A COREQUISITE PATHWAY FOR MATHEMATICS:
PAIRING A DEVELOPMENTAL LAB WITH A GATEWAY COURSE

by

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B.S.E., University of Central Missouri, 1997
M.S., University of Central Missouri, 2002
M.S., Montana State University, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

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Manhattan, Kansas

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Abstract

Low success rates in developmental mathematics courses have caused a growing concern for many institutions including moderately selective four-year universities. As a result, institutions have adopted various course redesign models, such as the emporium and replacement models, which take advantage of interactive online learning tools. Though these models have proven successful for increasing completion rates in algebra intensive courses, the models do not address additional concerns for developmental students enrolled in liberal arts mathematics courses. The co-requisite model of instruction is an alternative pathway for students with developmental needs. This model allows students to enroll in the required general education gateway mathematics course concurrent with a developmental mathematics lab, which offers student-centered instruction and just-in-time support for student learning. This study examined the implementation of a co-requisite model of instruction, at one moderately selective four-year university, by investigating the potential of multiple variables for predicting student success.

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Approved by:

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Dedication

To my boys: Cole, Chet and Christopher

To my brothers: Chris and T.J.

Chapter 1- Introduction

Background

American higher education institutions have served as the battleground for arguments in favor of and against developmental education programs for more than 400 years (Parker, Bustillos, & Behringer, 2010). Instructional reform efforts have recently been at the frontline of developmental education forces, resulting from research indicating uniquely low success rates and increasingly high failure rates for students enrolled in developmental mathematics courses (Boylan & Bonham, 2011; Boylan & Saxon, 1996; Capt, Oliver, & Engel, 2014; Edgecombe, 2011; Gerlaugh, Thompson, Boylan & Davis, 2007; Saxon & Boylan, 2001). Critics argue that developmental mathematics courses have created obstacles for students who are working toward a degree or professional certification by lengthening the time to graduation as most developmental math courses are offered for institutional or elective credits only, adding additional semesters to a student's program of study (Bailey, Jeong & Cho, 2010; Parker et al., 2010; Parsad & Lewis, 2003). Others claim "remedial education costs tax payers twice, teaching academic skills in college that students should have acquired in high school" (Saxon & Boylan, 2001, p. 2).

Contrasting research suggests students completing developmental mathematics courses are just as successful in college-level courses as those students who met college-level or gateway course requirements without remediation (Bailey, Jaggars, & Scott-Clayton, 2013; Brothen, & Wambach, 2004; Damashek, 1999; Smittle, 2003). One study found students who persevered in developmental mathematics course work "were better prepared for college mathematics courses than equivalently mathematically skilled students who did not take a developmental course" (Weinstein, 2004, p. 230). Results from a study by Noble and Sawyer (2013), involving 118,000 students enrolled in one of 75 institutions, found that students enrolled in developmental courses "can complete bachelor's degrees in six years at a rate similar to or higher than that of non-developmental students in five years" (p.63). Additionally, Fernandez, Barone, and Klepfer (2014) reported that developmental education students borrow funds at the same rate and in lower amounts than their peers.

Students enrolled in developmental courses are considered "at-risk" students in need of a variety of instructional methods rather than traditional college lectures alone (Bonham & Boylan, 2011; Mathematics Special Professional Interest Network, 2002; Osterholt & Barratt, 2010). In addition to academic deficits, these students also require assistance in learning the "norms and expectations involved in being a university mathematics student" (Weinstein, 2004, p. 232). Students with developmental needs frequently display high levels of mathematics anxiety and report low self-esteem in mathematics (Smittle, 2003). For these students, the social and emotional realm of university culture can be quite different than their high school experiences. Changes in learning environments, social settings, academic expectations, and personal freedom can contribute to educational challenges (Moore, 2005). Persevering through frustrations and knowing how to deal with stress can also be overwhelming to students with developmental needs (Osterholt & Barratt, 2010). Some researchers recognize the need for developmental courses in preparing underprepared students for college culture along with the rigor of college-level course work through collaborative learning (Moore, 2005; Osterholt & Barratt, 2010).

Although there has recently been research conducted in the field of developmental education, driven by the non-profit organization Complete College America (CCA) established in 2009, most has focused primarily on community college students where about 60 percent of entering students require remediation (Complete College America, 2011). Little research has included developmental students enrolled at four-year institutions; despite reports that approximately 80% of public four-year institutions provide developmental coursework and that approximately 30% of students at these institutions enroll in some form of developmental coursework (“Beyond the Rhetoric,” 2010; Noble & Sawyer, 2013; Parsad & Lewis, 2003; Sparks & Malkus, 2013). A statistical report by Parsad and Lewis (2003) found that institutions generally offer a greater number of developmental mathematics courses than reading or writing courses. One study asserts that “approximately half of the students entering the less selective four-year institutions are not ready for college” even though these students have completed college-preparatory curriculum (“Beyond the Rhetoric”, 2010).

Quantitative studies on developmental course work have concentrated on course redesign models that replace classroom interaction with interactive online resources, overlooking the possible advantages of engaging co-requisite courses. Preliminary evaluations of the co-requisite model “indicate that co-requisite approaches are associated with higher grades and higher completion rates in introductory college-level courses” (Cullinane, 2012, p. 2). However, current articles reporting success of co-requisite courses do not contain substantial evidence of success nor do they investigate how traditional placement policies impact students in a non-traditional developmental pathway (Center for Community College Student Engagement, 2016; Vandal, 2014).

Purpose of the Study

The co-requisite course model offers a pathway of multiple advantages for developmental students by improving cognitive development while supporting social and emotional growth through student-centered, collaborative learning. The traditional pre-requisite algebra pathway relied heavily on student placement in appropriate pre-requisite algebra courses based on standardized assessments, such as the ACT. Because the co-requisite model allows developmental students to enroll directly in the required gateway mathematics course, it seems that traditional algebra placement policies may no longer provide adequate guidelines for enrollment. Likewise, standardized assessments may no longer be appropriate measures for predicting student success in this non-traditional pathway or in courses other than algebra.

The purpose of this study was to investigate the relationships between ACT math score, high school grade point average, attendance in a co-requisite developmental math lab, and mathematics anxiety levels with general education mathematics course performance and student achievement. The following research questions served to guide this study:

Research Questions

1. What is the relationship between gateway course performance, for students enrolled in co-requisite mathematics courses, and each of the following factors: ACT math score, high school grade point average, co-requisite lab attendance, and mathematics anxiety?
2. What is the relationship between student achievement, for students enrolled in co-requisite mathematics courses, and each of the following factors: ACT math score, high school grade point average, co-requisite lab attendance and mathematic anxiety?
3. To what extent do ACT mathematic score, high school grade point average, attendance in a developmental lab, and mathematic anxiety predict student performance in the gateway course for students enrolled in co-requisite mathematics courses?

Significance of the Study

This study contributes to the current body of knowledge focused on developmental education reform at the local, state and national levels by extending research previously limited to community colleges. Strategies for teaching high-risk college students should not be limited to community college classrooms, but should reach out to university classrooms as well. This study may also add to the current research on course redesign models by investigating variables that predict student success in the co-requisite model of instruction for liberal arts mathematics courses. Results of this study have the potential to suggest promising instructional practices addressing critical learning issues faced by developmental students by exploring a model of instruction designed to support social, emotional and intellectual growth.

Limitations of the Study

The sample size of the study is limited by the location of the participating university and could impact research results. Data was collected from one moderately selective four-year institution, over a total of three semesters of co-requisite instruction. It is possible that the results of this study are representative of the university's culture, which could be significantly different than that of other four-year institutions across the nation. Factors such as instructor training and experience are unique to the participating institution.

Definitions of Terms

The following terms are defined as they are related in the context of this dissertation. The researcher developed all definitions not accompanied by a citation.

Co-requisite course model: This model enrolls students in remedial and college-level courses in the same subject at the same time. Students receive targeted just-in-time academic support, in a developmental lab, to help boost their understanding and learning of the college-level course material (Complete College America, 2016).

Course redesign: The process of “re-conceiving whole courses (rather than individual classes or sections) to achieve better learning outcomes at a lower cost by taking advantage of the capabilities of information technology” (Twigg, 2011, p. 26).

Developmental education: “Developmental education is a comprehensive process that focuses on the intellectual, social, and emotional growth and development of all students. Developmental education includes, but is not limited to, tutoring, personal/career counseling, academic advisement, and coursework” (National Association for Developmental Education, 2014, p. 1).

First-generation student: Undergraduate students whose parents never earned a postsecondary degree.

Gateway mathematics course: A required college credit-bearing, general education mathematics course.

Student achievement: For this study, student achievement is defined as the difference in student performance on a pre and post assessment. This difference was used to identify changes in student content knowledge and skills.

Student-centered instruction: Instruction consisting of “an array of complementary approaches to teaching and learning, drawing from multiple theories and trends in education” (Walters et al., 2014, p. 3).

Student performance: A course letter grade of ‘C’ or higher is necessary for the progression to subsequent mathematics courses at most four-year institutions. However, not all students will take more than one general education mathematics course. For this study, student performance was measured by the letter grade earned in the gateway mathematics course. This letter grade was transformed to a numerical value for calculating student performance.

Conceptual Framework

Zone of Proximal Development

Developmental education has often been referred to as remedial education. However, the term remedial implies that there is something to be corrected or fixed. To express developmental as remedial implies that something in the students' background, culture, prior education, or ability to construct knowledge is injured or broken and must be remedied or repaired (Parker et al., 2010). The term *developmental* suggests a growth process or change that can be promoted with assistance (Parker et al., 2010). Developmental education is then better defined as an educational structure, which includes "a holistic focus on cognitive and affective development of students, acknowledges a spectrum of learning styles and needs, and promotes an interdisciplinary range of approaches and student services" (Lundell & Collins, 2001). This structure may include the remediation of deficiencies as just one component (Parker et al., 2010).

Vygotsky, an educator and psychologist of the 20th century, addressed the social and cultural bases of student development in his Zone of Proximal Development (ZPD) theory (Alves, 2014; McKenney, 2013; Moll, 2014; Wass & Golding, 2014; Zaretskii, 2009). While other theorist believed that "biological maturity had to be experienced before certain types of learning could occur," Vygotsky believed that appropriate pedagogy could generate a learning process leading to development (Ornstein & Hunkins, 2013, p. 107). The ZPD theory suggests that with proper scaffolding techniques students are "able to operate at a higher level than they could on their own" and that scaffolding enables students to "learn to operate independently" at higher levels over time (Wass & Golding, 2014, p. 672). The basic idea of the ZPD theory is that instructors must use strategies which present content "so that it is slightly too hard for students to do on their own, but simple enough for them to do with assistance" without offering too much structure or lessening the level of rigor (Wass & Golding, 2014, p. 671). Students learn by solving problems and meeting challenges, so it is important for instructors to not simply remove the challenge but to assist students so that the students can accomplish the task. Assistance may come in the form of prompts from the teacher or classmates, graphic organizers, peer tutoring, or collaboration (Wass & Golding, 2014).

Student-Centered Instruction

Unlike traditional education models, developmental education places a greater emphasis on student development rather than on teacher knowledge. Conventional lecture courses reflect a teacher-centered model of instruction where the teacher holds the knowledge and attempts to transfer the knowledge to assumingly acceptable students. In this traditional lecture format, some students “feel overwhelmed by the amount of material covered in each lecture” (Twigg, 2011, p. 27). Herman (2012) found that teacher-centered lecturing remains the most used format of delivery in traditional STEM (science, technology, engineering and mathematics) courses. On the other hand, developmental courses can provide an opportunity to create an environment for student-centered learning allowing teachers to consider multiple learning styles, individual student needs and cognitive development while encouraging students to take ownership of their learning. Utilizing student-centered pedagogical approaches supported by the ZPD theory, involving students in active learning rather than expecting students to listen to lectures, can also have long-term benefits in additional courses taken throughout the program of study (Weimer, 2011).

Implementing the ZPD theory through student-centered instruction, considered a progressive design, is typically associated with elementary, middle, and secondary mathematics content but is seldom employed in a university course (Wass & Golding, 2014). At the university level “the discipline is a major organizer for the curriculum” allowing textbooks to influence instructional decisions (Ornstein & Hunkins, 2013, p. 165). However, the content of developmental mathematics courses is often equivalent to that of secondary mathematics, suggesting secondary curricular and instructional practices may be appropriate in the developmental mathematics program (Kull, 1996).

A student-centered design prevents the textbook, technology or the teacher from becoming the focus of instruction and allows the student to actively engage in learning through experiments, investigations, problem solving and discourse facilitated by the teacher. Student-centered instruction often involves greater student collaboration through cooperative learning structures, which can support the social and emotional growth of students, alleviating mathematics anxiety while allowing students to build knowledge. Osterholt and Barratt (2010) encourage university level developmental instructors to “move toward student-centered learning in which regular, structured collaborative activities are integrated into the content as the primary delivery system for emotional and social aspects of learning” (p. 27).

This study investigated the results of implementing a co-requisite model of instruction for students with developmental needs at a four-year institution of higher education. In this model, students attended the required gateway mathematics course while concurrently participating in a developmental mathematics lab taught with a student-centered instructional approach. This model focused on supporting students in their major program of study rather than simply re-teaching high school mathematics content though a teacher-centered format (Cullinane, 2012). The developmental lab allowed students to engage with applications of mathematical concepts aligned to curriculum objectives determined by the gateway course.

