit in gateway courses.

Achieving the Dream (AtD) began its work in 2004 as a granting organization, funded by the Lumina Foundation, for institutions to increase persistence and completion among various student populations ("History," 2019). AtD ("Project Information," 2019) had five underlying principles for its member institutions:

1. Secure leadership commitment.
2. Use data to prioritize actions.
3. Engage stakeholders.
4. Implement, evaluate, and improve intervention strategies.
5. Establish a culture of continuous improvement.

After the first six years, AtD became an independent non-profit organization identifying three important issues for institutions enacting change. The first issue was most innovations were relatively focused, affecting small populations of students. The second was most of the changed implemented with these innovations were, while successful in their own right, not large enough or sustained enough to increase the overall improvement of the AtD institutions. Research conducted by the Community College Research Center (CCRC) revealed the third issue, most developmental assessments and coursework did not increase student success, while accelerated programs did (Columbia University, 2013).

At the same time, AtD became involved with the Bill and Melinda Gates Foundation. Their work coincided with the work of the Developmental Education Initiative (DEI) (Columbia University, 2013). DEI's task was to examine AtD institutions and identify innovations in developmental education, which met two criteria. The first criterion was student outcomes improved with the innovations (i.e., pass rates, persistence, completion, etc.). The second criterion was full implementation of the innovation at the institution. These insights, gained by DEI and AtD, led the Bill and Melinda Gates Foundation to form Completion by Design (CBD) in 2011. CBD ("Project Information," 2019) had eight founding principles:

1. Accelerate entry into coherent programs of study.
2. Minimize the time required to get college ready.
3. Ensure that students know the requirements to succeed.
4. Customize and contextualize instruction.
5. Integrate student supports with instruction.
6. Continually monitor student progress and proactively provide feedback.
7. Reward behaviors that contribute to completion.

8. Leverage technology to improve learning and program delivery.

The participating institutions had great flexibility in implementing a subset of these principles. CBD saw a wide variety in the implementation, which provided feedback on the implications of the combinations of principles.

All of these actions, taken together, led to the publication of *Redesigning America's Community Colleges* (Bailey, Jaggers, & Jenkins, 2015) the CCRC's book outlining the Guided Pathways model. The Guided Pathways model calls for an end to the "cafeteria" approach in which students have a multitude of choices when navigating community college. Instead, to better serve today's student population, community colleges need to reduce the number of choices students have to make while going into and through programs of study, making it easier for institutions to monitor their progress.

In 2016, the American Association of Community Colleges, with funding provided by the Bill and Melinda Gates Foundation, launched The Pathways Project, signing on thirty community colleges across America. This project was designed to build "capacity for community colleges to design and implement structured academic and career pathways *at scale,* for all of their students," ("The Pathways Project," 2019).

One of the most effective innovations which address CBD's principles 1 and 2 is corequisite remediation. Corequisite remediation refers to programs in which students dually enroll in developmental courses designed specifically to support the learning in the college-level gateway course. Corequisite courses vary widely from dedicated lab support to computer-aided instruction to classes with their curriculum (Belfield, Jenkins, and Lahr, 2016; Campbell & Cintron, 2016; Royer & Baker, 2018)

Corequisite courses allow many more students to complete their gateway coursework in their first year of enrollment by changing the structure of DM sequences (McClenney, Dare, & Thomason, 2013). Traditional three-course DM sequences require at least four semesters to complete the gateway mathematics course. Corequisite models allow students to shorten this to three, and in some cases two, semesters. In the first semester, students enroll in one DM course building a foundation for the college level gateway coursework. In the second semester, students enroll in the gateway course and the corequisite course, concurrently. This structure moves students to and through gateway courses faster than the traditional structure.

Corequisite developmental courses are being heavily promoted by Complete College America (CCA) (2019). CCA, in their Executive Summary, ("The Blueprint", 2019), give six pillars for co-requisite programs:

Pillar One: Purpose, not placement.

Pillar Two: Treat all students as college students.

Pillar Three: Deliver academic support as a corequisite.

Pillar Four: All students should complete gateway courses in one academic year.

Pillar Five: Develop multiple math pathways into programs of study.

Pillar Six: Corequisite support is the bridge into programs of study.

In Pillar Five, CCA mentions multiple math pathways. These math pathways, also called Mathways, refer to institutions providing more than one gateway mathematics course. Traditionally colleges and universities have used College Algebra as the gateway course. College Algebra, historically speaking, is a course designed to prepare students for Calculus courses ("Strategies," 2019). In their report, *New Rules: Policies to Strengthen* *and Scale the Game Changers*, CCA calls for institutions to create gateway mathematics courses designed to promote student learning in their program of study, especially when their program only requires one college-level mathematics course. For instance, journalism majors do not need preparation for Calculus. These students would be better served with a curriculum "designed to help them navigate the increasingly data-driven world" ("Strategies," 2019, p. 14).

The development of these Mathways has expanded the number of college-level mathematics courses available to students. Currently, there are many variations of the courses offered. The most common offerings are College Algebra, Quantitative Reasoning, Elementary Statistics, and Mathematical Modeling, sometimes called Functions ("The Blueprint," 2017). Institutions in "The Pathways Project" require students to meet with an advisor before enrolling each semester. In the initial meeting, before the first semester of enrollment, students are encouraged to select a meta-major (McClenney & Dare, 2013). Meta-majors are clusters of majors similar to colleges used by universities. For example, liberal arts departments are usually referred to as a college and would be classified as a meta-major. Meta-majors also have similar degree requirements. At institutions, these meta-majors select the most appropriate gateway mathematics course.

The full-scale implementation of corequisite courses to support multiple gateway mathematics courses has been shown to increase the numbers of students completing their gateway mathematics course within their first year of enrollment in multiple states. Table 2.1 illustrates the successes in Georgia, West Virginia, Tennessee, and Indiana ("The Blueprint," 2017).

Table 2.1

Percent of Students Completing Gateway Mathematics Courses Before and After Implementation.

State	Before Implementation (within Two Years)	After Implementation (within One Year)
Georgia	20%	63%
West Virginia	14%	62%
Tennessee	12%	61%
Indiana	29%	64%

("The Blueprint," 2019).

To illustrate and better understand the impact of these innovations, consider the aggregate success of these four states before and after implementation, 19%, and 63%.

Synthesis of Corequisite Research

Corequisite developmental courses are in the early stages of implementation. Because of this, formal research in peer-reviewed journals is sparse. Most of the research is being conducted within and published through the associations promoting corequisites, CCA, AACC, etc. This is not to say their research isn't to be trusted, but it has not gone through a rigorous review process.

Tennessee has been a leading adopter of the corequisite approach. Belfield, Jenkins, and Lahr (2016) analyzed the statewide implementation of corequisite courses in Tennessee's 13 community colleges. They reported two significant findings. The first is that 51% of DM students completed their gateway course within the first semester which was the Fall of 2015. These results compare favorably to 12% of DM students who would complete a gateway mathematics course within one year in the previous model. The second finding was the financial impacts on students who enrolled in corequisite courses. Belfield, Jenkins, and Lahr (2016) reported that the cost per students' success, completing a gateway course, went from $7,720 for students in the prerequisite model to $3,840 for students in the corequisite model. This research shows the gains in students completing gateway mathematics courses and savings for students who are in corequisite model DM courses.

Indiana has also implemented corequisite DM courses statewide through Ivy Tech Community College (Royer & Baker, 2018). Ivy Tech Community College (ITCC) is the only community college in Indiana with 40 campuses. In the three years before the implementation of corequisite DM courses, ITCC's DM courses had a 49% success rate, while only 36% went on to enroll in a gateway mathematics course. Of those who enrolled in the gateway mathematics course, only 29% successfully completed the course. Royer and Baker (2018) reported the completion rates for students in the corequisite model of the first five semesters. The completion rates varied from 52% to 64%, a marked improvement from the previous prerequisite model.

Campbell and Cintron (2016) reported on a statewide pilot of corequisite DM courses over three years in Louisiana. Five public community colleges participated in the pilot. Participants were entering students who had ACT Math scores of either 17 or 18, two points from qualifying for college-level mathematics in Louisiana. Of the students who enrolled in the pilot courses, 67.8% were successful in completing their gateway mathematics course. Campbell and Cintron reported these successes despite the different models used. Each of the institutions implemented the corequisite courses in their own way. Institutions use a two- or three-hour DM course, while others use mandatory Math Lab time with tutors.

Kashyap and Mathew (2017) studied student success in a Quantitative Reasoning (QR) course by placing students in one of three models, a prerequisite model, a corequisite model, and one in which students only enrolled in the QR course. Using Chi-square and ANOVA analyses, they reported the students in the corequisite model earned higher grades than students in the other two models. These results are an important finding because it not only compares corequisite students to prerequisite students but also a student enrolled only in the college-level QR course.

Critique of Current Research. The current body of literature on the study of corequisite DM courses is sparse since the innovation is relatively new. Tennessee and Indiana were among the early adopters of statewide corequisite models (Belfield, Jenkins, & Lahr, 2016; Royer & Baker, 2018). Several states are in the early stages of implementing the model ("Spanning the Divide," 2019, "Where We Work," 2019).

The research reports mostly on the percentage of students who complete gateway mathematics courses within their first year of enrollment, overall course success rates post-implementation, or smaller scale designs (Belfield, Jenkins, & Lahr, 2016; Campbell & Cintron, 2016; Kashyup & Mathew, 2017; Royer & Baker, 2018). This proposed study wishes to take a closer look at the course success rates by comparing them to the success rate before the implementation of corequisite DM courses. The proposed study also aims to answer the question of how students' in corequisite DM courses success rates in the gateway course compare to their peers enrolled in the gateway course alone.

Theoretical Framework: Adult Learning Theory

The Adult Learner: A Neglected Species was originally published in 1973, but has gone through revisions several times (Knowles, 1973, 1978, 1984, 1990, 1998, 2011). In his texts, Knowles gives the history of the development of his theory for adult education, advancements in theory, and practices supported by the theory (Knowles, Holton, & Swanson, 2011). Knowles' theory of adult education is called andragogy and begins with the belief adults learn differently than children, and, as such, differs from pedagogical practices. This review will cover each of these areas and make connections to practices in K-12, community college, and four-year university settings.

Assumptions of Andragogy. The assumptions of andragogy are a departure from pedagogical models of education. In pedagogical models, the teacher makes all of the decisions about the topics to teach, the methods to employ, and the sequence of the learning (Knowles, 2011). Knowles did not wish to set up andragogy as a competitor of pedagogy; rather, he put his assumptions of andragogy as an alternative for educators to consider.

Knowles' adult learning theory (2011) is comprised of six andragogical assumptions (Figure 1), which also have implications in pedagogy: (1) The Need to Know, (2) The Learners' Self-Concept, (3) The Role of the Learners' Experience, (4) Readiness to Learn, (5) Orientation to Learning, and (6) Motivation.

