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Corequisite Mathematics: A Program Analysis at the College Level

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COREQUISITE MATHEMATICS: A PROGRAM ANALYSIS AT THE COLLEGE LEVEL

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APPROVAL OF DISSERTATION

We, the faculty supervising the work of Shannon Miller-Mace, affirm that the dissertation *Corequisite Mathematics: A Program Analysis at the College Level*, meets the high academic standards for original scholarship and creative work established by the Curriculum and Instruction program and the College of Education and Professional Development. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Many incoming college freshmen who do not meet minimum standardized exam cut-score requirements are often determined to be not ready for college-level coursework and registered for pre-requisite, multi-semester, remedial course sequences. The goal of pre-requisite courses is to prepare students for college-level courses prior to enrollment in college-level classes. However, based on multiple studies, traditional, pre-requisite developmental education has become a barrier to student success. In contrast, the co-requisite instructional model enrolls students into their college-level, credit-bearing course in their first semester on a college campus, improving the likelihood of success in those courses and beyond. The purpose of this study was to determine the effectiveness of implementing a corequisite curriculum into a college algebra course. To help with this determination, the study compared student success in a corequisite college algebra course to student success in a non-corequisite college algebra course, a traditional college algebra course, and success in subsequent precalculus classes. Another purpose was to examine faculty perceptions of their experiences teaching non-corequisite college algebra courses and corequisite college algebra courses. Faculty perceptions on initial transition preparedness, implementation of evidence-based teaching theories, and continued improvements were collected using interviews. This study showed corequisite mathematics benefitted students typically labeled developmental. This study also confirmed that academically at-risk students are capable of learning complex ideas and concepts at the college-level, and can be successful without slow-paced, extended remediation. Faculty benefitted from the training, collaboration, and resources provided for the implementation of new course curricula like the corequisite model. It was evident from this study, with the corequisite model, faculty continue to support students as they progress in their mathematics courses.

CHAPTER 1

INTRODUCTION TO THE STUDY

Mathematics departments across the nation have been challenged to support under-prepared learners who are entering the college arena. Finding ways to support these students so they can be successful at the same level as their peers is an ongoing debate among academics and professional educators. This study examined the performance of a mathematics program implementation from Fall 2017 to Spring 2020 in Marshall University's Department of Mathematics. The study's focus was to first document the performance of students in the newly implemented mathematics curriculum from Fall 2018 to Spring 2020, then offer a comparison to student success in more traditional curricula offered in the department from Fall 2017 to Spring 2019.

The study addressed the department's transition from non-corequisite instructional models of college algebra mathematics remediation toward just-in-time, co-requisite models of instruction. Corequisite instruction specifically refers to the use of redesigned support courses that create a pathway directly to a student's major-required, credit-bearing gateway course, without the requirement to have any specific standardized placement exam score. Rather than taking a pre-requisite remediation course sequence, implementing corequisite support allows students who need additional support in college-level math to enroll in their credit-bearing courses and receive extra help (Complete College America, 2021a).

STATEMENT OF THE PROBLEM

Many incoming college freshmen who do not meet minimum standardized cut-score requirements are often labeled as developmental students and promptly registered for slow-paced, multi-semester, preparatory course sequences. These pre-requisite remediation course sequences are intended to remediate mathematical deficiencies identified by standardized tests. The ultimate goal of the pre-requisite course is to fully prepare students for college-level courses prior to their enrollment in college-level classes. Based on multiple studies, traditional, pre-requisite developmental education has become a barrier to student success. In contrast, the just-in-time nature of the co-requisite instructional model is the type of restructuring that enrolls students into their college-level, credit-bearing course in their first semester on a college campus, improving the likelihood of success in those courses and beyond (Goudas & Boylan, 2012).

PURPOSE OF THE STUDY

The purpose of this study was to determine the effectiveness of implementing a corequisite curriculum into a college algebra course. To help with this determination, the study compared student success in a corequisite college algebra course to student success in a non-corequisite college algebra course sequence. Data were collected to look at student performance measures, such as final course grade upon completion, in both corequisite college algebra courses and non-corequisite remediation college algebra course sequences, as well as traditional offerings of college algebra. Another purpose was to examine faculty perceptions of their experiences teaching non-corequisite college algebra courses and corequisite college algebra courses. Faculty perceptions on initial transition preparedness, implementation of evidence-based teaching theories, and continued improvements will be collected using interviews.

SIGNIFICANCE OF THE STUDY

This study was important because of its potential to reveal strengths and weaknesses in implementing corequisite curricula. The report from this study will provide an opportunity for evidence-based decision-making on developmental education specifically within the MU Mathematics Department. Additionally, this study was significant on a broader scale, similar to other doctoral research, such as results reported by Moening and Sallon (2016), for its potential to inform the wider mathematics community on program implementation. According to the Tennessee Board of Regents Vice Chancellor Denley (2016), the education community is starting to see initial improvements promised by piloted corequisite courses. While there is still more analysis to be done, improvements in student success due to the corequisite courses are apparent in full-scale implementations, with substantial increases in students' success rates in both the university and community college sectors (Denley, 2016). This study will attempt to close the loop on program implementation and inform efforts in the mathematics community to improve the success of developmental students at the college level.

Corequisite models ask educators to trade working through pre-requisite content objectives and mastering rote skills presented without context for a more complex, content-specific presentation of abstract ideas, real-world situations, and practical questions. Theoretically, students gain access to higher-order thinking earlier in their mathematical learning by being exposed to the college-level content, all the while being supported with just-in-time scaffolded knowledge and skills that help students master required learning objectives (Logue et al., 2019). Indeed, there is significant evidence that academically at-risk students are capable of learning complex ideas and concepts at the college level. These students can be successful and do not need slow-paced, extended remediation (Denley, 2017).

Students benefit from the active learning processes of applying, reflecting, sharing, and observing both in and out of the classroom, while also functioning as both learners and teachers. Such integration helps students more closely associate the practical value of learning theoretical concepts. This study will shed some light on any consistencies or divergences in the instruction of these models when putting theory to practice. Difficulty in making the transition from theory to practice arises, at least in part, from the failure of the teacher to integrate both theory and practice into the same course in the curriculum in ways that are relevant and meaningful to the student. To close the loop on program implementation, identifying the level of faculty preparedness, transition efforts, and continued improvements is crucial to determining the level of success and the effectiveness of the implementation (Vandal & Todd, 2020).

RESEARCH QUESTIONS

This study will address the following four research questions:

1. Is there a significant difference in student performance between corequisite college algebra students and non-corequisite college algebra students at Marshall University?
2. Is there a significant difference in student performance between corequisite college algebra students and traditional college algebra students at Marshall University?
3. Is there a significant difference in student performance in subsequent courses between corequisite college algebra students, non-corequisite college algebra students, and traditional college algebra students at Marshall University?
4. What are the perceptions of faculty who taught both corequisite and non-corequisite college algebra courses at Marshall University?

OPERATIONAL DEFINITIONS

For this study, the following operational definitions are used:

Corequisite College Algebra Students – These are typically freshman-level students taking mathematics courses using corequisite policies, like integrated support and just-in-time instruction, without the requirement of an additional pre-requisite semester of preparatory mathematics. Students are placed into an expanded version of the traditional college-level college algebra course, rather than the first course in a pre-requisite developmental college algebra course sequence. For this study, students with ACT 17-20 enrolled in MTH 127 College Algebra Expanded (5 hours) offered Fall 2018 – Spring 2020 face-to-face on the main campus at Marshall University are considered corequisite students.

Non-corequisite College Algebra Students – These are typically freshman-level students taking college algebra courses using policies aligning with pre-requisite models of instruction, including a strict hierarchy of college-level content and limited instructor flexibility. A portion of students enrolled in non-corequisite courses will have completed a pre-requisite developmental course before enrolling in an expanded version of a traditional college algebra course. The other portion of non-corequisite students is enrolled directly into an expanded version of the traditional course offerings. For this study, students with ACT 17-20 enrolled in MTH 127 College Algebra Expanded (5 hours) offered Fall 2016 – Spring 2018 face-to-face on the main campus at Marshall University are considered non-corequisite college algebra students. For those who complete the sequence, the first course (MTH 102 Preparation for College Math) was an emporium model developmental course designed to mitigate mathematical gaps from high school to college. The second course (MTH 127 College Algebra Expanded) was an extended 5-hour version of the traditional college algebra course. Together these two courses represent the courses that students from Fall 2017 to Spring 2018 would take before entering the next course in their major.

Non-terminal College Algebra Students - Students enrolled in corequisite, non-corequisite, or traditional college algebra who have a major that requires successful completion of college algebra to enroll in a higher-level mathematics course, also required for their major.

Terminal College Algebra Students – Students enrolled in corequisite, non-corequisite, or traditional college algebra who have a major that only requires college algebra, rather than a subsequent higher-level mathematics course. These students are not required to take more mathematics courses that require college algebra as a pre-requisite for enrollment.

Traditional College Algebra Students – These are typically freshman-level students taking college algebra courses using traditional methods of course delivery, like lecture and textbook assignments. While it may be the case some instructors of traditional college algebra incorporate aspects of corequisite instruction into their courses, there is no expectation faculty cover pre-requisite content with embedded remediation or integrated support in the same ways as non-corequisite and corequisite courses are designed. Students are placed into the traditional college-level college algebra course, without the requirement of an additional pre-requisite semester of preparatory mathematics, as long as they have the appropriate enrollment criteria. For this study, students with ACT 21+ enrolled in MTH 130 College Algebra (3 hours) offered Fall 2016 – Spring 2020 face-to-face on the main campus at Marshall University are considered traditional college algebra students.

Final Course Grade – The final grade a student earns in either the corequisite or non-corequisite college algebra courses. Students earn standard letter grades of A, B, C, D, or F. Students who withdraw receive a W as their grade. For this study, this data was requested and permission for access was granted through the Marshall University Mathematics Department and College of Science. Students may have multiple grades across semesters in both the corequisite and non-corequisite college algebra courses.

Enrollment Criteria – For grouping purposes, the enrollment criteria for placement in either the corequisite, non-corequisite, traditional college algebra course, or pre-calculus course was the ACT score.

Subsequent Course Grade - The grade a student earns in the course following their corequisite, non-corequisite, or traditional college algebra courses. Students earn standard letter grades of A, B, C, D, or F. Students who withdraw receive a W as their grade. For this study, MTH 132 Precalculus was the course on which the analysis was focused. This course has consistently been one with a particular cohort of students in either corequisite or non-corequisite college algebra courses must take. Success in this subsequent course may offer further insight into student performance.

Student Major – The academic major listed for each student in the data. For this study, there were a variety of majors considered when comparing student performance across the different types of college algebra courses. The reported comparisons were narrowed to discuss implications for students who take college algebra as their only mathematics course (terminal) and others who take the course as a pathway to calculus (non-terminal).

Faculty Perceptions - These are the thoughts, expressions of, and ideas communicated by the faculty to the interviewer for the study concerning corequisite college algebra courses. Three major categories of perceptions will be analyzed: Preparedness to Transition, Incorporation of Teaching Theories, and Continued Improvements

DELIMITATIONS OF THE STUDY

This study examined student performance in college algebra on the main campus of Marshall University for Fall 2017 through Spring 2020 semesters. Only students who were enrolled in face-to-face, main campus course offerings were considered. Faculty interviews included only those individuals teaching both non-corequisite and corequisite college algebra courses on the main campus during the specified semesters. Faculty teaching online, off-campus, or dual-credit courses were not considered. Also, while faculty who were selected for interviews taught both non-corequisite and corequisite college algebra, they were not the only faculty members responsible for teaching all sections of college algebra from which the student data was collected. Therefore, data gathered about students' final grades were not necessarily final course grades from the five faculty members interviewed for this study.

CHAPTER 2

REVIEW OF THE LITERATURE

The purposes of this study were to contribute to the growing data used to analyze the effectiveness of corequisite instruction on student achievement, present faculty perspectives of the implementation of a corequisite model of instruction, and measure the educational impact of corequisite models in the classroom. This study focused on determining ways corequisite education programs might advance student achievement, rather than attempting to critique other methods. This chapter will present common challenges in remedial mathematics education throughout recent decades which have influenced policy decisions on developmental course offerings at the college level. Through initial comparisons between traditional remediation of developmental students and the current corequisite course designs at the college level, some deliberation on learning theories emerges to support corequisite-related pedagogical approaches. Recognition of the impact corequisite programs have at the college level is presented and echoed by many national mathematics and educational organizations. Specifics about the development and implementation of co-requisite college algebra courses at Marshall University are provided.

CHALLENGES IN REMEDIAL EDUCATION

Remedial mathematics education is a critical topic for developmental students and educators across the nation. Many students are required to continue their education by enrolling in institutions of higher learning, rather than being encouraged into technical programs or community colleges. The push for students to enter institutions of higher learning has resulted in various challenges in mathematics education for students and those institutions. One of those challenges is accommodating a cohort of students who need developmental mathematics education.

In an interview by Levine-Brown and Anthony (2017), Hunter Boylan defines developmental education as "the integration of academic courses and support services guided by the principles of adult learning and development" (Levine-Brown & Anthony, 2017, p. 18). Boylan argues there is a collective misunderstanding of developmental education. Many students, educators, and institutions have incorrectly associated developmental education as an exclusive minority student issue, which it is not. Boylan explains how the current rush to take advantage of the financial benefit of new developmental education initiatives has ended up allowing the adoption of policies that do not necessarily achieve the intended outcomes for the targeted students. Boylan clarifies that policies encouraging institutions to use multiple measures to advise and place students and provide professional development for faculty are crucial to the success of developmental education. Levin-Brown and Anthony finish the interview by asking Boylan for any advice for professionals in the field on how they should approach the current developmental education climate: "We have to be the committed people who implement thoughtfully and ground what we do in appropriate research and theory. Professionals…need to be participants in the reform, not be victims of it" (Levine-Brown & Anthony, 2017, p. 21).

As institutions of higher learning have increasingly been tasked to find ways to support students with various educational foundations, the developmental population has become an increasing majority. First attempts at providing developmental education in this new environment have served to be financially beneficial to the institutions. However, they were not successful overall in achieving the intended goals of remediating, improving student performance in other classes, and improving retention and graduation rates. Scott-Clayton and Rodriquez (2012) claim much of the information used to make policy decisions about developmental education is based on decades-old national datasets which do not reflect current needs in developmental education policy. Nearly all studies to date focus on outcomes for students who score just below or above placement exam cutoff scores. In turn, much of our understanding of the probable causal effects of developmental education excludes students who begin with low placement scores and who stand to benefit the most from remediation (Scott-Clayton & Rodriquez, 2012). Moreover, studies examining the impact of developmental education have not accounted for institutional characteristics that might influence developmental program outcomes. Sanabria, Penner, and Domina (2020) confirm this by claiming, despite the prevalence of remediation, previous research presents contradictory findings regarding its short and long-term effects. With their research, the authors suggest, while many students may benefit from remedial education, a substantial number of students struggle with traditional remedial coursework and fail to realize its overall intended benefits (Sanabria et al., 2020).

Benken et al. (2015) explain how most of the students placed into developmental education courses have similar characteristics. A majority of developmental students take more course work hours in mathematics than is required for their major of study. A majority of developmental students have taken some type of mathematics all four years of their high school careers. Additionally, a majority of developmental students take three or four years of instruction to pass the minimum requirements for college entry. This is troublesome since many developmental students who plan to attend college have already mastered enough of the content in college algebra to be successful in their academic majors, as well as their careers. The authors agree it is crucial to incorporate curricular alignment from the secondary level to prepare developmental students for the demands of college, no matter what academic pathway they choose. The misalignment of the secondary curriculum with the skills necessary to succeed in college increasingly impacts other affective components like student self-perception, confidence, attitudes and beliefs, and anxiety, which are all linked to persistence and motivation (Benken et al., 2015).

Considered one of the biggest obstacles to learning in the mathematics classroom, Buckley et al. (2016) research reveals how mathematics anxiety is characterized by both physiological (e.g. increased heart rate) and cognitive symptoms (e.g. negative thoughts). State mathematics anxiety, defined to be when “fear [is] felt on-task or in the moment when an individual is presented with mathematical information” and trait mathematics anxiety, defined to be a “stable, well-developed negative attitude or concern regarding mathematics that leads to avoidance of mathematics” can both be attributes of a developmental student (Buckley et al., 2016, p. 161). Both of these types of mathematics anxiety draw on parts of the brain that are involved in problem-solving. Therefore, resources normally put to use to engage in the mathematical content cannot be used to complete mathematical tasks, and performance suffers. These anxieties also have an impact on working memory. Furthermore, the authors’ research indicates highly mathematically anxious individuals activate the centers of the brain associated with the detection and experience of pain. And interestingly enough, this pattern of brain activation was only observed in anticipation of a mathematics task and not during task completion, corresponding with conceptualizations of anxiety, where failure is anticipated and control over the outcome seems unachievable (Buckley et al., 2016).

DEVELOPMENTAL EDUCATION AT THE COLLEGE LEVEL

Many developmental course designs at the college level provide consistent objective grading, content coverage, and mastery of course materials. These objectives were incorporated into developmental courses as required prerequisite sequences for higher-level college learning. As Bahr (2008) notes, some evidence points to the notion that remediation, in some form, can be helpful. Bahr claims students who successfully remediate in developmental programs can find success overall in their academic future. However, the author notes that the problem with initial developmental course designs is a vast majority of the students are unable to achieve success in those programs (Bahr, 2008).

Bonham and Boylan (2011) wrote a decade ago about a great deal of research identifying promising practices to improve the quality of developmental mathematics instruction. However, for these efforts to be successful, the authors say "it will be necessary for professional associations, foundations, policymakers, and developmental mathematics instructors to collaborate in changing the way developmental mathematics courses are structured, taught, and delivered" (Bonham & Boylan, 2011, p. 8). The authors are concerned this work will be neither easy nor short-term but urge "it is a process that must be undertaken if educational opportunity is to remain a reality in U.S. postsecondary education. We can no longer deny our weakest and poorest citizens the opportunity to obtain a college credential simply because we are unable to teach them how to factor polynomials" (Bonham & Boylan, 2011, p. 8). Echoing this concern, Crisp and Delgado (2013) find developmental education may even prohibit developmental students, who initially enroll in community college, from successfully transferring into institutions of higher education to continue their education. They claim, "although developmental students were slightly more likely to persist when compared with non-developmental students (79% compared to 77%), counter to prior research, no significant relationship was found on the whole between remediation and student persistence, both before and after accounting for selection bias and covariates thought to impact student success" (Crisp & Delgado, 2013, p. 112). The authors call into question whether the enormous costs to students, community colleges, and states are justifiable (Crisp & Delgado, 2013). Trying to save money became one of the major arguments for redesigning developmental courses using less faculty contact and more computerized learning, like that of the emporium model.

Mathematics Emporium. One major overhaul some institutions implemented as an initial attempt at developmental education was to design math emporium model courses. Webel et al. (2017) define math emporium as "computer labs that employ software packages…as the primary means of delivering course content. Rather than listening to an in-person lecture, students progress through the course topics at their own pace, moving to more advanced topics only when they are ready" (Webel et al., 2017, p. 356). These were one-size-fits-all courses designed to remediate knowledge gaps for every student identified as deficient by standardized placement scores. The idea is by using technology to automate the grading of homework questions, students get immediate feedback on their work, and instructors can focus on assisting students who are struggling. The authors point out some organizations like the National Center for Academic Transformation, which help sponsor institutions in the conversion to these redesigned efforts which claim an average of 36% reduction in cost over traditional courses. However, as the authors also point out, the research into the effectiveness of math emporium models is largely based on aggregate final exam scores or passing rates and does not address variables that measure whether students' actual and perceived academic educational needs are being met (Webel et al., 2017).

When considering completion rates, length of completion time in the program, success in the college-level mathematics courses, and other contributing factors to success in the program, Childers and Lu (2017) found that computer-based mastery learning in developmental mathematics classrooms, even with newer course designs, show no dramatically different results in students' success and achievement of course outcomes. Whether educators are discussing bridging the gap between procedural and conceptual learning in subjects like college algebra, or students' attitudes about feeling isolated and underserved in emporium courses, there are significant concerns about adopting these models with such negative results (Webel et al., 2017).

Accelerated Learning Programs. In their initial form, corequisite models were primarily created in the form of companion courses aiming to support students as they work through the college-level content in their regular courses. One initial prominent model with this structure, developed by Professor Emeritus Peter Adams at the Community College of Baltimore County, was the Accelerated Learning Program (Accelerated Learning Plan, 2021). This corequisite model, aimed at developmental English students, was developed as a 3-hour, non-credit integrated reading and writing course paired together with a 3-credit hour college composition course. The model was designed to remediate English deficiencies identified by standardized test scores, simultaneously covering college-level content, by grouping 10 non-corequisite students with 10 corequisite students in a co-mingled college-level course. The 10 corequisite students were also enrolled in a support course where they have the opportunity to focus on critical reading, writing, and thinking in a small cohort.

The main benefits of the Accelerated Learning Plan (ALP) include eliminating exit points for students, reducing stigma, improving attachments, encouraging cohort effectiveness, changing attitudes toward the developmental course, allowing more individual attention, allowing time for dealing with non-cognitive issues, and allowing students with development placement in writing and reading to enroll in a credit composition course. With this program, student completion rates in the College Composition course have doubled compared to the stand-alone sequential developmental model. The ALP model is now a nationally recognized program that has served as a successful model for many other institutions (Accelerated Learning Program, 2021).

According to Complete College America (2017), the key pedagogic features that make ALP courses successful include the backward curriculum design, active learning in a writing classroom, integrated reading and writing, addressing non-cognitive issues, thinking skills in the writing classroom, improving students' ability to edit their writing, syllabus design, and reading/writing projects, not essay assignments. The model is also well-known for harnessing a lower student-to-teacher ratio, but also increases the workload for students to 6-credit hours. Complete College America advises teachers to incorporate these pedagogical features; and while specifically targeting developmental English students, apply these pedagogical strategies directly to address the needs of developmental mathematics students (Complete College America, 2017).

Mathematics Pathways. Another structural change adopted by institutions across the country that are redesigning developmental courses is the implementation of mathematics pathways. Complete College America (2018b) describes mathematics pathways as an opportunity for institutions to encourage students to enroll in and complete gateway, college-level courses their first academic year. The pathways, normally consisting of at least quantitative reasoning, statistics, and algebra courses, provide options that are relevant to a student's program of study. Rather than encouraging all students to take a single, one-size-fits-all college algebra course, effective mathematics pathways enroll students in courses like statistics and quantitative reasoning as an entry-level course. Institutions are encouraged to define a finite set of mathematics pathways aligned to programs of study and/or meta-majors (Complete College America, 2018b).