Summary

While the debate between critics and supporters of developmental education continues, new branches of discussion have grown. These new branches include: 1) developmental education programs at four-year universities in addition to those at community colleges; 2) course redesign models that have replaced classroom instruction with interactive online resources; 3) alternative placement guidelines and program pathways; 4) improved instructional strategies for developmental courses. Traditional placement guidelines have relied heavily on standardized test scores as a means for identifying appropriate student placement in a traditional pre-requisite algebra pathway. A student-centered approach to teaching has been identified as a necessity for addressing the social, emotional and intellectual growth of students with developmental needs, rather than a traditional teacher-centered or content-centered approach.

Transitioning from a traditional teacher-centered algebra pathway to a non-traditional student-centered quantitative reasoning pathway requires an examination of traditional pathway placement policies. The purpose of this study was to investigate relationships between variables, used in a traditional placement pathway, and their contributions to predicting student performance in a non-traditional co-requisite pathway. Because student-centered learning places a greater emphasis on the student, rather than the teacher, and is recommended for advancing social, emotional and intellectual growth of students with developmental needs, this study also explored relationships between attendance in a student-centered lab and mathematics anxiety with student performance in the associated gateway mathematics course.

Chapter 2 - Literature Review

Gateway Mathematics

Previous research studies have offered insight into salient aspects of the current study. The purpose of this chapter is to review relevant literature on the following topics: 1) the historical role of gateway mathematics courses; 2) the traditional mathematics pathway; 3) the reform of developmental mathematics; 4) characteristics of students with developmental needs and success teaching practices for these students; 5) general placement practices for developmental courses.

Historical Perspective

In order to understand where we are going, we must first have knowledge of where we have been. Many of the first American colleges through the 1700s and 1800s were modeled after English colleges, with a focus on training the mind essentially through rote learning (Tucker, 2012). During most of the 1700s students entering college were of a very young age, often as young as 15 and 16, with only a couple of years of education beyond primary school, leaving them scarcely able to read and write (Arendale, 2011; Tucker, 2012). This age was reduced to matriculate some as young as twelve years old during the American Civil War (Munsch et al., 2015). As the enrollment age was dropping, the level of mathematics taught was expanding. Geometry was taken during the senior year of college in the early 1700s but by the beginning of the 1800s geometry became a part of the freshmen curriculum (Arendale, 2011).

Admission criteria, in the early 1800s, fell on the student's ability to pay tuition. As long as a student was able to pay the required tuition fees, he was admitted regardless of his level of academic preparedness (Boylan & White, 1987). By the mid-1800s college students were required, upon admission, to demonstrate proficiency on mathematics examinations (Arendale, 2011). Institutions seeking to “selectively admit” students set admissions standards “higher than the skill and mastery level of average high school graduates” (Arendale, 2011, p. 60). As less selective institutions began opening doors to students with varying academic preparation, administrators found it necessary to create distinct departments to serve the academic needs of underprepared students who “sometimes outnumbered the ‘regular’ college admits” (Arendale, 2011, p. 62). In 1949, the Department of Preparatory Studies at the University of Wisconsin became one of the first to offer remedial courses in reading, writing and arithmetic to accommodate underprepared students (Arendale, 2011; Boylan, 1988; Boylan & White, 1987). To bring structure to the wavering admissions criteria and to address the diverse academic levels of entering students, the College Entrance Examination Board was established in 1890.

In 1862 the Morrill Act “stimulated another period of growth” in higher education, calling for a greater focus on education related to agriculture and mechanical engineering (Boylan & White, 1987, p.4). The Morrill Act allowed states to receive federal land for the purpose of establishing institutions focusing on practical agricultural education without excluding liberal arts studies. The impact of this federal legislation resulted in additional growth in college enrollment including an increase in the number of underprepared students. Nearly “84 percent of the land grant institutions provided some form of remedial education by 1889” (Arendale, 2011, p. 66). In addition, American schools saw a tremendous increase in the number of immigrants with “language differences, poor schooling backgrounds, and the assimilation of the numerous cultures” into the public classrooms following the Civil War (Parker, Bustillos, & Behringer, 2010). At the beginning of the 1900s, prescribed programs of study shifted to an optional elective system to meet the needs and requests of this new population of students, which caused an increase in overall college enrollment but a decline in mathematic programs of study (Tucker, 2012).

In 1913, the U. S. Commissioner of Education determined the objectives of the College Entrance Examination Board, to standardize the admission process across the county and raise academic standards, had not been met as 80 percent of America's higher education institutions continued to offer college preparatory programs (Boylan, 1988). By this time, "more than 80 percent of the nearly 400 postsecondary institutions in the U. S. had established some sort of college preparatory program" with more than 40 percent of first-year college students enrolled in these programs (Arendale, 2011, p. 63). In addition, overall secondary school enrollment was increasing while high school algebra courses saw a continuous decrease in enrollment from 1909 until 1955 (Klein, 2002; Snyder, 1993). Table 2.1 displays the percentages of high school students enrolled in high school algebra courses.

Table 2.1

U.S. High School Students Enrolled in Algebra (Klein, 2002)

School Year	Algebra Enrollment
1909-1910	56.9%
1914-1915	48.8%
1921-1922	40.2%
1927-1928	35.2%
1933-1934	30.4%
1948-1949	26.8%
1952-1953	24.6%
1954-1955	24.8%

Following World War I (1914-1918) and under the influence of recommendations voiced by education reform leader John Dewey, American education systems began to require formal schooling through the 12th grade. This change was followed by a dramatic increase in college enrollment causing colleges "to lower standards to accommodate many of the applicants" (Tucker, 2012, p.4). World War II (1939-1945) provided an additional need for mathematicians with knowledge of "aerial combat, fluid mechanics, shock fronts, code breaking, logistics, and designing the atomic bomb" (Tucker, 2012, p. 8). This need increased the demand for high school mathematics teachers along with increased enrollment of college freshman in calculus courses. During this time, research was also conducted on the essential mathematical needs of enlisted service men. Reeve (1943) and his colleagues found that enlisted men were "ill prepared to cope with the quantitative situations" they would encounter in basic training and that high school students had "limited proficiency in mathematics, and that the war has served only to highlight the evils of a long standing condition" (p. 244). Though these deficiencies were brought to light, little change in mathematics curriculum followed (Schoenfeld, 2004). As a result of the G.I. Bill a great number of services men, nearly 1.1 million, enrolled in postsecondary institutions. Of these, "as many as two-thirds did not have the requisite study skills to succeed in a postsecondary environment" (Parker, Bustillos, & Behringer, 2010, p. 12).

In the 1952 publication, Commission of the Financing of Higher Education, democracy was accused of playing an extreme role in American higher education through the open access admission of excessive numbers of "students who lack intellectual interests" and through efforts to "attend the educational system to their sub-intellectual needs and capacities" (Castator, 1995, p. 18). Eventually, institutions found it necessary to require a core curriculum for all college students in order to provide more structure for content delivery to larger groups of students.

Shadowing the lead of Harvard president Lawrence Lowell and Princeton president Woodrow Wilson, general education requirements were adopted by institutions throughout the nation.

The next great influence on mathematics education arrived with the launch of the Russian spacecraft, Sputnik, in 1957. American politicians attributed poor quality public schools to the Soviet Union's lead in the "space race," igniting education reform efforts (Hofmeister, 2004; Mirel, 2011; Tucker, 2012). This event fueled the Cold War competition placing mathematicians, engineers and scientists in high demand. Calculus became a first-year mathematics course for most college freshman, making college algebra a remedial course for those students not yet ready for calculus studies. Since this time, college algebra has been "considered by many institutions to be the lowest level for which general post-secondary credit can be given" (Herriott & Dunbar, 2009, p. 75).

While the United States had a stronger need for mathematicians, during the Cold War, policymakers focused on mathematics education at both the high school and college levels by reforming course offerings and graduation requirements. When students entered college underprepared for calculus, they were enrolled in college algebra in order to become prepared for calculus as calculus was then viewed as the gateway course for mathematics training. The purpose of college algebra was simply to prepare students for calculus, and this remains the case for many American institutions even today, based on the "content and pedagogy" of current courses (Herriott & Dunbar, 2009, p. 76).

Our national education system continued to experience additional changes in student demographics, growth in technology, and K-12 mathematics curriculum prompting the need for college education reform. Throughout the twentieth century and into the twenty-first, mathematics education in American public K-12 schools experienced multiple phases. Lambdin and Walcott (2007) describe these phases as drill and practice, meaningful arithmetic, new math, back to basics, problem solving, and the current standards and accountability phase. The drill and practice phase emphasized rote memorization of facts and was followed by the meaningful arithmetic phase, which concentrated on real-world applications. The *new math* phase gave attention to the understanding of structure, logic, set language and the need for a spiraled curriculum (Kull, 1996). This phase is also recognized for the introduction of calculus courses at the high school level (Klein, 2002). However, the back to basics chapter returned attention to knowledge and skill development through rote memorization, paper and pencil calculations, and drill and practice (Kull, 1996). The problem-solving period returned focus to discovery learning and the thinking process. Finally, the accountability and assessment phase brought us to standards-based curriculum along with preparation for high stakes state-level testing throughout elementary, middle and secondary grades (Lambdin & Walcott, 2007). With each phase came changes and innovations in mathematics education.

During the late 1900's the United States experienced a shift from students entering college prepared for calculus to a more common group of students entering college with a solid high school mathematics background yet unprepared for college mathematics even at the introductory level. As researchers investigated this concerning situation, attention fell on the National Council of Teachers of Mathematics' 1989 publication *Curriculum and Evaluation Standards for School Mathematics*. These standards were designed to address more than curriculum by declaring equity for all students through improved pedagogy and assessment (Gutstein, 2003; Hofmeister, 2004). The NCTM was challenging the belief that some demographic groups were not capable of learning mathematics and calling for social justice through curriculum reform that would accentuate problem-solving, the use of technology and differentiated instruction for students in K-12 public schools (Kull, 1996; NCTM, 2000; Schoenfeld, 2004). The NCTM's standards were eventually accepted as a framework for state standards, causing the nation to de-emphasize traditional algebra and calculus training in our high schools while emphasizing the use of technology and advocating discovery learning through problem solving (Klein, 2002; Schoenfeld, 2004). Disagreements between those who believed in student-centered, discovery learning and those who believed in traditional systematic training instigated what was referred to as the Math Wars (Klein, 2007; Lambdin & Walcott, 2007; Schoenfeld, 2004).

As high schools accepted this challenge for change, a gap grew between high school achievement levels and college entry levels. By this time, "more than 75% of all American colleges had preparatory departments" (Kull, 1996). An increasing number of college freshmen were found to be in need of remedial education resulting from the assumed "widespread breakdown of academic preparedness from secondary schools" (Munsch et al., 2015). One cause for the need in remediation was the difference between instructional strategies, including curriculum resources adopted by high school educators versus strategies and resources retained by university professors (Klein, 2007; Schoenfeld, 2004). While public K-12 classrooms moved through the different phases of mathematics education, university classrooms remained unchanged, causing large enrollment numbers in pre-college level mathematics courses.

Traditional Mathematics Pathways

College algebra, once viewed as a springboard for mathematics training, is now often listed as a terminal course for many college majors. This begs the question: if college algebra was intended to prepare students for calculus, and students no longer need calculus, what purpose does college algebra now serve? Further, why is developmental mathematics meant to prepare students for college algebra if college algebra is only meant to prepare students for calculus? One study, conducted at the University of Nebraska at Lincoln, found that approximately 20% of students completing college algebra continued in the calculus sequence, yet college algebra was a required course for most students (Herriot & Dunbar, 2009). Furthermore, although college algebra enrollment numbers were high, the typical success rate was not. Gordon (2008) suggested that the focus of college algebra needed to change from the traditional lecture format of instruction for the purpose of preparing students for calculus based on "rote manipulation" to a "meaningful and relevant" course dedicated to real-world situations offering a smoother "transition between high school and college mathematics" (p. 518). Gordon's suggestions supported recommendations publicized by the National Council of Teachers of Mathematics (NCTM), Mathematics Association of America (MAA) and the American Mathematical Association of Two Year Colleges (AMATYC) (Gordon, 2008).

In a 2010 study conducted by the College Board of Mathematical Sciences (CBMS), researchers found that a greater number of students were enrolled in mathematics courses below college level than at college level in two-year colleges. This created a great concern at the community college level and the concern is now reaching four-year institutions, especially those which offer open or moderately selective enrollment. The CBMS research also found that more students were enrolled in pre-college and introductory level courses than calculus courses at four-year institutions (see Table 2.2). Furthermore, the CBMS report noted that more than 65% of college algebra instructors, in mathematics departments at four-year colleges, continue to identify traditional lecture as the primary instructional method.

Table 2.2

Approximate Percent of Mathematics Enrollment

	Two-Year College Mathematics Programs			
Year	1995	2000	2005	2010
Precollege Level	58%	60%	61%	61%
Introductory Level (including Pre-calculus)	21%	22%	20%	20%
Calculus	9%	8%	7%	7%
Other	12%	10%	12%	12%
	Four-year Institutions			
Year	1995	2000	2005	2010
Precollege Level	15%	14%	13%	11%
Introductory Level (including Pre-calculus)	42%	45%	44%	44%
Calculus	37%	35%	37%	38%
Other	6%	6%	6%	7%

Note. Adapted from *Conference Board of the Mathematical Sciences Survey* by the American Mathematical Society (2010).

Universities today are taking a closer look at the traditional algebra pathway to determine whether this pathway is sufficient for all major areas of study or whether college algebra has been emphasized to the point of excluding other valuable applied mathematical concepts (Cooper, 2014). Universities have recently approved alternatives to college algebra in answer to demands made by colleges of art, education, business, health and humanities whose students benefit more from courses focused on reasoning, problem-solving and statistics. Institutions have increased the number of gateway courses offered to include courses such as basic statistics and liberal arts mathematics. These new alternatives have opened the doors for students who enter college with a solid grasp of mathematics and are ready to enroll in a freshman level course assumed to be of equal rigor to college algebra. However, offering these alternative courses does not directly address the additional concern for students who are accepted into moderately selective institutions yet are not mathematically prepared for college level coursework. Nor do these alternative courses, taught in a traditional format, provide a solution for students who struggle to learn from a teacher-centered lecture course.