The first assumption of "the need to know" means that adult learners need to see the benefit of the learning because "adults need to know why they need to learn something before undertaking to learn it," (Knowles, Holton, & Swanson, 2011, p. 63). Teachers, who Knowles advocates taking the role of facilitators, should present the reason for the learning by framing it as making the learner more effective in learning or affecting the quality of life. Some adult learners will come into a learning situation already knowing why they need to learn a skill, or concept. An example would be a learner taking a specific class or obtaining a certificate to become more employable. In either case, adult learners' engagement in the learning process will increase when they understand why they need to obtain or interact with new skills or information.

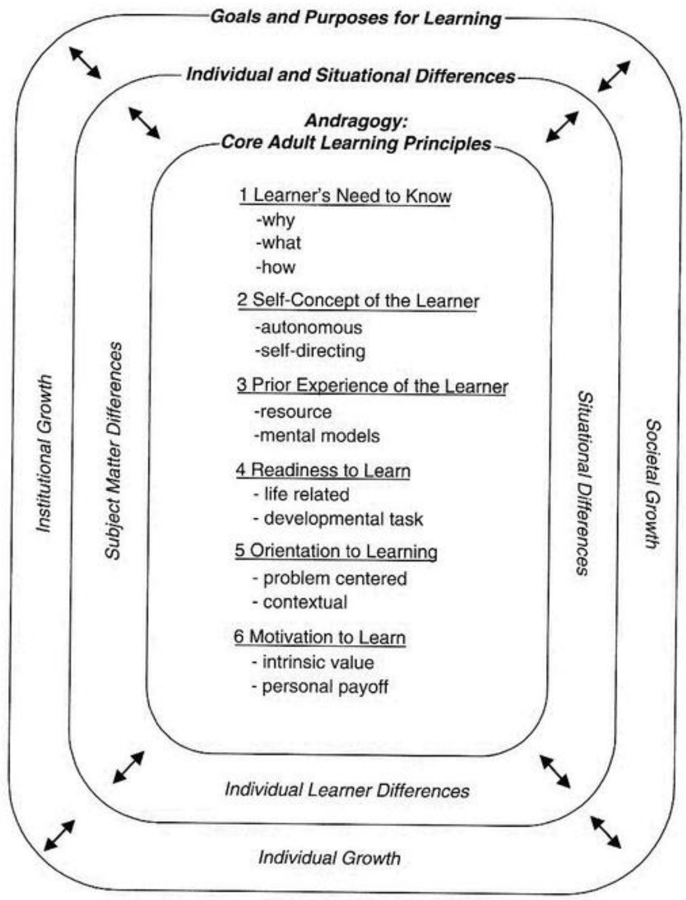

Figure 2.1. Knowles' (2011) Andragogy in Practice. [Used with permission, see Appendix A]

Knowles' (2011) second assumption is "learners' self-concept" (p. 63) in which adult learners need to be seen as capable of self-direction and responsible for decision-making. Adult learners do not respond well in situations in which others are imposing their will on them. They need to be co-creators of their knowledge. "Adults have a self-concept of being responsible for their own decisions, for their own lives" (Knowles, Holton, & Swanson, 2011, p. 63). This assumption of self-concept is in contradiction to an adult learner's history with educational activities in which they were passive recipients of knowledge.

The third assumption of andragogy is "the role of the learners' experiences" (Knowles, Holton, & Swanson, 2011, p. 64). Adult learners have had more experience simply because they have been alive longer. "Adults come into an educational activity with both a greater volume and a different quality of experience from that of their youths" (Knowles, Holton, & Swanson, 2011, p. 64). These experiences create a deeper and more diverse background knowledge. The experiences can be positive or negative. Adult learners returning to school can tend to feel they will struggle to learn again. However, Knowles suggests, "that for many kinds of learning, the richest resources for learning reside in the adult learners themselves" (p. 64).

Readiness to learn, (Knowles, Holton, & Swanson, 2011) is the fourth assumption of andragogy. "Adults become ready to learn those things they need to know and be able to do to cope effectively with their real-life situations" (Knowles, Holton, & Swanson, 2011, p. 65). The major implication from this assumption is that adult learners need their learning tasks to be timed appropriately with their developmental stage. The learners need to be in a position emotionally, developmentally, and socially for learning to impact their real-life situations.

The fifth assumption, "Adults are motivated to learn to the extent that they perceive that learning will help them perform tasks or deal with problems that they confront in their life situations" (Knowles, Holton, & Swanson, 2011, p. 66), means adult learners orientation needs to be life-, task-, or problem-centered. Adult learners' engagement will increase while learning concepts presented in real-life contexts. These contexts, when they mirror the learner's life, will enhance and deepen the learning experience.

The final assumption of andragogy is motivation. "Adults are responsive to some external motivators (better jobs, promotions, higher salaries, and the like), but the most potent motivators are internal pressures (the desire for increased job satisfaction, self-esteem, quality of life, and the like)," (Knowles, Holton, & Swanson, 2011, p. 67). While adults may respond to external motivators, internal motivators are more likely to spur learning. As Knowles (2011) explains, "Growth takes place when the next step forward is subjectively more delightful, more joyous, more intrinsically satisfying" (p. 46).

Implications for Higher Education. One major implication for higher education lies within a trouble area for community colleges. Developmental Education, specifically mathematics, traditionally has high enrollments, but also low pass and completion rates (Bailey, 2009; Bailey, Jeong, & Cho, 2010; Columbia University, 2015; Melguizo, Koslewicz, Prather, & Bos, 2014). Co-requisite models of developmental education are spreading across the nation ("Spanning the Divide," 2019). Co-requisite developmental courses are taken in conjunction with college-level coursework, instead of the traditional model in which developmental course sequences serve as prerequisites for the college-level course. For example, in the tradition DE model, a developmental math student would be enrolled in and required to pass a course such as intermediate algebra to be allowed to enroll in a college algebra course. In a corequisite model, this same student dually enrolls in the college algebra course and a support course. This support course is meant to provide “just-in-time” assistance to students who are learning difficult content in the college-level course. Just-in-time assistance in the co-requisite course agrees with andragogical assumptions. The student recognizes the need to know what is being offered in the support course because it directly relates to the college-level course. The learner’s self-concept is evident in the learner’s ability to direct their own learning choices. The readiness to learn of this adult learner originates from the desire to succeed in the college-level course. Developmental math students in community colleges, motivated by the desire to earn a degree, are required to pass a general education mathematics course.

Community colleges serve higher rates of underrepresented minorities and socioeconomically disadvantaged students than their four-year university counterparts (Rhoads, & Valadez, 2016). Many community college students are educationally disadvantaged, low wage earning, and low skill adults in search of the knowledge and skills needed to improve their real-life situations (Knowles, Holton, & Swanson, 2011). Adult learning at community college learners fits the assumptions of andragogy, but, as Knowles indicates, have the weakest link to the assumption of self-concept as these learners carry with them a life experience of not being successful in academic ventures (Knowles, Holton, & Swanson). The issue of self-concept can lead to a lack of self-confidence about the basic skills of reading and math. Adult learners need high levels of support at the outset of the learning exercise. Motivation is high for the low-wage earner because of their desire to better their economic position in society.

Educators of adult learners need to be aware of their adult learners’ self-concept, their motivations for engaging in learning and attuned to the needs of their adult developmental learners. Additionally, developmental educators should make their learning activities as relevant as possible for their adult learners. Adult educators should also recognize the potential for low confidence in their students when the learning experiences are with unfamiliar subject matter. Lastly, developmental educators should understand the educational experience of their students as this history may not be a positive experience from which to draw. Attention to the assumptions of andragogy is paramount to successful educational experiences for adult learners.

Conclusion

The purpose of the chapter is to give the context of the literature for the proposed study. The literature review began with the historical perspectives of freshman-level mathematics, developmental education, and community colleges were presented as the context. Next, the literature review examined and synthesized the body of literature for corequisite developmental courses. Corequisite research is sparse due to the newness of the innovation.

Finally, an analysis Knowles (2011) Adult Learning Theory is the final section of the literature review. The context of the current study is presented in Chapter 3.

CHAPTER III

CONTEXT OF THE STUDY

The purpose of the study was to analyze the implementation of multiple gateway mathematics courses and corequisite developmental mathematics (DM) courses using data collected from a large, multi-campus, Midwestern community college. The use of multiple gateway courses means a transition from a “College Algebra for All” approach to offering more than one freshman-level mathematics course for students. Corequisite DM courses are DM courses taken concurrently with a gateway course instead of taking the DM courses sequentially, adding semesters to completion of a gateway course.

The community college used in the study will furthermore be referred to as Midwestern Community College (MCC).

Placement

MCC’s state governing board mandates institutions must have approved placement procedures and policies which adhere to state minimum requirements (State website). For example, institutions using ACT and SAT scores to admit students into gateway mathematics courses must adhere to minimum scores, 19 and 510, respectively. MCC has used similar placement policies throughout the four years included in the current study. If a student cannot be placed into a gateway mathematics course using ACT or SAT, MCC administers the ACCUPLACER placement test. The ACCUPLACER test can refer first-time enrolling (FTE) students to DM or gateway mathematics courses (The College Board, 2019). MCC mathematics faculty voted to use ACCUPLACER for placement testing, as well as, the cut scores for each of the courses in its mathematics sequence.

The use of single-measure high-stakes tests is a topic of debate for researchers and institutions (Bahr, Hetts, Hayward, Willett, Lamoree, Newell, Sorey, & Baker; 2019). Placement tests are not highly correlated with success in the course to which a student is referred. Alternative measures are being advocated for and implemented at some institutions, such as the use of high school grade point average (HSGPA). The debate mainly centers around whether a single test score can accurately assess a student's skill level. Bahr et al. (2019) reported HSGPA to be more predictive of course success than ACCUPLACER, even considering students may not enroll in college directly after graduating high school. Bahr et al. (2019) argues that HSGPA reflects non-cognitive characteristics, such as motivation, grit, and self-efficacy. The argument for using placement tests, such as ACCUPLACER and ALEKS, is a prevailing notion that they do measure skill level in some form. Beginning in the Fall semester of 2019 MCC will begin to use HSGPA in its placement policies and procedures.

Once students are placed, there are three ways a student can enroll in a course. Typically, students enroll in the course to which they were referred based on their ACT, SAT, or ACCUPLACER scores. Students can also choose to enroll in any course lower in the sequence than the one to which they were referred. Finally, students can re-enroll in a course they did not successfully complete either by withdrawing from or failing the course.

State Partnership with the Dana Center

Before implementing multiple gateway and corequisite DM courses, MCC's placement, success, and completion rates closely matched the national data reported by Bailey, Jeong, and Cho (2009) while using a traditional DM sequence. MCC referred 68% of first-time enrolling students to developmental education. Of the students referred to the lowest level DM course, just over 30% finished the gateway mathematics course, College Algebra, within four years (MCC website). Other two-year institutions in MCC's state had similar placement, success, and completion data. The high rates of students referred to DM courses, and low success and completion rates in those courses statewide led MCC's state governing board to sign on with the Dana Center at the University of Texas at Austin ("Where We Work," 2019). The Dana Center has several initiatives aimed at preparing students for success in mathematics and science. Their work in DM includes The Dana Center Math Pathways (DCMP). DCMP promotes two specific innovations, corequisite DM courses, and multiple gateway mathematics courses, to states looking to improve their DM students' success, retention, and graduation rates. DCMP works with institutions in 18 states across the US to improve outcomes for students in mathematics ("Where We Work," 2019). The Dana Center began promoting DCMP in 2009 ("Our History," 2019).