A contributor to the National Center for Academic Transformation, Twigg (2011) discusses several problems identified among initial remediation attempts in developmental courses. In many cases, students who took prerequisite courses in traditional developmental math sequences were not prepared for the courses that were required in their major. This was especially true for students in algebra pathways, where many get stuck on their first module that covers skills like graphing inequalities. Many faculty members have discovered, with certain course policies in place, students manage to pass these prerequisite developmental courses with assessment grades as low as a D and without the ability to do basic graphing and other skills that are essential to success in the college-level mathematics course. Students are sometimes given a sense they have mastered material by only completing an 80% mastery level for assignments in the course content, leaving some essential prerequisite skills unmastered. Students could earn as low as 20% on comprehensive final exams and still earn a C grade overall in the course. Confronted with this situation, some colleges have pushed the remediation into the college-level courses and created review modules to help address the deficiencies. The problem then becomes that these students get bogged down in the review modules. Students did recognize that they were in the appropriate higher-level course but are defeated by the notion they could not do the review, which prohibited access to the college-level material. This observation provides a catalyst to say that student success using pre-requisite developmental course sequences has little to no correlation to success in their next course (Twigg, 2011).

According to the Dana Center Math Pathways (2017), initial pathway designs were focused on developmental students because of the gains made to help these students accelerate through their program of study. The authors acknowledge, due to the evidence of high failure in traditional developmental mathematics course sequences, it is a moral imperative to focus on this population first. However, seeing the tremendous success of these math pathways, the vision for who may benefit has expanded. Moving forward with experience from initial pathway designs, the Dana Center now encompasses the ethos that “all students need and deserve the opportunity to learn mathematics content that is meaningful to their academic and career goals and learn that content in an environment designed to enhance their development as independent learners and critical thinkers” (Dana Center Math Pathways, 2017, p. 153).

> Furthermore, to imply that pathways only apply to developmental students perpetuates inequity by establishing a two-tiered system in which students who are placed directly into college-level mathematics are funneled into College Algebra or STEM pathways, and developmental students are funneled into alternative pathways. This inevitably leads to a perception that the non-algebraic-intensive pathways are less rigorous and less desirable. (Dana Center Math Pathways, 2017, p. 153)

Logue et al. (2017) found that with the introduction of a statistics pathway, students who were placed directly in college-level statistics did far better than their counterparts who started in remedial classes; even when students in remedial classes were given extra support. The authors also report students enrolled directly into college-level statistics were more likely to pass their initial math course, and as many as three semesters after the study, had completed more college credits than their counterparts. This suggests these students can pass math pathway courses without the need for pre-requisite remedial coursework (Logue et al., 2017). As many math departments continue to redesign their developmental course and implement pathways based on newer versions of policies for developmental instruction for students entering college-level remediation courses, Logue et al. (2017) note many students never end up taking the needed coursework. The authors continue to say that even if students are enrolled, they may never pass their required remediation courses theorized to increase college-level performance (Logue et al., 2017).

One way to increase student success is to implement more robust advising by gathering student input on their interests for students to be placed in the most appropriate pathway. Rather than placing students into convenient one size fits all preparation courses, academic advisors should immediately be able to place students into a more appropriate pathway and one that fits their academic needs. The downside is that students who end up choosing to switch majors will be required to enroll in freshman-level coursework on a different pathway. Scott-Clayton et al. (2014) indicate under-placement is much more common than over-placement. They also claim that adding standardized test scores to transcript information does little to change the placement of the student and the use of more accurate screening tools would enable institutions to remediate substantially fewer students without compromising college success (Scott-Clayton et al., 2014).

EMERGENCE OF COREQUISITE EDUCATION

As the mathematics education community reflects on the use of initial remediation models and policy decisions, many have admonished the detrimental effects some of the traditional developmental course designs and institutional policies have on students, faculty, and institutions. Rather than continuing to focus on logistics and administrative factors applied to determining course offerings, educators have begun to take a look at more pedagogical approaches, based on several different learning theories and educational philosophies, to address achievement gaps and perceived educational experiences. In a collection of case studies, Richardson and Dorsey (2019) define co-requisite courses as those that “take many forms: boot camps, extended hours each week with embedded support content, separate but linked support courses that run throughout the semesters, mandatory tutoring, compressed courses, stretch courses, and other structures—all of which enable a student to complete a college-level course while receiving developmental mathematics support" (Richardson & Dorsey, 2019, p. 43).

Corequisite instructional models provide just-in-time remediation and remove the need for semester-long and, oftentimes, year-long prerequisite course sequences that delay student progress in their two- and four-year plans. Corequisite courses, designed as single-semester, college-level courses with built-in support, remove non-credit bearing courses from student's plan of study and add courses that count toward graduation. These aspects make corequisite courses much more appealing to students in general, which may be a key factor in why students find success in them in greater numbers than those in traditional prerequisite developmental courses.

To support this, the Lumina Foundation (2016) released several reports with Complete College America to illustrate early results and promote general plans for ways institutions may move forward with implementing successful policies for remedial students. The executive summary of the report on corequisite remediation includes a "blueprint" to "build your own corequisite remediation program on a solid foundation using six pillars" (Lumina Foundation, 2016, p. 6). The Lumina Foundation list includes: (1) purpose, not placement, (2) treating all students as college students, (3) delivering academic support as a corequisite, (4), all students should complete gateway courses in one academic year, (5) develop multiple math pathways into programs of study, and (6) corequisite support is the bridge into programs of study (Lumina Foundation, 2016).

One of the most vital decisions that can positively influence the performance of developmental students is to incorporate theories of learning into these co-requisite models. Much of the theoretical framework that underpins the corequisite model comes from different educational learning theories and philosophies: procedural skills and conceptual knowledge, just-in-time teaching, motivation and persistence, complexity and transformation, and equality, equity, and justice. Additionally, maximum effectiveness in using these theoretical frameworks can be achieved when educators close the gap between theory and practice in the classroom.

Procedural Skills and Conceptual Knowledge. Perhaps one of the most important theories underpinning corequisite education is the overall shift in assumptions about student ability made by faculty and administrations. Many documented experiences with developmental education are based on the unsubstantiated notion students are not prepared or cannot think on a higher conceptual (the what and why) level until they have mastered all the necessary prerequisite procedural (the when and how) skills. From the Instructional Practices Guide published by the Mathematical Association of America (Abell et al., 2019), when students learn procedures connected to conceptual foundations, they have more success in using procedures, recall procedures for a longer period, and use procedures flexibly and effectively in any problem-solving situation. The group asserts, without a foundation in conceptual understanding, students grasp at procedures they have managed to remember in hopes it will produce the correct result, without really thinking about if they have made an appropriate choice. This is because "conceptual understanding involves knowing what to do and why it works, while procedural fluency involves deciding and knowing how to do it" (Abell et al., 2019, p. 42). And thus, we must reconsider the notion that students must show mastery over procedure before being exposed to conceptual frameworks to solve problems.

Based on this theory, a study by Quarles and Davis (2016) indicates that the type of mathematics taught in developmental classes affects student outcomes. Specifically, instruction focused on procedural skills may not be preparing students for college mathematics. Their results challenge the assumption that increased student learning in remedial mathematics improves student outcomes. Procedural algebra skills were not associated with higher grades in college-level math. Conceptual mathematics proficiency was associated with higher grades in general education math, but further research will clarify whether this trend continues into precalculus (Quarles & Davis, 2016).

Just-In-Time Teaching. Another component of successful corequisite courses incorporates refined pedagogical approaches like just-in-time instruction. Gavrin et al. (2003) describe just-in-time teaching environments, initially created by the Indiana University and Perdue University Indianapolis and the US Air Force Academy for physics courses targeting non-traditional students, where "students and instructors communicate with one another outside of class time, and the information is used to adjust the content and format of the classroom lesson" (Gavrin et al., 2003, p. 2). This communication, occurring daily or in specified intervals, can be synchronous or asynchronous, or a mix of both, can occur between the instructor and individual students or teams of students and relies on a combination of high-tech and low-tech methods. Specifically, the communication aims to meet the challenges of students who are not committed to learning mathematics by "introducing several small assignments in addition to traditional problem sets to encourage students to pace themselves appropriately, creating an environment that is student-centered" (Gavrin et al., 2003, p. 3). This strategy is firmly based on education research and strengthens the notion that students learn best when they are actively engaged rather than passively receiving information (Gavrin et al., 2003).

Gavrin et al. (2003) claim just-in-time instruction "intentionally increases the quantity and quality of (1) student-to-student interaction, (2) student-to-faculty interaction, and (3) time-on-task" (Gavrin et al., 2003, p. 3). Beginning with warm-up exercises before the lecture begins, just-in-time instruction promotes interactive lectures that "do not simply go over the questions in an isolated section of the lecture, rather [it] frames [the] lecture in terms of an analysis of various student responses" (Gavrin et al., 2003, p. 4). Additionally, essays, puzzles, intra-class communications, and recitation sections are all possible components of a well-developed just-in-time approach. Incorporating just-in-time teaching is an encouraging and effective way to improve retention, student attitudes, and cognitive gains. The authors are clear to say that this method allows for addressing more challenging concepts in class, rather than getting bogged down with the remedial content (Gavrin et al., 2003).

Motivation and Persistence. When given more challenging mathematical concepts to consider, we must help students adjust their motivation sets, and in the face of struggle, help them remain persistent. Ryan and Deci (2000) assert ways teachers can move from extrinsically motivating to intrinsically motivating students, the more likely students are to have knowledge achievement gains (Ryan & Deci, 2000). Benware and Deci (1984) provide one way to accomplish this shift in motivation. The authors claim, rather than asking students to learn material for taking a test, asking students to learn a topic to teach it to someone else is a much more intrinsically motivating task. For some time now, educators have known using this form of self-determination theory asks students to learn in such a way that they are made resident experts of a particular topic (Benware & Deci, 1984). This dramatically affects students' views on what competence means in the curricula developed in corequisite models, and ultimately changes their motivational mindset to a more academically aggressive one.

In an interview, mathematician Andrew Wiles (2017), who recently gained notoriety by providing proof of Fermat's Last Theorem (a 400-year-old previously unproven mathematical theory), hopes educators can reclaim the image of mathematics by replacing the emotion that resides within the fear of failure with the joy of success and coping effectively when stuck on a problem. Among students who struggle with mathematics, it is socially acceptable to claim to be bad at math as a way to avoid the struggle. Wiles notes these same patterns as he speaks with folks around the world. People are generally not comfortable with the state of being stuck, especially when learning mathematics. In addition to finding ways to improve mathematical motivation, supporting students' persistence through the material in challenging courses drums up their mathematical courage, which will ultimately make them more confident learners (Wiles 2017). Improving motivation and persistence can be very compelling predictors of success for developmental students in corequisite courses.

Another compelling aspect of corequisite courses is that they allow for instructional flexibility of the course curriculum. Students are offered a consistent curriculum structure that also incorporates the flexibility to allow for adjustment of curriculum delivery based on student needs. For example, asking students to complete low-stakes, participatory tasks can engage them with the course content and begin to move the responsibility of learning onto their shoulders. Studies by Kim and Hodges (2012) began to show decades ago that implementing a simple emotion check for students can have dramatic impacts on the way students remember experiences during their remedial or co-requisite courses. Educators who provide students the opportunity to reflect on their learning are increasing student responsibility to make appropriate choices for their learning. Students who find confidence are far savvier at navigating through new, challenging topics. Students need a variety of methods of support, and faculty who provide environments that accommodate different learning styles, personalities, and learning needs, help more students develop the strength they need to succeed.

Complexity and Transformation. In addition to student confidence, educators embracing the complexity of ideas must encourage transformational learning, while being comfortable with their personal growth. Presenting students with complex structures rather than only basic ideas provides educators the opportunity to emulate the type of behavior that is expected within their discipline. Foster (2012) discusses approaches like explanatory reductionism which support the idea mathematics is best learned with building blocks and assembling them into secondary structures. However, when this reduction takes place for the student, rather than by the student, it may be dangerously disempowering. Foster argues mathematics curriculum overall has taken an increasingly reductionist flavor, which constitutes a misunderstanding of learning theories like constructivism, and concludes that this limits the student's ability to enjoy mathematics and solve richer, more worthwhile problems (Foster, 2012).

The meaning gained from teaching, learning, and social interaction must require a real sense of inquiry and dedication to the idea that learning never stops. Boyles (2018) claims educational models, in general, are moving away from traditional techniques of transmission, where information is solely transferred from one person (the educator) to another (the student). New models use more transactional methods that take more of a collaborative and inquiry approach, transferring information back and forth. Going even further, Boyles states that for transformational learning to occur, teachers must demonstrate academic rigor and know their content areas well enough not to be the center of attention. Educators must also be interdisciplinary, curious, and willing to share power and control with their students, perhaps asking more questions than they give answers. This requires teachers to be comfortable with uncertainty and embrace failure, in the sense that making mistakes can often lead to the best educative experiences (Boyles, 2018). Learning never stops, and this must be exemplified to students.

Equality, Equity, and Justice in Mathematics Education. Broadly, corequisite education solves many of the initial challenges identified regarding obstacles in developmental education. In an interview by Levine-Brown and Anthony (2017), Hunter Boylan explains how developmental education, striving to promote an environment that minimizes mathematics anxiety, must support equality, equity, and justice in the classroom and beyond. Equality in mathematics education assumes that everyone will benefit from the same access to support for their learning. In this category, everyone receives the same level of instruction and is all treated in the same way. However, students come together from differing backgrounds and levels of ability and knowledge. Having equality in education is not enough. Equity in mathematics education involves meeting individual needs, giving people different levels of support for what they need to learn. Each student's prior experiences will influence their general knowledge and will contribute to the list of things they need to learn to be successful. Equity in mathematics education demands that all students should not be required to complete the same coursework across the board, and assessment of their skills will also be multi-faceted to capture various strengths within the course content. The current system of higher education, however, rewards those who can do well on standardized tests by allowing an accelerated progression through their academic pathway. This narrow measure may not capture the array of academic ability among students entering mathematics courses at the college level.

Justice in mathematics education ensures that the limitations of instructional support are removed and assessment accommodations are met. Supporting students who are at a disadvantage upholds equitable access to education that must be afforded to every human being.

Gutiérrez (2013) suggests rather than putting energy into producing successful high-stakes test-takers, educators should seriously re-consider the kind of thinkers being produced in the current system of rewards. In an attempt to frame equality, equity, and justice in mathematics education with a sociopolitical frame of mind, the author states educators must be prepared to transform mathematics education in ways that provide more socially just practices. Because elements of knowledge, power, and identity are interwoven and arise from social discourse, real justice in education mandates a broadened professional language. Collectively, academia must focus on research for the public good and challenge the ideology that privileges knowledge for one group over another. Developing this inclusive language and inter-disciplinary, collaborative effort is an effective way to improve the mathematical competence of students and facilitate the transcendence of professionals in the mathematics education field (Gutiérrez, 2013).

Theory to Practice. Each of the philosophies discussed so far integrates to build an overall theory supporting the implementation of corequisite policies and the vision used to successfully achieve goals of academic success. Continuing to find a convergence of this learning theory will consistently improve the outcomes in mathematics remediation. According to Blouin et al. (2009), faculty who are supported to continue their research will benefit from learning about theories related to corequisite instructional models. The authors claim, even in related fields, there are three major areas to focus on in an innovative corequisite course: "(1) rejecting the use of the majority of classroom time for the simple transmission of factual information to students; (2) challenging students to think critically, communicate lucidly, and synthesize broadly to solve problems; and (3) adopting a philosophy of evidence-based education as a core construct of instructional innovation and reform" (Blouin et al., 2009, p. 1). They argue that most educational programs focus on short-term measures such as semester course grades, aggregate grade point averages, and standardized exams. However, they should be attempting to measure the true impact on students with more appropriate indicators of success. For example, authentic assessment techniques such as portfolios, performance assessment projects, self-assessments, and collaborative efforts in solving a complicated real-world problem, are more reflective of student ability and knowledge achievement. According to the authors, usage of such measures of success “are appropriate indicators of the likelihood of success in the next level of content acquisition, but do not necessarily reflect a student's capability of integrating that content, in a meaningful way, into a long-term professional career” (Blouin et al., 2009, p. 3). The authors begin by saying “as long as the standard practice in the academy is to focus on short-term educational outcomes measured as the lowest common denominator, simple content delivery, and mastery will always drive decisions made by programs, by individual faculty members in the classroom, and by students” (Blouin et al., 2009, p. 2). The authors believe “the public deserves our very best effort. To provide that effort, we must rethink, reengineer, and recommit to a truly scholarly approach to education, but one that is consistent with contemporary society” (Blouin et al., 2009, p. 2).

Educators in professional degree programs are charged with multiple responsibilities in the classroom. J. Wrenn and B. Wrenn (2009) say that educators are asked to apply

their professional knowledge in a variety of settings to serve our communities, reflect on how to improve practice from our experiences in the classroom, observe students engaging in learning experiences, and share with students the knowledge gained from experiences and scholarship within the profession. To accomplish these actions, educators must serve as both teacher and learner in both classroom and field (Wrenn & Wrenn, 2009). This kind of integration of theory and practice is foundational to co-requisite instruction and is key to any co-requisite program implementation.

NATIONAL RECOGNITION AND OTHER CONTRIBUTIONS

According to the Dana Center for Mathematics Pathways (2017), for institutions interested in implementing effective corequisite courses, there are many considerations. The first is using pre-existing initiatives and resources on campus that complement the work. These could include guided mathematics pathways, course content and pedagogy redesign, and pathway re-alignment. Also included are enrollment initiatives like utilizing multiple measures for course placement, and other persistence initiatives like programs designed to facilitate the development of a growth mindset and productive persistence for all students. The second consideration asks institutions to review multiple avenues of improvement on existing resources like placement protocols, student support structures, academic calendar structures, staffing needs, workload credit hours and financing, and graded assignments. The third consideration is a focus on co-requisite content, which requires major effort and dedication from the faculty and departments to review and edit existing courses and perhaps create some courses from scratch. The fourth consideration discussed “cultural shifts” addressing collaborative work, early alert systems and interventions, explicit instruction, and ongoing formative assessments among engaged faculty and departments. The fifth consideration is the need for continuous improvement of the policies and courses to keep them up-to-date, consistently meeting the academic needs of the students, supporting the instructional needs of the faculty, and meeting accreditation criteria of the institution (Dana Center for Mathematics Pathways, 2017).

While there are still changes coming quickly in the corequisite field, the inadequacies of traditional developmental mathematics sequences and the reported positive effects of corequisite instruction indicate a significant impact on student learning overall and specifically in mathematics learning. Authors Logue et al. (2019) report their results of quasi-experimental analyses demonstrating that policies requiring corequisite mathematics remediation result in higher pass rates for corequisite mathematics remediation than those requiring traditional remediation. Here traditional remediation means pre-requisite course sequences that prohibit students from enrolling in their college-level, credit-bearing courses. Corequisite groups in these reports not only demonstrated significantly higher quantitative course pass rates but also success in many other disciplines, as well as significantly higher graduation rates (Logue et al., 2019).

In a thorough analysis from the state of Virginia, Beamer (2020) describes several misconceptions and concerns surrounding current reforms in the developmental education field. Beamer refutes the misconception claiming developmental student enrollment directly into credit-level coursework has a disastrous effect on grade outcomes in gatekeeper courses. The author reports evidence of several studies suggesting even when students do pass required prerequisite developmental coursework, students may have forgotten a majority of the skills learned there before having an opportunity to use those skills in a college-level course. So, claiming developmental students who progress through pre-requisite developmental coursework are more prepared than students who enroll directly is dismissed in Beamer's results. Beamer provides supporting research indicating corequisite students are more able to be successful in college-level coursework than in typical remedial course sequences. This contrasts the previously accepted notion that developmental students are unable to succeed in college mathematics unless they show proficiency with pre-requisite material before they enroll in college-level courses. Several other concerns, such as the worry that new placement measures will inaccurately identify students as ready for college math and having more developmental students in college-level classes will send failure rates up, are also dismissed based on the reported success of students in corequisite courses (Beamer, 2020).

In initial results regarding developmental education at the college level, Park et al. (2018) detail how underprepared first-time-in-college students in Florida were given the option to enroll in developmental education courses regardless of their prior academic preparation. Students in the study were given three choices of mathematics pathway: (1) enrollment in developmental mathematics, (2) direct enrollment into intermediate algebra, or (3) enrollment in no mathematics course. Among the students who enrolled in the intermediate algebra pathway, a small percentage also enrolled in developmental mathematics in the same semester. The results from those first-time-in-college students indicated those who received same-semester developmental support were more likely to pass intermediate algebra compared with similar underprepared students who took intermediate algebra without developmental support (Park et al., 2018).

In Texas, research reports from Daugherty et al. (2018) detail five common types of corequisite models implemented across Texas Community Colleges: (1) paired-course models, (2) extended instructional time models, (3) Accelerated Learning Program models, (4) academic support service models, and (5) technology-mediated support models. Major challenges identified in these implementations included lack of stakeholder buy-in, issues with scheduling and advising, limited instructional preparation and support, and uncertainty with state policy. There were efforts to curate buy-in and address challenges deemed essential to successful implementation. Other strategies to improve success, like dedicated time for instructional design, professional development, and administrative decisions like small class sizes, were important but became financial burdens on the institution. It is worth noting a few unique features, such as the use of a single instructor for the corequisite courses and mixed-ability peer groups, which seemed to show effectiveness. But these choices often faced challenges with scheduling, advising, and buy-in across the institution (Daugherty et al., 2018).

Consistent with these features, Atkins and Beggs (2017) reported their study results of a developmental corequisite program implementation suggesting student success may be improved through pathways, just-in-time support, and evidence-based instructional methods. The authors conclude "students who were unable to demonstrate acceptable mathematics proficiency based on the ACT were able to demonstrate college-level mathematics mastery with this model of just-in-time, learner-centered support…Students receiving corequisite treatment were able to move through the developmental and gateway sequence more efficiently…and completed coursework at a reduced credit load, which corresponds to decreased cost burden which is another factor impacting retention and persistence" (Atkins & Beggs, 2017, pp. 21-22).