Developmental Education

Traditional Model

Helping underprepared students succeed in achieving a college-level education has been a challenge for four-year institutions for a very long time (Boylan & Bonham, 2011). Debates on whether or not these students should be admitted to four-year institutions have taken place since at least 1828 when the Yale Report called for terminating the practice of accepting inadequately prepared students (Jehangir, 2002). Those opposing remediation, or the offering of developmental courses in higher education, claim that the financial burden is too high and that the quality of education is too low. On-the-other-hand, those supporting developmental education efforts argue that improving the intellect of this group of students will enrich the intellect of the entire community (Boylan & Bonham, 2011; Saxon & Boylan, 2001). One study (Munsch et al., 2015) describes developmental education as the “great equalizer in higher education; it provides students with opportunities despite past academic performances” (p. 6). The debate started over 175 years ago and is still active today.

Regardless of the oppositions to developmental education, the number of institutions offering college preparatory courses grew. Nearly 80 percent of higher education institutions offered remedial courses and support services from the early to mid-1900s (Arendale, 2011). As a result of offering college preparatory courses for underprepared students, it became necessary to measure students' entry level math skills and content knowledge to determine who was truly in need of developmental assistance and at what level. Eventually, institutions came to rely on standardized, multiple choice placement tests. The American College Test (ACT), created in 1959, was the first college admissions test grounded on information taught in secondary schools and used to determine college readiness (ACT, 2015). This standardized test, along with similar assessments, was used to determine appropriate algebra placement for incoming freshman across the nation. ACT scores were intended to provide an empirical indicator of student readiness for college-level course work for the "most commonly taken entry-level college courses" specifically college algebra and calculus (Clough & Montgomery, 2015, p. 2).

When students were identified as needing developmental course-work, determined by standardized test scores, they were placed in pre-college level courses labeled pre-requisites. In order to serve the diverse student population entering college unprepared for calculus, universities historically offered a pre-requisite course, college algebra. As enrollment increased in these moderately and openly selective institutions, the number of underprepared students increased. Universities began seeing a greater number of students ill-equipped even for college algebra. Though these students were often recent high school graduates, an increasing number were non-traditional students including military veterans. Historical actions such as the G.I Bill, Civil Rights, Women's Movement, and the Immigration Act all pushed education doors wide open for people who previously had little access to post-secondary education (Capt, Oliver, Engel, 2014). To serve this new population of students who had minimal academic training, universities began to offer developmental courses such as intermediate and introductory algebra in order to prepare these new student populations for college algebra.

Students, not meeting the recommended ACT score for entry into college algebra, were considered developmental students who needed remediation before enrolling in a college-level course. Though mathematics pathways are beginning to change by no longer requiring college algebra of all students, the pre-requisite system remains in place at many institutions. Until recently, intermediate and introductory algebra courses were considered pre-requisites for all gateway mathematics courses, including liberal arts courses, at many four-year universities. These developmental pre-requisite courses are typically assigned no mathematics credit because the content is considered to be below college level. Instead, these courses are assigned elective credits that may or may not apply to the number of credits necessary for graduation (Munsch et al., 2015).

Now that many institutions have created alternative pathways, no longer requiring college algebra for all students, there is a new concern for the preparation of developmental students for meeting the required gateway mathematics course. Intermediate and introductory algebra courses were not necessarily designed to prepare students for courses focused on statistics, logic, set theory or finance. Universities are beginning to realize that there is not one pre-requisite course sufficient for preparing students to enter every gateway course now offered (Edgecombe, 2011; Parker et al., 2010).

Developmental Reform

As pathways have transitioned from once requiring college algebra for all major programs of study to now offering alternatives based on the prescribed program of study, preparation for these gateway courses must be considered. We once prepared students for calculus by offering college algebra. We then began to prepare students for college algebra by offering developmental algebra courses. How do we now best prepare students who have a choice between college algebra, statistics and liberal arts mathematics courses?

Some critics of developmental education would argue that developmental courses are only obstacles, preventing students from graduating with a degree or professional certificate. These critics might suggest removing all developmental courses from university offerings or allowing students to elect placement into these courses rather than relying on a more traditional placement policy centered on assessment scores (Brothen & Wambach, 2004). Several states have already "eliminated the state funding of developmental education from four-year institutions" (Wilson, 2012, p. 34).

Often, the voices of such critics fail to be heard as there are louder voices coming from those involved in developmental education initiatives such as the Bill and Melinda Gates Foundation, the Carnegie Foundation for the Advancement of Teaching, and the National Center for Academic Transformation (NCAT). In addition to investors willing to fund developmental education initiatives, voices of developmental students have been heard asking for a chance to be successful and for help in dealing with math anxieties (Weinstein, 2004). Supporters of reformed developmental education believe that there are multiple alternatives for preparing students for college level math courses or assisting students through concurrent developmental and gateway courses while alleviating anxiety and promoting adjustment to university culture (Jaggars, Hodara, Cho, & Xu, 2015; Russell, 2008; Zachry, 2008).

Reforming developmental mathematics courses requires an examination of teaching strategies, delivery models, curriculum, cognitive theory and teacher commitment (Bonham & Boylan, 2011; Smittle, 2003). Offering a variety of instructional delivery formats, enhancing learning with technology, engaging students with project-based and cooperative learning structures, allowing students more time on task and providing faculty with quality professional development are considerations that can lead to successful restructuring of developmental education programs and courses (Osterholt & Barratt, 2010). In addition, employing valid and reliable placement practices can improve program effectiveness (Brothen & Wambach, 2004).

The NCAT recommends six different course-redesign models: supplemental, replacement, emporium, online, buffet, and linked workshop (Twigg, 2011). The supplemental model encourages an active learning environment within a lecture setting and provides out-of-class technology-based supplemental instruction. The number of face-to-face class meetings is reduced with the replacement model and substituted with out-of-class online interactive activities. The emporium model, currently the most popular model, completely eliminates traditional lecture and utilizes online learning resources while offering personalized assistance through face-to-face tutoring (Moore, 2001). A fully online course eliminates all in-class meetings and utilizes a web-based learning management system. The buffet model allows for customization of student learning based on each student's background knowledge and learning style.

Finally, the linked workshop offers just-in-time support through supplemental instruction linked to the student's college-level course. Each of the six models has proven advantages along with disadvantages. For example, we know that "students actually learn math by doing math rather than spending time listening to someone talk about doing math," and these models allow for fewer or no lectures while increasing time on task (Bonham & Boylan, 2011, p. 4). However, Bonham and Boylan (2011) warn that students can develop an overreliance on technology and caution instructors to always consider students' needs and skills when redesigning courses. Hieronymi (2012) reminds educators and policy-makers technology should not be confused with college teaching stating, “Education is not the transmission of information or ideas. Education is the training needed to make use of information and ideas” relating educators to coaches and “personal trainers in intellectual fitness” (p. 1).

Co-requisite Model

One additional model, similar to the linked workshop, is the co-requisite model of instruction often described as an acceleration strategy (Booth et al., 2014). With this model, students who would typically enroll in a developmental course rather than a gateway course, based on placement test scores, are able to enroll in the required gateway course and a developmental lab concurrently. For example, a student might enroll in a required quantitative reasoning course that meets on Monday, Wednesday and Friday. At the same time, the student also enrolls in a developmental lab meeting on Tuesday and Thursday. The student receives traditional instruction in the general education course while receiving “targeted support to help boost their understanding and learning of the college-level course material” in the developmental lab (CCA, 2001, p. 2).

The co-requisite model does not focus “just on the goal of improving remedial course completion but also, and more significantly, on completion of the entry-level, credit bearing college courses” (CCA, 2011, p. 2). The co-requisite pathway “eliminates the structural flaw of pre-requisite remedial sequences” by removing what could be a long sequence of remedial course work (Vandal, 2014). With this model, students are able to immediately begin with the general education requirement, thus reducing time to graduation, saving tuition costs, and eliminating the transition from developmental course work to college-level course work, hence removing obstacles. Prior research also proposes that developmental students progressing quickly toward required college credit-bearing courses are more likely to persist to college completion (Booth et al., 2014).

The co-requisite model of instruction provides opportunities for students to experience a variety of instructional strategies. Students receive a traditional lecture in the gateway course and participate in cooperative learning structures in the developmental lab. The lab environment offers an opportunity for collaboration, which in turn supports cognitive development (Osterholt & Barratt, 2010). Such forms of social learning can also alleviate anxiety by providing peer support, as students become independent learners (Smittle, 2003). With smaller class sizes, instructors of co-requisite math labs have the ability to offer structured learning activities while providing frequent feedback and encouraging students to monitor their own progress. These affordances are not often found in large-enrollment gateway courses taught in a traditional lecture format.

Early evaluations of the co-requisite model conducted by The Charles A. Dana Center, a research unit of the University of Texas at Austin, indicates potential increases in grades, persistence and completion rates in gateway mathematics courses (Cullinane, 2015). Two and four-year institutions in Minnesota, Tennessee, Indiana and Georgia have adopted the co-requisite model, despite claims that not enough research has been conducted to determine what works well and for whom (Smith, 2015). One study (Booth et al., 2014) found that accelerated models do not work as well for those students who “lack a higher level of commitment and motivation” (p. 6). Current research on developmental course redesign lacks information and strong evidence of the success or failure of a co-requisite model of instruction for students in four-year institutions and has yet to address the issue of using a traditional algebra placement policy in a non-traditional pathway.

Research Site Design

The co-requisite developmental lab, offered at the research site, was specifically designed to support the social, emotional and intellectual growth of students with developmental needs through student-centered activities. Students enrolled in this particular model attended the required gateway course three days a week receiving three college credit hours for the mathematics course. These students were also enrolled in a supporting developmental lab, which met the remaining two days each week and carried two hours of elective credits. In this model, students generally received traditional lecture in the gateway course while participating in student-centered activities in the developmental lab.

Small student teams, generally 2 to 4 students per team, were created through a random selection process each day. The use of small teams served two purposes; providing students opportunities to build relationships and allowing students to learn from their peers through mathematical conversations. Activities often involved the use of manipulatives such as algebra tiles, dice, cards, three-dimensional shapes, and teacher-generated materials. Technology enhanced tasks and investigations were also used to engage students and promote student discussions. Figure 2.1 exemplifies students participating in engaging data collection activities designed to help the students build conceptual understanding of probability and statistics content.

Figure 2.1 *Students participating in hands-on lab activities*.

In order to encourage the development and use of mathematical language, students participated in vocabulary building tasks requiring the use of technology. For example, while working with a partner, students developed personal definitions of given geometry terms. After completing a term sheet students were asked to find real objects illustrating each of the terms (see Appendix C for an example of a term sheet used). Figure 2.2 is an image, submitted by one student, illustrating intersecting lines. This image was presented along with the student's explanation of how the image represented her understanding of intersecting lines. Additional examples of student activities and strategies used in the co-requisite model implemented for this study can be found in Appendix E.

Figure 2.2 *Cosmetic case displaying intersecting lines.*

Students with Developmental Needs

Student Characteristics

At one point in time, the majority of developmental students were white males with less than one third representing minorities (Boylan, 1999). A more recent report by Fernandez, Barone and Klepfer (2014) suggests that female and minority community college students are more likely to take developmental courses. Of the minorities represented, African-American and

Hispanic students signify the largest groups (Boylan, 1999; Nora & Crisp, 2012). Females are more likely to enroll in or be placed in developmental mathematics courses than are males (Boylan, 1999; Sparks & Malkus, 2013).

Students with developmental needs often share a variety of characteristics, in addition to being underprepared for college-level course work. These students are often the "most at-risk population for drop-out and stop-out" (Munsch et al., 2015). Many such students are first generation college students, receiving some form of financial aid, working a part-time job, supporting a spouse and children, or are military veterans (Booth et al., 2014; Boylan, 1999). Research has also found that many underprepared students lack external support from family and friends, are less willing to take chances, lack academic confidence and report lower self-esteem (Castator, 1995). Students with developmental needs also share common non-cognitive or affective characteristics as well. Factors such as motivation, attitude, and willingness to seek help are essential to student success (Boylan, 2009). Bitner, Austin, and Wadlington (1994) identified math anxiety and low math self-concept as characteristics of many college students placed in developmental mathematics courses.

Mathematics anxiety has been described as a multidimensional psychological construct, usually linked to a negative experience, that interferes with a student's capability to perform mathematical operations (Bai, Wang, & Frey, 2009; Helal & Hamza, 2011). Bekdemir (2010) described mathematics anxiety as "an illogical feeling of panic, embarrassment, flurry, avoidance, failing and fear" which prevents conceptual learning (p. 312). Betz (1978) was one of several researchers who identified math anxiety as a critical factor influencing student learning and achievement in mathematics. In a study of 652 college students, Betz found that “math anxiety occurs frequently among college students and that it is more likely to occur among women” (Betz, 1978, p. 441).