After signing on to the DCMP, MCC's state governing board communicated two decisions to every institution of higher education. The first was that each institution must offer more than one choice of gateway mathematics courses instead of only directing students towards the traditional College Algebra course. The second was that each institution needed to redesign its DM sequence in such a way that 75% of entering students could attempt a gateway course within the first fall and spring semesters of enrollment by utilizing corequisite DM courses. These decisions have a greater impact on community colleges than on their four-year counterparts. The first complication is due to considerations that need to be made concerning the transferability of courses. Community colleges have to offer gateway mathematics courses other than College Algebra that four-year universities will accept as transfer credit. The state's governing board publishes a course transfer matrix the outlines courses that are guaranteed to transfer between public institutions of higher education in the state. Community colleges utilizing multiple gateway courses have to consider which courses adhere to the standards of the transfer matrix. While DCMP advocates for institutions to offer three or more gateway mathematics courses, schools in MCC's state could only guarantee two courses would transfer to four-year institutions within the state, College Algebra and Quantitative Reasoning.

Another potential complication of offering multiple gateway courses is matching gateway mathematics courses to specific majors. One institution may require College Algebra while another may require a Quantitative Reasoning course. Community colleges in this Midwestern state must be very intentional and careful when creating gateway mathematics courses. For example, a Psychology major must make a decision in regard to where they intend to transfer. Of MCC's three major transfer partners, two require College Algebra and the other requires Quantitative Reasoning. MCC's advisers must be careful when communicating the implications of choosing the four-year transfer institution to a Psychology major.

One barrier to requiring all institutions to create a sequence in which 75% of students could enroll in a gateway course is that the state included in the study is an open access state. Open access means there are no minimum requirements to enroll in a community college. In contrast, states such as Texas have Adult Basic Education (ABE) requirements for admission to its community colleges. This ABE requirement means prospective students must demonstrate a minimum of 8th grade proficiency in reading, writing, and mathematics before enrolling. In contrast, students enrolling in college in an open access state may not have basic reading, writing, and/or mathematics skills. The lack of an ABE requirement is a potential barrier to ensuring that 75% of first-time enrolling students have the opportunity to enroll in a gateway mathematics course in their first year of enrollment (State Governing Board Website). Students with low skill levels may require more DM courses in preparation for gateway mathematics coursework.

The Mathways Project

In the fall semester of 2016, MCC's mathematics faculty began redesigning their policies for their DM course sequence through gateway courses in reaction to the state governing board's decisions that each institution should offer multiple gateway and corequisite DM courses. The state's decisions were communicated to MCC's mathematics faculty. With this information, and recognizing the complications of transferability and open access, MCC's mathematics faculty began planning the implementation of multiple gateway courses with corequisite DM courses. The plan examined the current policies (Figure 3.1) and began discussions on how to make the necessary changes.

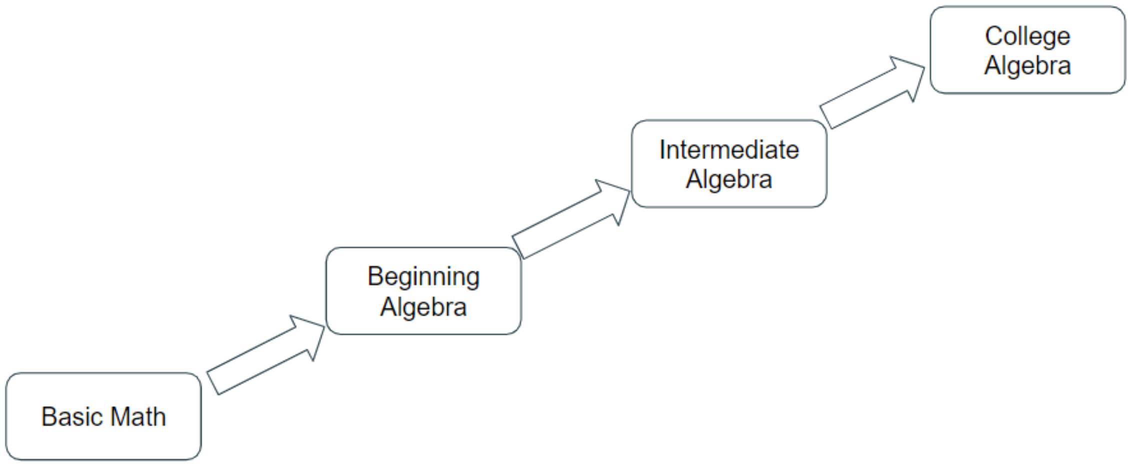

Figure 3.1. MCC's developmental mathematics sequence before the fall of 2017.

Students who enrolled while MCC utilized the sequence before the fall of 2017 (Figure 3.1) could potentially have been required to pass four courses to earn credit in College Algebra. A student referred to Basic Math would have to choose to enroll in the course, pass the course, then choose to enroll in the next course. If the student enrolled in each course in consecutive semesters and passed each course, the student would need four semesters to complete the sequence. Any student who does not pass a course would be faced with the choice of re-enrolling in the course.

The mathematics faculty made four decisions over several faculty meetings in regard to their policy redesign efforts. The first decision was to rename the College Algebra course to Precalculus 1. Renaming the course more accurately described the intent of the course, preparation for Calculus. The second decision was to rename Math for Critical Thinking to Quantitative Reasoning and to use this course as the second gateway course. The renaming of this course created consistency with other institutions in the state. The third decision was to rename the lowest two DM courses Foundations to be consistent with the naming of developmental reading and writing courses at MCC, which are named Reading Foundations and Writing Foundations. The last decision was to create a Mathways Project Leadership Team to manage the project.

The Leadership Team consisted of the Dean of Science and Mathematics, the three Faculty Department Chairs, two academic advisors, two at-large members, and the leaders of each of the three curriculum teams; Precalculus (PC), Quantitative Reasoning (QR), and Foundations. The Leadership Team met each month of AY17 (fall 2016 and spring 2017) for progress reports from each curriculum team and to discuss next steps in the process. The researcher was the Faculty Department Chair of Developmental Mathematics, and therefore a member of the Leadership Team. The researcher also served on the PC and Foundations curriculum teams.

The team developed a revised DM sequence after the implementation of the policies from The Mathways Project (Figure 3.2). A student referred to Math Foundations I, the lowest level course could potentially complete a gateway course in three semesters. Such a student would need to enroll in and pass Math Foundations I and then Math Foundations II. After passing Math Foundations II the student would next enroll in PC or QR and the paired Essentials course. For example, a student whose degree plan requires QR would enroll in Essential of QR and QR concurrently.

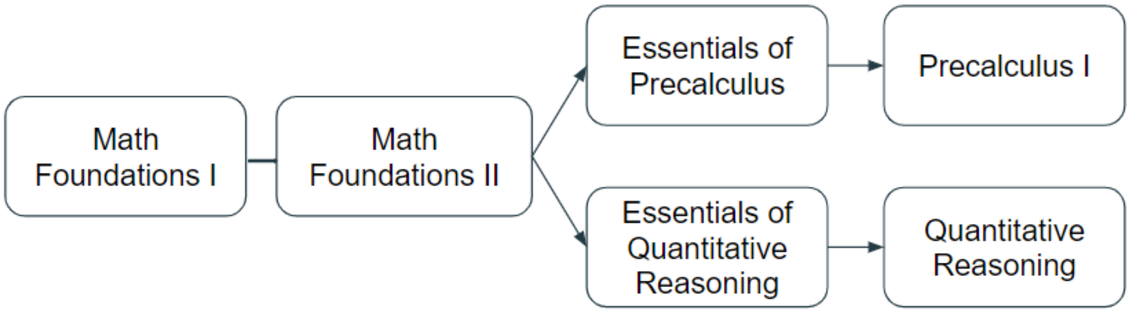

Figure 3.2. MCC's developmental mathematics sequence beginning the fall of 2017.

The PC team met monthly to modify the existing College Algebra course to ensure the course met state governing board standards for transferability and included content for Calculus preparation. The process of modifying College Algebra to PC did not include major changes to the course's content. Next, the PC team began the process of creating the corequisite course, Essentials of Precalculus. Students who would enroll in the Essentials of PC course also concurrently enroll in the PC course. This concurrent enrollment means students would be enrolled in one three-credit hour DM and one three-hour college-level, gateway mathematics course. The first step of creating the corequisite course was to identify which topics were not taught in the lower level DM courses but were necessary for success in the PC course. The team's next step was to create a course calendar for the PC course, then create a calendar for the Essentials course. For example, in PC students learn the Quadratic Formula which requires the skill of simplifying a radical expression. Simplifying radical expressions is not a topic in the Math Foundations II course. Since the skill is needed in PC, but not taught in MF II, the PC team elected to add it to the content covered in Essentials of PC.

The creation of the Essentials calendar required an examination of the topics being taught in the PC course. The team then determined the sequence of topics to be taught in the Essentials course, thus ensuring the instruction of the support topics was provided before they were needed for the more advanced topics in the PC course. From the above example of teaching simplifying radicals, the team ensured simplifying radical expressions was taught in Essentials before the quadratic formula was taught in PC. The intent of the design of the Essentials course was to provide "just in time" support for the learning of the PC content.

State signs with DCMP	MCC's Mathways Project	Mathways Implementation	Data Collection	Data Collection/ Analysis
AY16	AY17	AY18	AY19	AY20

Figure 3.3. MCC's Mathways Project Timeline.

After the creation of the course learning objectives, core content, and calendars, the PC team then produced common course assignments (see Appendices B and C). These common assignments included homework, quizzes, and tests. The PC team used Pearson's MyLabsPlus to create these items (Pearson, 2019). The faculty chose MyLabsPlus after trying several different online delivery platforms from multiple publishers in the spring semester of 2017. The fact that most of MCC's courses were already using MyLabsPlus was also a factor in its selection. With all the changes to the DM sequence, the implementation of corequisite courses, and an additional gateway mathematics course the faculty felt changing the online delivery system of the courses was one change too many. The PC team created a MyLabsPlus course with sample assignments, quizzes, and tests. This MyLabsPlus course was then made available for copying to all full-time and part-time faculty teaching the course. However, the MyLabsPlus course was not mandatory for use by adjunct or full-time faculty. The PC course not only serves as a prerequisite to the Calculus sequence but also to Elementary Statistics.