In a blog by the National Council of Teachers of Mathematics then President Shaughnessy (2011) writes about the concern of endless algebra. He describes a typical student having taken algebra I, algebra II, and perhaps even pre-calculus in high school, only to then take intermediate algebra, college algebra, and yet again another pre-calculus course. Shaughnessy asks two questions of his readers "(1) Are we really offering our secondary students an appropriate mathematics experience? (2) What can we do to provide students with relevant, coherent mathematical options on the pathway throughout high school and as they move into college?" (Shaughnessy, 2011). The author notes that many students who find themselves in the never-ending algebra sequences realize they do not ultimately need calculus and end up leaving mathematics after college algebra. These students rarely ever take other math courses and have a negative disposition to the field of study. The author urges educators and institutions to consider whether the current mathematics paths prepare students for existing fields that are changing rapidly, as well as emerging fields that do not exist yet. Shaughnessy says, in his view, "the current deadly sequence of ever-repetitive and out-of-touch experiences in algebra will not accomplish [these intended] goals. It is time that we replace the eternal algebra transition from high school to college with some viable and exciting 21st-century mathematic alternatives" (Shaughnessy, 2011).

DEVELOPMENTAL MATHEMATICS AT MARSHALL UNIVERSITY

Being among the first in the country to implement the corequisite model at a system-wide scale, West Virginia is known as a leader when it comes to piloting initiatives with inventive and decisive action to address the continued issues arising from remedial education at the college level (Vandal, 2017). Considered a transformational leader by Complete College America (2021b), West Virginia, within just one year of reforms, dramatically increased the success rates of students placed into remedial math. Before the reforms, only 14% of students placed into remedial math completed the associated gateway course within two years. After implementing corequisite reforms, success rates skyrocketed up to 62% of students placed into remedial math were completing the associated gateway course within the first year (Complete College America 2021b). At institutions of higher learning in the state, like Marshall University (MU), developmental programs have coalesced swiftly over the past few years based on the experiences of the past decade. The MU Department of Mathematics continues to be at the forefront in adopting evidence-based practices and policies that support all types of learners, providing appropriate training, and supporting the professional development of the faculty.

Community College Support. Like many of the institutions in the early 2000s, the MU Math Department began to address the needs of developmental students using existing resources on their campus. The Marshall Community & Technical College (MCTC) (2007-2008), located on the main campus of MU, provided remedial mathematics education for MU students with ACT scores ranging from 1-11 (Basic Mathematics), 12-15 (Elementary Algebra), and 16-18 (Fundamental Mathematical Concepts and Intermediate Algebra). These developmental courses were recorded on transcripts as credit/no-credit courses and, while students registered in the courses were able to count those credit hours toward full-time enrollment from semester to semester, successful completion of the courses did not allow for the credit hours to count toward a student's grade point average or required number of hours for graduation. These MCTC courses were supported by an Academic Skills Center offering supplemental instruction by a computer program, videos, cassettes, programmed materials, teacher assistance, and other math study strategies. The MCTC catalog promised a passing grade in the developmental course work would "eliminate all deficiency/remedial courses" and allow for "immediate registration for college-level math courses" (Marshall Community & Technical College, 2007, p. 22).

Similar to other initial attempts to support students, the developmental courses offered by Marshall Community & Technical College at that time focused much more on the consequences of failure, rather than the results of success, stating "students who do not complete the developmental courses in three semesters will be suspended for 6 months" and "failure to complete all remaining developmental course work in the first two semesters of being reinstated will results in suspension for one calendar year. Having returned after one calendar year, students who are unable to complete the required coursework will be dismissed from the college for two consecutive years" (Marshall Community & Technical College, 2007, p.22). It appears most of the program description contains an *if you are not able to do this, you will be dismissed* mentality. There is little in the program description to detail the supports provided by the program or how students should utilize them to ensure success in the courses. There is even less in the program description about the theoretical framework and instructional methods used to help students remediate their knowledge gaps

Forced on the institutions by the WV State Legislature in 2008, the Marshall Community & Technical College separated from Marshall University and became Mountwest Community and Technical College (MCTC). According to the West Virginia Code (2021), the intent of the articles drafted required the "program review and approval process of community and technical college education be separate and distinct from baccalaureate education" (18B-3C-6-b). Additionally, the articles clarify how "independently accredited community and technical colleges shall serve as higher education centers for their regions by brokering with colleges, universities and other providers, in state and out of state, to ensure the coordinated access of students, employers and other clients to needed programs and services" (18B-3C-6-c). Given the strong relationship developed between the two institutions, Marshall University and Mountwest Community & Technical College (2015) drafted an omnibus articulation agreement on how MCTC would continue to work together with MU to support this particular population of students by:

> … providing academic advising that will counsel students to enroll in general education and other prerequisite courses that will prepare students to complete a baccalaureate degree at MU, helping a student prepare a MU application package that includes an admission application, transcript, intended major, transfer fee or waiver, and consent for MU to share academic information with MCTC. (Marshall University & Mountwest Community & Technical College, 2015, pp. 1-3)

This solid relationship and continued trust facilitated achieving the goals of supporting developmental students.

While MCTC was no longer explicitly and solely responsible for taking care of the developmental needs of Marshall students, Alexanderson (2009) detailed the separation agreement, highlighting the connection between the two institutions which ultimately allowed for a fair settlement and a continued, strong working relationship. The separation of the two institutions created an education gap that needed to be filled. Students already accepted into the institution would need to have appropriate mathematics courses offered to continue in their programs of study. Working closely together, the MU Mathematics Department and the MU University College began to tackle this developmental student need by implementing mathematics workshops. This work provided a starting point for the development of prerequisite course sequences, mathematical pathways, redesigned emporiums, bridge programs, and corequisite courses.

Mathematics Workshops. Without the support of a dedicated developmental program from MCTC, beginning in the fall of 2009 through the spring of 2010, faculty from the MU Mathematics Department were hired within the University College (UC) to teach similar developmental courses called Mathematics Workshops. University College on the MU campus is dedicated to serving conditionally admitted students as well as those students who have undecided majors. This section of MU is also responsible for supporting developmental students. While there were hundreds of students who needed this support, there were only two mathematics faculty members hired to teach the developmental students and thus, adjustments to the way the courses were delivered had to be made to meet this high demand.

To service the developmental students, the math faculty developed two courses Workshop Math 001 (enrolling students with ACT 16 and below) and Workshop Math 002 (enrolling students with ACT 17 and 18). These courses contained traditional lecture elements, paper worksheets, and assessments, but did attempt to automate some of the assignments within coursework to provide more immediate feedback to students as they were completing the course content. University College was able to provide dedicated lab space, the Mathematics Achievement and Remediation Zone, or the MARZ tutoring lab, for these students to get extra support directly from the faculty and additional tutors. Given the heavy workload and increasing demand for the courses, the Mathematics Workshops were ultimately transferred to the MU Mathematics Department where they became part of a prerequisite developmental course sequence.

Developmental Course Sequence. In the fall of 2010, having recently acquired the two faculty members from University College and the entire population of developmental students the Mathematics Workshops was servicing, the MU Math Department created and implemented a traditional developmental course sequence, Mathematics Skills I and Mathematics Skills II. This pre-requisite developmental course sequence was required for all students who wished to enroll in 100-level mathematics courses but did not meet standardized placement scores to enroll directly. Mathematics Skills I was intended for students with ACT math scores of 16 and below. Students who complete Mathematics Skills I then enrolled in Mathematics Skills II. Students with an ACT score of 17 and 18 could enroll directly into Mathematics Skills II, without taking Mathematics Skills I. Both of these developmental courses were 3 credit hour courses and were graded as credit/no credit for the final course grades. Students who earned credit in Mathematics Skills II were eligible to enroll in any freshman-level mathematics course for which a minimum ACT score of 19 was the pre-requisite. These prerequisite developmental courses included the use of traditional lecture classes coupled with more robust supportive digital homework programs to support the large number of students who were enrolled.

The success of students in these courses varied and, in addition to pedagogical conversations within the department facilitated by faculty attendance to regional and national conferences, the MU Math Department continued to look for effective ways to support the students who were still struggling to complete the prerequisite developmental course requirements. One initial attempt within the department included the use of Open Education Resources (OER) and the Kaleidoscope Open Course Initiative. Kaleidoscope was a national initiative to use OER and an online platform with data feedback and platform support from mathematics and programming professionals in a teaching and learning community. The MU math department piloted this program in the Mathematics Skills II courses to promote increased success rates for students in the developmental sequence.

As Thanos (2013) explains, there are three major aspects of collaborative course designs within the OER community: (1) eliminate textbook costs as a barrier to student success, (2) improve course designs and materials based on student learning results, and (3) create a collaborative community that will share learning and investments to support and sustain this change. The course materials used within the MU Mathematics Department in the Mathematics Skills II OER pilot were free textbook materials.

While the specific Kaleidoscope OER initiative was not exclusively adopted within the MU Math Department for all developmental courses, the decision to pilot several sections of the OER Mathematics Skills II course provided professional development for faculty involved with teaching this population of students. Faculty teaching these courses began meeting weekly throughout the semester to informally discuss the successes and challenges faced in the developmental classroom. The faculty continued to use the OER course redesigns for teaching entry-level courses. This provided a glimpse into ways to break through some of the obstacles developmental students had preventing them from being successful at the college level. OER later became a significant component in developing corequisite courses for both the community colleges and institutions across West Virginia.

Developmental Pathways. According to a Report Card released by the West Virginia Higher Education Policy Commission (WVHEPC) & Community & Technical College System (CTCS) (2011),

> … one of the groups least likely to graduate is those enrolled in developmental courses. Of bachelor's degree-seeking students nationally, only 35% who need developmental education graduate as compared with 56% of those who do not need developmental education. For those associate degree-seeking students, only about 10% of those who need developmental education graduate, compared to about 14% of those who do not need developmental education. This is particularly troubling for those seeking an associate's degree, as more than 50% need some form of remediation. (West Virginia Higher Education Policy Commission & Community & Technical College System, 2011, p. 2)

From a secondary Report Card from WVHEPC and CTCS (2013), "the proportion of students passing developmental math courses increased by 0.5 percentage points from 49.1 percent in 2011 to 49.6 percent in 2012. When compared to passing rates in 2008, the proportion declined 4.7 percentage points" (West Virginia Higher Education Policy Commission & Community & Technical College System, 2013).

While it was difficult for most developmental students to pass the Mathematics Skills I, Mathematics Skills II developmental course sequence, those students who were able to complete the coursework successfully were enrolling but not finding success in gateway courses. One course, in particular, the expanded college algebra course, intended for students coming from the developmental sequence, was a challenge for students to pass the first time, with a majority of developmental students earning D/Fs. At this point, there was a concerted effort among members of the associated course committees in the MU Math Department to assess the curriculum aligned for degree majors across campus. There was a push to get students who did not need college algebra out of that course and into other courses that would better fit their needs. One course that was highlighted, Concepts and Applications, was a quantitative reasoning course that contained discussions of logic, conversions, statistics, and some key algebra topics. Promoting this course as an academic pathway for students, the MU Math Department facilitated a redesign for the quantitative reasoning pathways by piloting national redesign strategies for that particular population of developmental students.

One pilot, namely the use of Quantway, a Carnegie Math Pathways (2020) curriculum program that provides students with a firm conceptual mathematical understanding to master developmental or college-level goals, used a unique pedagogical approach promoting collaborative learning, addressing social-emotional factors that affect students. Quantway lined up with the pathways approach promoted nationally and was solely focused on supporting students who needed a quantitative reasoning course for their major. At MU, the quantitative reasoning courses were generally aimed at nursing majors and students in the College of Liberal Arts and were not intended to be for students who were considering majors in the Science, Technology, Engineering, and Mathematics (STEM) fields. A four-credit-hour expanded version of the quantitative reasoning course was created, a corequisite version, specifically to enroll developmental students with ACT 17 and above to remediate those students within the college-level course itself without the need for prerequisite developmental coursework.

Developmental Emporium. As the MU mathematics department continued to balance the ever-changing needs of developmental students with the legislative mandates from the state, part of the reforms that occurred within the department regarding developmental courses were influenced by financial reasons. The Academic Affairs Department of Marshall University (2015) and West Virginia Higher Education Policy Commission announced a change to replace Mathematics Skills I and Mathematics Skills II with a redesigned version of developmental courses, Preparation for College Mathematics A and Preparation for College Mathematics B. Details about the redesign looked promising as it incorporated changes that would help more students find success in developmental courses. However, implementation was met with pushback from faculty who advocated for more instructional time to build stronger relationships with the developmental students, rather than less contact time.

These redesigned courses incorporated computerized instructional content in a modular format at a reduced cost to students from traditional physical textbooks. The more robustly supported digital platform allowed for students to progress with a mastery-based approach to the course content. However, the structure of these courses at the time was one of individualized instruction from a computer program rather than traditional lecture and classroom discussion. Since most of the digital assignments were graded automatically, this minimized the workload time afforded to faculty teaching the courses. This, in turn, drastically increased the number of sections each faculty member was responsible for teaching each semester. The increased number of sections in a faculty member's workload increased the student-to-faculty ratio significantly, and the computer-focused nature of the course decreased the faculty members' autonomy and ability to provide high-quality instruction within the classroom.

One major benefit of the emporium redesign was the alignment of both developmental courses with mathematics pathways. Unlike the students in the old prerequisite development course sequence, where students in Mathematics Skill I course were required to move into Mathematics Skills II course before enrolling in their chosen pathway course, students in Preparation for College Math A was designed to support quantitative reasoning students and Preparation for College Math B would be designed to support college algebra students. Aligning the curriculum in Preparation for College Mathematics A to support students who will eventually enroll in the quantitative reasoning course and Preparation for College Mathematics B to support students who would eventually enroll in college algebra course removed the multi-semester, sequential nature of the developmental courses sequences that students had been required to take up to that point.

The first-year implementation of Preparation for College Math A and Preparation for College Math B courses had mixed consequences. With the initial development policies in place, Preparation for College Math A was a generally successful course. However, the vast majority of students in Preparation for College Math B were not able to complete the required coursework to progress to their gateway courses. These courses were showing no significant difference from their predecessors in closing the gap between prerequisite skills and being ready for college courses. While this redesign of the developmental courses offered at MU attempted to incorporate learning theories known to promote success among the developmental student population, ultimately, these courses failed to meet the state requirements set out regarding giving college credit for remedial coursework. After several reconsiderations of the curriculum and implementation policies in consultation with faculty, the MU Mathematics Department decided to return to a lower student-to-faculty ratio, include time in class for instruction, and provide faculty with preparation and grading time to give students feedback on their work.

Summer Bridge Program. While the transition from Mathematics Skill I and II to Preparation for College Math A and B was taking place, Marshall University worked to support developmental students with additional exposure to the content necessary for success in college-level math courses before they started their courses in fall semesters. Faculty from the MU Mathematics department coordinated with University College to develop a summer preparatory math camp to address student success in gateway courses. The MU Summer Bridge Program was implemented for the first time in the summer of 2012. In a student satisfaction survey report by the Director of MU University College (Stepp, 2012), the program targeted admitted freshmen, scheduled to enroll in Fall 2012 and identified as needing developmental math and/or English. Additional targeted students were those who were already conditionally admitted but were in danger of university dismissal if the placement was not achieved by the end of the fall 2012 semester. The program was offered at no cost to students.

The Summer Bridge Program (SBP), taught by MU math faculty, was a self-selective workshop, meaning students were allowed to choose whether or not they enrolled rather than being required to enroll. The University College and MU Mathematics Department worked together to support students in this program. The SBP focused on the benefit successful completion of the developmental coursework could have on students' progress toward successful completion of college-level coursework. Successful completion of the Summer Bridge Program made students eligible to enroll in 100-level gateway courses in the fall 2012 semester, rather than enrolling in developmental courses. The program promoted collaboration among students and asked students to reflect on successful academic strategies in preparation for their fall semester courses.

Corequisite Redesign. According to the West Virginia College Completion Task Force (2014), one key factor in increasing college completion is “reducing the time it takes students to earn a certificate or degree” (West Virginia College Completion Task Force, 2014, p. 3). The task force recommended a complete transformation of developmental education in the state so that students could acquire the skills they need and move quickly into credit-bearing college-level courses. The authors claimed, “developmental education is a serious challenge in West Virginia and across the country and a major impediment to reducing time to degree” (West Virginia College Completion Task Force, 2014, p.3). Furthermore, the authors state that “maintaining the status quo will not work. Every aspect of the way developmental education is taught in West Virginia needs to be rethought and revamped for students to be successful” (West Virginia College Completion Task Force, 2014, p. 8). Describing the academic barriers to college completion, the authors say “developmental courses present a psychosocial as well as an academic barrier to students’ success in college. Helping students acquire the skills they need, when and where they need them, can build confidence and enthusiasm as well as the academic knowledge that is crucial to their success” (West Virginia College Completion Task Force, 2014, p. 11).

Further changes to the West Virginia state laws re-defined an institution’s ability to support developmental students at the college level. The West Virginia Higher Education Policy Commission (2010a) determined that:

> Degree-seeking students in West Virginia public colleges and universities must demonstrate that they possess the minimum academic skills essential for success in their

> chosen program of study. Academic skill proficiency in mathematics, writing, and reading is demonstrated by meeting established placement standards in mathematics, writing, and reading. Students not satisfactorily demonstrating these skills must remediate deficiencies through successful completion of specific developmental education courses, corequisite courses, or other entry-level college credit courses that provide supplementary academic support programs or services. If the developmental skill deficiencies are addressed through an embedded or co-requisite approach with a college-level entry course, the student can receive college credit for the course which will count toward graduation. (West Virginia Higher Education Policy Commission, 2010a, p. 1)

The WVHEPC also defined co-requisite courses to mean:

> … credit-bearing courses that provide aligned academic support for the entry-level credit-bearing course and are required as a component of the entry-level course. Co-requisite courses are designed for students who did not meet admission requirements for entry-level math or English courses. Course content is the same as the traditional credit-bearing course but additional required attendance/instruction and/or participation in academic support structures is required for successful completion of the course. Stretch courses are one example of co-requisite course delivery. (West Virginia Higher Education Policy Commission, 2010a, p. 2)

With the acceptance of corequisite models at the state level, the MU Mathematics Department began looking for alternative methods to support the developmental students normally supported within the MCTC. Rather than continuing to focus on redesigns for the developmental courses, the aim was to identify those students who would now be entering college-level courses at MU without the required support of prerequisite developmental courses.

The MU Mathematics Department revisited the quantitative reasoning course by incorporating many of the learning theories that support corequisite instruction. At first, the success in corequisite quantitative reasoning course allowed the MU Math Department to extend offering the course to students just below the original cut scores ACT 16, requiring any student below this to still take the developmental course Preparation for College Math A. After incorporating further explicit elements of a corequisite design, the cut score for enrollment was lowered even further to allow all students on the quantitative reasoning pathway to be directly placed into the course at the college level. Ultimately, with students finding success overall, this decision eliminated the requirement to take any developmental course, and since students no longer needed to take it, Preparation for College Math A was slowly phased out of the course offerings.

The course offerings and policies continued to change quickly within the MU math department during this time. Contrary to expectations aligned with national trends, the Marshall University (2016) Compact Update reported continued increased levels of success with 76% of developmental students passing Preparation for College Math A and/or Preparation for College Math B in 2014, up from 68% passing Mathematics Skills I and Mathematics Skills II in 2010. Additionally, the same students increased their pass rates in the college-level courses, like quantitative reasoning, and expanded college algebra, from 45% in 2010 to 58% passing college-level courses in 2014. The report claimed, “recent changes to the developmental education/college-level curriculum are probably responsible for the increases” (Marshall University, 2016, p. 2). Indeed, changes like pathways implementation coupled with evidence-based learning theories that support corequisite remediation continue to have a positive effect on developmental students.

Continuing to make decisions to improve these passing rates at MU, an additional course was created from scratch within the math department to align with the idea of pathways and corequisite instruction. First offered Fall 2019, both Foundations of Statistics and Foundations of Statistics-Expanded are freshman-level statistics courses that are designed for business majors and other undecided students. With the successful experience of the quantitative reasoning course redesign, Foundations of Statistics and Foundations of Statistics-Expanded were created to mirror the success. Foundations of Statistics offered the entry to an additional pathway for students to enter, rather than taking college algebra, and Foundations of Statistics-Expanded incorporated some corequisite learning theories to allow students with any cut score to enroll in the course. Currently, the Foundations of Statistics and Foundations of Statistics-Expanded courses are running as expected with no major reported issues, and faculty report students are as successful in these statistics courses as they are in the quantitative reasoning courses.

As the MU Math Department celebrated student success in the quantitative reasoning and statistics pathway, there was still work to be done concerning the success of students taking college algebra. As it stands, students taking College Algebra Expanded encounter several barriers traditionally inherent to required developmental courses. These barriers include large gaps in knowledge, understanding the connection between conceptual ideas and procedural skills, finding the motivation to tackle complex topics, being persistent in completing the course, and ascending to more transformational thinking required for higher learning. Faculty in the department, in consultation with course committees, continue to discuss incorporating learning theories supporting corequisite instruction into the expanded version of the College Algebra Expanded course. This new corequisite redesign incorporated peer-reviewed, free online learning materials, and textbooks, coupled with an inexpensive and individually responsive homework platform. At this point, students with ACT 17 and above can enroll in the course, but any student below this is still required to complete Preparation for College Mathematics B. The math department continues to make improvements to the expanded college algebra course, as it still seems to be the biggest hurdle in the department for developmental students who are expecting to progress into engineering, mathematics, computer science, and other STEM-related majors.

Faculty Scholarship. The consistent re-evaluation and re-invigoration of the freshmen developmental courses in the department was and is influenced by mandates from the state, as well as calls to action from faculty. The state of West Virginia supported faculty training on corequisite models beginning Spring 2017 when the West Virginia Higher Education Policy Commission (WV HEPC) brought in representatives from The Dana Center in Texas, a nationally recognized organization promoting the most up-to-date evidence-based policies for developmental student success. At this time, meetings were already happening with the WV Math Task Force, a committee of higher education faculty, and representatives from the WV Department of Education to deliberate the development of quantitative reasoning and college algebra courses that would transfer seamlessly among the institutions.