Additional studies have identified pre-service teachers as maintaining the highest levels of math anxiety and displaying poorer attitudes toward mathematics compared to students of other undergraduate college majors (Gresham, 2007; Sloan, 2010). This group of teacher candidates includes those preparing for careers in early childhood, elementary and special education. If pre-service teachers retain this anxiety it could be conveyed to students in future classrooms. Teachers with mathematics anxiety unintentionally “transmit their avoidance and fear of mathematics to their students” causing a growing number of mathematically anxious students at all levels of education (Gresham, 2007, p. 183). Teachers who suffer from mathematics anxiety tend to use more traditional methods of instruction - devoting class time to whole-class lecture, focusing on algorithms and expecting seatwork from students - rather than considering individual learning styles or the need for varied instructional strategies such as cooperative learning structures (Aslan, 2013; Bekdemir, 2010; Sloan, 2010).

Sloan (2010) suggests that university instructors “should create a supportive atmosphere with mutual respect and acceptance” in order to establish an “emotional climate that is inviting and reassuring” for students in order to prevent the onset of student anxiety toward mathematics (p. 254). Other suggestions for preventing, or at least minimizing, anxiety include making mathematics relevant, developing small-group lessons, encouraging student discussions and using manipulatives to assist student transition between concrete and abstract concepts (Gresham, 2007; Sloan, 2010).

Successful Teaching Practices

"Effective teaching in developmental education is one of the most challenging jobs in the college teaching profession" (Smittle, 2003, p. 10). As a result of her research on successful developmental education programs, Smittle (2003) identified the following six principles of effective teaching for developmental course instructors:

1. Commit to teaching underprepared students
2. Demonstrate good command of the subject matter and the ability to teach a diverse student population
3. Address non-cognitive issues that affect learning
4. Provide open and responsive learning environments
5. Communicate high standards
6. Engage in ongoing evaluation and professional development

Research has taught us that teacher attitudes and anxieties are transferred to students; therefore, teachers should not be haphazardly assigned to teach a developmental course if they are not willing to work with underprepared students or to address their non-cognitive issues, which may include anxiety toward mathematics. This includes the first- time teacher who may be willing to accept the teaching assignment and may have the necessary professional credentials, but may not have in-depth knowledge of the content and may only be comfortable teaching in a traditional lecture format (Smittle, 2003). Bonham and Boylan (2011) found that small-group instruction "significantly increases math confidence" and that another effective method for alleviating math anxiety is "to create a safe learning environment in which students feel comfortable expressing themselves without fear or ridicule" (p. 4). Not all mathematics instructors are comfortable or capable of providing the environment necessary for developmental students who are often mathematically anxious students.

Another important element for student success is the ability to understand and use the language of mathematics, including terms and symbols (Stahl, Simpson, & Hayes, 1992).

Instructors with a solid command of mathematics should be able to employ strategies effective in moving students beyond the rote memorization of textbook definitions. By assisting the development of conceptual understanding through "multiple definitions, examples, characteristics, synonyms, and antonyms" students can cultivate greater vocabulary fluency for effective communication in current and subsequent courses (Stahl, Simpson, & Hayes, 1992, p. 5). Immersing students in engaging experiences can provide opportunities for conceptual development of vocabulary along with required content knowledge. Stahl, Simpson, and Hayes (1992) advise instructors to be aware of, and use, "research validated strategies" rather than wasting time reinventing strategies (p. 7).

Osterholt and Barratt (2010) emphasize the need for instructors to also look beyond academic deficits to identify non-cognitive barriers such as study habits, time management, emotional perspectives, and student's self-belief. As today's developmental student requires more than content remediation, instructors must be both prepared and capable of offering a variety of instructional methods including collaborative learning environments despite the university culture of gripping to traditional methods of teaching, specifically lecturing. Student collaboration-whether in pairs or small groups-emphasizes the value of cooperation, provides non-threatening feedback, promotes communication, and encourages student accountability (Osterholt & Barratt, 2010). For instructors to be successful in implementing a variety of methods, they must continue to participate in ongoing professional development.

Placement Practices

Standardized Test Scores

Capt, Oliver, and Engel (2014) posit that the "purpose of placement tests is to determine whether students are ready for college-level courses or if they first need developmental education" (p. 6). Belfield and Crosta (2012) conjecture that correct placement of students in appropriate courses is an essential step on the student's pathway to graduation, yet the accuracy of placement decisions is often questionable. Traditionally, institutions have had the freedom to establish placement policies including determining the standardized placement test used and the recommended score for entry into college-level courses. Generally, institutions relied on standardized assessments, such as the American College Test (ACT), to determine placement in developmental courses (Belfield & Crosta, 2012; Grigorenko et al., 2009; Moore, 2005; Parker et al., 2010). With the recent downfall in economic stability and movement toward performance funding, state level higher education agencies have taken a leading role in determining acceptable cut-scores on the ACT (Russell, 2008; Wilson, 2012). Though standardized placement score consistency across state institutions may be helpful, critics continue to argue that standardized assessments were designed to measure achievement not aptitude and should not be used to predict student success (Saxon & Morante, 2014). Capt, Oliver, and Engel (2014) suggest that testing can unintentionally lead to problems for underprepared students who are placed inappropriately. Vandal (2014) proposes "assessment and placement practices at many colleges result in many college-ready students being placed into remedial courses" (p. 1). For this reason, Brothen and Wambach (2004) recommend developing a range of valid and reliable placement testing procedures rather than basing decisions on one test score. In addition to these concerns, standardized tests such as the ACT are intended to measure preparedness for the commonly taken college-level courses and for mathematics this means preparedness for college algebra (Clough & Montgomery, 2015). The ACT was not to measure achievement or predict success in liberal arts courses.

High School Grade Point Average

A second measure of academic preparedness, used by many institutions, is high school grade point average (Bridgeman, Pollack, & Burton, 2008; Burdman, 2012; Parker et al., 2010; Ziomek & Svec, 1997). One problem with using the high school grade point average for placement is that some students may have completed high school several years before entering college, leaving their high school performance inapplicable to present capabilities (Belfield & Crosta, 2012). In addition, some students may not have completed high school in a traditional American school system, leaving these students without a traditional high school transcript from which to pull the high school grade point average. Allen and Sconing (2005) admit that though factors such as motivation and study habits are important to success the meaning of the high school grade point average is likely to differ among high schools across the nation making this data less useful than ACT scores.

Prior research also suggests that using high school grade point average for college admission and placement considerations could be a mistake, due to the subjective nature of grading practices and the possibility of grade inflation (Ziomek & Svec). The phrase *grade inflation* refers to the practice of assigning higher grades to student work without evidence of a parallel increase in student achievement or displayed ability (Hodges, 2014; Ziomek & Svec, 1997). Though grade inflation may minimize student complaints and earn instructors high marks on course evaluations, it is unfair to students (Stanoyevitch, 2008). Grade inflation can result in the deterioration of work ethic for some students and create a false sense of confidence in others

(Stanoyevitch, 2008). Grade inflation also generates an inaccurate measure of student performance, which can lead to inappropriate placement in subsequent course work (Barriga et al., 2008; Hodges, 2014; Pattison et al., 2013; Stanoyevitch, 2008; Ziomek & Svec, 1997).

Attendance

Prior research regarding the relationship between class attendance and academic performance has revealed somewhat conflicting conclusions (Wheland, Konet, & Butler, 2003). Differences in the findings of each study could be related to study design and methodology. In a review of literature, Golding (2011) found that observational studies revealed positive correlations between attendance and performance whereas experimental studies produced unclear results (p. 41). Golding also found that students might have attended classes with strict attendance policies enforcing penalties for non-attendance. However, attendance in these courses did not ensure motivation nor did it necessarily guarantee student engagement in the course content (Golding, 2011). Supporting data appeared in an earlier study by Berenson, Carter and Norwood (1992) comparing the performance of students governed by a compulsory attendance policy with that of students not required to attend class. This study found no significant difference in academic performances between the two groups (Berenson, Carter, & Norwood, 1992; Wheland, Konet, & Butler, 2003). Moore (2005) found that “attendance accounted for 64.4% of the variation in students’ grades,” meaning students attending the course regularly had a “greater probability of making a high grade in the course” compared to students who did not attend regularly (p. 36). Moore’s study involving first-year students in an introductory biology course, revealed that class attendance was “more important for the academic success of developmental education students” than scores on standardized assessments (Moore, 2005, p. 39).

Crede, Roch, and Kieszczynka (2010) conducted a meta-analysis study of the relationship between class attendance and grades. The results of this study showed that attendance is strongly correlated with course grades and that this finding is consistent with learning theories emphasizing the "importance of repeated and extensive contact with information and repeated practice of skills" (p. 285). Clifton, Baldwin, and Wei (2012) conducted a study involving 427 developmental students enrolled in a first-year chemistry course. Correlations between high school chemistry grades, high school mathematics grades, time from graduation, gender and attendance were calculated with the college chemistry grades. Again, attendance was found to have the highest correlation with grades. Clifton, Baldwin, and Wei (2012) suggest that attending classes allows students to be more engaged in the course material, fostering course success.

Attendance in associated course labs has also been found to be a valuable component of course success. Moore (2008) conducted a four-year study of 1,697 students, examining the relationship between participation in a science lab and performance in the lecture portion of an associated introductory science course. Students received traditional lecture in the science course and investigated the lecture concepts in the associated lab. Moore found that lab attendance was positively correlated with the lecture course grade indicating, "lab attendance is a strong predictor not only of lab performance, but also of performance in lecture and in the overall course" (p. 68). Moore concluded that higher attendance rates in the science lab might have been due to the interactive nature of the lab. He also suggests that attendance is critical to success as higher course performance is strongly associated with attendance (Moore, 2008).

Summary

Historically, college algebra was required of those students who were unprepared for calculus in order to prepare them for calculus, which was considered the gateway to mathematics instruction. Over time, it was determined that calculus was no longer a necessity for all college majors and college algebra became the required general education course. Liberal arts mathematics and statistics courses have recently become accepted general education courses as well.

Developmental mathematics courses, once believed to be necessary pre-requisites for students unprepared for college algebra, have been identified as obstacles for students seeking a degree or professional certificate, causing universities to reform the traditional delivery methods by including interactive online learning resources. However, the content of these developmental algebra courses has not changed much in the past several years even though the courses are now being used as pre-requisites for courses other than college algebra. Though the new delivery methods may be beneficial to many students, these methods do not address additional issues of concern.

From among the numerous course redesign models, the co-requisite model of instruction provides an opportunity to support developmental students in their gateway mathematics course while offering an environment and instructional strategies that could alleviate anxiety toward mathematics and build student self-esteem. The co-requisite model of instruction has the potential to support underprepared students, to reduce time to graduation by removing obstacles and to minimize the cycle of transferring math anxiety to future generations. However, this model has been underrepresented in current research on developmental education reform efforts, especially at four-year universities (Munsch et al., 2015; Twigg, 2011).

Traditional mathematics placement policies rely heavily on standardized algebra intensive assessments designed to measure achievement, not aptitude. Though states are gradually developing consistency on recommended placement scores, the placement model was designed for identifying appropriate algebra courses for students of various levels. Today, students have gateway course choices that are not algebra intensive. Traditional algebra placement models may no longer be effective or appropriate for non-traditional pathways. Current research on placement policies focus on placement in pre-requisite pathways while little research has addressed placement issues associated with co-requisite pathways. Additionally, prior research has investigated correlations between course attendance and course success in a traditional pathway, however no research was found to examine correlations between attendance in co-requisite developmental labs and gateway course success.

Chapter 3 - Research Methodology

Research Design

This study sought to explore the co-requisite mathematics pathway by examining relationships between available variables and academic success. The value of these variables as predictors of academic success, in a non-traditional mathematics pathway, was also investigated in order to improve current placement practices. Participants in this study were students enrolled in a required gateway mathematics course simultaneously with a developmental specialized mathematics lab, at a moderately selective four-year institution.

The purpose of this explanatory study was to investigate the relationships between ACT math score (ACT-M), high school grade point average (HS-GPA), attendance in a co-requisite developmental math lab (ATT), and mathematics anxiety (MA) with gateway course success (GCS) and student achievement (SA). These variables were examined to assess their value in predicting academic outcomes for undergraduate students enrolled in gateway mathematics courses paired with developmental mathematics labs. Suitable predictors of student success are needed to guide decisions regarding enrollment procedures and the design of the co-requisite pathway. The following research questions served to guide this study:

1. What is the relationship between gateway course performance, for students enrolled in co-requisite mathematics courses, and each of the following factors: ACT math score, high school grade point average, co-requisite lab attendance, and mathematics anxiety?
2. What is the relationship between student achievement, for students enrolled in co-requisite mathematics courses, and each of the following factors: ACT math score, high school grade point average, co-requisite lab attendance, and mathematics anxiety?

3. To what extent do ACT mathematic score, high school grade point average, co-requisite lab attendance, and mathematic anxiety level predict academic outcome for students enrolled in co-requisite mathematics courses?

The remainder of this chapter will provide descriptions of the research setting, participants, design of the study, quantitative data collection methods, instruments used and data analysis techniques applied in consideration of the research questions.

Data Collection

Setting and Participants

University C has one main campus central to the mid-west state and one regional campus located approximately 45 miles northwest of the main campus. There were 9,838 undergraduate students enrolled in the fall semester of 2014 with the average age being 23 and a greater number of female than male students. The average ACT composite score for entering freshmen is 21.8. This university reports a 16-to-1 student-to-faculty ratio. This university also houses five academic colleges: College of Health, Science and Technology, College of Business and Professional Studies, College of Arts, Humanities and Social Sciences, College of Education, and the Honors College.

University C piloted one co-requisite lab course during fall of 2014 with 15 students enrolled and two co-requisite lab courses in the spring of 2015 with a total of 23 students enrolled. Participants in this study also included 51 undergraduate developmental students enrolled in co-requisite lab courses in the Fall 2015 semester, at University C.