The QR team modified a course in MCC's catalog *Math for Critical Thinking*. This course was chosen because it met the requirements for transferability to other institutions in the state in regard to the state's transfer matrix. The course learning outcomes and core content underwent major revisions. First, the QR team created the gateway course. Then the *Essentials for QR* course in a similar fashion to the PC team. Similar to the PC track, students concurrently enroll in one three-credit hour DM and one three-hour college-level, gateway mathematics course. The QR team also created MyLabsPlus courses for any faculty teaching the course to use. QR is for students who do not need Calculus preparation. QR does serve as a prerequisite to Elementary Statistics, but in most cases is not only a gateway mathematics course but also a terminal mathematics course. The content of QR includes probability, basic statistics, financial mathematics, and logic. These topics, except compounding interest, are not taught in the PC course. The QR team renamed *Math for Critical Thinking* to *Quantitative Reasoning* to match the national trend for mathematics courses for non-STEM majors ("The Case for Mathematics Pathways," 2019).

In both cases of Essentials courses, whether for PC or QR, the math faculty agreed on two policies for student success after consulting with institutions in other states which had implemented similar courses. The first policy is that the gateway course, PC or QR, should have both concurrently enrolled Essentials students and those who are not. Enrolling both students who are in the corequisite and those who are not demonstrates to the students in the corequisite they are in a college-level gateway mathematics course. Secondly, each of the pairings of Essentials with either PC or QR would have the same faculty member as the instructor. Having the same instructor for both the corequisite and gateway course encourages students to ask questions and creates a pseudo-cohort. All the institutions MCC consulted suggested these policies for the success of the redesign. Not all the institutions MCC consulted began with these policies, but all of them currently employ both policies after seeking to improve their initial implementation.

The Foundations team also modified and renamed existing courses. In the previous DM sequence, the lowest two courses were Basic Math and Beginning Algebra. These courses, now named Math Foundations I and Math Foundations II, serve as prerequisites to the Essentials and gateway pairing of either QR or PC. The Foundations team also worked to implement a process in which students in the lowest level DM course, Math Foundations I, could take the college's placement test in the fourth week of the semester to qualify for the second level course, Math Foundations II, which started in the fifth week.

The policy changes brought forth by The Mathways Project created a sequence in which a student placed in the Math Foundations I course could complete a gateway course in two semesters if they qualified for Math Foundations II in the fourth week of Math Foundations I. Once a student completed the Math Foundations courses, they could enroll in either QR or PC with a corequisite Essentials course. MCC implemented the policy changes from The Mathways Project in the fall semester of 2017, known as academic year (AY) 18. These policies were created and implemented so that FTE students could earn credit for a gateway mathematics course within their first fall and spring enrollment.

This chapter provided the context for the current study. Chapter 4 will present the methodology, research questions, and the data analysis plan.

CHAPTER IV

METHODOLOGY

The purpose of the current study was to examine the implications of the implementation of corequisite developmental mathematics courses with College Algebra/Precalculus, by evaluating course success rates in multiple ways. Additionally, the current study explored potential differences between the success rates of students enrolled in both PC and the corequisite DM course. Chapter four describes the theoretical foundation, research design, participants, and the data analysis procedures of the current study.

Research Questions

The current study specifically addressed the following research questions:

1. What effect does the implementation of corequisite developmental mathematics and multiple gateway mathematics courses have on the percentage of first-year students who pass a gateway course within one year?
2. Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?

3. Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?

Epistemology

Quantitative research comes from an objectivist epistemology (Crotty, 1998). Objectivist researchers seek to make discoveries about the objects of study (Crotty, 1998). These discoveries must have the ability to be replicated in similar tests (Freund, Wilson, & Mohr, 2010; Nolan & Heinzen, 2010). Quantitative research arises from a belief in the scientific method of observing, experimenting, and comparing. Both positivist and post-positivist rely on a set of rules governing the scientific method. Comte (1853), to whom the term positivism is attributed, believed the scientific method applied to both natural and human sciences (Crotty, 1998). Post-positivism seeks empirical observation and measurement and theory verification (Creswell, 2017), meaning discovering something, then proving the discovery to be true is not a means to gain scientific knowledge. Rather knowledge is gained by, “making a guess and then finding themselves unable to prove the guess wrong” (Crotty, p. 31).

Methods of quantitative research involve hypothesis testing. Hypothesis testing is the empirical verification of knowledge by objective means. Both positivists and post-positivists believe there is little, or no, value in subjectivity. In hypothesis testing the researcher arrives at a null and alternative hypothesis, collects data, performs statistical analyses, and draws inferences which are then generalized to the population (Freund, Wilson, & Mohr, 2010; Nolan & Heinzen, 2010). The null hypothesis is established and assumed to be true, then is verified or falsified by objective observation and analysis.

Post-positivist hypotheses come from research questions which lend themselves to statistical analyses investigating the possible relationships between sets of independent and dependent variables (Creswell, 2017; Crotty, 1998).

Research Design

For the current study, the researcher employed an ex post facto design. Ex post facto studies are those which occur after the fact and without interference by the instructor (Salkind & Silva, 2010). The researcher chose to conduct an ex post facto quasi-experimental comparison design when investigating the research questions. According to Ary, Jacobs, Sorensen, and Walker (2014), when the conditions for experimental designs are not met, a quasi-experimental design is appropriate. When the researcher(s) cannot randomly assign participants to groups for analysis, quasi-experimental designs are used (Ary, Jacobs, Sorensen, & Walker, 2014; Bhattacherjee, 2014). For this study, the students were not randomly assigned to the corequisite DM course. The students enrolled themselves after either being placed into the course using the college's placement policy or by succeeding in the prerequisite course. Students enrolled in the corequisite course under one of three conditions. The first condition was the student succeeded in the prerequisite DM course. The second condition was that the student was placed in the corequisite course following the college's placement policies and procedures. The third condition was that a student voluntarily enrolled in the corequisite DM course even though the college determined they were qualified for the gateway mathematics course.

For the first two questions, the researcher utilized a matching method. Matching methods aim to compare two groups, "with the same values of these [observable] values...and display no systematic differences in the reactions to the policy reform," (Blundell & Dias, 2000, p. 429). Using the matching method allows the researcher to use matched populations for comparisons before and after policy implementation when there are no systematic differences in how one would expect the subjects to react to the policy. The researcher used the matching method since there are no reasons to expect the populations enrolling at the community college before the implementation of the policies from The Mathways Project would react differently than the population of students enrolling afterward.

Participants

The context for the current study was presented thoroughly in Chapter 3. The current study analyzed the implementation of policies for the DM sequence at Midwestern Community College (MCC). MCC changed its DM sequence from a three-course sequence leading into a single gateway mathematics course, College Algebra, to a sequence with two DM courses leading into two gateway mathematics courses, Quantitative Reasoning (QR) and Precalculus 1 (PC), with corequisite support courses (Figures 3.1 and 3.2).

The policy changes implemented at MCC emanated from its state governing board. The state governing board communicated with all public higher education institutions that their DM sequence must be able to place 75% of all first-time enrolling (FTE) students in such a way that they can enroll in a gateway mathematics course within one year using corequisite support courses. The state governing board also relayed the decision that each institution should offer more than one gateway mathematics course.

MCC's total enrollment for fall and spring ranges between 15,000 and 18,700 each semester since the fall semester of 2015, the beginning of academic year 16 (AY16). Table 4.1 gives the demographic information for MCC's fall enrollments since AY16, as reported by MCC to their state governing board and accrediting body (MCC website).

The participants for the current study were students at MCC. The sample for RQ1 included all first-time enrolling (FTE) students for the fall semesters of AY16 through AY19. The analysis for RQ1 compared the percent of FTE students completing a gateway mathematics course within the first fall and spring semester of enrollment at MCC. The comparison was between AY16 and 17, the two years before the policy changes, and AY18 and 19, the two years after the implementation of the policies from the Mathways Project, Table 4.2.

Table 4.1

MCC's Demographic Information

Gender	AY16	AY17	AY18	AY19
Female	60%	60%	61%	63%
Male	39%	39%	38%	37%
No Response	<1%	1%	<1%	<1%
Enrollment Status	AY16	AY17	AY18	AY19
Full Time	34%	33%	30%	29%
Part Time	66%	64%	70%	71%
Race/Ethnicity	AY16	AY17	AY18	AY19
American Indian	8%	7%	7%	7%
Asian	4%	4%	4%	4%
Black/African American	8%	8%	8%	8%
Hispanic/Latin(x)	7%	7%	7%	11%
Pacific Islander	<1%	<1%	<1%	<1%
White	58%	58%	57%	52%
Two or More	9%	10%	10%	12%
Non-resident Alien	2%	2%	2%	2%
Unknown	4%	4%	4%	4%
Age	AY16	AY17	AY18	AY19
Under 18-21	47%	51%	53%	54%
22-29	28%	26%	26%	24%
30-39	15%	13%	13%	13%
40-49	7%	6%	6%	6%
50 and	3%	4%	2%	3%
Enrollment	AY16	AY17	AY18	AY19
Total	17,160	17,135	16,897	16,391
First-Time Enrolling	4,023	4,052	3,839	3,495

Table 4.2

MCC's Demographic Information for Research Question 1

Gender	AY 16 and 17	AY 18 and 19
Female	3013 (57%)	2984 (59%)
Male	2246 (43%)	2034 (41%)
No Response	1 (<1%)	10 (<1%)
Enrollment Status	**AY 16 and 17**	**AY 18 and 19**
Full-Time	2712 (51%)	1862 (37%)
Part-Time	2583 (49%)	3222 (63%)
Race/Ethnicity	**AY 16 and 17**	**AY 18 and 19**
American Indian	355 (7%)	313 (6%)
Asian	183 (3%)	181 (4%)
Black/African American	547 (10%)	530 (10%)
Hispanic/Latinx	654 (12%)	718 (14%)
Pacific Islander	5 (<1%)	6 (<1%)
White	2620 (50%)	2342 (46%)
Two or More	583 (11%)	661 (13%)
Non-resident Alien	185 (4%)	135 (3%)
Unknown	152 (3%)	190 (4%)
Age	**AY 16 and 17**	**AY 18 and 19**
Under 21	4291 (82%)	4211 (84%)
22-29	515 (10%)	475 (9%)
30-39	272 (5%)	224 (4%)
40-49	98 (2%)	72 (1%)
50 and Over	38 (1%)	41 (1%)

The participants for the analysis for RQ2 included students who took College Algebra during AY16 and 17 and students who took PC during AY18 and 19. The analysis did not include students from online, Honor, or concurrent enrollment sections. In order to answer RQ3, the researcher included only students enrolled in a PC section paired with a corequisite course for AY18-19, the first two years after policy implementation. The participants for this analysis also excluded online, Honor, and concurrent sections.

Procedures

Once the current study was approved, the researcher applied for approval from the institutional review boards (IRB) of both Oklahoma State University and MCC. After gaining approval from both IRBs, the researcher requested data from MCC's Office of Institutional Research and Assessment.

Data Collection. The data requested included a list of FTE students for the fall semester of AYs 16-19 and their gateway mathematics completion status. The data also included the grade distributions of each section of College Algebra/PC for both the fall and spring semesters of AYs 16-19. Once the researcher obtained the data, in the form of Excel spreadsheets, the researcher used pivot tables to separate and organize the data into more manageable spreadsheets. To obtain the data required to answer RQ1, the researcher used pivot tables to get an Excel spreadsheet with the grade distributions of FTE students for each of the AYs included in the study. RQs 2 and 3 required section-level data instead of individual student counts. To obtain a spreadsheet with section-level success rates. The researcher used pivot tables to get the grade distributions, then used equations to get the number of students who earned an A, B, or C, and the total number of students. Next, the researcher used Excel equations to get the success rates for each section included in the study by dividing the number of students who earned an A, B, or C by the total number of student in the section.