That same Spring 2017 semester, many faculty members across the MU campus, including six faculty members from the MU Mathematics Department attending a workshop on the nature of varying elements of corequisite learning. Presented by Peter Adams, the workshop discussed an overview of the Accelerated Learning Program (ALP) implemented in institutions to address the needs of developmental math and English students. The workshop focused on addressing non-cognitive issues faced by developmental students, like life issues that become overwhelming and affective issues that make them give up like fear, anxiety, and feelings that students are not college material. This workshop discussed how the ALP model attempts to remedy them by helping faculty find ways to ask students to be productively persistent, master college behavior, develop a feeling of belonging, and find support to successfully cope with life problems:

Further support was extended to faculty across WV from HEPC for travel to national conferences like VERTEX. In Fall 2018, the VERTEX conference specifically discussed the successful concurrent and corequisite enrollment of developmental students from both high school and college. The WV HEPC and MU Mathematics Department both supported travel for faculty to attend the National Inquiry-Based Learning conference dedicated to helping all students gain a sense for why we study mathematics and train faculty to incorporate evidence-based practices to promote engagement and interest in the subject of mathematics, two aspects key to supporting developmental student success. The MU Mathematics Department also directly supported faculty in presenting and attending the Mathematical Association of America (MAA) regional conference in Fall 2019. This Researcher, Shannon Miller-Mace, MA, ABD, gave an invited address at the conference on the progress MU has made to accommodate and support the success of developmental students. Many of the suggestions submitted to departmental committees (both the quantitative reasoning/statistics committee and the college algebra committees) aligned with new research brought back to the department from faculty attending these regional and national conferences. These suggestions related to making changes to course pathway options, adjusting course policies and the online platform, providing support to faculty, and asking for the real-time, semester, and longer-term data analysis to influence curricular decisions.

Many of the learning theories mentioned above were major influences in the redesigns of the corequisite instructional models used within all the pathways offered at Marshall University.

To facilitate curriculum development, faculty in the mathematics department created learning communities. These groups were informal and driven by faculty interest in discussing the courses they were teaching. When the college algebra course committee was preparing for new semesters, faculty gathered to discuss the previous semester's successes and challenges. These course-specific discussions were instrumental in influencing new policy decisions on just-in-time instruction, facilitating digital course access, and other foundational strategies to support student success.

A formal group founded more recently, by members of the MU Mathematics Department, including this Researcher, Shannon Miller-Mace, MA, ABD, was called the Tri-State Mathematics Educator Community (TRIMEC) (Miller-Mace & Mummert, 2019). This group expanded the goals of the previous informal meetings to discuss evidence-based pedagogy, assessment practices, technology usage, and equity in mathematics education specifically related to mathematics instruction. The group's first year of meetings centered around the official release of the MAA Instructional Practices Guide and invited faculty in related fields from the entire Marshall campus and the surrounding institutions. At the same time, another group focused on IBL was formed, and faculty were encouraged to continue discussions on ways these two groups might address supporting students as well as faculty training on new evidence-based practices.

The faculty learning communities changed dramatically as the 2019 coronavirus pandemic hit and were instrumental to the final transitions the entire department made at the end of the Spring 2020 semester. When COVID-19 forced Marshall University to move to fully virtual, remote instruction, many courses were already somewhat developed in an online learning platform, and the department was able to use the support of the faculty learning communities to transition courses to virtual, remote instruction with relative success. These connections kept faculty engaged with their course work, as well as making sure to implement best practices for corequisite courses.

CHAPTER 3

RESEARCH METHODS

Chapter 3 presents the methods used to study the implementation of a corequisite model for college algebra students at the college level. This chapter includes the research design, population and participants, instrumentation, and data collection procedures. Finally, the statistical analysis used to answer the research questions is described.

RESEARCH DESIGN

With institutional review board permission, this descriptive and quasi-experimental study with a mixed-methods approach was designed to analyze student performance data and faculty perceptions from both the current corequisite college algebra courses, previous non-corequisite college algebra courses, traditional college algebra courses, as well as student performance data in precalculus courses.

This study consisted of two types of analysis: quantitative methods (to analyze the final course grades of students in the cohorts) and qualitative methods (to analyze the perceptions of the faculty interview responses). The quantitative analysis compared final course grades of student cohorts from before and after implementation of the co-requisite model of instruction in college algebra courses at Marshall University. The analysis included overall final course grades and disaggregated data based on student major and enrollment in a developmental course before enrollment in college algebra. The qualitative analysis categorized patterns that emerge from interview question responses from faculty who taught non-corequisite and corequisite versions of college algebra.

POPULATION AND PARTICIPANTS

The student population examined were first-time freshmen who enrolled and completed either an expanded version of college algebra or the traditional version of college algebra at Marshall University (MU). The analysis of the student population initially included many different majors across the MU campus. However, with the implementation of mathematics pathways, the analysis of the student population narrowed to focus on students who are on the Science, Technology, Engineering, and Mathematics (STEM) track. Other participants of the study included faculty in the MU Mathematics Department who have taught college algebra, both in the original non-corequisite course format, as well as the redesigned corequisite course.

INSTRUMENTATION

Student Data. There were several measures used in this study to analyze student performance and to group students for comparison. The measures used to analyze student performance overall will be the Final Course Grade. The final course grades collected were attributed to non-corequisite college algebra, corequisite college algebra, traditional college algebra, and precalculus students.

Each student enrolled in non-corequisite college algebra, corequisite college algebra, traditional college algebra, and precalculus were categorized by their Placement Criteria, including placement exam scores from American College Testing (ACT), which determine their eligibility to be enrolled in the courses in this study. One other categorical measure used for grouping and performance analysis was a student’s Major. While comparisons of student performance were made across all majors in the analysis of initial performance in each of the college algebra courses, the study narrowed analysis to students on a STEM pathway to calculus by looking at performance in precalculus.

Students in non-corequisite college algebra were enrolled using a minimum Enrollment Criteria of ACT 17. These students were identified as those who have enrolled in courses from Fall 2017 to Spring 2020 with non-corequisite interventions, like pre-requisite instructional assignments, however, some elements of developmental student support were present, like extra support from teaching assistants in the lab setting, and use of low stakes interactive, digital content aimed to engage students in active learning in the classroom.

Students in corequisite college algebra were enrolled using a minimum Enrollment Criteria of ACT 17. These students are identified as those who have enrolled in college algebra courses with additional corequisite interventions, like just-in-time instruction, use of open educational resources, and more formal theoretical corequisite pedagogies including metacognition and active learning strategies.

Students in traditional college algebra were enrolled using a minimum Enrollment Criteria of ACT 21. These students were homogenous throughout the targeted student data and have generally experienced the same course policies throughout the study. One major comparison factor from early semesters to later semesters of this course offering was the change to open resource course materials and encouragement to include active learning strategies.

Students in precalculus were enrolled using a minimum Enrollment Criteria of ACT 24. In Fall 2017 through Spring 2019 semesters of this study's targeted student data, these students only came from non-corequisite college algebra and traditional college algebra courses, with a small number of students in pilot sections of corequisite college algebra. In the Fall 2019 and Spring 2020 semesters of this study's targeted student data, students enrolled in precalculus became increasingly corequisite college algebra and traditional college algebra students, however, there may be some students who delayed enrollment and would have come from non-corequisite college algebra. This created somewhat uneven sample sizes with some of the comparisons.

Faculty Perceptions. Faculty perceptions on the transition from non-corequisite instruction to corequisite instruction were obtained using responses from interviews. Faculty were selected from the members of the mathematics department based on their previous experience teaching both non-corequisite and corequisite college algebra courses during the Fall 2017 to Spring 2020 semesters. As noted in the delimitations in Chapter 1, while faculty who were selected for interviews taught both non-corequisite and corequisite college algebra, they were not the only faculty members responsible for teaching all sections of college algebra from which the student data was collected. Therefore, data gathered about students' final grades were not necessarily final course grades from the five faculty members interviewed for this study.

Gathering faculty perceptions via interviews required the use of an instrument. The creation and use of the following interview questions were carefully considered based on several factors. Multiple faculty and student survey instruments used at other institutions across the nation, including documents provided by Richardson, manager of the Dana Center Higher Education Course Programs, were referenced to create the list of interview questions. The Dana Center Mathematics Pathways (2018) Notes from the Field influenced the questions on faculty understanding of corequisite education. In other documents provided by Richardson, the Assessing Co-Requisite Courses- Roane Student Survey influenced the question on the level of implementation each faculty member felt they have achieved, and the Formative-Summative Assessment of Program document influenced questions comparisons of the program.

Several other interview protocol documents provided by this Doctoral Committee Member, R. Childress, influenced questions on challenges and growth, as well as both the structural categorization of the questions and the format of the document. The questions referencing teaching theories were constructed by this Researcher, Shannon Miller-Mace, MA, ABD to address the teaching and learning theories mentioned in Chapter 2. The interviews were conducted with the following Interview Protocol as the core content to be targeted. However, the wording of questions may be adjusted and follow-up questions may be added during the interview to gather more refined information as is typical for exploratory studies.

Interview Protocol

Section 1: Initial Transition Process - To begin, let's start the conversation with some preliminary questions about just how things got started.

1. What is your understanding of the corequisite college algebra course model?
2. What steps have you taken to address the transition from non-corequisite course offerings to corequisite?
3. What resources did the institution provide, such as internal or outside conferences, seminars, etc., to aid you in your transition?
4. What surprises or unexpected events did you experience in the initial transition?
5. What are the differences you have experienced between teaching non-corequisite courses versus corequisite courses, specifically regarding remedial or developmental mathematics education?

Section 2: Culture of Evidence-Based Teaching - For this section, let's talk about how corequisite courses approach performance expectations and what strategies, if any, you have employed (or are planning to employ) to incorporate the model into your courses.

6. Procedure versus Conceptual – On a pendulum scale where one side represents only written robotic procedures and the other side represents only thinking conceptual ideas, to

which side do your corequisite courses measure? Would this be consistent for all your courses?

7. Just-in-time Teaching – How has just-in-time instruction affected your course preparation? What effects does this teaching technique have on the student experience during class and overall student success?

8. Motivation and Persistence – In what ways do you try to motivate your students? What examples of persistence training like growth mindset are explicitly incorporated into your corequisite course?

7. Complexity and Transformation – How much time do you spend reviewing prerequisite material in a 15-week course? Do students interact with this material in a different way than at the college level?

10. Equity and Social Justice **–** What equity or social justice issues did you see students experience as you transitioned from prerequisite to corequisite instruction? How was it resolved?

11. Theory to Practice – In what ways are students made aware of the underlying pedagogy, teaching philosophies, or learning theories utilized in your corequisite courses? How aware are they about why they are being asked to complete specific assignments?

Section 3: Challenges, Growth, and Continued Professional Development - In this section, we can transition to discussing any new obstacles and what we expect moving forward.

12. How did teaching corequisite courses change your relationship with teaching developmental students? What effects has the transition had on other aspects of your teaching?

13. What specific success/achievements did you encounter in your transition and instruction? How did you confirm/celebrate them when they arose?

14. What specific challenges/obstacles did you face in your transition and instruction? How did you address/overcome these when they arose?

15. What resources are available as you continue in your position as a faculty member teaching corequisite students, such as training, conferences, and other resources? To what extent has participation been beneficial in your transition to the corequisite model?

16. During your transition and instruction, and at key points during your teaching duties, how were you able to examine your transition and redirect your transition efforts when needed to change the course offerings?

17. As a faculty member with this experience, what would you say to future faculty members who will teach a corequisite course?

In Conclusion - You have been most patient, thoughtful, and reflective in your responses. Do you have any other comments, observations, or suggestions that you would like to contribute?

LIMITATIONS

One important limitation to note when analyzing student performance is the influence of out-of-the-classroom factors. Perhaps more pertinent to this study was the limitation of using final course grades as a measure of success in student performance. According to Canfield et al. (2015), there is considerable doubt among educators of the reliability and validity of using final course grades to measure student performance. This criticism most often targets outcome evaluation. The authors note some of the contentions come from the varying methods by which grades are assigned, with some programs and teachers using extraneous assessments of participation, attendance, assessments not related to the targeted course outcomes, and variation of the instructor's grading criteria; all of which contributes to a non-standard sense of assignment of final course grades. Furthermore, critics say there is no check for reliability since final course grades are based on the assessment of one instructor, and there is no connection to student achievement in future courses (Canfield et al., 2015).

Given this rationale, there is a strong case for why there is such hesitancy to use final course grades to assess student performance. However, Canfield, Kivisalu, Van Der Karr, King, and Phillips (2015) conducted a multitrait-multimethod analysis of convergent validity and discriminant validity of college undergraduate students' final course grades over 12 years. Therefore, these researchers conclude "contrary to ongoing criticism that course grades are not a reliable and valid means of evaluating student learning outcomes, this analysis shows course grades are effective. These findings support the continued use of letter grades (A, B, C, D, etc.) as effective means to evaluate student learning outcomes in undergraduate education" (Canfield, Kivisalu, Van Der Karr, King, & Phillips, np). So, while the use of final course grades is still under contention among researchers, the researcher of this study cautions heavy reliance on the results of this study. But at the same time, the researcher does not dismiss the information gained from the study since course grades are a way of evaluating student performance.

The final version of the corequisite college algebra course was offered only in the Fall 2019 and Spring 2020 semesters. This resulted in a small group of corequisite college algebra students (new MTH 127) compared to non-corequisite (old MTH 127) and traditional (MTH 130) college algebra students. Due to the relatively low frequency of corequisite students' final course grades, the Chi-Square analyses sometimes contained expected values below five for many of the tests. Therefore, reliance on conclusions made here about student performance among college algebra students must be taken into consideration as a limitation of the Chi-Square analyses.

Other limitations included influences on faculty perceptions. Responses from faculty were potentially influenced by prior experience teaching developmental students, attitudes toward transitioning from secondary education to higher education, and personal knowledge of and interest in the corequisite model.

DATA COLLECTION PROCEDURES

Data on student performance was collected from existing data handled by the MU College of Science and provided by the MU Department of Mathematics. A formal request for data was sent to the Chairman of the Department of Mathematics, who with approval from the Dean of the College of Science, forwarded the request to Marshall University's Institutional Research department for necessary action. Student data collection using Marshall University Banner Extraction and Reporting Tool (MUBERT) contained the following course level identifiers: course enrolled, semester enrolled, campus location, and type of course offering. The student data collection request also had the following labels for each student: anonymous student identification number, major, placement score, and course letter grade. The study used data analysis software (SPSS) to run appropriate statistical tests on the quantitative data collected.

In addition to gathering the student data, faculty perceptions on corequisite and pre-requisite instructional models in college algebra were collected using interviews. Each faculty member was interviewed separately. After each initial interview was recorded, the transcript of the interview was provided to the faculty member to confirm their responses. This study aimed to gain faculty perceptions on teaching theory and pedagogy of corequisite and non-corequisite courses by interviewing willing faculty members who have taught both courses. Overall, the study attempted to gain some insight into the effectiveness of the implementation of Marshall University's corequisite college algebra course.

STATISTICS FOR ANALYSIS OF THE RESEARCH QUESTIONS

Research Question 1

Is there a significant difference in student performance between corequisite college algebra students and non-corequisite college algebra students at Marshall University?

The analysis compared Corequisite versus Non-corequisite College Algebra Student Performance in College Algebra. Subsets of students across Enrollment Criteria were compared also. Comparisons included the use of the Chi-Squared test to find significant differences in the distribution of Final Course Grades. The Mann-Whitney U test was used to confirm significance and provide mean ranks. Cramer's V was used to measure the effect size of significant differences.

Research Question 2

Is there a significant difference in student performance between corequisite college algebra students and traditional college algebra students at Marshall University?

The analysis compared Corequisite versus Traditional College Algebra Student Performance in College Algebra. Subsets of students across Enrollment Criteria and Student Majors were compared also. Comparisons included the use of the Chi-Squared test to find significant differences in the distribution of Final Course Grades. The Mann-Whitney U test was used to confirm significance and provide mean ranks. Cramer's V was used to measure the effect size of significant differences.

Research Question 3

Is there a significant difference in student performance in subsequent courses between corequisite college algebra students, non-corequisite college algebra students, and traditional college algebra students at Marshall University?

The analysis compared Corequisite versus Non-corequisite versus Traditional College Algebra Student Performance in Subsequent Precalculus Course. Subsets of students across Enrollment Criteria and Student Majors were compared also. Comparisons included the use of the Kruskal-Wallis test to determine if any significant differences exist between the three groups of students. Post Hoc Pairwise Comparisons reported significant differences among some pairs of courses. Bonferroni Correction was considered to reduce the likelihood of a Type I error. The Chi-Squared test was used to confirm significant differences in the distribution of Final Course Grades. The Mann-Whitney U test was used to confirm significance and provide mean ranks. Cramer's V was used to measure the effect size of significant differences.

Research Question 4

What are the perceptions of faculty who taught both corequisite and non-corequisite college algebra courses at Marshall University?

The analysis will use qualitative transcription and coding techniques to analyze faculty interview responses. Faculty Perceptions are generally categorized as follows:

- Initial Transition Process – measures perceptions of "awareness and preparation for corequisite instruction"
- Culture of Evidence-Based Teaching – measures perceptions of "incorporation and implementation of corequisite pedagogies"
- Challenges, Growth, and Continued Professional Development - measures perceptions of "improvements on corequisite and growth of faculty"

CHAPTER 4

DATA ANALYSIS AND FINDINGS

Chapter 4 presents information on the participants, data collection, and data analysis of the four research questions.

PARTICIPANTS

This study included two types of participants: students and faculty. Students enrolled in non-corequisite college algebra (old MTH 127), corequisite college algebra (new MTH 127), traditional college algebra (MTH 130), and pre-calculus (MTH 132) from Fall 2017 to Spring 2020 at Marshall University. A total of 2249 students were included from three groups: corequisite college algebra, non-corequisite college algebra, traditional college algebra students. Precalculus final course grades were considered if the grades were attributed to one of the three types of college algebra students. Only course sections offered face-to-face on the main campus were included in the data analysis. Faculty teaching both non-corequisite and corequisite college algebra courses from Fall 2017 to Spring 2020 were the second type of participant. A total of 5 out of 6 eligible faculty on the main campus teaching face-to-face offerings of the college algebra courses participated in the interview process. Faculty responses to the interview protocol were included in the data analysis.

Student final course grades were analyzed using several different grouping variables. The first grouping variable was the course type: corequisite, non-corequisite, and traditional students. Comparisons of all student data in the groups are presented first. Then, if the sample size permits, subsets based on enrollment criteria and majors of the data were used to compare student groups within the course types. Comparing subsets across enrollment criteria and student majors narrowed the variability of the groups for more specific comparisons.

The first grouping variable was student enrollment criteria in the form of ACT scores. Students enrolled in non-corequisite or corequisite college algebra were required to have a Math ACT 17+. Students enrolled in traditional college algebra were required to have Math ACT 21+. Students enrolled in pre-calculus were required to have a Math ACT 24+. Any students who had Math ACT <17 were typically enrolled in a preparatory mathematics emporium course, but some students with this score were enrolled in sections of college algebra.

The second grouping variable was student majors. Students enrolled in non-corequisite, corequisite, and traditional college algebra included a variety of student majors. Non-corequisite college algebra courses contained a much wider variety of student majors. Part of the corequisite implementation included removing some student majors from college algebra to statistics or quantitative reasoning, which resulted in sampling with far fewer corequisite students than non-corequisite students to include in the comparisons. Majors that require students to complete college algebra to move on to higher-level mathematics courses were defined as non-terminal students. Majors, where students are not expected to move onto higher mathematics and are expected to only take college algebra, were defined as terminal students.

Students in the data set that took college algebra as a non-terminal course were expected to continue taking more mathematics courses that require college algebra as a prerequisite. These non-terminal majors included: Geology, Mechanical Engineering, Biological Science, Biomechanics, Chemical Sciences, Chemistry, Digital Forensics, Environmental Chemistry, Mathematics, Physics, Safety Technology, Applied Mathematics, Biochemistry, Computer and Information Technology, Forensic Chemistry, Biomedical Engineering, Electrical/Computer Engineering, Computer and Information Security, Computer Science, Computer Science Pathway, Engineering, Engineering Pathway, Mechanical Engineering Pathway, Safety, Pre-

Biology, Pre-Chemistry, Pre-Computer IT, Pre-Computer Science, Pre-Digital Forensics, Pre-Engineering, Pre-Environmental Science, Pre-Geology, Pre-Mathematics, Pre-Natural Resource Rec Managements, Pre-Science, Science Pathway, Nursing, Medical Lab Technology, Athletic Training, Communication Disorders, Dietetics, Exercise Science, Health Sciences, Medical Laboratory Science, Nursing, Pre-Health Professions, Pre-Nursing, Psychology, Health Care Management, Secondary Education. Note that Secondary Education majors are only required to take college algebra if they are specializing the mathematics, science, or another STEM field. All other secondary education majors take a separate, non-college algebra course.

Students in the data set that took college algebra as a terminal course are not expected to continue taking more mathematics courses that require college algebra as a prerequisite, although, the college algebra course perhaps was a prerequisite to other courses in their major requirements. The terminal majors included: Anthropology, Communication Studies, Creative Writing, Early Childhood Education, Economics, Elementary Education, English, History, International Affairs, Journalism, Political Science, Sports Management, Theatre, Video Production, Accounting, Energy Management, Entrepreneurship, Finance, International Business, Management, Information Systems Management, Marketing, Music, Visual Art, Geography, Social Work, Business Pathway, Liberal Arts General pathway, Pre-Teacher Elementary Education, Pre-Teacher Secondary Education, Regent's Degree.

Students in the data set that took college algebra with no specific major listed for their enrollment criteria did not belong in the terminal and non-terminal groupings. These students were enrolled in college algebra typically by advisors in case those students end up choosing a non-terminal major. They were grouped and labeled as undecided students within the data analysis.

DATA COLLECTED

IRB approval was gained before data collection began (see APPENDIX A). Data collected from students for this study included student performance measures in the form of final course grades, as well as grouping variables in the form of ACT scores and student majors. Data collected from faculty interviews included faculty perceptions on teaching both co-requisite and non-corequisite courses.

DATA ANALYSIS

Throughout this analysis, comparisons were made using all of the available data in comparison groups. Generalized conclusions were made based on these results. To be able to make more specific conclusions about the full implementation of a corequisite model, subsets of the data were chosen by removing student data for those who took the pilot sections of the corequisite course during Fall 2018 and Spring 2019. To make student groups even more specific, comparisons are made again after student final grade data was narrowed down further by removing the entire Spring 2020 semester due to the COVID-19 pandemic. This exclusion of data was due to the impact that the pandemic had on the teaching and learning for everyone, including the implementation of the corequisite courses at Marshall University. Removing pilot data and the pandemic semester was considered in comparisons where the sample sizes permitted.

Research Question 1

Is there a significant difference in student performance between corequisite college algebra students and non-corequisite college algebra students at Marshall University?