Co-Requisite Model

This research was focused on three semesters of a co-requisite pilot program in which students with developmental needs were enrolled into two concurrent courses. One of these courses was the required gateway mathematics course determined by each student's program of study. The second course was a developmental mathematics lab designed to support the objectives of the gateway course. There were nine sections of two different gateway courses, one algebra-modeling course and one quantitative reasoning course (see Appendix E for individual course learning outcomes). Two full-time mathematics professors each taught one section of the gateway courses while two graduate assistants taught the remaining seven sections of gateway courses, over the three semesters. Each gateway instructor developed his or her own evaluation system, independent of the other instructors. Some instructors accepted late work while others did not. Some instructors offered extra credit in the gateway course while others did not. Each instructor set his or her own weighted grading scale, some including course attendance and others not. The researcher, a full-time faculty member with training in developmental education, taught the co-requisite developmental labs. Each lab course followed the same evaluation policy set by the researcher.

Students participating in this pilot attended the gateway course on Monday, Wednesday and Friday of each week. Students typically experienced traditional teacher-centered instructional methods, primarily lectures, in the gateway courses. However, instructional strategies varied by instructor and curriculum unit. These students also attended a developmental lab on Tuesday and Thursday of each week. Developmental labs were designed to be student-centered by incorporating cooperative learning structures, peer-learning tasks, and technology enhanced activities. The purpose of the developmental lab was not to re-teach content but to allow students an opportunity to build knowledge through experience, discussion and reflection.

Gateway courses were taught in traditional classroom environments with a larger number of students enrolled. The developmental labs were held in a computer lab setting but often relocated outdoors or into hallways allowing students mobility and access to additional tools and resources. Developmental lab enrollment was limited to sixteen students allowing the instructor to better monitor student activity, gage student participation, and implement formative assessment strategies. The smaller class size offered opportunities for students to build self-confidence while experiencing hands-on learning. Cooperative learning structures used afforded opportunities for students to strengthen peer-relationships, helping students acclimate to university culture while relieving anxieties.

Quantitative Data

In past years, it was not uncommon for academic placement policies to be determined at the institutional level. However, with the recent focus on higher education reform, "pressure to develop a coherent placement assessment policy framework has made placement policy a state-level issue" for an increasing number of states (Burdman, 2012, p. 2). Several states now require a statewide-standardized assessment cut score for entry into gateway mathematics courses. One of the most commonly used standardized placement tools is the American College Test (ACT). Allen and Sconing (2005) assert that the ACT assessment provides "an objective measure of students' academic achievement and readiness for college" (p. 1). When placement decisions are based only on the ACT score, unnecessary obstacles to student progression can occur (Burdman, 2012). Research also suggests that augmenting test scores with additional information such as the student's high school grade point average might lead to a speedier and more effective advancement through college (Allen & Sconing, 2005; Belfield & Crosta, 2012; Burdman, 2012; Grigorenko et al., 2009). In fact, Belfield and Crosta (2012) found that "high school GPA is by far a better predictor of success" than many standardized tests.

In addition to academic preparedness, behaviors linked to self-regulation and intrinsic motivation influence academic performance. Prior research has identified class attendance as one non-cognitive factor impacting college student success in mathematics courses (Wheland, Konet, & Butler, 2003). In one study, Golding (2011) reported a positive correlation between attendance and performance within the same class. Clark, Gill, Walker and Whittle (2011) also studied the correlation between attendance and performance, finding that lower performances were related to higher absentee rates in the same course. These studies involved courses using traditional lecture-based models of instruction and did not identify a causal relationship between attendance and performance. No research was found on the relationship between attendance in a developmental course and performance in the paired gateway course.

The initial quantitative data (ACT-M, HS-GPA and GCS) for this study was obtained from the participating university's Office of Institutional Research. This data was drawn from student enrollment in the co-requisite pilot program during the 2014-2015-college year. Attendance (ATT) in the pilot co-requisite labs was taken daily by the lab instructor and recorded in an Excel spreadsheet during the 2014-2015-college year. Each student's average attendance rate for the semester was calculated and used in this study. These variables (ACT-M, HS-GPA, ATT) were used to calculate the correlation of each with gateway course performance (GCS). Next, a multiple regression analysis was conducted and used to predict academic outcomes for a new cohort of students enrolled in co-requisite courses in the fall semester of 2015. Additional quantitative data, student achievement (SA) and level of mathematics anxiety

(MA), from the fall 2015 semester cohort were then collected and analyzed to identify additional relationships. Specifics for how this data was collected are described in detail in the data analysis section.

Gateway Course Performance

In order for students to progress in the mathematics sequence at University C, a final letter grade of C or higher must be earned. However, for students required to complete only one general education mathematics course, a letter grade of D is accepted for fulfilling this requirement. Each gateway mathematics instructor defines the student evaluation system differently. Some instructors assign homework and others do not. Some instructors weight tests more heavily while others do not. For the purpose of this study, student performance in the gateway mathematics course was measured using the final course score indicated by a letter grade, rather than selecting a single letter grade as the target for gateway success. Letter grades were converted to discrete numerical values as shown in Table 3.1.

Table 3.1

Letter Grade Conversion

Final Course Letter Grade	Numerical Value
A	4
B	3
C	2
D	1
F	0

Student Achievement

Because student evaluation systems differed among gateway course instructors, the final course grade was only one measure of academic outcome. Knowing it is possible for students to experience cognitive growth and skill developments yet fail to meet course expectations (Nomi & Allensworth, 2013), the developmental education department at University C, created and currently administers a pre-test for students entering a developmental mathematics course (see Appendix D). This test is used to identify students' general strengths and weaknesses in basic algebra concepts. For the purpose of the study, this 30 item selected response pre-test was used as both a pre and post-test to measure student achievement (SA).

Mathematics Anxiety

Richardson and Suinn (1972) developed a Mathematics Anxiety Rating Scale (MARS), consisting of 98 questions requiring Likert-type responses ranging from 1 (low anxiety) to 5 (high anxiety). From this instrument grew several offspring including revised and abbreviated versions of the original instrument for undergraduate students, adult online learners, adolescents and elementary students. Multiple researchers attempted to reduce the number of questions without compromising the accuracy of results. Many of these related studies used only small sample sizes and lacked reliability and validity data (Rounds & Hendel, 1980).

Fennema and Sherman (1976) developed a tool for measuring students' attitudes toward mathematics. The Mathematics Attitudes Scales (MAS) included a subscale for mathematics anxiety. Betz (1978) conducted a study, involving 652 students at Ohio State University, using a revised version of the Fennema-Sherman anxiety tool. For this version to be appropriate for college students, only 10 of the original 12 items were used by Betz to measure math anxiety in college students.

During the third class session of the Fall 2015 semester, participants in this study were invited to complete the 10-item Revised Mathematics Anxiety Scale (R-MAS). The instrument was provided to students along with the human subjects consent form. Students were given information concerning the study and were invited to participate. The 10-item revised scale is appropriate for college students and was selected for its ability to gain information from students while minimizing the time required of students to participate. For each item on the R-MAS, participants were asked to indicate the level of anxiety they feel. For this study, the 10-item R-MAS was administered in a paper version rather than an online version. This was an effort to improve timeliness of responses and reduce coverage error (Dillman, Smyth & Christian, 2009). Once students completed the instrument, it was placed into a manila envelope. All envelopes were collected and stored by the researcher. Once the data was collected and recorded for each section, identifying marks were removed.

Data Analysis

Methods and Procedures

Quantitative analysis requires multiple steps in order for the researcher to identify trends and determine relationships among variables (Creswell & Plano, 2011). The initial phase of this study required collecting an archived sample of quantitative data from the first two semesters of the co-requisite pilot program. This data was used to examine the relationships between each quantitative variable (ACT-M, HS-GPA, and ATT) and student performance in the gateway course (GCS). This examination included calculating the Pearson Correlation Coefficients to determine the strength of any relationships found. The next step was to compute a multiple-regression equation for the independent predictor variables (ACT-M, HSGPA, ATT), based on the archived data. Once each regression model had been computed it was tested for significance through an analysis of regression using an F-ratio. The F-ratio determined whether the predicted variance was significantly larger than would be expected if no relationship existed between the independent and dependent variables.

Additional academic data was collected for the new cohort at the start of the fall semester. Participants were asked to complete the 30-item selected response pre-test in order to establish a base-line achievement score for each student. Students were asked to complete this test a second time at the end of the semester. Results of the pre and post-tests were analyzed using a repeated-measures design. This design was useful in measuring changes over time and reduced problems caused by individual differences such as IQ. A two-tailed t-test was used to determine any significant change in mathematics achievement after participation in the co-requisite model. Student achievement levels were then used as the dependent variable in computing additional regression models for predicting achievement outcomes. Furthermore, at the start of the fall semester, participants were asked to complete the 10-item R-MAS. Results from this survey were later used to compute an additional regression model with mathematics anxiety serving as an independent variable for predicting academic outcome.

Role of the Researcher

The researcher is currently a doctoral student in the Curriculum and Instruction program at Kansas State University and is employed as an assistant professor of developmental mathematics at University C. She is responsible for the education of approximately 350 developmental mathematics students; including the supervision and training of adjunct instructors, facilitation of online education resources, course scheduling, and creation of co-requisite mathematics curriculum.

Ethical Considerations

Confidentiality of the participants was maintained, as data does not include names or any other identifiable individual information. To ensure protection of the participants, this proposal was reviewed and approved by the Committee for Research Involving Human Subjects (IRB) at the supervising institution. The purpose of the study was disclosed to the participants and they were informed that participation in the study was voluntary. Disruption at the participating site was minimal.

Chapter 4 - Results

Data Analysis

The purpose of this study was to investigate relationships between multiple variables and academic outcomes of students with developmental needs who were enrolled in a co-requisite model of instruction for college-level mathematics. Quantitative data for this study came from a total of three semesters of a pilot co-requisite program. The data include students' high school grade point averages (HS-GPA), ACT mathematics sub-scores (ACT-M), and gateway course scores (GCS) provided by the institutional research office at the participating university. Additional quantitative data included students' daily attendance rates (ATT) in the co-requisite developmental lab course, student achievement scores (SA) taken from the results of a pre- and post-test, and student self-reported mathematics anxiety scores (MA).

Archived Data

This study began with archived data from a sample of 38 subjects enrolled in the co-requisite model during the 2014-2015 academic year. Four of these subjects did not have an ACT-M score on file, three of the subjects did not have a HS-GPA score on file, and three subjects withdrew from the courses resulting in elimination from this study. The archived data set, taken from the sample n_1=28, will be referred to as n_1 for the remainder of this study. Approximately 92% of the students in this sample are female students. Approximately 76% of these students are majoring in some field of education including elementary, early childhood, middle school and special education areas. Of this sample, 93% successfully passed the associated gateway mathematics course, meaning these students earned at least the minimum score required for their individual program of study.

Students enrolled in the fall 2015 semester represent the sample used in the second phase of this study. Initially, 51 students were invited to participate however, one student did not wish to participate, one student withdrew from the courses, six students did not have an ACT-M score on file, two students did not have a HS-GPA score on file, and ten students did not complete the post-test. A total of 20 subjects were eliminated from this study, leaving a sample size of $n_2 = 31$. This second sample will be referred to as n_2 for the remainder of this study. Approximately 77% of the students in this sample are female. Approximately 77% of the students in this sample are majoring in some field of education including elementary, early childhood, technology, speech and special education areas. For this sample, 100% of the participants successfully passed the associated gateway mathematics course. Meaning each student achieved at least the minimum score required to earn the necessary credit for his or her program of study.

Correlation and Multiple Regression

A Pearson Product Moment Correlation was computed initially with the archived data, to begin to answer the first research question. The Pearson correlation was used to measure the degree of the relationship between two variables (Gravetter & Wallnau, 2013). SPSS Statistics 23 was the statistical package used to calculate means, standard deviations, Pearson's correlation coefficients and regression coefficients, as SPSS has been acknowledged for superiority in performing statistical analysis at a professional level (Feinberg & Siekpe, 2003; Prvan, Reid, & Petocz, 2002). A preliminary analysis was run on the archived ACT-M, HS-GPA and ATT data for n_1, to determine the strength of the individual relationships with GCS. The mean ACT-M score was found to be 16.750 with a standard deviation of 1.430. The mean HS-GPA was 3.191 with a standard deviation of 0.420. The mean ATT rate was 0.797 with a standard deviation of 0.148. The correlation, used to measure and describe the consistency of the relationship, was calculated first for ACT-M with GCS, finding a significant correlation, $r = 0.356$, $p < 0.05$. Correlations were then calculated for HS-GPA and ATT with GCS. An analysis of the data revealed no significant correlation between HS-GPA and GCS, $r = 0.220$, $p > 0.05$. The correlation between attendance in the developmental lab (ATT) and the gateway course score (GCS) was significant, $r = 0.524$, $p < 0.01$. The descriptive statistics are displayed in Table 4.1; correlations between pairs of variables are reported in Table 4.2. Significant correlations for the archived data n_1 are noted in the table.

Table 4.1

Archived Data Descriptive Statistics

Variable	Mean	Standard Deviation	N
ACT-M	16.750	1.430	28
HS-GPA	3.190	0.420	28
ATT	0.797	0.148	28
GCS	2.750	1.110	28

Table 4.2

Archived Data Correlation Matrix

Archived Data		GCS	ACT-M	HS-GPA	ATT
ACT-M	Pearson Correlation	0.356*	1	-0.012	0.077
	Sig. (1-tailed)	0.032		0.476	0.348
	n_1=28				
HS-GPA	Pearson Correlation	0.220	-0.012	1	-0.226
	Sig. (1-tailed)	0.130	0.476		0.124
	n_1=28				
ATT	Pearson Correlation	0.524**	0.077	-0.226	1
	Sig. (1-tailed)	0.002	0.348	0.124	
	n_1=28				
* Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed).					