Data Analysis. The comparison groups for RQ 1 are MCC's FTE students. Group 1 is the FTE students in academic years 2016 and 2017 (AY16 and AY17). Group 2 is the

FTE students in academic years 2018 and 2019 (AY18 and AY19). These groups represent the last two academic years before the policy changes and the first two academic years post policy changes. The researcher used a Chi-square test (Freund, Wilson, & Mohr, 2010) to detect differences in the proportion of FTE students earning gateway mathematics credit in their first year of enrollment. When employing a chi-square test for detecting differences in two proportions, a two-by-two contingency table is utilized. The columns of the contingency table are the categories of the FTE students, those who successfully completed a gateway mathematics course (C) and those who did not (NC). The rows of the contingency table are the comparison groups.

The researcher used the same chi-square test to analyze the difference in the proportions of FTE students completing a gateway mathematics course for each demographic group in Table 4.1. When using Excel to calculate each participants age, the researcher had to add four years to the participants in AY16 to account for the difference in the date used to calculate age and the AY of FTE status. The researcher used similar methods to accurately obtain the ages for FTE student in AYs 17, 18, and 19.

Chi-square tests for differences in proportions have two assumptions (Freund, Wilson, & Mohr, 2010). The first assumption concerns the sample size. The sample must be large enough so that each cell in the contingency table has values greater than five. The second assumption is the independence of data. The assumptions were met for the chi-square test.

The comparison groups for RQ2 are MCC students who took College Algebra/PC during AYs 16-19. The researcher conducted an independent t-test to detect differences in the success rates for College Algebra/PC students pre- and post-policy change.

Independent t-tests can be used to detect differences between the means of two groups of data (Freund, Wilson, & Mohr, 2010; Nolan & Heinzen, 2010). The assumptions for an independent t-test are: 1) the data are independent, 2) the data should be scale data, 3) the data should be normally distributed, and 4) the data should have homogeneity of variance (Bhattacherjee, 2014; Freund, Wilson, & Mohr, 2010). The assumptions for the t-test for RQ 2 and 3 were met. The researcher will discuss the assumptions further in the next chapter.

For the independent t-test, the researcher used the section-level success rates for College Algebra students from AY 16 and AY 17, the two years before the implementation of the policy changes from the Mathways Project, and the section-level success rates for each PC section in AY 18 and AY 19. Success rates were calculated by dividing the number of students earning as A, B, or C by the total number of students by including the number of students earning a D, F, or W. Online, Honor, concurrent enrollment, and PC sections that did not have a corequisite course paired with it in the analysis were not included. Additionally, the researcher used a chi-square test of two proportions to test for differences in success rates of students who enrolled in College Algebra/Precalculus 1 when disaggregating the data by demographic groups.

To investigate RQ3, the researcher conducted an independent t-test to detect differences in the success rates of PC students enrolled in a corequisite course, and students only enrolled in PC. Group 1 was the sections of PC containing students not enrolled in the corequisite DM course. Group 2 contained the sections of PC with students enrolled in both the PC course and the corequisite DM course. Table 4.3 serves as a summary of the data analysis for the current study's research questions.

Table 4.3

Data Analysis by Research Question.

RQ1: What effect does the implementation of corequisite developmental mathematics courses have on the percentage of first-year students who pass a gateway course within one year?		
Data	Participants	Analysis
The proportion of MCC FTE students completing gateway mathematics course within one fall and spring	All MCC FTE students for AYs 16-19	Chi-square test for differences in proportions
RQ2: Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?		
Data	Participants	Analysis
Section-level success rates (number of students with a grade of ABC divided by the total including students with a DFW)	Students enrolled in College Algebra/PC for AYs 16-19, excluding online, Honor, and concurrent sections	Independent t-test
RQ3: Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?		
Data	Participants	Analysis
Section-level success rates (number of students with a grade of ABC divided by the total including students with a DFW)	Students enrolled in PC sections which had corequisite support sections paired with them excluding online, Honor, and concurrent sections for AYs 18-19	Independent t-test

Conclusion

This chapter described the theoretical foundation, research design, participants, and data analysis procedures for the current study. The fifth chapter will present the results of the data analysis. The sixth chapter will present a discussion of the results, as well as suggestions for further research.

CHAPTER V

RESULTS

The purpose of this study was to examine the implications of the implementation of corequisite developmental mathematics courses by evaluating course success rates in multiple ways. The study sought to gain insight specifically into the effects of enrolling students who have not completed a traditional developmental mathematics (DM) sequence into college-level gateway mathematics courses. The study had three objectives. The first of which was to determine if significantly more students were able to succeed in a gateway mathematics course within the first fall and spring of enrollment for first-time enrolling (FTE) students. The second objective was to compare the success rates of students pre- and post-policy implementation. The last objective was to compare the success rates of the students enrolled in both the corequisite course and the gateway mathematics courses and the students only enrolled in the gateway course.

Research Questions

In order to achieve the objectives of the study, the researcher sought to answer the following three research questions:

1. What effect does the implementation of corequisite developmental mathematics courses have on the percentage of first-year students who pass a gateway course within one year?
2. Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?
3. Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?

Research Question One

The first research question (RQ1) asked what effect does the implementation of corequisite developmental mathematics courses have on the percentage of first-year students who pass a gateway course within one year? RQ1 was an analysis comparing the proportion of FTE students completing a gateway mathematics course when comparing the two years pre-policy implementation and the two years post-policy implementation. The purpose of RQ1 was to investigate whether the policies from the Mathways Project accomplished the goal of increasing the proportion of FTE students who earned credit for a gateway mathematics course within one fall and spring of enrollment.

Participants. The participants included in the analysis for RQ1 were all FTE students for the fall semesters of academic year (AY) 2016 through 2019. Table 5.1 shows the FTE populations for AY16-AY19 and the number of those students who completed a gateway mathematics course within their first fall and spring of enrollment.

Table 5.1

First-Time Enrolling Students and Number of Students Completing Gateway Math

	Academic Year	FTE Count	Completers Count
Pre-Implementation	2016	3269	652
	2017	3319	643
Post-Implementation	2018	3485	925
	2019	3499	975

The contingency table for the chi-square test for differences in two proportions compared the proportions of gateway mathematics course completers for AY16 and 17 versus AY 18 and 19. AYs 16 and 17 were the last two years of Midwestern Community College using the three-course DM sequence which led to one gateway mathematics course, College Algebra. These two years were also the two years pre-policy implementation. AYs 18 and 19 were the first two years post-policy implementation of corequisite DM courses and two gateway mathematics courses. Table 4.2 shows the demographic information of the participants.

Results. A chi-square test for two proportions requires two assumptions to be met. The first is no cell can have an amount less than five. The second is the independence of observations. The contingency table for the analysis has all cell values above five, and the data were all independent observations. Therefore, the assumptions of the chi-square test were met.

A chi-square test for differences in two proportions was conducted at an alpha level of .05 to answer RQ1. The null hypothesis was that there was no difference in the proportion of FTE students completing a gateway mathematics course within their first fall and spring enrollment when comparing AYs 16 and 17 to AYs 18 and 19. The alternative hypothesis was that the proportion of FTE students completing a gateway mathematics course within their first fall and spring enrollment in AYs 18 and 19 would be greater than the proportion for AYs 16 and 17. The proportion for AYs 16 and 17 was $\widetilde{p}_1 = .197$, and for AYs 18 and 19 was $\widetilde{p}_2 = .272$. The chi-square test showed a statistically significant difference in the two proportions (χ^2 (1) = 106.889, $p < .001$). Therefore, the null hypothesis that there is no difference in the proportions of FTE students completing a gateway mathematics course within the first fall and spring of enrollment pre- and post-policy implementation was rejected. Additionally, the odds ratio calculated for the chi-square test was 1.53.

In addition to analyzing the differences in the proportions of FTE students earning credit in a gateway mathematics course within one fall and spring enrollment for the entire FTE sample, the researcher also analyzed the differences for each demographic group in Table 4.1. Table 5.2 is a summary of the results. Three groups, students with "no response" for gender, students 50 or older and Pacific Islander students, did not meet the assumption for a chi-square test of two proportions of each cell having a count of five or more, and therefore were not analyzed.

Table 5.2

Summary Analysis by MCC's FTE Demographics

Gender	p_1	p_2	χ^2	p-value	Odds Ratio
Female	.2210	.3552	72.99	<.0001	1.61
Male	.2801	.4130	40.8	<.0001	1.47
Enrollment Status	p_1	p_2	χ^2	p-value	Odds Ratio
Full-Time	.3669	.6800	142.41	<.0001	1.85
Part-Time	.1161	.1968	50.34	<.001	1.69
Race/Ethnicity	p_1	p_2	χ^2	p-value	Odds Ratio
American Indian	.2056	.2780	2.92	.0874	1.35
Asian	.4372	.6630	5.48	.0193	1.52
Black/African American	.0786	.1472	10.12	.0015	1.87
Hispanic/Latinx	.2141	.3565	18.83	<.0001	1.67
White	.2821	.4308	57.27	<.0001	1.53
Two or More	.2110	.3268	12.07	.0005	1.55
Non-resident Alien	.2541	.4667	7.50	.0062	1.84
Unknown	.1842	.3368	5.86	.0155	1.83
Age	p_1	p_2	χ^2	p-value	Odds Ratio
Under 21	.2892	.4158	71.70	<.0001	1.44
22-29	.0621	.2232	40.31	<.0001	3.59
30-39	.0515	.1250	7.19	.0073	2.43
40-49	.0510	.1806	5.86	.0155	3.54

Note: p_1 represents AYs 16 and 17, p_2 represents AYs 18 and 19

The analysis of each demographic group included was statistically significant, except students who identified as American Indian (p = .0874).

Research Question Two

The second research question (RQ2) asked, are there differences in the success rates of College Algebra/Precalculus 1 students before and after the implementation of corequisite courses? If so, what are those differences? RQ2 was an analysis comparing the success rates of students who took College Algebra pre-policy implementation and students who took Precalculus 1 post-policy implementation. The purpose of RQ2 was to investigate if allowing students who had not completed a DM sequence to enroll in Precalculus 1, along with a corequisite DM course, affected the success rates for the course.

Participants. The analysis for RQ2 included all College Algebra/Precalculus 1 sections, excluding online, Honor's, and concurrent enrollment sections. The participants from AYs16 and 17 enrolled in College Algebra pre-policy implementation. These students were either placed into College Algebra or had successfully completed all or part of the DM sequence, depending on their original placement. The participants from AYs 18 and 19 were enrolled in Precalculus 1 (PC) post-policy implementation. These students were either placed into PC, were enrolled in the corequisite DM course, either by placement or by successfully completing part of the DM sequence. All students enrolled in College Algebra were college ready according to the placement policies at that time. Some students enrolled in PC were college-ready, but some were not deemed college-ready according to the new Mathways policies.