To compare the student performance of corequisite students to the non-corequisite students in MTH 127 College Algebra - Expanded, it was important to consider the enrollment criteria for corequisite and non-corequisite courses. Both corequisite and non-corequisite courses required students to have Math ACT 17-20, however, the data collected contained students outside of this category. Selective comparisons of student performance data homogenized the student population by looking at limited samples across enrollment in each course, making comparisons between more similar groups. One goal of the comparisons was to determine if the preparatory course should continue to be offered, or if the corequisite course can be the standard entry course for all students with Math ACT <21.

The Chi-Squared test for independence was used to find differences in distributions of final course grade frequencies to measure student performance between students taking each type of college algebra curriculum: non-corequisite college algebra –pre-requisite developmental remediation, and corequisite college algebra –collaborative, just-in-time remediation. Table 1 through Table 5 present comparison analysis for Subgroup 1- students enrolled in non-corequisite and corequisite college algebra. Table 6 through Table 11 present comparison analysis for Subgroup 2 - students enrolled in each course type non-corequisite and corequisite with enrollment criteria ACT <17, ACT 17-20, ACT 21+, or No ACT Entry. The Man-Whitney U test and Cramer’s V effect size measures were included for comparisons that contain significant differences using the Chi-Square test.

Table 1- Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students showed no significant differences in overall student performance for all students, including all ACT levels, those without an ACT score on file, as well as all majors, including those students without a major listed on file. Although there was no significance, passing grade frequencies (A, B, C) increased 5.6% from 70.1% with non-corequisite students to 75.7% with corequisite

students. Note that the number of non-corequisite students is higher than the co-requisite student population, but each *n* is close enough to make the comparison reasonable

Table 1 – Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students
Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 913	220 24.1%	221 24.2%	199 21.8%	116 12.7%	157 17.2%	5.179**	.269
Fall 2018-Spring 2020	Frequency % Corequisite n = 436	106 24.3%	118 27.1%	106 24.3%	43 9.9%	63 14.5%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 51.39.*

Table 2 shows the Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students Removing Pilot Sections of Fall 2018 and Spring 2019. Pilot sections offered prior to the Fall 2019 semester provided the basis for policies in the corequisite courses but were not identical to full-scale implementation. Some pedagogies used in the pilot courses were not ultimately incorporated into the full-scale version of the corequisite college algebra course deployed across all sections of the course starting Fall 2019. For example, each of the pilot sections required students to work collaboratively in groups to work through course content; however, this was not a requirement for all faculty when the corequisite course was fully implemented across all sections. Rather than assuming performance in the pilot sections is equivalent to full departmental offerings of corequisite courses from Fall 2019 and Spring 2020, removing the pilot sections from data analysis made comparisons more valid by eliminating some differences in student experiences.

Although there was no significance with this comparison, passing grade frequencies (A, B, C) increased 4.4% from 70.1% with non-corequisite students to 74.5% with corequisite students. Note that the removal of the pilot section student data decreased the number of corequisite students adding to the difference in magnitude in sample sizes.

Table 2 – Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students – Removing Fall 2018 and Spring 2019 Pilot Sections

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 913	220 24.1%	221 24.2%	199 21.8%	116 12.7%	157 17.2%	7.081**	.132
Fall 2019-Spring 2020	Frequency % Corequisite n = 329	96 29.2%	89 27.1%	60 18.2%	31 9.4%	53 16.1%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 38.94.*

Table 3 shows Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students Removing Spring 2020. The Spring 2020 semester was dramatically changed with the COVID-19 global pandemic which forced Marshall University to transition to a completely virtual learning environment. This change affected both students and faculty. Rather than assuming performance in the Spring 2020 corequisite sections is equivalent to departmental offerings from Fall 2019 which were on campus and face-to-face, removing the Spring 2020 sections eliminated differences in student experiences among the corequisite students. Comparing differences in frequencies in student performance when removing the Spring 2020 semester, made comparisons more valid. The comparison of data with the Spring 2020 semester removed still had no significant differences in student performance, but student performance went up 7% from 70.1% to 77.1%. Note that the removal of the Spring 2020 data decreased the number of corequisite students adding slightly to the difference in sample sizes.

Table 3 – Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students – Removing Spring 2020 Sections

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2018	Frequency % Non-corequisite n = 913	220 24.1%	221 24.2%	199 21.8%	116 12.7%	157 17.2%	7.030**	.134
Fall 2018-Fall 2019	Frequency % Corequisite n = 324	84 26.0%	80 24.8%	86 26.5%	33 10.2%	41 12.7%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 39.03.*

Table 4 shows Subgroup 1 Non-Corequisite versus Corequisite Students Removing Fall 2018 and Spring 2019 Pilot Courses and Spring 2020 Pandemic Semester. In this case, there was a significant difference in the distributions of final course grades when comparing non-corequisite college algebra to corequisite college algebra students. There was almost no difference in final grade frequencies, however, there was a slight increase of 0.3% from 76.0% with traditional to 76.3% with corequisite. The significant difference in student performance (at $p<0.05$ level) may have occurred where the percentage of students earning grade A increased by 10% from 24.1% for non-corequisite students to 34.1% for corequisite students. However, taking out these data values made the number of non-corequisite students heavily outweigh the number of corequisite students. The Cramer's V measure was used to compute the effect size for significance describing the quality of the significant difference found when comparing the data.

The reported effect size was V=.094. Given the 4 degrees of freedom, the effect was between .05 and .15 and is categorized as a small to medium effect size.

Table 4 – Chi-Square Test for Subgroup 1 Non-Corequisite versus Corequisite Students – Removing Fall 2018 and Spring 2019 Pilot Sections and Spring 2020 Pandemic Sections

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 913	220 24.1%	221 24.2%	199 21.8%	116 12.7%	157 17.2%	9.938**	.041*
Fall 2018-Fall 2019	Frequency % Corequisite n = 217	74 34.1%	51 23.5%	40 18.4%	21 9.7%	31 14.3%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 26.31.*

In further analysis of the significant difference found in Table 4, Table 5 - Mann-Whitney U Test for Subgroup 1 Non-Corequisite versus Corequisite Students Remove Pilot Courses and Spring 2020 presents the Mann-Whitney U analysis for each type of student. The Mann-Whitney U non-parametric test was used to analyze the possible differences in frequencies in student performance of non-corequisite and corequisite college algebra students. The results indicated there was a statistically significant difference (at $p < 0.05$) between frequencies of student final grades due to the type of course in which the student was enrolled. Examining the mean ranks showed a higher mean rank for the corequisite students indicating students earned higher grades overall in the corequisite courses.

Table 5 – Mann-Whitney U Test for Subgroup 1: Non-Corequisite and Corequisite Students Removing Fall 2018 and Spring 2019 Pilot Sections and Spring 2020 Sections
Student Performance in MTH 127 College Algebra - Expanded

Course Type	Mean Rank	Mann-Whitney U Statistic	p value attained
Non-Corequisite (n = 913)	552.45	110978.000	0.005*
Corequisite (n = 217)	620.42		

* Significance attained at $p < 0.05$.

Student enrollment criteria, like placement test scores and specifically, ACT scores, determined the course in which students are enrolled. To further analyze the performance of non-corequisite versus corequisite students, comparisons of the student performance over different ACT were tested. Note that while removing both the pilot and spring sections did make a difference in student performance overall in research questions 1, removing pilots and spring in this situation did not leave enough student data in the samples to make reasonable comparisons in some cases. Table 6 - Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT <17 showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 15.6% from 63.9% with non-corequisite students to 79.5% with corequisite students.

Table 6 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT <17
Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 122	13 10.7%	33 27.0%	32 26.2%	22 18.0%	22 18.0%	7.818	0.098
Fall 2018-Spring 2020	Frequency % Corequisite n = 88	9 10.2%	26 29.5%	35 39.8%	7 8.0%	11 12.5%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.22.*

Table 7 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 17-20 showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 6.2% from 67.7% with non-corequisite students to 73.9% with corequisite students.

Table 7 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 17-20

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 607	142 23.4%	141 23.2%	128 21.1%	79 13.0%	117 19.3%	3.960**	0.411
Fall 2018-Spring 2020	Frequency % Corequisite n = 245	60 24.5%	68 27.8%	53 21.6%	28 11.4%	36 14.7%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 30.77.*

For this grouping of students, the sample sizes were larger. So, making comparisons after removing the pilot and pandemic student data seems more reasonable. Table 8 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 17-20 Removing Pilot Sections and Spring 2020 Sections showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 10.5% from 67.7% with non-corequisite students to 77.2% with corequisite students.

Table 8 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 17-20 Removing Pilot Sections and Spring 2020 Sections

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 607	142 23.4%	141 23.2%	128 21.1%	79 13.0%	117 19.3%	8.240**	.083
Fall 2018-Spring 2020	Frequency % Corequisite n = 136	44 32.4%	37 27.2%	24 17.6%	12 8.8%	19 14.0%		

* Significance attained at $p < 0.05$. *** 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.66.*

Similar to comparing performance for students with ACT level <17, removing pilot and spring sections did not leave enough student data in the sample to make reasonable comparisons for the ACT 21+ grouping. Table 9 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 21+ showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 4.6% from 86.7%% with non-corequisite students to 91.3% with corequisite students.

Table 9 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with ACT 21+

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017- Spring 2019	Frequency % Non-corequisite n = 68	31 45.6%	16 23.5%	12 17.6%	5 7.4%	4 5.9%	2.301**	.681
Fall 2018- Spring 2020	Frequency % Corequisite n = 23	8 34.8%	9 39.1%	4 17.4%	1 4.3%	1 4.3%		

* Significance attained at $p < 0.05$. ** *5 cells (50.0%) have expected count less than 5. The minimum expected count is 1.26.*

Table 10 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with No Reported ACT showed no significant differences in overall student performance. Passing grade frequencies (A, B, C) decreased 6.7% from 79.3% with non-corequisite students to 72.6% with corequisite students.

Table 10 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with No ACT Reported

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017- Spring 2019	Frequency % Non-corequisite n = 116	34 29.3%	31 26.7%	27 23.3%	10 8.6%	14 12.1%	4.177**	0.383
Fall 2018- Spring 2020	Frequency % Corequisite n = 80	29 36.3%	15 18.8%	14 17.5%	7 8.8%	15 18.8%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.94.*

For this grouping of students, the sample sizes were larger. So, it was more reasonable to compare these without the pilot and spring sections. Table 11 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with No Reported ACT Removing Pilot Sections and Spring 2020 Sections showed no significant differences in overall student performance. Passing grade frequencies (A, B, C) decreased 2.5% from 79.3% with non-corequisite students to 76.8% with corequisite students.

Table 11 – Chi-Square Test for Subgroup 2 Non-Corequisite versus Corequisite Students with No ACT Reported Removing Pilot Sections and Spring 2020 Sections

Student Performance in MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017-Spring 2019	Frequency % Non-corequisite n = 116	34 29.3%	31 26.7%	27 23.3%	10 8.6%	14 12.1%	4.345**	0.361
Fall 2018-Spring 2020	Frequency % Corequisite n = 43	19 44.2%	8 18.6%	6 14.0%	4 9.3%	6 14.0%		

* Significance attained at $p < 0.05$. ** *1 cells (10.0%) have expected count less than 5. The minimum expected count is 3.79.*

Research Question 2

Is there a significant difference in student performance between corequisite college algebra students and traditional college algebra students at Marshall University?

Comparisons made between traditional college algebra students and corequisite college algebra students included only those students whose ACT score would enroll them in each course. Students in traditional college algebra should have Math ACT 21-23. Students in corequisite college algebra should have Math ACT 17-20. The following tests for significance removed students with Math ACT <17 and Math ACT 23> from both courses to make the student in the comparison groups more similar before comparing the performance of students across different majors.

The Chi-Square Test for independence was used to find differences in the distribution of passing grade frequencies between students taking each type of college algebra curriculum: MTH 130 - traditional college algebra courses, and MTH 127 - corequisite college algebra courses. The Man-Whitney U test and Cramer's V effect size measures were included. Tables 12 through 18 present the Chi-Square analysis for subgroups of students from the data. Subgroup 3 consisted of Corequisite Students versus Traditional Students with terminal majors, non-terminal majors, and undecided majors. Subgroup 4 contained Terminal students enrolled in corequisite and traditional college algebra courses. Subgroup 5 was Non-terminal students enrolled in corequisite and traditional.

Table 12 for Subgroup 3 Corequisite Students versus Traditional Students with Math ACT 17-23 showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 1.3% from 73.5% with traditional students to 74.8% with corequisite students.

Table 12 – Chi-Square Test for Subgroup 3 Corequisite Students versus Traditional Students with Math ACT 17-23

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 261	66 25.3%	74 28.4%	55 21.1%	29 11.1%	37 14.2%	1.558**	.816
Fall 2017 – Spring 2020	Frequency % Traditional n = 397	95 23.9%	116 29.2%	81 20.4%	37 9.3%	68 17.1%		

* Significance attained at $p < 0.05$. *** 5 cells (0.0%) have expected count less than 5. The minimum expected count is 26.18.*

For this grouping of students, the sample sizes were larger. So, it was more reasonable to compare these groups without the pilot and spring sections. Table 13 – Chi-Square Test for Subgroup 3 Corequisite Students versus Traditional Students with Math ACT 17-23 Removing Pilots and Spring 2020 showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 4.0% from 73.5% with traditional students to 77.5% with corequisite students.

Table 13 – Chi-Square Test for Subgroup 3 Corequisite Students versus Traditional Students with Math ACT 17-23 Removing Pilot and Spring 2020

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 147	49 33.3%	39 26.5%	26 17.7%	13 8.8%	20 13.6%	5.108**	.276
Fall 2017 – Spring 2020	Frequency % Traditional n = 397	95 23.9%	116 29.2%	81 20.4%	37 9.3%	68 17.1%		

* Significance attained at $p < 0.05$. ** *5 cells (0.0%) have expected count less than 5. The minimum expected count is 13.51.*

Table 14 – Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Terminal College Algebra Enrollment showed no significant differences in overall student performance, and there was almost no difference in passing grade frequencies (A, B, C) with a small increase of 0.2% to 75.3% with corequisite students from 75.1% with traditional students.

Table 14 – Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Math ACT 17-23 with Terminal College Algebra Enrollment

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 49	9 18.4%	20 40.8%	11 22.4%	4 8.2%	5 10.2%	1.879**	.758
Fall 2017 – Spring 2020	Frequency % Traditional n = 67	8 11.9%	28 41.8%	13 19.4%	7 10.4%	11 16.4%		

* Significance attained at $p < 0.05$. ** *1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.65.*

Table 15 – Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Terminal College Algebra Enrollment removing pilots and spring 2020 showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 8.7% from 71.4% with traditional students to 80.1% with corequisite students.

Table 15 – Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Math ACT 17-23 with Terminal College Algebra Enrollment removing pilot and spring 2020

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 15	4 26.7%	4 26.7%	4 26.7%	1 6.7%	2 13.3%	4.008**	.405
Fall 2017 – Spring 2020	Frequency % Traditional n = 63	6 9.5%	26 41.3%	13 20.6%	7 11.1%	11 17.5%		

* Significance attained at $p < 0.05$. ** *4 cells (40.0%) have expected count less than 5. The minimum expected count is 1.54.*

Table 16 - Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Non-Terminal College Algebra Enrollment shows no significant differences in overall student performance, and there was almost no difference in passing grade frequencies (A, B, C) with a decrease of 0.8% to 75.1% with corequisite students from 75.9% with traditional students.

Table 16 – Chi-Square Test for Chi-Square Test for Subgroup 4 Corequisite Students versus Traditional Students with Math ACT 17-23 with Non-Terminal Enrollment

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 158	43 27.2%	46 29.1%	31 19.6%	13 19.6%	25 15.8%	.229**	.994
Fall 2017 – Spring 2020	Frequency % Traditional n = 273	75 27.5%	74 27.1%	56 20.5%	24 8.8%	44 16.1%		

* Significance attained at $p < 0.05$. *** 5 cells (0.0%) have expected count less than 5. The minimum expected count is 13.56.*

For this grouping of students, the sample sizes were larger. So, it was more reasonable to compare student data without the pilot and spring sections. Table 17 - Chi-Square Test for Subgroup 3 Corequisite Students versus Traditional Students with Non-terminal Enrollment Removing Pilot Sections and Spring 2020 Sections showed no significant differences in overall student performance, but passing grade frequencies (A, B, C) increased 1.5% from 75.1% with traditional students to 76.6% with corequisite students. Note that the removal of the Spring 2020 data decreased the number of corequisite students adding slightly to the difference in sample sizes.

Table 17 – Chi-Square Test for Subgroup 3 Corequisite Students versus Traditional Students with Math ACT 17-23 with Non-terminal Enrollment Removing Pilot Sections and Spring 2020 Sections

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 115	36 31.3%	31 27.0%	21 18.3%	11 9.6%	16 13.9%	.931**	.920
Fall 2017 – Spring 2020	Frequency % Traditional n = 273	75 27.5%	74 27.1%	56 20.5%	24 8.8%	44 16.1%		

* Significance attained at $p < 0.05$. ** *0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.37.*

Table 18 – Chi-Square Test for Subgroup 5 Corequisite Students versus Traditional Students with No Major Reported shows no significant differences in overall student performance, however passing grade frequencies (A, B, C) increased 4.8% from 67% with traditional students to 71.8% with corequisite students. Note that while removing both the pilot and spring sections might show a difference in student performance overall, doing so in this situation was not enough student data to make reasonable comparisons.

Table 18 – Chi-Square Test for Subgroup 5 Corequisite Students versus Traditional Students with Math ACT 17-23 with No Major Reported

Student Performance in MTH 130 College Algebra and MTH 127 College Algebra – Expanded

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 78	16 20.5%	17 21.8%	23 29.5%	13 16.7%	9 11.5%	4.467**	.347
Fall 2017 – Spring 2020	Frequency % Traditional n = 57	12 21.2%	14 24.6%	12 21.2%	6 10.5%	13 22.8%		

* Significance attained at $p < 0.05$. *** 5 cells (0.0%) have expected count less than 5. The minimum expected count is 8.02.*

Research Question 3

Is there a significant difference in student performance in subsequent courses between corequisite college algebra students, non-corequisite college algebra students, and traditional college algebra students at Marshall University?

For research question three, the analysis shifted from groups with a wider variety of students to more specific categories. The students included in research question three are considered non-terminal and include only those non-corequisite, corequisite, and traditional students who moved on to take pre-calculus. As before, it made sense to make comparisons after removing both the pre-calculus student grades recorded for the pilot section students, as well as the student grades recorded in the pandemic semester. Non-corequisite, corequisite, and traditional student enrollment in the pre-calculus courses was low, since most students who took the pre-calculus course enroll directly with Math ACT 24. This meant, in a lot of cases, removing both pilot courses and pandemic semester eliminated too many student course grades, leaving insufficient data to make reasonable comparisons. Note that most of the data analyzed here from the precalculus final course grades for corequisite students were collected from the Spring 2020 pandemic semester.

Table 19 – Kruskal-Wallis Test for Subgroup 6 MTH 127 Non-corequisite students versus MTH 127 Corequisite Students versus MTH 130 Traditional students who complete MTH 132 pre-calculus showed significant differences in overall student performance. Looking at the mean ranks in each group, it seemed the differences occurred in the traditional college algebra course.

Table 19 – Kruskal-Wallis Test: Subgroup 6 MTH 132 Final Course Grades due to College Algebra Course Experience
Student Performance in Subsequent Precalculus Course

	Number of Students	Mean Ranks Non-Co MTH 127	Co MTH 127	Traditional MTH 130	Kruskal-Wallis Statistic	p Value Attained
MTH 132 Course Grade Attainment	159	70.99	71.43	93.91	9.778	.008 *

* Significance attained at p<0.05

To further analyze the differences between the three groups of students, Table 20 – Post-Hoc Pairwise Comparisons for Subgroup 6 MTH 127 Non-corequisite students versus MTH 127 Corequisite Students versus MTH 130 Traditional students who complete MTH 132 pre-calculus showed significant differences in overall student performance in pairwise comparisons. Considering the initial pairwise comparisons, there was no significant difference between non-corequisite students and corequisite students (p = 0.965). The significant differences occurred when comparing non-corequisite students to traditional students (p = .003), as well as comparing the corequisite students to traditional students (p = .030). According to the table, the adjusted significance levels similarly indicated no significant difference when comparing non-corequisite and corequisite students (p =1.00). The adjusted significance values also indicate a significant difference between non-corequisite and traditional students (p = .010), however, there was no longer a significant difference found between corequisite and traditional students (p = .089).

Table 20 – Post Hoc Pairwise Comparisons: Participant MTH 132 Grades due to College Algebra Course Experience
Student Performance in MTH 132 Pre-Calculus

	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Non-corequisite vs Corequisite	-.440	10.161	-.043	.965	1.000
Non-corequisite vs Traditional	-22.926	7.822	-2.931	.003	.010
Corequisite vs Traditional	-22.485	10.342	-2.174	.030	.089

* Significance attained at p<0.05

To further analyze differences between these groups, Table 21- Chi-Square Test for Subgroup 6 MTH 127 Non-corequisite students versus MTH 127 Corequisite Students who completed MTH 132 pre-calculus showed no significant differences in overall student performance. However, passing grade frequencies (A, B, C) increased 4.3% from 62.3% with non-corequisite students to 66.6% with corequisite students. The low number of students in the samples was noted.

Table 21 – Chi-Square Test for Subgroup 6 MTH 127 Non-corequisite versus MTH Corequisite Students who completed MTH 132 Pre-Calculus
Student Performance in MTH 132 Pre-Calculus

Academic Semester		Overall Student Performance Levels A	B	C	D	F	Chi-Square	p value attained
Fall 2017 – Spring 2020	Frequency % Non-corequisite n = 70	8 11.4%	18 25.7%	18 25.7%	7 10.0%	19 27.1%	1.692**	.792
Fall 2017 – Spring 2020	Frequency % Corequisite n = 27	2 7.4%	9 33.3%	7 25.9%	1 3.7%	8 29.6%		

* Significance attained at p < 0.05. ** *5 cells (50.0%) have expected count less than 5. The minimum expected count is 1.29.*

Table 22 – Chi-Square Test for Subgroup 6 MTH 127 Non-Corequisite students versus MTH 130 Traditional Students who complete MTH 132 pre-calculus showed no significant differences in overall student performance. Passing grade frequencies (A, B, C) decreased 16.7% from 79% with traditional students and 62.3% with non-corequisite students. It was noted that while removing both the pilot and spring sections might show a difference in student performance overall, doing so in this situation will not leave enough student data in the samples to make reasonable comparisons. The Cramer's V measure was used to compute the effect size for significance describing the quality of the significant difference found when comparing the data. The reported effect size was V=.279. Given the 4 degrees of freedom, the effect was above .25 and was categorized as a large effect size.