Using this data, regression analyses were conducted to address the third research question concerning predictability. Initially, a simple regression was calculated predicting subjects' gateway course performance (GCS) based on their ACT-M. The regression equation was not significant ($F(1, 26) = 3.769$, $p > .05$) with an R^2 of 0.127. Based on this finding, ACT-M cannot be used to predict gateway course performance. Simple regression was then calculated using HS-GPA to predict GCS. Again, the regression equation was not significant ($F(1, 26) = 1.32$, $p > 0.05$) with an R^2 of 0.048. Gateway course performance cannot be predicted based on HS-GPA. However, using attendance in the developmental lab (ATT) as the predictor variable, a simple regression equation was found to be significant (F $(1, 26) = 9.852$, $p < 0.01$) with an R^2 of

0.275. Thus, 27.5% of the variation in gateway course performance can be explained by differences in developmental lab attendance. The prediction equation for this model is GCS = -0.386 + 3.935(ATT). Each model is summarized in Table 4.3 with the ANOVA summarized in Table 4.4.

Table 4.3

Archived Data Regression Model Summary

Model Summary Dependent Variable: GCS				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1 ACT-M	0.356	0.127	0.093	1.057
2 HS-GPA	0.220	0.048	0.012	1.103
3 ATT	0.524	0.275	0.247	0.963

1 Predictor variables: (Constant), ACT-M

2 Predictor variables: (Constant), HS-GPA

3 Predictor variables: (Constant), ATT

Table 4.4

Archived Data ANOVA Summary

ANOVA					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1					
Regression	4.209	1	4.209	3.769	0.063
Residual	29.041	26	1.117		
Total	33.250	27			
2					
Regression	1.607	1	1.607	1.320	0.261
Residual	31.643	26	1.217		
Total	33.250	27			
3					
Regression	9.137	1	9.137	9.852	0.004
Residual	24.113	26	0.927		
Total	33.250	27			
1 Predictor variables: (Constant), ACT-M Dependent variable: GCS					
2 Predictor variables: (Constant), HS-GPA Dependent variable: GCS					
3 Predictor variables: (Constant), ATT Dependent variable: GCS					

To obtain a more accurate prediction a multiple regression analysis was calculated (Gravetter & Wallnau, 2013), using the Enter Method, to predict gateway course performance based on students' ACT-M, HS-GPA, and ATT. A significant regression equation was found (F (3, 24) = 7.816, $p < 0.01$) with an R^2 of 0.494 (see Table 4.5). Thus, 49.4% of the variation in gateway course performance can be explained by the differences in ACT-M, HS-GPA, and ATT. Subjects' predicted performance is equal to -7.809 + 0.245(ACT-M) + 0.938(HS-GPA) + 4.354(ATT). The significance level of ACT-M and HS-GPA is less than 0.05 while the significance level of ATT is less than 0.01. The ANOVA summary and coefficients are displayed in Table 4.6.

Table 4.5

Archived Data Multiple Regression Model Summary

Model Summary-ENTER Method				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.703	0.494	0.431	0.837
1 Predictor variables: (Constant), ATT, ACT-M, HS-GPA				

Table 4.6

Archived Data ANOVA and Coefficient Matrix

ANOVA-ENTER Method					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1					
Regression	16.431	3	5.477	7.816	0.001
Residual	16.819	24	0.701		
Total	33.250	27			
1 Dependent variable: GCS	Predictor variables: ATT, ACT-M, HS-GPA				
Coefficients					
Model	Unstandardized Coefficients		Standardized	t	Sig.
	B	Std. Error	Beta		
1					
(Constant)	-7.809	2.491		-3.134	0.005
ACT-M	0.245	0.113	0.315	2.165	0.041
HS-GPA	0.938	0.394	0.355	2.380	0.026
ATT	4.354	1.122	0.580	3.880	0.001

Analyzing the data, including all three variables, with the Stepwise Method allowed for the removal of any variable that did not significantly contribute to the regression model. Results of the Stepwise regression indicate that attendance in the developmental lab (ATT) was the best single predictor of the three variables used and that the most appropriate regression model includes all three predictor variables, as seen in Table 4.7. The Stepwise Method regression equation is identical to the Enter Method regression equation previously stated.

Table 4.7

Archived Data Stepwise Model Summary

Stepwise Model for Archived Data				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.524	0.275	0.247	0.963
2	0.629	0.395	0.347	0.897
3	0.703	0.494	0.431	0.837
1 Predictor variables: (Constant), ATT 2 Predictor variables: (Constant), ATT, HS-GPA 3 Predictor variables: (Constant), ATT, HS-GPA, ACT-M				

Fall 2015 Cohort Data

Data from the fall 2015 cohort were analyzed in the same manner with the addition of mathematic anxiety levels (MA) and student achievement levels (SA). Data taken from the fall 2015 cohort revealed higher means for all variables compared to the archived data. Descriptive statistics and the Pearson Product Moment Correlation were computed for n_2. Descriptive statistics are displayed in Table 4.8 while the Pearson correlations are reported in Table 4.9.

Table 4.8

Fall Cohort Descriptive Statistics

Variable	Mean	Standard Deviation	N
ACT-M	17.548	1.287	31
HS-GPA	3.348	0.523	31
ATT	0.886	0.098	31
MA	3.197	.983	31
SA	1.807	3.124	31
GCS	3.420	0.848	31

Table 4.9

Fall Cohort Correlation Matrix

Cohort Data		GCS	ACT-M	HS-GPA	ATT	MA	SA
ACT-M	Pearson Correlation	0.393*	1	0.178	0.083	-0.315*	-0.014
	Sig. (1-tailed)	0.014		0.169	0.328	0.014	0.470
	n_2=31	31	31	31	31	31	31
HS-GPA	Pearson Correlation	0.329*	0.178	1	0.125	-0.135	0.188
	Sig. (1-tailed)	0.035	0.169		0.252	0.234	0.156
	n_2=31	31	31	31	31	31	31
ATT	Pearson Correlation	0.307*	0.083	0.125	1	-0.135	-0.115
	Sig. (1-tailed)	0.046	0.328	0.252		0.245	0.270
	n_2=31	31	31	31	31	31	31
MA	Pearson Correlation	-0.403*	-0.315*	-0.135	-0.135	1	0.071
	Sig. (1-tailed)	0.012	0.042	0.234	0.235		0.351
	n_2=31	31	31	31	31	31	31
SA	Pearson Correlation	0.044	-0.014	0.188	-0.115	0.071	1
	Sig. (1-tailed)	0.407	0.470	0.156	0.270	0.351	
	n_2=31	31	31	31	31	31	31
* Correlation is significant at the 0.05 level (1-tailed).							

For the 2015 cohort, gateway course performance was significantly related to all four variables tested. Student GCS was significantly correlated with ACT-M, $r = 0.393$, $p < 0.05$; HS-GPA, $r = 0.329$, $p < 0.05$; ATT, $r = 0.307$, $p < 0.05$; and MA, $r = -0.403$, $p < 0.05$. To determine whether there was a significant change in student achievement (SA), measured by the difference in scores earned on the pre and post-tests, the *t*-statistic was computed. Using a repeated-measures design, the difference score (D value) was computed by subtracting the post-test score from the pre-test score. The sample mean difference, M_D, was then calculated, $M_D = 2.103$.

$$H_0\colon \mu = 0 \ \textit{There is no change in student achievement levels.}$$

$$H_1\colon \ \mu \neq 0 \ \textit{There is a change in student achievement levels.}$$

For this test, an alpha level of $\alpha = 0.01$ was used. For this sample, $n_2 = 31$, the *t*-statistic had $df = n_2 - 1 = 30$. For $\alpha = 0.01$, the critical value is ± 2.75. Because the *t* value obtained ($t = 3.219$, $p < 0.01$) fell in the critical region, the null hypothesis $H_0\colon \mu = 0$ was rejected concluding there was a significant change in student achievement following participation in the co-requisite mathematics courses. However, there was no significant correlation between student achievement (SA) and ACT-M ($r = -0.014$, $p > 0.05$), HS-GPA ($r = 0.188$, $p > 0.05$), ATT ($r = -0.115$, $p > 0.05$), or MA ($r = 0.071$, $p > 0.05$).

The initial simple regression analysis for predicting students' gateway course performance based on ACT-M found a significant regression equation (F (1, 29) = 5.310, $p < 0.05$) with an R^2 of 0.155 indicating 15.5% of the variance in students' performance is explained by the variance in ACT-M. However, a simple regression analysis found students' HS-GPA was not a significant predictor (F (1, 29) = 3.529, $p > 0.05$) with an R^2 of 0.108. In addition, ATT was not found to be significant (F (1, 29) = 3.020, $p > 0.05$) with an R^2 of 0.094. Neither HS-GPA nor ATT can be used to predict student performance. However, students' mathematics anxiety (MA) did produce a significant regression equation (F (1, 29) = 5.609, $p < 0.05$) with an R^2 of 0.162 indicating 16.2% of the variance in student performance can be explained by the variance in mathematics anxiety levels. The model summary for each regression can be found in Table 4.10. Table 4.11 contains the ANOVA summary.

Table 4.10

Fall Cohort Simple Regression Model Summary

Fall Cohort Simple Regression Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1 ACT-M	0.393	0.155	0.126	0.793
2 HS-GPA	0.329	0.108	0.078	0.814
3 ATT	0.307	0.094	0.063	0.820
4 MA	0.403	0.162	0.133	0.789
1 Predictor variables: (Constant), ACT-M 2 Predictor variables: (Constant), HS-GPA 3 Predictor variables: (Constant), ATT 4 Predictor variables: (Constant), MA				

Table 4.11

Fall Cohort ANOVA

Fall Cohort ANOVA					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1 Regression	3.335	1	3.335	5.310	0.029
Residual	18.214	29	0.628		
Total	21.548	30			
2 Regression	2.338	1	2.338	3.529	0.070
Residual	19.210	29	0.662		
Total	21.548	30			
3 Regression	2.032	1	2.032	3.020	0.093
Residual	19.516	29	0.673		
Total	21.548	30			
4 Regression	3.492	1	3.492	5.609	0.025
Residual	18.056	29	0.623		
Total	21.548	30			
Dependent variable: GCS 1 Predictor variables: (Constant), ACT-M 2 Predictor variables: (Constant), HS-GPA 3 Predictor variables: (Constant), ATT 4 Predictor variables: (Constant), MA					

A multiple regression was calculated to predict students' performance based on ACT-M, HS-GPA, ATT, and MA. A significant regression equation was found (F (4, 26) = 3.448, $p <$ 0.05) with an R^2 of 0.347 indicating 34.7% of the variance in students' performance can be explained by the differences in ACT-M, HS-GPA, ATT, and MA. Students' predicted performance is equal to -1.675 + 0.166(ACT-M) + 0.358(HS-GPA) + 1.920(ATT) – 0.227(MA). None of the four variables is a significant predictor ACT-M (Β = 0.166, p > 0.05), HS-GPA (Β =

0.358, $p > 0.05$), ATT (B = 1.920, $p > 0.05$) and MA (B = -0.227, $p > 0.05$) (see Table 4.12 for the regression summary).

Table 4.12

Fall Cohort Multiple Regression Summary

Model Summary				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.589	0.347	0.246	0.736
Predictor variables: (Constant), MA, ATT, HS-GPA, ACT-M				

ANOVA					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1 Regression	7.469	4	1.867	3.448	0.022
Residual	14.079	26	0.542		
Total	21.548	30			

Coefficients					
Model	Unstandardized Coefficients		Standardized	T	Sig.
	B	Std. Error	Beta		
1					
(Constant)	-1.675	2.489		-0.673	0.507
ACT-M	0.166	0.111	0.253	1.496	0.147
HS-GPA	0.358	0.263	0.221	1.360	0.186
ATT	1.920	1.386	0.223	1.385	0.178
MA	-0.227	0.145	-0.263	-1.561	0.131

Analyzing the data, including all four variables, with the Stepwise Method allowed for the removal of any variable that did not significantly contribute to the regression equation. Results of the Stepwise regression indicate that mathematic anxiety (B = -0.347, $p < 0.05$) is the single best predictor of the four variables used and that the significant equation includes only mathematic anxiety as a predictor (F (1, 29) = 5.609, $p < 0.05$) with an R^2 of 0.162, eliminating the remaining three variables. The regression equation is GCS = 4.529 – 0.347(MA). See Table 4.13 for model summary, Table 4.14 for ANOVA, and Table 4.15 for the coefficient matrix.

Table 4.13

Fall Cohort Stepwise Model Summary

Fall Cohort Model Summary				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.403	0.162	0.133	0.789
1 Predictor variables: (Constant), MA				

Table 4.14

Fall Cohort Stepwise ANOVA

Fall Cohort Stepwise ANOVA					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1 Regression	3.492	1	3.492	5.609	0.025
Residual	18.056	29	0.623		
Total	21.548	30			

Table 4.15

Fall Cohort Stepwise Coefficient Matrix

Coefficient Matrix					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
1					
(Constant)	4.529	0.490		9.251	0.000
MA	-0.347	0.147	-0.403	-2.368	0.25
Dependent variable: GCS					

Combined Samples

To further explore possible regression models, final analyses were conducted on the larger data pool combining n_1 with n_2, using the sample $n_3 = 59$ and predictor variables ACT-M, HS-GPA, and ATT. Mathematics anxiety scores and student achievement data were not available for n_1 therefore MA and SA could not be used as variables for the sample n_3. To understand the relationship among variables, the Pearson correlations were calculated and are described in Table 4.17 while descriptive statistics are summarized in

Table 4.16.