Results. The researcher investigated the data to ensure it met the assumptions for an independent t-test. The first assumption is the normality of the data. The normality of data sets is determined by its skewness and kurtosis. The data used in the analysis had a skewness of -0.114, with a standard error of 0.137. If the absolute value of the skewness is more than 2, the data are too skewed to use parametric tests of significance. The kurtosis of the data was -0.484, with a standard error of 0.274. Kurtosis measures the shape of the data. If the absolute value of the kurtosis is beyond two, the data's shape is out of the range of normality, meaning parametric tests cannot be used. The second assumption tested was the homogeneity of variances. Levene's test for equality of variances revealed the two samples to have equivalent variances ($F = 0.786$, $p = 0.376$). Therefore, the data set used in the analysis met the assumptions for an independent samples t-test.

An independent samples t-test was conducted at an alpha level of .05 to answer RQ2. The null hypothesis stated that there was no significant difference in the success rates of College Algebra/Precalculus 1 students comparing pre- and post-policy implementation. The alternative hypothesis was that there was a difference in the success rates. When comparing the differences in the success rates pre- ($M = .665$, $SD = .178$) and post-policy implementation ($M = .690$, $SD = .161$), the independent samples t-test was not shown to be statistically significant ($t(313) = -1.235$, $p = .218$). Therefore, the researcher failed to reject the null hypothesis. The result provides evidence to suggest there is no difference in the success rates of College Algebra/Precalculus 1 pre- and post-policy implementation.

The researcher used chi-square tests of two proportions to detect differences in the proportions of students succeeding in the College Algebra/Precalculus 1 course by gender, enrollment status, and race/ethnicity. Similar to RQ1 students with "no response" for gender and Pacific Islander students were excluded because there were not enough in the sample to satisfy the assumptions of the chi-square test. Table 5.3 displays the summary results of this analysis.

Table 5.3

Summary Analysis by MCC's Demographics

Gender	p_1	p_2	χ^2	p-value
Female	7541	.7516	0.01	.9065
Male	.6607	.6384	0.78	.3784
Enrollment Status	p_1	p_2	χ^2	p-value
Full-Time	.7175	.7164	0.00	.9590
Part-Time	.7163	.6534	3.31	.0638
Race/Ethnicity	p_1	p_2	χ^2	p-value
American Indian	.7000	.6282	0.97	.3249
Asian	.8000	.8286	0.29	.6253
Black/African American	.7255	.6389	1.02	.3125
Hispanic/Latinx	.7248	.6842	0.71	.4000
White	.7148	.6981	0.55	.4600
Two or More	.6101	.6545	0.74	.3906
Non-resident Alien	.8372	.8478	0.02	.8907

Note: p_1 represents AYs 16 and 17, p_2 represents AYs 18 and 19

Research Question Three

The last research question (RQ3) asked, are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences? RQ3 was an analysis comparing the success rates in Precalculus 1 of students enrolled in a corequisite course and those who were not. The purpose of RQ3 was to investigate if students who had not completed a DM sequence and needed a corequisite DM course, along with Precalculus 1, succeed at the same rate as students who only enrolled in the Precalculus 1 course.

Participants. The participants for RQ3 are students enrolled in PC sections for AYs 18 and 19. The comparison groups were 1) students only enrolled in the PC course, and 2) students enrolled in both the PC course and the corequisite DM course.

Results. The researcher investigated the data to ensure it met the assumptions for an independent t-test. The first assumption was the normality of the data. The data set had a skewness of -0.258 with a standard error of 0.153. If the absolute value of the skewness is more than 2, the data are too skewed to use parametric tests of significance. The kurtosis of the data was -0.548, with a standard error of 0.306. Kurtosis measures the shape of the data. If the absolute value of the kurtosis is beyond two, the data's shape is out of the range of parametric tests. The second assumption tested was the homogeneity of variances. Levene's test for equality of variances revealed the two samples to have equivalent variances ($F = 0.429$, $p = 0.513$).

An independent samples t-test was conducted at an alpha level of .05 to answer RQ3. The null hypothesis stated that there was no difference in the success rates of students enrolled in both PC and the corequisite DM course, and students only enrolled in the PC course. The alternative hypothesis stated that there is a difference in the success rates of students enrolled in both PC and the corequisite DM course, and students only enrolled in the PC course. When examining the differences in the success rates of students enrolled in both PC and corequisite DM course ($M = .678$, $SD = .195$) and students only enrolled in PC ($M = .702$, $SD = .190$), the independent samples t-test was not shown to be statistically significant ($t\ (250) = 1.019$, $p = .309$). Therefore, the researcher failed to reject the null hypothesis. The result provides evidence to suggest there is no difference in the success rates of students enrolled in both PC and the corequisite DM course, and students only enrolled in the PC course.

Conclusion

This chapter presented the results of the analyses for each research question. The sixth chapter will include a discussion and the implications of the results, and areas for further research on the topic of developmental mathematics and corequisite courses.

CHAPTER VI

DISCUSSION

The current study sought to analyze the implementation of corequisite developmental mathematics (DM) courses and multiple college-level mathematics courses. Several foundations, think-tanks, and associations are promoting these measures to higher education institutions (Bailey, Jaggers, & Jenkins, 2015; “History,” 2019; “The Blueprint,” 2019). The goal of these measures is to improve student retention and graduation by allowing an increased number of first-time enrolling (FTE) students an opportunity to take a gateway mathematics course within their first fall and spring of enrollment. This chapter will discuss the findings of the analysis and the future of research on this topic.

Staggering numbers of FTE students are entering college and are referred to DM coursework, as much as 70% (Bailey, Jeong, & Cho, 2010; Okimoto & Heck, 2015). Only 31% of community college students referred to DM courses complete the sequence within three years (Bailey, Jeong, & Cho, 2010). Completing a DM sequence does not necessarily ensure the student will complete the gateway mathematics course or graduate. Community colleges have spent enormous amounts of time and resources to identify problems with DM courses and implement strategies to address those issues (Bailey, 2009; Bassett & Frost, 2010; McClenney & Dare, 2013; Merseth, 2011).

One innovation that is being promoted and implemented in community colleges across the nation is corequisite DM course and the use of multiple gateway mathematics courses. Corequisite DM courses differ from traditional DM sequences. Institutions using traditional models have either two or three DM courses to be completed in succession since each course in the sequence serves as a prerequisite for the next course (Bailey, Jeong, & Cho, 2010). In contrast, corequisite DM courses are taken concurrently with a college-level gateway course (Columbia University, 2013; McClenney, Dare, & Thomason, 2013). The use of corequisite courses allows students traditionally labeled as not college ready in mathematics to enroll in a gateway mathematics courses to satisfy their degree requirements. The use of multiple gateway mathematics courses allows institutions to guide students to courses with content more aligned with their major ("The Blueprint," 2019).

This study analyzed the effectiveness of the implementation of corequisite DM courses and multiple gateway courses. Additionally, the impacts of implementing these measures on a College Algebra course success rates.

Research Questions

In order to analyze the effectiveness of the implementation of corequisite DM and multiple gateway mathematics courses, the researcher sought to answer the following three research questions:

1. What effect does the implementation of corequisite developmental mathematics courses have on the percentage of first-year students who pass a gateway course within one year?

2. Are there differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses? If so, what are those differences?
3. Are there differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1? If so, what are those differences?

Interpretation of Results

This section will discuss the interpretation of the results of the individual research questions first, and then further discuss the implications of these results for community colleges, mathematics departments, and students.

Research Question One. The first research question (RQ1) sought to analyze the effect of the implementation of corequisite developmental mathematics courses on the percentage of first-year students who pass a gateway course within one year. More specifically, the objective of RQ1 was to examine the implementation of corequisite DM courses and multiple gateway courses brought forth by the policy changes at Midwestern Community College (MCC). The chi-square test was used to analyze the two academic years (AYs 16 and 17) pre- and post-policy implementation. The results suggest that the proportion of FTE students completing a gateway mathematics course significantly increased from $p_1 = .197$ to $p_2 = .272$ ($\alpha = .05$, $p < .0001$).

The significant difference between the two proportions indicates that MCC met one of the major goals in the policy implementation, to increase the proportion of students completing a gateway mathematics course within one year. Previous research has shown that students who complete a gateway course within the first year are more likely to be retained for the next year (Bailey, Jaggers, & Jenkins, 2015). MCC's implementation of an abbreviated DM sequence which leads students to corequisite enrollment with a gateway course has led to two years of increased proportions of FTE students completing their gateway course, (Table 6.1).

Table 6.1

Proportion of FTE Students Completing Gateway Mathematics Course in One Fall and Spring

	AY	Proportion	Two-Year Aggregate
Pre-Implementation	16	.200	----
	17	.194	.197
Post-Implementation	18	.265	-----
	19	.279	.272

The overall results did not achieve the threshold of being above 60%, as reported by Complete College America ("The Blueprint," 2019), but does show tremendous progress. Major significant distinctions between MCC's state and the states included in "The Blueprint" (2019) exist. One is that MCC has two courses before corequisite enrollment, instead of zero or one course. Another difference is that MCC is an Open Access institution while the states included in CCA's report have Adult Basic Education requirements. This requirement means that incoming students must be able to perform at least a high school level in mathematics, reading, and writing. The last major difference is that MCC currently does not force students to enroll in DM courses in their first semesters. This distinction means that FTE students may choose to delay enrollment in

DM courses, adversely effecting the proportion of FTE students who earn a gateway mathematics credit within one fall and one spring.

In addition to examining the increase in success rates for all students, an analysis was conducted to examine subgroups to determine if there were significant increases in those student groups as well. This analysis was conducted because research suggests that placement practices using standardized testing creates inequity between racial groups (Bahr, 2015). Once the data was disaggregated by demographic groups, all but four groups (students with "no response" for gender, students older than 50, and students who identified as either Pacific Islander or American Indian) showed a significant increase in the proportion of FTE students successfully completing a gateway mathematics course. Students with "no response" when asked gender, students 50 years old or older, and Pacific Island students did not have counts more than five in order to meet the assumptions of the chi-square test of two proportions, and thus were not analyzed using this method.

When the data were separated by race/ethnicity, FTE students identifying as American Indian had an increased proportion, but not at a level of statistical significance ($p = .0874$). A troubling finding is the proportion of African American students who are succeeding in a gateway mathematics course within the first fall and spring. While the proportion did increase significantly from $p_1 = .0786$ to $p_2 = .1472$, the proportion of African American students is thirteen percentage points behind the next lowest race/ethnicity. While the data is concerning, examination of the odds ratio shows that African American/Black students are now 1.87 times more likely to earn their gateway mathematics credit. This result can be related to MCC's placement procedures utilized over the four years included in the study. MCC primarily used ACCUPLACER, ACT, and SAT scores to place students in the DM sequence. Beginning with AY20 MCC began using high school GPA (HSGPA) because research (Castro, 2013; Freedle, 2003; Jaschik, 2015; Rattani, 2016; Santelices & Wilson, 2010) has shown that standardized tests, such as the ACT and SAT, are culturally biased and the use of HSGPA to be both more predictive of success in DM and gateway mathematics courses and less racially biased (Bahr et al., 2019). White students did realize the most significant gain, from p_1 = .2821 to p_2 = .4308, followed closely by students who identified as Hispanic/Latinx, from p_1 = .2141 to p_2 = .3565. Asian students both started and ended with the greatest proportion of students completing a gateway mathematics course, from p_1 = .4372 to p_2 = .6630.