Table 22 – Chi-Square Test for Subgroup 6 MTH 127 Non-Corequisite versus MTH 130 Traditional Students who completed MTH 132

Student Performance in MTH 132 Pre-Calculus

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Non-corequisite n = 70	8 11.4%	18 25.7%	18 25.7%	7 10.0%	19 27.1%	10.267**	.036*
Fall 2017 – Spring 2020	Frequency % Traditional n = 62	19 30.6%	16 25.8%	14 22.6%	6 9.7%	7 11.3%		

* Significance attained at $p < 0.05$. *** 0 cells (00.0%) have expected count less than 5. The minimum expected count is 6.11.*

In further analysis of the significant difference found in Table 20, Table 23 – Mann-Whitney U Test for Subgroup 6 Non-Corequisite versus Traditional Students presents comparisons of each type of student. The results indicated there was a statistically significant difference (at $p < 0.05$) between frequencies of student final grades due to the type of course enrolled. Examining the mean ranks showed a higher mean rank for the traditional students indicating students earned higher grades overall in the traditional courses

Table 23 – Mann-Whitney U Test for Subgroup 6: Non-Corequisite and traditional Students

Student Performance in MTH 132 Pre-Calculus

Course Type	Mean Rank	Mann-Whitney U Statistic	p value attained
Non-Corequisite (n = 70)	57.59	2893.5.000	0.004*
Traditional (n = 62)	76.56		

* Significance attained at $p < 0.05$.

Table 24 for Subgroup 6 MTH 127 Corequisite students versus MTH 130 Traditional Students who complete MTH 132 pre-calculus shows no significant differences in overall student performance. Passing grade frequencies (A, B, C) decreased 12.4% from 79.0% with traditional students and 66.6% with corequisite students. Note that while removing both the pilot and spring sections might show a difference in student performance overall, doing so in this situation will not leave enough student data in the samples to make reasonable comparisons.

Table 24 – Chi-Square Test for Subgroup 6 MTH 127 Corequisite versus MTH 130 Traditional Students who completed MTH 132

Student Performance in MTH 132 Pre-Calculus

Academic Semester		Overall Student Performance Levels					Chi-Square	p value attained
		A	B	C	D	F		
Fall 2017 – Spring 2020	Frequency % Corequisite n = 27	2 7.4%	9 33.3%	7 25.9%	1 3.7%	8 29.6%	9.380**	.052
Fall 2017 – Spring 2020	Frequency % traditional n = 62	19 30.6%	16 25.8%	14 22.6%	6 9.7%	7 11.3%		

* Significance attained at $p < 0.05$. ** *3 cells (30.0%) have an expected count less than 5. The minimum expected count is 2.12.*

Research Question 4

What are the perceptions of faculty who taught both corequisite and non-corequisite college algebra courses at Marshall University?

There were three major categories of questions included in the faculty interview protocol. The first segment contained questions about the initial transition process and contains interview questions 1, 2, 3, 4, and 5. The second segment addressed the culture of evidence-based teaching contained within the corequisite courses and contains interview questions 6, 7, 8, 9, 10, and 11. The third segment asked about challenges, growth, and continued professional development and contains interview questions 12, 13, 14, 15, 16, 17, as well as one more question on additional thoughts from faculty.

Section 1: Initial Transition Process

Interview Question 1

What is your understanding of the corequisite college algebra course model?

To analyze faculty perceptions on interview question one, faculty responses were coded under "accurate understanding of corequisite model." Based on faculty responses, all five faculty members interviewed accurately described the structure of a corequisite teaching model and gave responses that indicated they understand the purpose of corequisite courses in the mathematics department. Only one faculty member indicated the perception of their understanding of the corequisite instructional model came from "limited experience" teaching the college algebra courses, otherwise, the faculty provided responses indicating they were aware of and had experience with the corequisite model.

One faculty described the corequisite model as "a course designed to be used as a solution for traditional college algebra for those students who are struggling with prerequisite skills." A second faculty described corequisite courses in terms of benefits that "allow [students] to take a full college algebra class that is that meets their degree requirements." Two of the faculty said that corequisite courses have "other requirements that students must take at the same time as [regular] course requirements" and that the courses "count for credit and [students] are given the support that includes just-in-time remediation." Two other faculty members described the corequisite model as being "professional" and discussed how the model "provides topic instruction along with in-time remediation" which makes "every day different. Every element of it. Nothing is ever the same." According to one faculty, in Fall 2017 the course offerings used a different online platform which "required a set number of assignments for everybody. It was called a corequisite model at the time, using a three-two class setup for lecture and lab instruction. Even though the three days in lecture, two days is lab was implemented, in my opinion, that was incorrectly labeled as corequisite from my understanding." The faculty mentioned course policies used in the old versions of the college algebra course saying, "at the time, a set of prerequisite assignments were set up inside the curriculum which doubled the workload for the students and wasn't tailoring assignments specifically to the students that needed them."

Interview Question 2

What steps have you taken to address the transition from non-corequisite course offerings to corequisite?

To analyze faculty perceptions on interview question two, faculty responses were coded under "transition steps taken." All five faculty members reported taking steps as part of their preparation for corequisite teaching. Faculty already familiar with the model and student population made little changes to their courses, others changed key components of their courses to align with the corequisite model.

One faculty mentioned that, initially, the college algebra courses are “completely designed by the committee and the chairman,” with assignments and a schedule of due dates given to instructors to follow. Multiple faculty members mentioned using extra class time for specific types of activities that engage the student with the course content. The faculty members talked about using the extra support time in the course for “classroom activities,” developing “classwork problems,” and having students “teach to learn.” One faculty member stated “the model works well,” and another faculty mentioned spending time “learning about what was happening nationally” with corequisite and believed it is a model that is successful at other institutions.

Another faculty described how the change to corequisite instruction has affected their course preparation and lesson delivery saying “I don’t focus as much on writing the remediation into my notes. I don’t need to instruct starting at baby step levels. Now, after working with them in the lab, I can identify who needs help and who can carry on.” This faculty also reported adjusting to “taking up graded homework assignments. I didn’t use to take up homework, I would just provide a list of suggested problems.”

When discussing specific actions taken in their classroom, one faculty member simply said, “I don’t know that you could list them all.” Some specific actions mentioned by faculty included a strategy where they “divide the class into smaller groups that are maintained throughout the semester.” Faculty members indicated that students are expected to “collaborate with their group to complete classroom work” prepared ahead of time. The groups work well for one faculty member because they see “students with questions who may be shy to ask questions to their professor, but they feel comfortable asking in their colleagues." Another faculty member said they have always tried "to be receptive and really get a feel for what the audience needs." They indicated that the methods used within the corequisite model align with much of what they had already been implementing in their classrooms for this particular student population, and that faculty felt affirmed in their prior decisions. They had always been trying to implement these kinds of strategies, they just "didn't have a name for it" until now.

Interview Question 3

What resources did the institution provide, such as internal or outside conferences, seminars, etc., to aid you in your transition?

To analyze faculty perceptions on interview question three, faculty responses were coded under "resources were provided." All five faculty members described the resources provided to help transition to corequisite teaching. Faculty described the seminars and training provided by the institution and the mathematics department to help them learn about the new teaching structure and course policies over time, as well as provided more details on the steps they took to transition to the corequisite model.

One faculty member mentioned getting "access to a new digital course software" and the "monthly trainings" provided on how to use it in the corequisite classroom. One faculty reported that "there were a lot of seminars offered, but I didn't attend. Mostly, I read through the information emails put out about the program change." Another faculty member discussed the resources and training provided by the state for the initial transition to corequisite claiming that at the time "the institution provided some resources, but probably the state provided more." One faculty member could not remember having attended any conferences on the topic, from the institution or nationally, but said there should be more resources "provided by either the university as a whole or the [mathematics] department offering corequisite." One faculty member said, "any information [from the course committee] could provide support when it comes to this kind of model." Another faculty member mentioned having good relationships with colleagues and "knowing who to ask" was an important way they gained information about the new teaching model.

Interview Question 4

What surprises or unexpected events did you experience in the initial transition?

To analyze faculty perceptions on interview question four, faculty responses were coded under "experienced expected events." All five faculty members interviewed reported experiencing some type of surprise or unexpected aspect regarding their transition to corequisite instruction.

One faculty was surprised by the initial "constraints placed on the instructor." Initial deployment of the corequisite model was much more rigid, unlike other forms of corequisite instruction in the department which were "very freeform" with a "generalized flow and targeted remediation" where we're encouraged to "use your intuition to supplement that." Another faculty member described teaching their first corequisite course and being surprised by "a couple of students having a tough time concentrating and struggling to adjust to the class schedule." However, after teaching the course again, the faculty suggested "that is not unexpected because it is a corequisite course. It was my first time teaching, and it showed me the difference in expectations I should have for students."

Another faculty described being surprised by the level of students. They claimed that "high school performance doesn't really give you an accurate idea about the level of students." The faculty continued to say "those students [in corequisite courses] did not get a good score on the ACT, but that doesn’t mean they are not good actually.” The faculty mentioned how some students “did not get a good score on the ACT” and perhaps could be placed in the wrong class suggesting that the “test is not always that accurate.” This faculty was surprised by how different the student preferences were in a single corequisite course saying, “one student confessed they didn't like lab days and [the class] should do five days of the lecture because she gets those concepts by me going over all questions [in lecture].” However, another student in the same class said “he wished that every day is the lab day. So, it's a good thing that we have a mix of labs and lectures, because you don't know what's best for them. Everyone sees things from a different perspective.”

Interview Question 5

What are the differences you have experienced between teaching non-corequisite courses versus corequisite courses, specifically regarding remedial or developmental mathematics education?

To analyze faculty perceptions on interview question five, faculty responses were coded under “found differences between non-corequisite and corequisite.” All five faculty members reported on the similarities and differences when comparing corequisite students to previous versions of developmental courses and their counterparts in traditional courses.

One faculty member described differences like the corequisite courses contain “students who need extra help. You have to explain things more and you have to be patient when discussing concepts.” This faculty indicated that students in traditional courses sometimes have “fake confidence” that “makes them not want to work,” but students in the corequisite courses were aware they needed extra help. Another faculty member described the classes as being similar said “there’s not much [difference]. People think the curriculum is going to be so burdensome. It isn't. But, it does take a teacher who can 'think quickly on your feet and be adaptive." This faculty uses said they use these kinds of techniques in all their classes.

Three of the faculty categorized the student experiences as being different. One faculty suggested that a major difference is "spending more time solving classwork problems or homework problems, or practice questions, using time in class" rather than lecture. Two of the faculty indicated that students were "getting through more of the material." The first faculty suggested this is the case "because the students seem more motivated to get their homework done because 1) if they have their assignments done, I don't make them come to the lab, or 2) because they are coming to lab and doing the assignments, getting support and actually learning material for a change." One faculty member suggested this is the case because "before we made changes toward corequisite when we were doing pre-requisite course sequences if the students weren't going to do something in class, I feel like there wasn't going to be much done. So, I felt as an instructor, I had to present all the material during a class meeting like a lecture but now it is not the case - that I feel the need to lecture because they are doing more."

Section 2: Culture of Evidence-Based Teaching

Interview Question 6

Procedure versus Conceptual – On a pendulum scale where one side represents only written robotic procedures and the other side represents only thinking conceptual ideas, to which side do your corequisite courses measure? Would this be consistent for all your courses?

To analyze faculty perceptions on interview question six, faculty responses were coded under "procedure or conceptual." All five faculty members reported some measure of their procedural versus conceptual focus in their classroom instruction.

One faculty described their position as "in-between. So, you want to actually make a balance here. Try to motivate them by giving them like maybe real-life applications." Another faculty indicated "at different times I do different things. Sometimes, I start off with the conceptual and then dig down to the procedural, and then other times I start off with the procedural and figure out how it can be used broadly in the real world." Another faculty said they 'kind of balanced things. There are some topics in college algebra that only involve procedural steps to get the final state. And there are some topics where you need some conceptual ideas in there just to try to paint the problem you're trying to solve. So, in that case, I tried to relate that particular problem to a real-world optimization scenario."

Another faculty described themselves as "60% procedure 40% conceptual. I do teach a lot of 'these are the steps you do', but when it is an important topic like intercepts. You can't just find the intercept over and over, you really need to know what they mean. I try to get a healthy balance of both. When it is a topic that they will see in Calculus, I try to lean to the conceptual side. But it depends on the topic." Another faculty said "I swing back and forth. I strive to do just about everything, something like presenting perpendicular lines. You are trying to get them to derive the products of the slopes is a negative one, but at the same time doing that say well, procedurally you would look at these steps like flipping and negation."

Interview Question 7

Just-in-time Teaching – How has just-in-time instruction affected your course preparation? What effects does this teaching technique have on the student experience during class and/or overall student success?

To analyze faculty perceptions on interview question seven, faculty responses were coded under "just-in-time instruction." Three faculty reported some type of positive effect just-in-time remediation is having on their corequisite classroom and the student experience. Two faculty discussed challenges adjusting to just-in-time instruction.

One faculty reported, when thinking about course preparation, “you need to keep in mind, you might want to spend 10 to 15 minutes answering questions about things that you actually are not planning to cover in that day.” The faculty member also reported that a fixed schedule is “a struggle” and that “we always tell our students ‘You need to ask questions.’ So, when they ask, we don't have enough time sometimes to answer those questions.” Another faculty suggested that they “don’t prepare just-in-time necessarily, other than just having that general framework. I just throw [the content] in.”

One faculty described how just-in-time instruction has impacted them saying “it's affected me as an instructor negatively because it means there's a possibility I might not be able to complete the course content for the semester. Usually, you have to spend more time on a particular topic unexpectedly, and that's going to affect some other later topics you are supposed to cover.” This faculty member reported positively on the student experience saying “the student tends to like it.” The faculty said because you spend more time on what they need most, students tend to “stay satisfactory” and seemed to understand the content more “perfectly. They don't tend to have bad experiences, or it doesn't really affect them, except the fact that there [may be] a topic I'm missing [at the end of] college algebra.”

Another faculty said when discussing the effects of just-in-time instruction on the student experience “I think that it's made the class much more engaging, because they know I'm just not a robot up there teaching my lesson.” This faculty mentioned “not prescribing remediation until the student needs it” and suggested that faculty not assume every student needs the same remedial material. The faculty claimed, “that's one of the reasons why I think the success of [the new curriculum] has been so great as opposed to [the old curriculum] because we had to prescribe remediation for students." The faculty said these across-the-board pre-requisite assignments just became "extra problems that [students] had to do."

Two of the faculty members described how just-in-time instruction helps them "get through more of the material." One faculty member said "it lets me teach the material at a medium to a high level. I am teaching more of a college-level, rather than teaching it from the ground up." The other faculty member said, "when setting up the schedule, it feels like there is a bit more attention grabbed at the beginning." The faculty member said that covering remedial material at the start of the course for a week or two, "where maybe [students] tune out or just think they know it, creates this lack of effort that affects their pace." This faculty member suggested that just-in-time remediation captures the needs of more students throughout the course.

Interview Question 8

Motivation and Persistence – In what ways do you try to motivate your students? What examples of persistence training like growth mindset are explicitly incorporated into your corequisite course?

To analyze faculty perceptions on interview question eight, faculty responses were coded under "addresses motivation and persistence." All five faculty members reported on some aspects of addressing both motivation and persistence in their corequisite courses.

One faculty reported that students "come in with a lot of fear, so seeing a kind, compassionate person, supportive, I think that that helps not only relieve their fears but motivates them." The faculty said they started using error correction type problems rather than multiple choice for instance. “That's really helpful and speaks to their growth. This kind of learning material helps students “feel confident that they're getting part of it.”

Another faculty reported encouraging students to “participate in the class problem solving, making sure they collaborate with colleagues in class because they tend to learn a lot.” This faculty member also encourages students to “complete their homework problems before the due time, and then come to class and share their experience of what works and what does not work.” The faculty member mentioned making sure students were aware they could email additional questions if time ran out in class and said “it looks like it works. Although there are some of them that don’t want to do anything, they still want to pass. Mostly those that take on the advice seem to do well.”

One faculty reported using “group activities” that students are enjoying for some extra credit. The faculty comments on student motivation how “they don't do their homework assignments, the existing homework assignments, and then they ask for extra credit. And I don't know, for some reason, awarding, extra credit, it gets their attention, and they just do it.” The faculty reported using a “replacement test, where if [students] do well on the final Test, [that would] replace your lowest test score. I feel like one test doesn't really give you a full idea about the level of the students in general, but I think this helps, along with the extra credit.”

Two faculty described a major motivator and persistence factor as “allowing [students] to continue to work on the assignments over time, with a flexible working schedule.” The faculty claim that “students can struggle with topics for several weeks over the course of a semester and eventually master those topics, with no penalty.” One of the faculty reported using multiple representations to help students be persistent saying “if [students] are stuck, I try to think of as many different ways to explain and present the material. Try to find their niche. If it doesn’t work to just talk about the graph, then let's talk about the equation at the same time." This faculty self-described as "not being much of a motivator. I have expectations that they have chosen to come to college, and that they want to take their classes. What I am focused on is that you actually do [the work]. Take your time. Do it as many times as you need to. Don't just chug out answers from a math solver. For me, the [college algebra] course committee's suggestion to take reductions [on assignments] after due dates is really de-motivating."

Interview Question 9

Complexity and Transformation – How much time do you spend reviewing prerequisite material in a 15-week course? Do students interact with this material in a different way than at the college level?

To analyze faculty perceptions on interview question two, faculty responses were coded under "approaches with complexity and transformation." Four out of five of the faculty reported on their approaches in the classroom regarding complexity and transformation regarding the time spent and student experience with incorporating pre-requisite content. Three faculty reported expecting students to start and have success with the college-level materials from the start of the semester while covering corequisite content as needed throughout the semester. One faculty described feeling the need to cover every topic from the ground up, which sometimes causes them to lose too much time and cut topics at the end of the course, but the faculty still incorporates the prerequisite content throughout the semester.

One faculty said "I think that would depend on the topic that we are covering. I don't like to do the review at the beginning of the semester. Spending two or three weeks to review. Then, [when we reach new content], every time we have to go back to the review on that one more time." This faculty also described how setting expectations low at the beginning of the semester gives students a false sense of confidence. Another faculty said they start the semester with the college-level material saying “I assume that they know how to do it, then if they don't, OK. Now we need to be in a small group or ask me, and then we get to the heart of understanding what we don't know. And that goes along with the growth mindset to feel comfort and confidence, too.” This faculty member said “I spend very little time going through lower-level stuff unless it is a topic I know they are currently struggling. I catch [remedial needs] on an individual basis, rather than make the whole class go through another lesson.”

Another faculty said they “probably [cover] less [remedial material] because I am no longer doing the week-to-two weeks of the review normally put at the beginning of the [college algebra] class. So that is eliminated.” This faculty said they only “use the contents of a Chapter 0 or Chapter P throughout the semester. So, some of [the remediation] might not be covered explicitly in class, if the students show they know it and we don’t need to cover that.”

One faculty said when they were teaching these kinds of courses, that at first, they didn’t “assume all these students have satisfied the prerequisites requirements for the class. So, all the problems are solved in a step-by-step approach. [The students] see it as a tool. So, I try, at least, to make sure the time difference between when topic one is taught and when topic two is taught is very close. If possible, teach them at the same time, find a way to try to structure everything so that one leans into the other directly. So, they see it as still part of college algebra, because it’s something ‘I’m supposed to know this before’ and they don't see it as something different than. They don't see it as a prerequisite. They see it as part of.”

Interview Question 10

Equity and Social Justice – What equity or social justice issues did you see students experience as you transitioned from prerequisite to corequisite instruction? How was it resolved?

To analyze faculty perceptions on interview question ten, faculty responses were coded under “experienced equity or social justice issues.” All four out of five of the faculty members reported experiencing equity or social justice issues in their corequisite courses. Each faculty described the way that corequisite courses have addressed those issues.

One faculty described how faculty “have to prepare your notes and construct examples to keep everybody in your class interested and motivated. And also, you want it to be doable. There are some students who were so excited about finally getting a good education, mathematical education that they really become engaged in a corequisite class. You know they're finally learning. They finally feel like they're in a safe environment and they just blossom. Those students are really rewarding because you know that they've never done that before in a class.” This faculty continued to say if we are “talking about money because I know [the old college algebra textbook] was more expensive than [the new materials] and that was kind of a barrier. Us transitioning to OER was really a benefit. They didn't buy the book anyway. I do think the new platform is cheaper and that may be some injustice rectified by that.” The faculty also mentioned that “the environment that we've created the corequisite [courses] - where we try to treat everyone the same, we try to assume the best about them instead of the worst - don't look at them as a bunch of pitiful people who can't do math or people who are taking up a college seat who can't do the math. Look at them as an opportunity for them to be a future stem person. And I'm a step on their ladder. I do think that the corequisite class helps to kind of level the playing field.

Another faculty reported that they have “seen a lot of average college algebra students do well in the corequisite course, and saving a lot of semester hours not taking prerequisite courses.” Another faculty mentioned that “there are still some students who cannot afford to buy an online license or who still struggle and try to take their classes without textbooks.” This faculty member said some of the corequisite students with lower enrollment criteria “are really good at math. [They are] getting placed under where they should be and being held back.” The faculty described the progression of courses taken by the developmental students saying “these poor kids have had to go from a developmental course worth no credit, to a developmental course worth some credit, and now are able to take college credit courses. A lot of those students from before [we implemented corequisite] would have to take [two prerequisite courses] and then their required course. And so many students failed and failed and failed. I hate that more than anything, like the idea that my math class is the thing that keeps a student from graduating. I try really hard not to be that barrier.”

One faculty said they noticed “if something happens, obviously there is more of a chance that people who are non-traditional, need to travel to get to campus, or other students with jobs and family responsibilities. If they get behind at any point or missed an assignment, not being able to work on it over the whole semester is an equity issue.”

Interview Question 11

Theory to Practice – In what ways are students made aware of the underlying pedagogy, teaching philosophies, or learning theories utilized in your corequisite courses? How aware are they about why they are being asked to complete specific assignments?

To analyze faculty perceptions on interview question eleven, faculty responses were coded under “addresses theory to practice.” All five faculty members reported on integrating theory to practice within their corequisite courses. Three faculty reported taking some type of step as part of their preparation for presenting corequisite content. Two faculty said they only bring those theories in as a reaction to student attitudes.