Table 4.16

Final Descriptive Statistics

Descriptive Statistics for $n_3 = 59$			
	Mean	Std. Deviation	N
GCS	3.102	1.029	59
ACT-M	17.169	1.404	59
HS-GPA	3.273	0.479	59
ATT	0.844	0.131	59

Table 4.17

Final Correlation Matrix

Correlations $n_3 = 59$				
	ACT-M	GCS	HS-GPA	ATT
ACT-M				
Pearson Correlation	1	0.430**	0.134	0.168
Sig. (1-tailed)		0.000	0.155	0.101
GCS				
Pearson Correlation	0.430**	1	0.304**	0.507**
Sig. (1-tailed)	.000		0.010	0.000
HS-GPA				
Pearson Correlation	0.134	0.304**	1	0.005
Sig. (1-tailed)	0.155	0.010		0.484
ATT				
Pearson Correlation	0.168	0.507**	0.005	1
Sig. (1-tailed)	0.101	0.000	0.484	
** Correlation is significant at the 0.01 level (1-tailed)				

Student performance in the gateway course (GCS) was significantly correlated with ACT-M ($r = 0.430$, $p < 0.01$), HS-GPA ($r = 0.304$, $p < 0.01$), and ATT ($r = 0.507$, $p < 0.01$). Using the Enter Method, a multiple regression equation was found to be significant ($F(3, 58) = 14.664$, $p < 0.01$) with an R^2 of 0.444 indicating 44.4% of the variance in student performance in the gateway course can be explained by differences in the ACT-M, HS-GPA, and ATT. The multiple regression equation is GCS = -5.718 + 0.234(ACT-M) + 0.555(HS-GPA) + 3.546(ATT). The model summary, ANOVA summary and coefficient matrix can be found in Table 4.18, Table 4.19, and Table 4.20 respectively.

Table 4.18

Final Enter Method Model Summary

Model Summary for $n_3 = 59$				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.667	0.444	0.414	0.788
Predictor variables: (Constant), ACT-M, HS-GPA, ATT				

Table 4.19

Final Enter Method ANOVA

ANOVA					
Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
1 Regression	27.281	3	9.094	14.664	0.000
Residual	34.109	55	0.620		
Total	61.390	58			
Dependent variable: GCS Predictor variables: (Constant), ACT-M, HS-GPA, ATT					

Table 4.20

Final Enter Method Coefficient Matrix

Coefficient Matrix					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
1 (Constant)	-5.718	1.457		-3.924	0.000
ACT-M	0.234	0.075	0.319	3.097	0.003
HS-GPA	0.555	0.218	0.259	2.551	0.014
ATT	3.546	0.801	0.452	4.429	0.000
Dependent variable: GCS					

Analyzing the data, including all three variables, with the Stepwise Method allowed for the removal of any variable that did not significantly contribute to the regression equation. Results of the Stepwise regression indicated that ATT was again the best single predictor of GCS, however a greater R^2 is achieved using all three variables (see Table 4.21). Again, a significant regression equation was found ($F(3, 58) = 14.664$, $p < 0.01$) with an R^2 of 0.444. This supports the regression model found using the Enter Method.

Table 4.21

Final Stepwise Model Summary

Final Stepwise Model Summary n_3=59				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	0.507	0.257	0.244	0.895
2	0.615	0.379	0.356	0.825
3	0.667	0.444	0.414	0.788
1 Predictor variables: (Constant), ATT				
2 Predictor variables: (Constant), ATT, ACT-M				
3 Predictor variables: (Constant), ATT, ACT-M, HS-GPA				

Summary of Results

The Pearson correlation was calculated to answer the first research question referring to the relationship between ACT math score, high school grade point average, co-requisite lab attendance, mathematics anxiety and gateway course performance. For n_1, a moderate yet significant correlation was found between student performance and ACT mathematics scores. For this sample, a strong significant correlation was found between student performance and attendance in the developmental lab. However, the relationship between student performance in the gateway course and high school grade point average was not significant. For the second sample n_2, a significant correlation was found between student performance in the gateway course and ACT mathematics score, high school grade point average, attendance in the developmental lab, and mathematic anxiety.

The second research question refers to the relationship of each variable with student achievement as measured by the difference in pre and post-test scores. Student achievement scores were not available for n_1. Though there was a significant change in test scores, there was no significant correlation between student achievement and the available variables for sample n_2.

The third research question refers to the extent ACT math scores, high school grade point average, attendance in the developmental lab, and mathematics anxiety levels can predict student performance in the gateway mathematics course. Multiple simple regressions and stepwise regressions were conducted to explore possible significant regression equations. Results from the multiple regression analyses, including the Enter Method and the Stepwise Method, indicate that attendance in the developmental lab is the best single predictor of students' performance in the gateway course.

Chapter 5 - Discussion

Overview

The purpose of this study was to investigate relationships between ACT mathematics scores, high school grade point averages, attendance in a developmental lab, mathematic anxiety levels and academic performances of students enrolled in a co-requisite model of instruction at a four-year institution. Specifically, the intent was to explore the strength of each relationship and to determine any value the variables have in predicting academic performance in a gateway mathematics course. The extent to which these variables are related to student performance and student achievement was examined. This study was exploratory in nature due to the lack of current research on appropriate placement guidelines for the co-requisite pathway. Statistical results of the examination were presented in Chapter 4.

Initial data analysis began with the compilation of archived data collected by the Office of Institutional Research at University C. This archived data consisted of ACT mathematics score, high school grade point average, and gateway course grade for students enrolled in the fall 2014 and spring 2015 semesters of a co-requisite pilot program. Additionally, developmental lab attendance rates were collected from the instructor's archived data. Archived data was then analyzed, using Pearson correlation, to determine the existence and strength of any relationship between variables. A correlation matrix was generated to examine relationships between ACT mathematic score, high school grade point average, attendance in the developmental lab and student performance in the gateway mathematics course.

Results for this sample indicated students' attendance in the developmental lab was strongly correlated with academic performance in the gateway mathematics course while the ACT mathematics score was moderately correlated with academic performance in the gateway mathematics course. No significant correlation was found between high school grade point average and academic performance in the gateway course. This analysis suggests that attendance in the developmental lab and ACT mathematic score may be important components of developmental course placement guidelines. To further investigate these relationships, additional data was collected from a new cohort of students enrolled in the co-requisite model in the fall semester of 2015. In addition to the four original variables, mathematic anxiety levels and student achievement scores were collected from the new sample.

A correlation matrix was generated for the new sample, in order to examine the relationship between ACT mathematics score, high school grade point average, attendance in the developmental lab, mathematics anxiety and student performance in the gateway course along with student achievement on a pre and post-test. Results of this analysis indicated moderate correlations between student performance and ACT mathematic score, high school grade point average, attendance in the developmental lab and mathematics anxiety. No significant correlation was found between student achievement and any of the measured variables. The results suggest that each of the variables may be important components of developmental placement guidelines though there is no value for predicting students' performance on the achievement assessment used for this study.

To further explore the relationships, a third correlation matrix was generated to examine the relationship between ACT mathematics, high school grade point average, attendance in the developmental lab and student performance in the gateway course for all students enrolled in the co-requisite model during one of the three semesters of the pilot program. Again, a strong correlation was found between attendance in the developmental lab and student performance in the gateway course. A moderate correlation was found between ACT mathematic score and performance. A weak to moderate correlation was found between high school grade point average and student performance. Mathematic anxiety levels were not available for all students and were not included in this analysis. Results indicated, once again, that attendance in the developmental lab might be an important component in developmental course placement.

Multiple regression analyses were conducted to determine the linear combination of predictors that relate maximally with the dependent variable. First, an analysis was conducted to determine the predictive value of a single variable. Next, a multiple regression was conducted using the Enter method, also known as the Forced Entry method. This method prevents the researcher from making decisions about the order in which each variable should be entered. Finally, a Stepwise analysis was conducted, allowing decisions about the order of the variables to be determined by mathematical criterion. This method selects the predictor with the highest simple correlation with the dependent variable and continues to search for additional variables that can explain the largest part of the remaining variance while removing predictors that no longer make a significant contribution to the model (Field, 2009).

For the first sample, n_1, attendance in the developmental lab proved to be the only significant variable for predicting student performance, using simple regression. However, the Enter method and Stepwise regression models both indicate that using all three variables (ATT, ACT-M, and HS-GPA) produces a better regression model for predicting student performance. For the second sample, n_2, ACT mathematic scores and mathematics anxiety levels each proved to be significant single predictors, while attendance in the developmental lab and high school grade point average did not. For this sample, the Enter method produced a significant regression model including ACT mathematic scores, high school grade point average, attendance in the developmental lab, and mathematic anxiety. However, none of the variables were found to be significant in this model. Finally, the Stepwise regression model found only mathematic anxiety to be a significant contributor to predicting student performance, eliminating all remaining variables from the regression model.

For the final exploration of regression models, both the Enter method and the Stepwise method were used to analyze the larger sample, n_3, collected by combining all ACT mathematic scores, high school grade point average scores, attendance rates and student performance scores from each of the three semesters. Mathematic anxiety and student achievement scores were not included in this analysis as these scores were not available for all subjects. Both the Enter method and the Stepwise analysis identified a significant regression model, which included all three variables. The analyses indicate that attendance in the co-requisite developmental mathematics lab is a significant component to student performance in the gateway mathematics course and should be considered, along with additional measures, when determining placement guidelines for the co-requisite pathway.

Results of the current study were varied. The quantitative outcomes in this study indicate that attendance in the developmental lab may significantly contribute to student performance in the gateway mathematics course paired with the developmental lab and that students' level of mathematics anxiety is a contributing factor as well. The results of this study also indicate that the best predictive model includes all variables: ACT mathematics score, high school grade point average, attendance in the developmental lab and mathematics anxiety level. Attendance in the developmental lab is not a factor that can be measured prior to enrollment in the co-requisite model but should be considered when establishing placement guidelines and developing course syllabi.

Discussion and Implications

Students are most often placed in developmental algebra courses based on the score earned on a standardized assessment intended to measure current content proficiency (Parker, Bustillos, & Behringer, 2010). Typically the ACT exam or a comparable assessment such as the Computer-adaptive Placement, Assessment, and Support System (COMPASS), ACCUPLACER, or the Scholastic Assessment Test (SAT) is used to determine whether or not students are in need of developmental course work (Parker, Bustillos, & Behringer, 2010). Critics challenge that such a practice is misused and lacks accurate predictive value for student performance (Saxon & Morante, 2014). In addition, the amplified examination of developmental education has encouraged higher education institutions to reevaluate traditional enrollment policies including the over reliance on standardized test scores. In a 2016 report by the Center for Community College Student Engagement (CCCSE) it was noted that such criticism of using high-stakes test to assess college readiness has "led to a push for using multiple measures for assessment and placement" (p. 1). Current research suggests supplementing standardized test scores with high school grade point average to reduce placement error rates (Belfield & Crosta, 2012). Additionally, the impact of non-cognitive factors and affective variables, such as course attendance, students' mathematics anxiety and instructional methods, should also be considered when making placement decisions (ACT Research, 2015; Saxon & Morante, 2014).

Findings from the present study suggest that there is a positive significant relationship between attendance in a student-centered developmental mathematics lab and academic performance in an associated gateway mathematics course. Discoveries also indicate that there is a negative significant relationship between mathematics anxiety and academic performance in a gateway mathematics course. Results imply that both attendance in the developmental lab and mathematics anxiety levels are strong single predictors of performance, while ACT mathematics score and high school grade point average are not strongly correlated with performance but do contribute to a significant regression equation.

This evidence is cause to reevaluate the current placement practice of using only ACT mathematic score or even the limited combination of ACT mathematic score and high school grade point average to determine appropriate course placement. Results of this study do not imply that there is enough evidence for eliminating ACT mathematics score or high school grade point average from placement guidelines. In fact, results indicate that all factors should be considered when determining appropriate placement. Using the high school grade point average alone is not recommended as research indicates, “there continues to be a gap between high school graduation requirements and college readiness” (CCCSE, 2016, p. 8). Russell (2008) suggests that the American K-12 education system was never designed to prepare all students for college so not all students who successfully graduate from high school are necessarily prepared for college course work.

One limitation with the present study is the sample itself. The use of a convenient sample from a single institution limits the generalizability of the study for other institutions. In addition, students in this study were enrolled in the co-requisite pilot program based on their ACT mathematic score or prior course enrollment, limiting the range of ACT mathematic scores included in the study and the number of students included in the sample. Students in the pilot program without both an ACT score and high school grade point average on record were eliminated from the study creating a very small sample size. Characteristics of the population at this university, or other institutions, may not be truly represented by the sample in this study.

Conclusions and Recommendations

Developmental mathematics, in higher education institutions, has been at the forefront of both academic and political research for many years. The reasons for low success rates in developmental courses vary from instructional format to placement policies implemented. This study was an attempt to investigate relationships between multiple variables and academic performance of students participating in a co-requisite mathematics pathway. Specifically, the study sought to explore the value of including student-centered instructional strategies to support students with developmental needs enrolled in a gateway mathematics course. The study also sought to explore the potential of considering a student-centered model when developing placement guidelines. Although findings were somewhat mixed, likely due to the small sample size, significant relationships were found between attendance in the developmental lab, mathematics anxiety, and student performance. Results of the current study also showed that the best academic predictor equations, for students participating in this pathway, included multiple variables rather than ACT mathematic score alone.