When separating students by enrollment status, full-time students realized the greatest increase in success rates, from 36.69% to 68%. Bahr (2009) reported that this is related to the fact that who enroll full-time complete more courses than students who enroll part-time, and that part-time tend to delay enrolling in mathematics courses.

Research Question Two. The second research question (RQ2) was designed to determine if there were differences in the success rates of College Algebra/Precalculus 1 students before and after implementation of corequisite courses. The objective of RQ2 was to examine the effect on success rates in College Algebra/Precalculus 1 when enrolling students who have not been deemed college ready by MCC's placement procedures into a gateway mathematics course with a corequisite support course. The researcher compared the success rates of College Algebra sections pre-policy implementation to the success rates of Precalculus 1 (PC) post-policy implementation.

The results showed no significant difference in the success rates pre- (*M* = .665) and post-policy implementation (*M* = .690). This result suggests that the success rates of College Algebra/Precalculus 1 were not affected by enrolling students who had not completed a DM sequence or did not qualify for a gateway mathematics course, according to placement policies.

This result is important to faculty who do not want to decrease the success rates of the College Algebra/Precalculus 1 course. Additionally, the chi-square tests of two proportions for gender, enrollment status, and race/ethnicity showed no significant difference in the success rates of students enrolled in College Algebra pre-policy implementation and students enrolled in Precalculus 1 post-policy implementation (Table 5.4). This result suggests that policy implementation neither disadvantaged nor advantaged students in any demographic group.

Research Question Three. The third research question (RQ3) sought to determine if there were differences in the success rates of Precalculus 1 students in the corequisite course and students who are only enrolled in Precalculus 1. The objective of RQ3 was to analyze the differences in the success rates of students enrolled in PC with the corequisite course and students enrolled only in PC. The researcher analyzed the success rates of PC students using only sections also paired with a corequisite DM course. Each of these PC sections had students also enrolled in the corequisite and those that were not. The analysis of the success rates showed no significant difference in the success rates of students enrolled in the corequisite course (*M* =.678) and the students enrolled in PC only (*M* = .702). This result provides evidence that students who have not yet completed a DM sequence can succeed in the gateway mathematics course of

Precalculus 1 at the same rate as those who are deemed college ready by MCC's placement policies. MCC students who have not completed a traditional DM sequence have completed an abbreviated sequence which serves as a prerequisite to enrolling in a corequisite DM course and the gateway course of Precalculus 1.

Synthesis of Results. The results of this study are important for advocacy for using corequisite courses and multiple gateway mathematics courses. When faculty are considering implementing these measures, there are generally three concerns. The first concern whether implementing corequisite courses and multiple gateway mathematics courses will increase the number of students finishing their college-level math in one year. The analysis of RQ1 suggests a significant increase, from 19.7% to 27.2%, with an odds ratio of 1.57. The odds ratio shows that FTE students are now 1.57 times more likely to earn their gateway mathematics credit within their first fall and spring of enrollment. Open access institutions, such as MCC, have little problem enrolling FTE students, retaining them is a much larger concern. While this is not solely the responsibility of the Mathematics Department, studies have shown that students who succeed and earn credit for gateway mathematics courses are significantly more likely to be retained (Bailey, Jaggers, & Jenkins, 2015). The policies MCC implemented had the desired effect; they significantly increased the proportion of FTE students earning their gateway mathematics credit within one year. An additional benefit was the inclusion of Quantitative Reasoning as a gateway mathematics course. Its inclusion means that students who enrolled in the course (non-STEM majors) were able to learn mathematics content more relatable to their majors (Bailey, Jaggers, & Jenkins, 2015).

Secondly, faculty do not want to include DM students in their college-level courses if it means the success rates of the college-level course will decrease. To do so would be to enroll students in a gateway mathematics course with a decreased likelihood of succeeding, creating another barrier between student and degree attainment. The results show that the success rate increased, but no to the level of statistical significance. Finally, faculty want to know if students who need a corequisite course can succeed at the same rate as those who do not. The results for RQ3 suggest that students enrolled in the corequisite support course succeed in the PC course at a similar rate to the students only enrolled in the PC course.

Implications

The results of this research have implications for institutions of higher education, particularly community colleges. Institutions which desire to increase the proportion of their entering students who earn credit for a gateway mathematics course within the first year on enrollment should consider the results of RQ1. The results showed a significant increase in FTE students earning gateway mathematics, from 19.7% to 27.2%. This result means that incoming students are now 1.57 times more likely to earn their gateway mathematics credit in their first fall and spring of enrollment. Past research reports that students who earn their gateway mathematics credit within the first year are more likely to be retained and are more likely to persist to graduation (Bailey, Jaggers, & Jenkins, 2015; "The Blueprint" 2019).

There are implications for mathematics departments, as well. Mathematics faculty should consider the differing skills needed for students in different majors. College Algebra/Precalculus prepares students for the Calculus sequence. However, many majors do not require calculus in any form. In the case of Jackson State (Bassett & Frost, 2010), the mathematics department asked other departments what mathematics skills they wanted their students to have, then designed modules to serve those needs.

Mathematics departments considering implementing a sequence similar to MCC's should be encouraged by the results of this research. Using multiple gateway mathematics courses and corequisite DM courses, MCC significantly increased the proportion of FTE students obtaining gateway mathematics credit in the first year, while not significantly affecting the success rates of Precalculus courses. Additionally, this research shows that students who enroll in Precalculus 1 with a corequisite DM course succeed at similar rates when compared to the students who enroll in only Precalculus 1. Mathematics departments should consider discontinuing the practice of serving as "gatekeepers" and act more like "gateways" to student success.

The research findings also have implications for students. In traditional three-course DM sequences, students placed in the lowest DM course had to pass four courses to obtain gateway mathematics credit. Students in this sequence would be required to complete at least four semesters of mathematics if the student passed each course and enrolled in the next one in sequential semesters. With MCC's model, a student with the same placement can enroll in Math Foundations 1 and test into Math Foundations 2 in the fourth week. If the student passes Math Foundations 2, they can then enroll in either Precalculus 1 or Quantitative Reasoning with corequisite support in their second semester. This student would obtain their gateway mathematics credit two semesters sooner than in MCC's previous model. By doing so, these students save tuition costs for the Math Foundations 1 course. This cost savings prevents some students from taking on student loans for another three-credit hours, decreasing their student loan debt after completing their degree. Student loan debt is a concern for all students (Avery & Turner, 2012; Ma & Baum, 2016), but can be especially troublesome for Black/African American students (Sullivan, Meschede, Shaprio, & Escobar, 2019). Sullivan, Meschede, Shaprio, & Escobar (2019) reports that student loan burdens have a longer term effect for Black/African American students, when compared to their white counterparts. Additionally, students enrolling in DM sequences similar to MCC's will see a shorter path to success.

Future Research

Many colleges and universities are implementing corequisite DM courses and multiple gateway mathematics courses ("The Blueprint," 2019; "Where We Work," 2019). There are many formats of delivering corequisite DM courses. For example, MCC used a three-hour course while others in the same state use a two-hour course or a lab. For this reason, additional research should be conducted to analyze each of these formats. Research could also be conducted to compare the formats to better identify best practices.

Specifically, at MCC, more research is needed to analyze the differences with the introduction of high school GPA (HSGPA) as a placement measure. This research showed there are alarmingly low rates of Black/African American students completing a gateway mathematics course within the first fall and spring of enrollment when compared to other races/ethnicities. Future research should explore if the use of HSGPA may be shown to have the desired effect of minimizing racial bias in the placement procedures at MCC.

Another area of research at MCC should be tracking the students who test out of Math Foundations 1 (MF1) into Math Foundations 2 (MF2) during the fourth week of the semester. Do those students succeed at the same rate as the students who had qualified for MF2 before the semester, either by placement or by succeeding in MF1? If the students who transfer into MF2 succeed in that course, do they then succeed in a gateway mathematics course while also enrolled in a corequisite DM course?

Conclusion

The purpose of this research was to examine the implementation of multiple gateway and corequisite developmental mathematics courses at Midwestern Community College. MCC implemented these innovations by changing the developmental mathematics policies after an academic year of planning. The policy changes resulted in significant increases in the proportions of first-time enrolling students obtaining credit in a gateway mathematics course, while not affecting the success rates of their College Algebra/Precalculus 1 course. Additionally, Precalculus 1 students who concurrently enrolled in the corequisite DM course succeeded at similar rates to students enrolled in only PC.

The results of this research can be used as advocacy for community colleges to implement multiple gateway mathematics and corequisite DM courses. Chapter 3 explains the context of the study and a roadmap to mathematics departments researching these innovations.

Students realize the greatest benefit from this research. As more institutions implement DM policies similar to MCC’s increasing numbers of students will obtain their gateway mathematics credit within the first year of enrollment, increasing their likelihood to persist towards graduation. Additionally, as fewer students are required to take a calculus preparation course, they will learn mathematics skills more applicable to their major and career choice. Both of these results lead to a better-educated populace, thus improving our democracy.

Finally, it is the opinion of the researcher that using more appropriate gateway mathematics and corequisite courses allows mathematics departments to stop acting as gatekeepers and begin acting as gateways to increased student success and graduation.

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APPENDICES

Appendix A: Permission to use graphic

ORANGE MAIL

Baker, Joshua <baka@ostatemail.okstate.edu>

Adult Learning Theory Graphic
3 messages

Baker, Joshua <baka@ostatemail.okstate.edu> Wed, Mar 20, 2019 at 1:21 PM
To: raswanson5@gmail.com

Dr. Swanson,
Can I have permission to use a graphic from your book with Dr. Knowles and Dr. Holton III regarding Andragogy in Practice?

Thank you for taking my call today.