Two faculty questioned the rationale for using a common final without explaining to students the purpose of the assessment. One faculty said the only answer they have ever given to that question is "Well, we need to see your scores compared to other groups." The faculty expressed concern that students are not getting a lot of information about the course before they register. This faculty said every once in a while, there is one student who resists course strategies like group work and "prefers to just work by themselves. I think that was the only time where [students] question *why are we doing this*." The faculty said that relationship building was crucial for getting students to be comfortable with one another and then they can develop their mathematical language. When the faculty would "walk between [the students] when they're sitting in groups, I would listen to what they're talking about. And actually, I'm learning from them because they say things in a way I've never said them."

Another faculty said they "try to keep it really simple for [the students]. And I don't burden them with a lot of unnecessary information. So, I don't say, hey, I'm putting us all together in groups for a constructivism experience, you know?" However, the faculty did report easing student tensions by explaining why students should write out their work while taking notes and on assessments, but generally this faculty reports explaining things as they see the students need it, not as a standard practice. The faculty said the learning theories are not always "something [the students] need to remember, they just need to know that the environment that I'm going to create is one in which everything we do supports their learning."

Another faculty reported bringing in information on learning theories in a reactionary way. "Usually, I tell them this when I see my student's reaction to a particular topic. When I see a kind of worried reaction to content, I tend to pause a little while and then try to let them know the reason why I'm teaching them something they think is too hard for them to comprehend.

Maybe they're more scared than what I expected, but it seems to work. Because I really don't want them to be scared, but I want them to know what to expect." One faculty reported requiring students to turn in practice work before exams as a "low stakes motivation to get them to study." The faculty said they "let [the students] know that I won't be grading the submission for right or wrong answers. I am going to look at it, and if you did it, you will get your points," which eases performance fears and gets students actively working on the mathematical content.

Another faculty said at least some of the learning theories are included "on the syllabus and in detailed instructions I give them about the assignments in the course." This faculty reported that students "do not feel as disengaged as they were before. I am only hearing pushback on the structure of the course when someone gets stuck in some of the refresher material in [the online platform]."

Section 3: Challenges, Growth, and Continued Professional Development

Interview Question 12

How did teaching corequisite courses change your relationship with teaching developmental students? What effects has the transition had on other aspects of your teaching?

To analyze faculty perceptions on interview question twelve, faculty responses were coded under "noted changes student relationships or teaching." All five faculty members reported on some aspects of their teaching they categorized as different from other versions of developmental teaching. One faculty described something they changed on their own, three described being affirmed in changes they had already made, and one described positive changes that were part of the course model.

One faculty described how they changed their assessments for corequisite students saying there are "all different types of students that you have in that class and the challenge of keeping the class is doable and enjoyable and interesting for all of them. Usually, if you teach advanced math classes and everybody is just all ears, they're not struggling." The faculty said they "think about all types of students and write an exam to example that," by using many different types of questions like matching, multiple-choice, free response, as well as error correction.

Three faculty expressed feelings of "affirmation" that some of what they were already doing in their classroom aligned with the corequisite structure. One said something that "really works and that has really changed my relationship with teaching my developmental students" is the collaborative practice assignments before exams. The faculty described "the impact that coming into class with a set of class problems, dividing students into a smaller group, as well. With low levels or lower-level classes, the part where you divide students in your class into smaller groups, distribute the classroom problems out to your students, to be completed by the end of the class time. Well, that really helps across all my classes." Another faculty reported that "breaking up the week into teaching and practicing" has helped create a flexible, manageable routine for the course.

Interview Question 13

What specific success/achievements did you encounter in your transition? How did you confirm/celebrate them when they arose?

To analyze faculty perceptions on interview question thirteen, faculty responses were coded under "experienced student achievements." Three out of five faculty members reported experiencing some type of student achievements with corequisite teaching. Two faculty members referenced previous answers as their successes with student achievement in the corequisite model.

One faculty reported students enjoying “activities on lab days,” and, “I think it is because maybe it's untraditional math. Not something like ‘OK, do this and that. Solve this full problem, with step 1234. I think maybe because it's a bit different, they seem like they are enjoying doing things in an untraditional way. They were really interested in answering and like getting the activity done.”

Another faculty reported that they had some “students who say they want to be math teachers in my corequisite college class!” That was exciting because they recognize the struggle that they've had. Yeah, and you know they were excited and I was excited for them and they said ‘I think I could have a lot to offer students because I have struggled in math.’ Anytime you can make something personal to you, I think it's more approachable to the other person. That was a success.”

Another faculty said the biggest success they experienced was “probably the first time I was able to make it all the way through the last material in the course semester. Sticking with the 3/2 model has been good.” Two faculty did not provide new answers but referenced previous discussions in their response to this interview question.

Interview Question 14

What specific challenges/obstacles did you face in your transition? How did you address/overcome these when they arose?

To analyze faculty perceptions on interview question fourteen, faculty responses were coded under “experienced student challenges.” Three out of five faculty members presented their specific examples of challenges. Two faculty did not report challenges.

One faculty described the “length of the course” as a challenge. “For some students, like meeting every day, five times a week, that's too much, because most other courses, they just need three times a week. So that could be one of the challenges to keep students motivated. And I think another challenge is changing their point of view about mathematics in general. Get students to feel like it's something doable. You could enjoy it, actually. We use it on a daily basis. Try to think of mathematics as a good thing. Changing their perspective about math and people who are doing math is a real challenge."

While discussing student challenges, another faculty described the "fixed mindsets of other faculty" as a challenge. "Trying to get other faculty who don't teach this class or this population of students to understand what this population needs and what the course needs to look like," and convincing administration and course developers about "the freedom that [faculty] need to present the material [when] that's needed."

One faculty reported a challenge regarding their course evaluations when they had a class that performed well but "during my course evaluation, my students actually said I pushed them too much! How do I solve that kind of challenge?" Two faculty members said they could not "think of anything notable" in terms of other challenges. Two faculty did not report any additional challenges on this question.

Interview Question 15

What resources are available as you continue in your position as a faculty member teaching corequisite students, such as training, conferences, and other resources? To what extent has participation been beneficial in your transition to the corequisite model?

To analyze faculty perceptions on interview question fifteen, faculty responses were coded under "current training participation." All five faculty members reported on the current professional development of their preparation for corequisite teaching. Four faculty reported on aspects of their training, and one faculty reported not being that active with their professional development currently.

One faculty mentioned that many opportunities were being offered by the institution, perhaps because of the pandemic including “training about the course policies and online software before the beginning of the semester.” Another faculty commented on “peer/faculty discussions” as a great way to get more knowledge about the implementation of the curriculum.

One faculty mentioned that at the start of the pandemic there were “tons of webinars and trainings available all the time. I did a lot of webinars and training [then], but those were more focused on “how do we do this online?” Another faculty mentioned that they “weren’t as active on professional development” as they should be. One faculty reported “reaching out to colleagues” as the main way they communicate about the information put out by the course committees and department chair.

Interview Question 16

During your transition, and at key points during your teaching duties, how were you able to examine your transition and redirect your transition efforts when needed to change the course offerings?

To analyze faculty perceptions on interview question sixteen, faculty responses were coded under “examined transition efforts.” Two of the five faculty members reported seeking out and making changes to their corequisite curriculum is a constant and important task. One faculty reported minimal changes being made to their corequisite courses. Two faculty reported on the restrictive nature of the non-corequisite forms of the college algebra course, and one of those discussed ways they examine their course offerings.

One faculty suggested that “nothing is ever the same in this class. Every class is different, every day is different.” Another faculty reported they “frequently do things differently. I may teach the same topic two different ways, with two back-to-back classes. I will always look for how I can do it better. I'm always looking for something that can be improved.” The faculty reported being able to take the experience in one class, “then after the class is over, I kind of globally look what worked. What didn't work… I make notes to myself. I look at day-to-day things that I can change and I look at course-wide things that I can change.” This faculty said that was not the case with older versions of the curriculum.

One faculty reported that they were not given much freedom to change the course at first. “The course has been designed with due dates and everything, so I don't even remember changing being able to change the dates. Maybe I had some changes in mind at that time. But no, I did not change anything.” The faculty reported wanting to know more about their student performance compared to other courses to make improvements. Another faculty reported they felt more like they had “found their sweet spot” and after teaching corequisite for several semesters and do not change much from day-to-day or course-to-course.

One faculty said to rely on student evaluations, “but, at the same time, you don't want to divert from your principles or your ways of teaching, because one student out of 30 says something that really makes you think easy, “is [my method] correct? Or am I really bad?” The faculty reported meeting regularly with colleagues teaching the same course helps. “I think it helps for the college algebra because you know there are times where we will meet and then faculty will be asked to discuss what they're facing now, what their students are facing, in particular with respect to the homework problems or with respect to the schedule they are using.” This faculty also mentioned in terms of their course creation and preparation, the “course committee coming up with the day-to-day schedule of what is expected to be completed, I think that helps a lot actually. That really doesn't happen for other courses."

Interview Question 17

As a faculty member with this experience, what would you say to future faculty members who will teach a corequisite course?

To analyze faculty perceptions on interview question seventeen, faculty responses were coded under "shared experience to guide future corequisite faculty." All four of the five faculty members shared advice with future corequisite instructors. Faculty focused on the positive aspects and reported on specific techniques to get corequisite faculty started thinking about their corequisite courses.

One faculty suggested that every faculty member "teach the course at least once. It will get [faculty] a new perspective about teaching. At least that's what I can tell you from my experience." The faculty said when new instructors begin the course, curriculum preparation will include mathematics content but must also include "how to keep the course fair to everyone and fun to everyone."

Another faculty said the first thing they would suggest is to "let go of control." The faculty says to have a general framework with flexibility built in, because "you can't prescribe every word that you're going to say." The faculty says "listen to your students. Ask them questions. Give them the opportunity to express either knowledge or apprehension. Look at body language. You have just got to adapt to whatever they're presenting you in that day." The faculty also suggested that instructors be subject matter experts.

One faculty said their "advice would be giving students working class sessions and allowing students to complete the classwork in a timely manner in their working groups while collaborating with each other helps a lot. And it really changes the performance of all the students." The faculty suggested in terms of time management that "for your first module, you probably want to assign 35% of your class time in the first module and the second will be 25% or something like that. You probably spend more time in the earlier discussion and schedule than in the latter. Yeah, this will be my advice." One faculty suggested that reaching out to colleagues to have discussions is the best way to get help with teaching a course.

In Conclusion

Do you have any other comments, observations, or suggestions that you would like to contribute?

To analyze faculty perceptions on interview question two, faculty responses were coded under "added further comments." Two faculty provided additional comments. Three faculty did not add anything to this response.

One faculty suggested that someone put together documentation about the best practices the MU Mathematics Department has accrued. The faculty said "it would be nice to have some kind of documentation about at least the basics ideas. If I'm a faculty going to teach this in the future, but I'm not really sure what the course is about or [if I have taught the course] last time and the course has changed."

Another faculty suggested that because of all the changes made throughout the years, the attention is given to evidence-based practices in the classroom and at the administration level, "college algebra, it's not a class that students just 'have to get through' anymore. It's actually the class that relates to their degree, and I think that they are engaged more," suggested implementing corequisite pathways has been beneficial for students and faculty. In particular, the faculty claimed that older versions of developmental college algebra coursework, "didn't really relate to anything except it was a hoop they had to jump through. Before then, they took their real class which was MTH 127. And so, what I'm talking about is that this is an accountable class, and I do think that a lot of them are engaged because they know the shame and stigma of remediation are removed. And I think that that's a positive thing both in their minds, and I think it should be a positive thing for the teacher."

CHAPTER 5

CONCLUSIONS AND DISCUSSIONS

Chapter 5 reports the conclusions, implications, and recommendations of the study results. The purpose of this study was to determine the effectiveness of the implementation of a corequisite model of instruction for college algebra students. The population of students used in the study consists of students taking college algebra and precalculus at Marshall University from Fall 2017 to Spring 2020. The sample of faculty interviewed was those faculty in the MU Mathematics Department who have taught both prerequisite and corequisite college algebra courses. This descriptive and quasi-experimental study with a mixed-methods approach analyzed student performance data in college algebra, faculty perceptions from both the current corequisite college algebra courses and previous non-corequisite college algebra courses, as well as student performance data in precalculus courses.

This study contained a quantitative analysis of the final course grades of students in the cohorts and qualitative analysis of the perceptions of the faculty teaching corequisite courses. The quantitative analysis compared final course grades of student cohorts from before and after full implementation of the co-requisite model of instruction in college algebra courses at Marshall University using the Chi-Square, Mann-Whitney U, and Kruskal-Wallace statistical tests. The qualitative analysis categorized patterns that emerge from interview question responses from faculty who taught non-corequisite and corequisite versions of college algebra.

The data collected for this study mainly consisted of student final course grades. Researchers and faculty understand the limitations to assume course grades only reflect student learning that has occurred from their experiences in academic courses (Canfield, Kivisalu, Van Der Karr, King, and Phillips, 2015). Given this limitation, whenever possible, pilot courses and the pandemic semester were removed to eliminate other variables that may have affected student performance in the form of final course grades. Thus, conclusions made here about student performance took into consideration these limitations and were presented alongside faculty perspectives to pinpoint their relevance to the study.

Research Question 1 Analysis

Is there a significant difference in student performance between corequisite college algebra students and non-corequisite college algebra students at Marshall University?

In the first Chi-Square comparison between all non-corequisite and corequisite students ($n = 1349$, $p = .269$), there was no significant difference in the student performances in college algebra overall. Passing grades frequencies were higher (+5.6%) among the corequisite students when compared to non-corequisite students. In the second Chi-Square comparison, there was no significant difference in the student performances in college algebra between non-corequisite and corequisite students ($n = 1242$, $p = .132$) excluding those students who took pilot courses in Fall 2018 and Spring 2019, however, passing grades frequencies were higher (+4.4%) among the corequisite students when compared to non-corequisite students. In the third Chi-Square comparison, there was no significant difference in the student performances in college algebra overall between non-corequisite and corequisite students ($n = 1237$, $p = .134$) excluding those students who took the course in Spring 2020 during the beginning of the COVID-19 pandemic, however, frequencies of passing grades were higher (+7.0%) among the corequisite students when compared to non-corequisite students.

In the fourth Chi-Square comparison, there was a significant difference in student performance in college algebra between non-corequisite and corequisite students ($n = 1130$, $p = .041$) excluding students who took pilot courses and during the pandemic. Even though there was only a small increase in passing grades overall (+0.3%), letter grades frequencies in the A category were much higher (+10.0%) among the corequisite students when compared to non-corequisite students. The Cramer's V measure (V = .094) indicates a small to medium effect size for this significance. To interpret this value, according to Coe (2002), it was important to note the "practical importance of an effect size depends entirely on its relative costs and benefits. In education, if it could be shown that making a small and inexpensive change would raise academic achievement by an effect size of even as little as 0.1, then this could be a very significant improvement, particularly if the improvement applied uniformly to all students, and even more so if the effect were cumulative over time" (Coe, 2002, p. 5). In the fifth comparison, the Mann-Whitney U test showed a significant difference overall between non-corequisite and corequisite students (n = 1130, p = 0.05) excluding students who took pilot courses and courses during the pandemic. This indicated that the mean ranks for corequisite students were higher than the mean ranks for non-corequisite students in the distribution of final course grades.

Based on these five reported results, corequisite students were performing as well, and when removing potential confounding variables that may arise by including the pilot courses and the pandemic semester, were performing significantly differently from non-corequisite students. In all comparison cases, passing grade frequency percentages for corequisite students were higher than those of non-corequisite students, generally indicating this model did not harm student performance, and in fact, helped students perform better in their college algebra course.

To analyze this further, student enrollment criteria were used to make comparisons between more similar groups of students, specifically, students with ACT <17, ACT 17-20, ACT 21+, and no ACT reported. In the sixth Chi-Square comparison, there was no significant difference in the student performances in college algebra between all non-corequisite and corequisite students with ACT <17 (n = 210, p = .098), however frequencies of passing grades were higher (+15.6%) among the corequisite students when compared to non-corequisite students. In the seventh Chi-Square comparison, there was no significant difference in the student performances in college algebra between all non-corequisite and corequisite students with ACT 17-20 (n = 852, p = .411), however, passing grades frequencies were higher (+6.2%) among the corequisite students when compared to non-corequisite students. Looking at this result more closely by removing both pilot courses and pandemic semester, in the eighth comparison, there was no significant difference in the student performances in college algebra between all non-corequisite and corequisite students with ACT 17-20 (n = 743, p = .083), however, passing grades frequencies were higher (+10.5%) among the corequisite students when compared to non-corequisite students.

In the ninth Chi-Square comparison, there was no significant difference in the student performances in college algebra between all non-corequisite and corequisite students with ACT 21+ (n = 91, p = .681), however, passing grades frequencies were higher (+4.6%) among the corequisite students when compared to non-corequisite students. In the tenth Chi-Square comparison, there was no significant difference in the student performances in college algebra between all non-corequisite and corequisite students with no ACT reported (n = 196, p = .383). This was the only comparison that showed lower passing grades frequencies (-6.7%) among the corequisite students when compared to non-corequisite students. Looking at this more closely by removing both pilot courses and pandemic semester, in the eleventh comparison, there was no significant difference in the student performances in college algebra overall between all non-corequisite and corequisite students with ACT 17-20 (n = 159, p = .361). Although the difference was less, this was again the only comparison where passing grades frequencies were lower (-2.5%) among the corequisite students when compared to non-corequisite students.

These additional results indicated that the corequisite instructional model was helping more students in each reported ACT category find success in college algebra. All students within the different ACT groups had higher passing grade frequencies, and the students with ACT <17 had the largest increase in passing final grade frequencies. However, this trend was not the same with the group of students that had no ACT reported. Those students did not perform better under the new model. There were far fewer students in the no ACT reported category than other ACT categories. Based on these additional reported results, the original conclusion that corequisite students were performing as well and, in almost all comparison cases, better than non-corequisite students was supported. From these results, this model does not harm student performance, and in fact, seemed to be helping them perform better in their college algebra course.

Research Question 2

Is there a significant difference in student performance between corequisite college algebra students and traditional college algebra students at Marshall University?

In the twelfth Chi-Square comparison between corequisite and traditional students ($n = 658$, $p = .816$), there was no significant difference in the student performances in college algebra overall, however, passing grades frequencies were higher (+1.3%) among the corequisite students when compared to traditional students. In the thirteenth Chi-Square comparison, there was no significant difference in the student performances in college algebra between corequisite and traditional students ($n = 544$, $p = .276$) excluding those students who took pilot courses in Fall 2018 and Spring 2019 and those who took the course in the spring 2020 COVID-19 semester, however, passing grades frequencies were higher (+4.0%) among the corequisite students when compared to traditional students.

Based on these reported results, corequisite students were performing as well and, in all comparison cases, are performing better than traditional students. At this point, the corequisite model again was not harming students, and in fact, seemed to be helping them perform equally well when compared to traditional college algebra students.

To make more specific conclusions about students on particular learning pathways, subsets of students were selected based on student majors categorized as terminal, non-terminal, and no major reported. In the fourteenth Chi-Square comparison, there was no significant difference in the student performances in college algebra overall between corequisite and traditional students with terminal majors ($n = 116$, $p = .758$). This was one of the few comparisons where frequencies of passing grades were slightly lower (-0.2%) among the corequisite students when compared to traditional students, but there was almost no difference here. In the fifteenth comparison, there was no significant difference in the student performances in college algebra overall between corequisite and traditional students with terminal majors ($n = 78$, $p = .405$) removing both pilot course offerings and the pandemic semester, however, passing grades frequencies were higher (+7.8%) among the corequisite students when compared to traditional students.

In the sixteenth Chi-Square comparison, there was no significant difference in the student performances in college algebra overall between corequisite and traditional students with non-terminal majors ($n = 431$, $p = .994$). This is the last of only a few comparisons where frequencies of passing grades were slightly lower (-0.8%) among the corequisite students when compared to traditional students, but again there was almost no difference in final grade frequencies here. In the seventeenth Chi-Square comparison, there was no significant difference in the student performances in college algebra overall between corequisite and traditional students with non-terminal majors (n = 388, p = .920) removing both pilot course offerings and the pandemic semester, however, frequencies of passing grades were higher (+1.5%) among the corequisite students when compared to traditional students. In the eighteenth comparison, there was no significant difference in the student performances in college algebra overall between corequisite and traditional students with no major reported (n = 388, p = .920), however, frequencies of passing grades were higher (+4.8%) among the corequisite students when compared to traditional students.

Based on these additional reported results, corequisite students overall were performing equally well, and in almost all comparison cases, were performing better than traditional students. The corequisite students with terminal majors, non-terminal majors, and no major reported were performing better in college algebra when removing the pilot section and pandemic semester data. Students that have a terminal major seemed to benefit the most from the implementation of the corequisite instructional model. From these results, the corequisite instructional model showed no harm to student performance, and in fact, seemed to be helping students perform equally well as traditional students in their college algebra course, no matter the major.

Research Question 3

Is there a significant difference in student performance in subsequent courses between corequisite college algebra students, non-corequisite college algebra students, and traditional college algebra students at Marshall University?

In terms of non-terminal student performance in subsequent courses, corequisite students were outperforming non-corequisite students in precalculus and were performing as well as traditional students. In the nineteenth comparison, the Kruskal-Wallis test found significant differences ($n = 159$, $p = .008$) among the subsequent final course grades in pre-calculus between the non-terminal students in the three cohorts: non-corequisite, corequisite, and traditional students. An initial comparison of mean ranks indicated that non-corequisite students ($n = 70$, mean rank = 70.99) and co-requisite students ($n = 27$, mean rank = 71.43) perform similarly, while traditional students ($n = 62$, mean rank = 93.91) perform much better overall. In the twentieth comparison, a Kruskal-Wallis post hoc analysis of the pairwise comparisons confirmed the significant difference between subsequent course grades in precalculus for non-corequisite and traditional students ($n = 132$, $p = .003$). The results also showed significant differences between the corequisite and traditional students ($n = 89$, $p = .030$). However, there was no significant difference between non-corequisite and corequisite students ($n = 97$, $p = .965$).