The results of this study suggest that additional research is needed to better understand implications of replacing the traditional pre-requisite pathway with the currently popular co-requisite pathway. A focus on revising current placement policies to include measures other than ACT mathematic scores and high school grade point average is needed. Future studies should include a larger sample size that more accurately reflects the characteristics of all developmental students including students with ACT scores beyond the range of those involved in this study. Researchers of forthcoming studies should also examine the possibilities of gender and ethnic differences of students identified as having developmental needs who are placed in co-requisite pathways based on traditional pre-requisite guidelines. Potential research should also include an examination of the predictive value of the high school grade point average of students who complete college preparatory work and of those who do not.

At the time this study began there was little research on the co-requisite model and few four-year institutions had reported implementing this alternative pathway, while research was plentiful and institutions quickly adopted the emporium model. Today, the co-requisite pathway is quickly being embraced by many states across the nation (Vandal, 2014). New reports, largely by Complete College American, are just beginning to surface. Our country is likely to see a tremendous increase in the implementation of the co-requisite model, however research must continue to include appropriate placement guidelines to ensure obstacles are truly removed from developmental education programs.

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Appendix A - Informed Consent Form

KANSAS STATE UNIVERSITY INFORMED CONSENT

PROJECT TITLE: Co-requisite Mathematics Courses: A Mixed Methods Study on Academic Outcomes

APPROVAL DATE OF PROJECT: 8/10/2015

EXPIRATION DATE OF PROJECT: 8/10/2016

PRINCIPAL INVESTIGATOR: Dr. Sherri Martinie

CO-INVESTIGATOR(S): Charlene Atkins

CONTACT NAME AND PHONE FOR ANY PROBLEMS/QUESTIONS: Please ask any questions you have now or later. Prof. Charlene Atkins is the primary investigator/researcher. You may contact Prof. Atkins at catkins@ucmo.edu or at 660-543-8586. Dr. Sherri Martinie is the supervising professor and can be contacted at martinie@ksu.edu. You may also contact the KSU Institution Review Board (IRB) at comply@ksu.edu.

IRB CHAIR CONTACT/PHONE INFORMATION*:*

- Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas (State University, Manhattan, KS 66506, (785) 532-3224.

- Jerry Jaax, Associate Vice President for Research Compliance and University Veterinarian, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224.

- (**PURPOSE OF THE RESEARCH:** The purpose of this study is to investigate the relationship between ACT math score, high school grade point average, attendance in a co-requisite developmental math lab and mathematics anxiety with gateway course success and student achievement. These variables will be examined to assess their value in predicting academic outcomes for undergraduate students enrolled in gateway mathematics courses paired with developmental mathematics labs. Suitable predictors of student success are needed to guide decisions regarding enrollment procedures and the design of the co-requisite pathway. (

- **PROCEDURES OR METHODS TO BE USED:** Participants' ACT scores, high school GPAs and course grades will be collected by the Office of Institutional Research at the University of Central Missouri. These data, along with data collected from a short, 10-item survey and a 30-item multiple choice pre/post test will be used to determine any relationships between these variables and academic outcomes. A randomly selected group of students will also be invited to participate in a focus group. Members of the focus group will be encouraged to share their thoughts and experiences related to the co-requisite model of instruction. (

 LENGTH OF STUDY: This study will last only one semester (Fall 2015).

 RISKS OR DISCOMFORTS ANTICIPATED: There will be no physical or non-physical risks of participating in (this study. There will be no damage to financial standing, reputation, employability, or civil liability.

 (**BENEFITS ANTICIPATED:** There is no guarantee that you will personally experience benefits from participating in this study however, others may benefit in the future from the information we gain through this study. From your participation, the mathematics pathway may be improved for future students at our institution and perhaps others. (

 EXTENT OF CONFIDENTIALITY: Identifiable information will be kept private and password protected either on the investigator's office computer or personal computer. Only the researcher and the Office of Institutional Research will have access to academic records. Participants' ACT scores, high school GPAs and course grades will be collected by the Office of Institutional Research. Participants will be assigned a random number and will not be identified by name or 700 #. A randomly selected group of students will also be invited to participate in a focus group at the end of this semester. Field notes and audio recordings will be kept in a locked cabinet and transcripts will be password protected on the investigator's computer. Records will be kept for a period of three years following the completion of this study. All participants will have the opportunity to read the completed report. If data is used in any additional publication, participants will be made known of the publication.

TERMS OF PARTICIPATION: I understand this project is research, and that my participation is completely voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

(Remember that it is a requirement for the P.I. to maintain a signed and dated copy of the same consent form signed and kept by the participant

Participant Name: **Participant Signature:**

Date:

Witness to Signature: **Date:**

Last revised on May 20, 2004

Appendix B - Abbreviated Math Anxiety Scale (AMAS)

Revised Mathematics Anxiety Scale (R-MAS)

Please respond to each of the following statements by placing an “x” in the appropriate box.

Statement	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. It wouldn’t bother me at all to take more math courses.					
2. I have usually been at ease during math tests.					
3. I have usually been at ease in math courses.					
4. I usually don’t worry about my ability to solve math problems.					
5. I almost never get uptight while taking math tests.					
6. I get really uptight during math tests.					
7. I get a sinking feeling when I think of trying hard math problems.					
8. My mind goes blank and I am unable to think clearly when working mathematics.					
9. Mathematics makes me feel uncomfortable and nervous.					
10. Mathematics makes me feel uneasy and confused.					

Appendix C - Sample Geometry Term Sheet

Classifying Angles					
Acute Angle	Less than 90^0		Right Angle	Measures 90^0	
Obtuse Angle	More than 90^0, but less than 180^0		Straight Angle	Measures 180^0	

Name	**Description**	**Sketch**	**Angle Pairs**	**Property**
Alternate Interior Angles	Do not have a common vertex. Are on alternate sides of the transversal. Within parallel lines.			
Alternate Exterior Angles	Do not have a common vertex. Are on opposite sides of the transversal.			
Corresponding Angles	One interior & one exterior angle on the same side of the transversal.			

Appendix D - Pre-Post Test

1. If x = 3, y = -7, and z = 9, what is the value of xz – xy ?
    a. -48
    b. 6
    c. 48
    d. 76

2. Vehicle A averages 20 miles per gallon of gasoline and Vehicle B averages 38 miles per gallon of gasoline. At these rates, how many more gallons of gasoline does Vehicle A need than Vehicle B to make a 2,280 mile trip?
    a. 54
    b. 59
    c. 60
    d. 114

3. If $\frac{a}{b} = \frac{2}{3}$ *and* $\frac{b}{c} = \frac{3}{4}$ *then* $\frac{c}{a} = ?$
    a. $\frac{1}{2}$
    b. $\frac{3}{4}$
    c. 2
    d. $2\frac{1}{2}$

4. If 4(x-3) = -15, then x = ?
    a. $-\frac{3}{4}$
    b. $-\frac{1}{2}$
    c. $\frac{3}{4}$
    d. 3

5. What is $\frac{2}{5}$ of 75% of $25,000?
   a. $5,000
   b. $6,250
   c. $7,500
   d. $9,000

6. Translate the following sentence into an algebraic expression: Twenty one is less than the sum of two and a number.
   a. $21 \leq 2 + x$
   b. $2 + x \leq 21$
   c. $21 > 2 + x$
   d. $21 < 2 + x$

7. Which of the following is equivalent to $(3x + 4)(2x – 5)$?
   a. $6x^2-20$
   b. $6x^2 -7x -20$
   c. $6x^2 +7x +20$
   d. $6x^2 – 7x + 20$

8. A baker has $5\frac{3}{8}$ cups of sugar in the pantry. Each cake she bakes requires ¾ cup of sugar. What is the largest number of whole cakes she can bake?
   a. 3 cakes
   b. 5 cakes
   c. 7 cakes
   d. 10 cakes

9. Which of the following expressions is equivalent to $x^2 – x$?
   a. $–x(x-1)$
   b. $–x(x+1)$
   c. $x(x-1)$
   d. $x(x+1)$

10. The high school band consists of freshmen, sophomores and juniors. The ratio of freshmen to sophomores to juniors is 4:3:2. There are 24 sophomores in the high school. How many students are in the band?
    a. 16
    b. 34
    c. 48
    d. 72

11. Last year, Sally earned an annual salary of $S. From her salary, $D was deducted for taxes. The remaining balance was Sally's take home pay. Which of the following represents the fraction of Sally's annual salary that is take home pay?
    a. $\frac{S-D}{S}$
    b. $\frac{S-D}{D}$
    c. $\frac{D}{S}$
    d. $\frac{D-S}{S}$

12. Bob is timing a race. He is 300 feet from the starting gun. Using 1,120 feet per second for the speed of sound, which of the following is closet to how many seconds after the starting gun is fired that Bob will hear the starting gun?
    a. 0.14
    b. 0.27
    c. 0.31
    d. 0.42

13. A rectangle has a length that is five feet longer than the width. If the area of the rectangle is 24 square feet, what is the width?
    a. 3
    b. 4
    c. 6
    d. 8

14. Which of the following operations will produce the largest result when substituted for the blank in the expression: 40 ___ (-3/4) ?
    a. Plus
    b. Minus
    c. Multiplied by
    d. Divided by

15. What are the possible values of y such that $xy^2 = 54$, $x < 10$, $y < 10$, and x and y are integers?
    a. 3
    b. 6
    c. -3, 3
    d. 1, 3

16. The points (2, 3) and (-4, 5) lie on a straight line. What is the slope-intercept equation of the line?
    a. Y = 3x + 11
    b. Y = -3x + 11
    c. Y = -1/3 x + 11
    d. Y = -1/3 x + 11/3

17. If $f(x) = x^2 + 7x$, then f(-3) = ?
    a. 12
    b. -30
    c. -12
    d. 30

18. The second term in an arithmetic sequence is -14 and the third term is -34. What is the first term?
    a. -20
    b. 1/14
    c. 6
    d. 14

19. What is the slope of the line represented by the equation 4y -12x = 6?
    a. 1
    b. 3
    c. 4
    d. 6
20. At a buffet restaurant, the price for dinner for an adult is $8.95 and the price for a child is $6.59. A group of 12 people went to the restaurant for dinner and paid a total of $90.88 excluding taxes and tip. How many adults were in the group?
    a. 10
    b. 7
    c. 5
    d. 3

21. Points A (2, 4) and B (-3, -5) lie in a standard (x, y) coordinate plane. What is the slope of line AB?

a. $-\frac{9}{5}$

b. -1

c. $\frac{5}{9}$

d. $\frac{9}{5}$

22. If $|x| = 7$, what are the possible values of x?

a. -7, 7
b. 7
c. -7
d. 1, 7

23. Consider the function f(x) = -x -9. What is the value of f(-3)?

a. -12
b. -6
c. 6
d. 12

24. Which of the following is the solution to 2(x-4) < -10?

a. X < -1
b. X > -1
c. X < 12
d. X > 24

25. Cole is five years older than Chet. Three years ago the sum of their ages was 31. How old is Cole now?

a. 15
b. 16
c. 20
d. 21

26. Two cars leave the same school at the same time. Car A travels north at 60 mph and Car B travels south at 66 mph. In how many hours will the two cars be 378 miles apart?

a. 3
b. 3.5
c. 5.5
d. 6

27. Evaluate the expression $\frac{2x+3y}{x+y}$ when x = -2 and y = 5.

a. $-\frac{11}{3}$
b. 19
c. 7
d. $\frac{11}{3}$

28. Evaluate the expression $2\frac{2}{3} \div \frac{1}{5}$.

a. $\frac{7}{15}$
b. $\frac{8}{15}$
c. $\frac{35}{3}$
d. $\frac{40}{3}$

29. Factor the trinomial: $x^2 + 2x - 3$.

a. (x-3)(x+1)
b. (x+3)(x-1)
c. (x-3)(x-1)
d. (x+3)(x+1)

30. Evaluate the expression: $\frac{-(3+7)-2\cdot 4^2}{2^2-6+(-1)}$

a. -64
b. -12
c. 14
d. 19

Appendix E - Developmental Lab Components

Student Learning Outcomes

Quantitative Reasoning Lab

- Think abstractly, critically, logically and independently
- Interpret and process numerical data
- Reason and solve problems in a variety of contexts using a variety of methods including available technology
- Communicate in both written and oral form using the language and notation of mathematics
- Appreciate mathematics for its cultural, historical and scientific value
- Value some of the historical developments of mathematics

Mathematical-Modeling Lab

- Demonstrate an understanding of fundamental mathematical concepts and methods in logic, linear functions, systems of linear equations and inequalities, linear programming, and nonlinear functions.
- Model situations from a variety of settings in generalized mathematical forms.
- Apply linear, quadratic, and exponential functions to real world data.
- Determine and apply situations of linear systems.
- Express and manipulate mathematical information and concepts in verbal, numeric, graphical, and symbolic form while solving a variety of problems.
- Shift among the verbal, numeric, graphical, and symbolic representations of mathematics relationships.
- Use appropriate technology in the creation, evaluation, and analysis of mathematical models.

Instructional Strategies

This is a student-centered lab using a variety of instructional strategies including cooperative learning structures, authentic learning tasks, individual and group assignments, special projects, and multi-media activities. All lessons, tasks, activities and assignments are directly aligned to the objectives of the required gateway course.

Grading and Evaluation for the Developmental Lab

Evaluation is based on student attendance, class work, and performance. Summative assessment scores are taken from the gateway course exams.

- Lab Attendance: 20%
- Class work: 30%
- Gateway course exams: 50%

Additional Assistance Provided to Students

- Open lab hours for students to work in the classroom outside of class time.
- Student lab assistants available for tutoring during open lab hours.
- Assistance with technology (laptops, computers, calculators)
- Advising on mathematics course sequence.
- Individualized study plans for struggling students.
- Extended office hours (walk-in, on-line, and by appointment).