--
Joshua Baker

Richard Swanson <raswanson5@gmail.com> Wed, Mar 20, 2019 at 1:39 PM
To: "Baker, Joshua" <baka@ostatemail.okstate.edu>

Joshua— Permission granted assuming a full citation appears with the graphic. Best Regards. —Richard Swanson
[Quoted text hidden]

Baker, Joshua <baka@ostatemail.okstate.edu> Wed, Mar 20, 2019 at 2:17 PM
To: Richard Swanson <raswanson5@gmail.com>

Thank you sir!
[Quoted text hidden]
--
Joshua Baker

Appendix B: MCC Course Learning Outcomes for Precalculus 1

MATH 1513 Precalculus 1 and MATH 0123 Essentials:

State Mandated Learning Objectives for MA 203 (corresponds to MCC's MATH 1513)

1. Identify quantities and changes in quantities in mathematical representations, and distinguish constants from variables.
2. Compute and interpret constant and average rates of change of quantities in multiple representations.
3. Create models for real-world situations through appropriate mathematical strategies.
4. Interpret functions and convert between their representations, including symbols, tables, graphs, and words.
5. Algebraically solve equations including linear, quadratic, polynomial, rational, radical, absolute value, exponential, and logarithmic.
6. Algebraically solve inequalities including linear, quadratic, polynomial, rational, and absolute value.
7. Solve systems of linear and non-linear equations.
8. Perform operations on functions and identify the properties and characteristics of functions. Such properties and characteristics include domain and range, increasing and decreasing, one-to-one, inverses, even and odd, end behavior, relative extrema, and vertical and horizontal asymptotes.
9. Identify and sketch graphs of functions including linear, polynomial, absolute value, rational, radical, piecewise functions, exponential, logarithmic, and use transformations of basic graphs.

MCC Course Learning Outcomes for MATH 1513:

Students will be able to:

1. Solve equations and inequalities. Chapter 1 *(Links to State Objectives 1, 3, 4, 5, & 6.)*
2. Identify the properties of functions. Chapter 2 *(Links to State Objectives 1, 2, 4, 8, 9, & 11.)*
3. Apply polynomial and rational theorems. Chapter 3 *(Links to State Objectives 3, 10, 11, & 12.)*
4. Analyze exponential and logarithmic functions. Chapter 4 *(Links to State Objectives 3, 4, 5 10, 11, & 12.)*
5. Solve systems of equations. Chapter 9 *(Links to State Objective 7.)*

Appendix C: MCC Precalculus 1 Core Content

Precalculus 1 Core Content

(This list does NOT represent the order in which these sections should be covered.)

Chapter 1:

Section 1.3: Complex numbers

Basic concepts: Example 1a,c

Operations on complex numbers: Examples: Example 2a,b,c, 5a,b,c

Section 1.4: Quadratic Functions

Square root property: Example 2

Completing the square: Examples 3, 4

Quadratic Formula: Examples 5, 6

Section 1.5: Applications and Modeling with Quadratic Equations

Applications: Examples 1 – 4

Section 1.6: Other Types of Equations and Applications

Rational Equations: Ex 1a, 2a

Work Rate Problems: Ex 3

Equations with Radicals: Ex 4, Exercise #74, Ex 5

Equations with Rational Exponents: Ex 7b

Section 1.7: Inequalities

Quadratic inequalities: Examples 5, 6, 7

Rational inequalities: Examples 8, 9

Solving polynomial inequalities: Exercise #96

Section 1.8: Absolute Value Equations and Inequalities

Absolute Value Equations: Ex 1a,b

Absolute Value Inequalities: Ex 2a, Ex 3 (change $>$ to $\geq$), Ex 4a,b,c

Chapter 2:

Section 2.1 Rectangular Coordinates and Graphs

Distance Formula: Examples 3, 4

Midpoint Formula: Example 5b, 6

Section 2.2 Circles

Center Radius Form of a Circle: Examples 1,2

General Form of a Circle: Examples 3, 4, discuss 5

Applications: Example 6

Section 2.3 Functions

Relations & Functions: Example 1

Domain & Range: Examples 2, 3

Determining Whether Relations Are Functions: Examples 4, 5

Function Notation: Examples 6, 7, 8

Increasing, Decreasing and Constant Functions: Examples 9, 10

Section 2.4 Linear Functions

Average Rate of Change: Example 8

Linear Models: Example 9

Section 2.5 Equations of Lines and Linear Models

Modeling Data (Linear regression): Examples 7 and exercise 63

Section 2.6 Graphs of Basic Functions

Continuity: Example 1

The Identity, Squaring, and Cubing Functions

The Absolute Value Function

Piecewise-Defined Functions: Examples 2,

Relation $x = y^2$

Section 2.7 Graphing Techniques (Transformations)

Stretching and Shrinking: Example 1

Reflecting: Example 2

Symmetry: Examples 3, 4

Even & Odd Translations: Example 5

Translations: Examples 6, 7, 8, 9

Section 2.8 Function Operations & Composition

Arithmetic Operations on Functions: Examples 2, 3

The Difference Quotient: Example 4

Composition of Functions and Domain: Examples 5, 6, 7, 8, 9

Chapter 3:

Section 3.1 Quadratic Functions and Models

Vertex Formula: Example 4

Exercises 25, 29

Quadratic Models: Example 5, 6 (linear regression)

Section 3.2 Synthetic Division

Synthetic Division: Example 1

Remainder Theorem: Example 2

Potential Zeros of Polynomial Functions: Example 3

Section 3.3 Zeros of Polynomial Functions

Factoring a Polynomial given a Zero: Example 2

Rational Zero Theorem: Example 3

Zero Theorem & Multiplicity: Example 4

Complex Zeros: Example 5

Section 3.4 Polynomial Functions: Graphs, Applications, and Models

Graphs of f(x) = ax^n

Increasing/Decreasing: Example 1

Behavior of graphs: Example 2

Locating a Zero: Example 5

Section 3.5 Rational Functions: Graphs, Applications, and Models

Graphing Rational Functions: Examples 1, 2, 3, 5, 6, 7, 8

Asymptotes: Example 4

Chapter 4:

Section 4.1 Inverse Functions

One-to-One Functions: Example 1, 2

Inverse Functions: Example 3, 4

Finding Equations of Inverse Functions: Example 5, 6, 7, 8

Section 4.2 Exponential Functions

Exponents and Properties

Evaluating Exponential Functions: Example 1

Graphing Exponential Functions: Example 2, 3

Exponential Equations: Example 6

Compound Interest: Example 7, 8

The number e and Continuous Compounding: Example 9

Exponential Models: Example 11

Section 4.3 Logarithmic Functions

Logarithms: Example 1

Logarithmic Equations: Example 2

Graphing Logarithmic Functions: Example 3, 4

Properties of Logarithms: Example 5, 6, 7

Section 4.4 Evaluating Logarithms and the Change of Base Theorem

Evaluating Common Logarithms: Example 1

Applications and Models with Common Logarithms: Example 2, 3, 4

Natural Logarithms: Example 5

Applications and Models with Natural Logarithms: Example 6

Logarithms with Other Bases: Example 8

Section 4.5 Exponential and Logarithmic Equations

Solving Exponential Equations: Example 1, 2, 3, 4

Solving Logarithmic Equations: Example 5, 6, 7, 8, 9

Applications and Models: Example 11

Section 4.6 Applications and Models of Exponential Growth and Decay

Growth Function Models: Example 1, 2, 3

Decay Function Models: Example 4, 5

Chapter 9:

Section 9.1 Systems of Linear Equations

Solve a system of 2 linear equations: Examples 1, 2, 3, 4

Solve a system of 3 linear equations: Example 6

Solve application problems involving a system of 3 linear equations: Example 9

Enrichment: Section 9.2 Matrix Solutions of Linear Systems

Solve systems of linear equations using Gauss-Jordan method: Examples 1, 2, 3, 4

Enrichment: Section 9.3 Determinant Solution of Linear Systems

Evaluate a 2x2 and 3x3 determinant: Examples 1, 3

Section 9.5 Nonlinear Systems of Equations

Solve a nonlinear system of equations: Examples 1, 2, 5

Section 9.7 Properties of Matrices

Perform matrix operations: Examples 2, 3, 4, 5, 6, 7

Chapter 10:

Enrichment: Section 10.1 Parabolas

Graphing Parabolas: Examples 1, 2

Exercises 1, 2 (Pg. 966) – Added as of 12/2017

Enrichment: Section 10.2 Ellipses

Graphing Ellipse: Examples 1, 4

Writing Equations of Ellipses: Example 2

Application of Ellipses: Example 6, 7

Enrichment: Section 10.3 Hyperbolas

Graphing Hyperbolas: Examples 1, 2, 3

Writing Equations of Hyperbolas: Example 5

Enrichment: Section 10.4 Summary of Conic Sections

Identifying Conics: Example 1, 2

Chapter 11: Changed to Enrichment as of 4/20/18 per new state CLOs

Enrichment: Section 11.1 Sequences and Series

Find terms of a sequence: Examples 1, 2

Evaluate a finite series using sigma notation: Examples 4, 5

Enrichment: Section 11.2 Arithmetic Sequences and Series

Find terms of an arithmetic sequence: Examples 2, 3, 4

Evaluate an arithmetic series using the sum formulas: Examples 7, 8, 9

Enrichment: Section 11.3 Geometric Sequences and Series

Find terms of a geometric sequence: Examples 1, 2, 3

Evaluate a finite geometric series using the sum formula: Examples 5, 6

Evaluate an infinite geometric series using the sum formula: Example 8

Appendix D: OSU IRB Approval

Oklahoma State University Institutional Review Board

Date:	06/11/2019
Application Number:	ED-19-79
Proposal Title:	Evaluating the Implementation of Mathematics Pathways
Principal Investigator:	Joshua Baker
Co-Investigator(s):	
Faculty Adviser:	Adrienne Sanogo
Project Coordinator:	
Research Assistant(s):	
Processed as:	Not Human Subjects Research

Status Recommended by Reviewer(s): Closed

Based on the information provided in this application, the OSU-Stillwater IRB has determined that your project does not qualify as human subject research as defined in 45 CFR 46.102 (d) and (f) and is not subject to oversight by the OSU IRB. Should you have any questions or concerns, please do not hesitate to contact the IRB office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

Appendix E: MCC IRB Approval

Human Subjects Review
Proposal Title: Evaluating the Implementation of Mathematics Pathways
IRB #: 19-013

Dear Researcher:

Your research proposal has been approved by the Institutional Review Board at [redacted] Community College. You are authorized to begin your research and implement this study as of the date of this email. This authorization is valid for one year from today. After this authorization runs out, you are required to submit a continuation or renewal request for IRB approval.

This approval is granted with the understanding that the research will be conducted within the published guidelines of the [redacted] Institutional Review Board and as described in your application. Any changes or modifications to the approved protocols should be submitted to the IRB for approval. Please use the IRB number provided above in all your communications regarding this study.

Thank you for sending us your application for research involving human subjects. By doing so, you safeguard the welfare of our students and federal funding of our college.

Best,

Allison

Allison E. Tifft, Ph.D.

IRB Intake Coordinator

VITA

Joshua Aaron Baker

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVALUATING THE IMPLEMENTATION OF MATHEMATICS PATHWAYS

Major Field: Mathematics Education

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Education with an Option in Mathematics Education at Oklahoma State University, Stillwater, Oklahoma in December, 2019.

Completed the requirements for the Master of Science in Mathematics Education at Northeastern State University, Tahlequah, OK in 2011.

Completed the requirements for the Bachelor of Science in Mathematics Education at Northeastern State University, Tahlequah, OK in 1998.

Experience:

Faculty Department Chair and Associate Professor of Developmental Mathematics, Tulsa Community College, Tulsa, OK, Jan. 2011-Present

Professional Memberships:

National Organization for Student Success, Oklahoma Association of Developmental Educators, Golden Key Member