When considering the Bonferroni adjusted significance values from the Kruskal-Wallis post hoc pairwise comparisons, the significant difference originally found between corequisite and traditional students was removed ($n = 89$, $p = .089$). According to Boone (2020), "on the spectrum of multiple comparison procedures, the Bonferroni procedure [applying the adjusted significance values] is considered a conservative approach. Procedures such as Fisher's least significant difference, Tukey's significant difference, and Student–Newman–Keuls test are considered more liberal, and Scheffé's method is considered more conservative. The conservative nature of the Bonferroni procedure is one of its assets, where if something is declared significant using the Bonferroni procedure, then one can be sure that the specified Type I error rate is truly preserved" (Boone, 2020). Applying the Bonferroni correction made achieving significance more difficult, decreasing the likelihood of a Type I error but increasing the likelihood of a Type II error. Applying the Bonferroni correction did not affect the original outcomes for the other two comparisons. So, while it was clear across multiple tests that a significant difference exists between non-corequisite and traditional students when comparing their performance in subsequent mathematics courses (precalculus), the case was not so clear for corequisite students versus traditional students.

To further analyze these results, Chi-Square tests were performed between each possible pairing of the three groups. In the twenty-first comparison, the Chi-Square test showed no significant difference in the student performances in pre-calculus overall between non-corequisite and corequisite students ($n = 97$, $p = .792$), however, frequencies of passing grades were higher (+4.3%) among the corequisite students when compared to non-corequisite students.

In the twenty-second comparison, the Chi-Square test showed a significant difference in the student performances in precalculus between non-corequisite and traditional students ($n = 132$, $p = .032$). Passing grades frequencies increased (16.7%), and letter grade frequencies in the A category were much higher (+19.2%) among the traditional students when compared to non-corequisite students. The Cramer's V measure ($V = .279$) indicates a large effect size for this significance. In the twenty-third comparison, the Mann-Whitney U test showed a significant difference overall between non-corequisite and traditional students ($n = 132$, $p = 0.004$). The mean ranks for traditional students ($n = 70$, mean rank = 57.59) were higher than the mean ranks for non-corequisite students ($n = 62$, mean rank = 76.56) in the distribution of final course grades, and thus, traditional students are performing much better overall compared to non-corequisite.

In the twenty-fourth comparison, the Chi-Square test showed no significant difference in the student performances on pre-calculus overall between corequisite and traditional students ($n = 89$, $p = .052$). Passing grades frequencies were much lower (-12.4%) among the corequisite students when compared to traditional students, but this was generally expected due to the differences in enrollment criteria in each course.

Based on these additional reported results of students' final course grades in subsequent mathematic courses, corequisite students were performing similarly to the non-corequisite students. Reviewing the crosstabs percentages, those corequisite students that continued into precalculus did not perform extremely well in the course compared to traditional students. Many corequisite students in the small sample earned F letter grades in precalculus. Perhaps these students were negatively affected by the pandemic semester and were unable to finish the course. If students did finish the course, perhaps they were unable to successfully transition from the original course expectations in the face-to-face classroom into a virtual classroom that presented new, challenging norms and policies.

Research Question 4

What are the perceptions of faculty who taught both corequisite and non-corequisite college algebra courses at Marshall University?

Analysis of faculty perceptions aimed to measure how well corequisite instruction was implemented in the deployment of the new corequisite teaching model. Faculty perceptions are categorized into three sections from the interview protocol focusing on Interview Section 1- Initial Transition Preparedness, Interview Section 2 – Culture of Evidence-Based Instruction, and Interview Section 3 - Continued Growth and Professional Development.

Interview Section 1 – Initial Transition Preparedness Analysis

Overall, the faculty gave responses consistent with the definition for describing the corequisite model of teaching. Faculty responses were also categorically favorable toward the corequisite model, suggesting that *starting with the college-level material is best.* Based on the detailed descriptions provided on the changes to the course over time, these faculty are accurately implementing the corequisite model. Faculty gave responses regarding their preparation to teach corequisite courses, indicating support (seminars and training) and resources (access to materials and experts in the field) were provided in some form, either through their colleagues, the mathematics department, and/or the state. Similar faculty development support systems are also found in corequisite implementation guides across the country. The *corequisite instructor should be prepared for a variety of scenarios in the classroom*. According to Atkins et al. (2018), the Missouri Department of Higher Education Corequisite at Scale Taskforce said "specialized professional development should be provided for faculty offering just-in-time social, emotional and intellectual support. The relationship between cognitive and non-cognitive or affective factors can impact student success and should not be disregarded. Low self-esteem, lack of confidence, attitude, and mathematics anxiety are barriers to student success and must be acknowledged and addressed by faculty instructing a support course. Adjunct faculty should also be included in the process of developing program practices, implementation, and professional development opportunities" (Atkins et al., 2018, p. 3).

Faculty described unexpected events in their transition, most of the faculty reporting that *more students can get through more college-level material*. Faculty reported that student attitudes were different in the corequisite college algebra courses, with one faculty being surprised at how challenging the materials seemed to their students at first. Then, expressed feelings of triumph when students adjusted to the change. Faculty described using different techniques in their courses to support learning in the new model, like peer collaboration and just-in-time instruction. These elements of the classroom experience indicate faculty were generally prepared to teach and deliver the course in a corequisite format. The level of faculty preparation seemed high and the program was implemented accurately.

Interview Section 2 Culture of Evidence-Based Instruction Analysis

All of the faculty reported using a balanced approach to incorporating procedure versus conceptual knowledge and explained their decision to present in either mode depending on the topic and difficulty level. Multiple faculty said they are presenting the college algebra material in multiple modes most of the time. Dreher et al. (2015) assert that multiple representations are not just about getting students' attention. The authors claim "only the combination of different representations affords the development of a rich concept image" (Dreher et al., 2015, p. 2). These authors also said understanding this purpose "may better support teachers in designing mathematical activities than seeing the main purpose of the multiple representations [as only] keeping pupils' attention" (Dreher et al., 2015, p. 2). The reports from faculty interviews in this study align with the notion corequisite instruction provides multiple representations of mathematical concepts to help students make connections between algebraic language, graphical representation, and worded descriptions, providing that deeper connection with the college algebra material.

Several of the faculty members reported time management flexibility being built into the course schedule is crucial. Just-in-time teaching has allowed multiple faculty members to focus on college-level material at the beginning of the semester and provide more individualized support. According to Persky (2012), "the purpose of the [just-in-time teaching] technique is to get students to engage with the material and provide feedback to students' thinking. Just in time teaching will help faculty identify their students' strengths, weaknesses, and learning styles to maximize the efficacy of the classroom session" (Persky, 2012, p. 39).

Faculty interviewed in this study reported using a variety of question types and activities, collaboration with group work, flexibility with assignment due dates as some of their methods for encouraging students to be motivated and persist through difficult topics. Motivational strategies like collaboration and problem-solving exercises in class were all used by faculty to create a classroom environment that sets high expectations but also provides support, both academically and emotionally. These kinds of corequisite course structures attempt to adjust the mindset and behavior of the corequisite students. According to Perksy (2012), "motivation involves initiating and sustaining behavior. It is based on the individual's beliefs on whether they can do it (i.e. self-efficacy) and why they want to do it (i.e. intrinsic/extrinsic)" (Persky, 2012, p. 17). Students still struggle with the content, but the key here for some of the faculty was the flexibility to stay with a topic for a long time to allow students to struggle with different aspects of the topic until the students make those connections and the solution finally makes sense to them.

In terms of being persistent in the face of difficult topics, perhaps students were not given the time and space to walk away from mathematics problems that are troubling them and return to the course content with a fresh eye. The corequisite college algebra course is a heavy workload for students and faculty and includes a high-stakes, comprehensive common final examination. According to their article on productive struggle, Champagne (2021) says educators "want our students to engage in productive struggle, but not at the expense of their understanding or their relationship with mathematics" (Champagne, 2021, p. 692). Faculty reported corequisite curriculum techniques increased student homework completion rates and brought into question the rationale for continuing to assess students with a common exam.

Champagne (2021) continues to say many “equate mathematics learning with a struggle that goes beyond a productive one.” As reported by some of the faculty, corequisite students typically have issues that occur with their family, employer, transportation, and other issues that affect their ability to focus on topics and complete the requirements in a course. Champagne (2021) says “we give ourselves, as educators, permission to walk away from work and come back later. We allow students to walk away from work in other content areas.” The author argues allowing students to walk away from troubling mathematics work, at least temporarily, is “one of the most important things we can do”, because “making space for students to walk away from a problem shows we trust them.” The author also warns if you push students to continue when they are not ready, “frustration can lead to mathematics anxiety” (Champagne, 2021, p. 693). With the more flexible scheduling, faculty reported that their attitudes and student attitudes about the course seemed to have shifted. There is *less student anxiety toward the course* and its requirements, and there is *less faculty disillusion with teaching a challenging student population*.

Multiple faculty reported that students are experiencing increased complexity and transformational learning happening in the corequisite college algebra classroom. In older versions of supported college algebra, students struggled and became discouraged when asked to complete remedial work that did not count toward their grade but were required to be completed before the college-level content was released. In the corequisite courses, *faculty were setting higher expectations* of their students and reported *students were progressing through more of the college-level material*. Rather than using a pre-determined set of remediation topics embedded into the course, letting remediation occur naturally more directly addresses student needs and creates a welcoming environment in which students are not afraid to participate. Faculty reported, and student data analysis confirm, many students struggled to complete a full set of pre-requisite assignments in addition to their college-level content. The corequisite model presents the college level and the remediation content together, rather than separating the remedial work from the college level. With this format, the corequisite model intrinsically makes students think we, as educators, believe they can do mathematics at the college level, rather than making them jump academic hurdles before letting them engage at the college level.

Every faculty reported some type of positive outcome in regards to equity and social justice issues that arose in their corequisite courses. Two faculty specifically mentioned the *success of built-in flexibility* of allowing students to turn in assignments late without penalty addresses some issues of equity in the corequisite course. Mainly, the idea is that students can be introduced to a topic and, over the course of a semester, have time to master the topic without penalty. Forcing a student to submit a partially complete assignment they do not understand for deductions of points seemed counter to the goal of any course – to get students to engage with the material to master it.

Bringing educational theories into the classroom and discussing why these theories matter can help students develop a real sense of self-responsibility, become more invested in persisting through challenges, and gain a deeper understanding of their learning. If a student asks *why are we doing this*, class time is used to explain the rationale in the corequisite model. Students and faculty benefit from being told why something works in addition to learning how it works. Like faculty, many students have pre-conceived notions about their learning. As suggested by a faculty member in the interview responses, bringing students into the educational process allows instructors to be more responsive to student needs by listening to students and using their perspectives to drive content and instruction.

Similarly, faculty are also asking why are we using the corequisite model. As suggested by faculty interview responses, resources like training and evidence-based instructional materials support faculty in specifically understanding why are we using the corequisite instructional model.

Interview Section 3 Continued Growth and Professional Development Analysis

Faculty reported changing their mindset from thinking *students cannot do college-level work and must complete all review materials* to thinking *students can do college-level work, given support.* Faculty reported challenges that students are still young and just need time to get more academic experience. Both in their description of student experiences in the classroom, and when reporting on their methods for course preparation and action research, faculty reported that *collaboration with colleagues and students is a crucial aspect to success* for their students and their success teaching corequisite students.

Segal (2009) reported in a dissertation on action research in mathematics education, "the ability of the teacher to reflect on their own action and to collaborate, with the goal of improving teaching, a school, relations, and learning, are essential aspects of action research making it practical and applicable to the specific educational setting in which it occurs" (Segal, 2009, p. 50). According to Segal's study on action research, "because of the successful collaboration of the educational researchers, teachers, mathematicians and children, the collaborators learned from each other, and the research had a richness and inclusiveness that is not possible in other kinds of research. It is the dialogue and other communications that occur in action research that build the bridges of collaboration and improvement within a community" (Segal, 2009, p. 49).

The reported availability of resources for continued professional growth through training and workshops is a good investment for helping faculty prepare for their courses. Several faculty members noted *time management makes a big impact in corequisite courses* in several ways. The faculty used suggested pedagogies to implement the corequisite model. The faculty re-designed aspects of the course in purposeful ways by aligning with course designs such as the Universal Design for Learning (UDL). Courses designed like UDL aim to reach as many students as possible. According to Lambert (2021), "an inclusive mathematics teacher [learns] to build in extra time when asking new students to solve challenging problems. Some students have a sense of learned helplessness, but one central goal of universally designed courses is supporting students to develop confidence in their abilities, becoming strategic sense makers in mathematics" (Lambert, 2021, p. 663). *Building courses that have a minimal, rigid structure, with flexibility built-in is key* to reaching the wide variety of students enrolled in the corequisite courses.

Further Comments Analysis

Previous versions of remedial courses at Marshall were developed entirely using emporium models. Students would spend at least one, and sometimes multiple semesters, trying to complete mostly static procedural, rote content from an online homework system before being registered for college algebra to the detriment of student progress in the program of study. The implementation of the current form of the corequisite model began well before the Fall 2017 semester and was driven by mandates from the state, the need to provide instructional opportunities for departmental teaching assistants, as well as calls to action from within the department to pilot ideas to help support this population of students. Through one of the redesign phases of college algebra into a corequisite model, the course transitioned to include a three-two classroom model. In the three-two classroom model, which is a hybrid between traditional course offerings and the emporium model, students would attend three days of traditional instruction in a classroom and two days of support in a computer lab. Faculty are encouraged to develop interactive, collaborative in-class activities using some suggested online tools to engage students on the three traditional days, and then use the two computer lab days to allow time and space for students to work and make progress on the course assignments. These twos aspect of the corequisite course have been well received and are having positive impacts on faculty attitudes and student performance.

IMPLICATIONS

To address the research questions on measuring the effectiveness of implementing corequisite instructional model for college algebra, this study compared corequisite to non-requisite student performance in college algebra, compared subsets of corequisite, non-corequisite, and traditional students across enrollment criteria and majors in college algebra, and compared corequisite, non-corequisite and traditional college algebra student performance in a subsequent mathematics course, precalculus. Based on these comparisons, this study indicates the corequisite model of instruction is doing no harm, and in many cases is improving the student performance in college algebra and subsequent mathematics courses.

In theory, the success of the corequisite students comes from having access to higher-order thinking earlier in their mathematical learning by being exposed to the college-level content first, and then being supported with evidence-based instructional practices in the classroom (Logue et al., 2019). This study confirms that, given evidence that academically at-risk students are capable of learning complex ideas and concepts at the college level, corequisite students can be successful and do not need slow-paced, extended remediation (Denley, 2017).

Corequisite mathematics, especially the model described in this study, benefits students typically labeled developmental. While in some of the comparisons the sample sizes were somewhat different and the pandemic semester was included, there seemed to be some room for improvement in subsequent courses regarding corequisite college algebra student performance when compared to traditional college algebra students. Additionally, the improvement noted with corequisite students when compared to non-corequisite students was minimal, at best. Faculty interviews revealed some faculty already used course policies that align with corequisite instruction. Faculty reporting of continued improvements of the non-corequisite college algebra course structure over time, like the three-two model and incorporating active learning into the classroom, could explain why full implementation of the corequisite model showed only small improvements in student performance in this study. Students were already exposed to some of the aspects of corequisite which may have improved student performance before full implementation.

Given these results, the MU Mathematics Department should continue to offer the corequisite college algebra course, to allow students to avoid remedial courses, begin their college-level material in their first semester of college, and progress through their program of study in a timelier manner. Generally, it would be beneficial for MU Mathematics Department to consider revising other mathematics courses to include corequisite techniques throughout all mathematics pathways, and recommend all freshmen take college-entry courses their first semester. Specifically, from both the quantitative and qualitative data analysis in this study, results indicated the department should consider implementing a corequisite model for the precalculus course, and perhaps the first course in calculus to continue to support this student population as they progress in their mathematics courses.

Faculty benefit from the training and resources provided for the implementation of new course curricula like the corequisite model. Giving faculty and students information they need to understand the why and not just the how changes their attitudes about learning mathematics. According to Collins and Winnington (2010), changing faculty attitudes has a dramatic effect on student performance. “Teachers nationally present attitudes in mathematics about the content and their own beliefs in their ability to teach mathematics. These attitudes, issues of math anxiety, and in many cases lack of confidence are interfering with these teachers’ ability to teach mathematics effectively” (Collins & Winnington, 2010, p. 1). Faculty welcome evaluation and review of the course to facilitate continued improvements on the courses they teach. The mathematics department should consider formalizing corequisite documentation for future instructors of the course, including a discussion of how to incorporate corequisite learning theories in the mathematics classroom as a key aspect of the academic awareness students and faculty need to find success in a corequisite mathematics course.

RECOMMENDATIONS FOR FURTHER STUDY

The analysis in this study shows some meaningful results for corequisite students as well as corequisite faculty. To continue analyzing the implementation of corequisite curricula, making improvements on the courses offered to students, here are some recommendations for further study. These suggestions aim to fill in missing pieces that this study could not reveal.

- Same comparisons of college algebra students with the SAT or other placement criteria, like completion of pre-requisite courses MTH 098, MTH 099, MTH 100, MTH 102
- Further comparisons of the cohorts of college algebra students without enrollment criteria and a major were reported. The performance of this group of students was not the same as other groupings.

- Take a closer look a corequisite students who are taking precalculus now. Many corequisite students were not successful in the subsequent precalculus course as evidenced by a large percentage of corequisite students failing grades. Perhaps the pandemic semester affected students' ability to finish the class. Perhaps the barriers that developmental students face are not being addressed in subsequent mathematics courses, and therefore their performance suffers when compared to traditional students.
- Complete follow-up interviews with faculty continuing to teach these courses and any new faculty. Also, interviews with faculty who teach precalculus might open a window into the needs of students at that level and inform offerings of corequisite college algebra.

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APPENDIX A: IRB APPROVAL

MARSHALL UNIVERSITY

www.marshall.edu

Office of Research Integrity
Institutional Review Board
One John Marshall Drive
Huntington, WV 25755

FWA 00002704

IRB1 #00002205
IRB2 #00003206

May 4, 2021

Edna Meisel, Ed.D.
COEPD, Curriculum & Instruction

RE: IRBNet ID# 1757203-1
At: Marshall University Institutional Review Board #2 (Social/Behavioral)

Dear Dr. Meisel:

Protocol Title:	[1757203-1] Co-Requisite Mathematics: A Program Analysis at the College Level	
Site Location:	MU	
Submission Type:	New Project	APPROVED
Review Type:	Exempt Review	

In accordance with 45CFR46.104(d)(1&2), the above study was granted Exempted approval today by the Marshall University Institutional Review Board #2 (Social/Behavioral) Chair/Designee. No further submission (or closure) is required for an Exempt study **unless** there is an amendment to the study. All amendments must be submitted and approved by the IRB Chair/Designee.

This study is for student Shannon Miller-Mace.

If you have any questions, please contact the Marshall University Institutional Review Board #2 (Social/Behavioral) Coordinator Anna Robinson at (304) 696-2477 or robinsonn1@marshall.edu. Please include your study title and reference number in all correspondence with this office.

Sincerely,

Bruce F. Day, ThD, CIP
Director, Office of Research Integrity

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Institutional Review Board
One John Marshall Drive
Huntington, WV 25755

FWA 00002704

IRB1 #00002205
IRB2 #00003206

May 13, 2021

Edna Meisel, Ed.D.
COEPD, Curriculum & Instruction

RE: IRBNet ID# 1757203-2
At: Marshall University Institutional Review Board #2 (Social/Behavioral)

Dear Dr. Meisel:

Protocol Title:	[1757203-2] Co-Requisite Mathematics: A Program Analysis at the College Level	
Site Location:	MU	
Submission Type:	Amendment/Modification	APPROVED
Review Type:	Exempt Review	

The amendment to the above listed study was approved today by the Marshall University Institutional Review Board #2 (Social/Behavioral) Chair. This amendment is a revision to the interview questions.

This study is for student Shannon Miller Mace.

If you have any questions, please contact the Marshall University Institutional Review Board #2 (Social/Behavioral) Coordinator Anna Robinson at (304) 696-2477 or robinsonn1@marshall.edu. Please include your study title and reference number in all correspondence with this office.

Sincerely,

Bruce F. Day, ThD, CIP
Director, Office of Research Integrity

APPENDIX B: CURRICULUM VITAE

Mrs. Shannon N. Miller-Mace
Marshall University
Mathematics
(304) 696-3796
Email: miller207@marshall.edu

Education

EDD, ABD, Marshall University College of Education and Professional Development, 2021.
Major: Curriculum & Instruction
Supporting Areas of Emphasis: Mathematics Curriculum Development at the High School and College Entry Level
Dissertation Title: Co-Requisite Mathematics: A Program Analysis at the College Level

MA, Marshall University Graduate College, 2006.
Major: Master of Arts in Mathematics
Supporting Areas of Emphasis: Chaos Theory/Dynamical Systems
Dissertation Title: Applying Newton's Method on Dynamical Systems in the Complex Plane

BS, Marshall University, 2005.
Major: Bachelors of Science in Mathematics
Supporting Areas of Emphasis: Minor in Spanish

High School Diploma, Wyoming County East High School, 2001.
Major: College Preparation
Supporting Areas of Emphasis: Mathematics and Spanish

Administrative Assignments

Program Coordinator, Harrison County Online Dual-Credit Courses, Department. (August 17, 2018 - May 17, 2020).

Program Coordinator, Summer Bridge Coordinator, Department. (May 7, 2012 - June 20, 2017).

Professional Memberships

Pi Mu Epsilon.

National Council of Teachers of Mathematics. (March 1, 2019 - Present).

Co-Coordinator, Tri-State Mathematics Educator Community. (August 2019 - April 2020).

Co-Coordinator, Educators Teaching Collaborative. (January 2019 - October 2019).

Development Activities Attended

Faculty Fellowship, "Hedrick Faculty Learning Community," Hedrick Faculty Teaching Award and CTL, Huntington, WV, USA. (March 2019 - Present).

Seminar, "Corequisite Instruction: Developing Effective Online Support," WV Higher Education Policy Commission, Charleston, WV, USA. (May 20, 2020).

Workshop, "Knewton alta Training for Faculty," MU Mathematics Department, Huntington, WV, USA. (August 30, 2019).

Seminar, "Co-requisite Structures for Algebraic Pathways," WV HEPC and CTCS, in conjunction with The Charles A. Dana Center at UT-Austin, Charleston, West Virginia, USA. (November 3, 2018).

Conference Attendance, "Vertex," University Texas Systems, Denver, CO, USA. (October 5, 2018 - October 6, 2018).

Conference Attendance, "National IBLT Conference," Mathematics Learning by Inquiry, Educational Advancement Foundation, and Mathematical Association of America, Denver, CO, USA. (June 2018).

Seminar, "Great Teachers Seminar," WVMATCY -, North Bend State Park, WV, USA. (June 18, 2018 - June 21, 2018).

Workshop, "Quality Matters Improving Your Online Course Training," MU Libraries and QM, Huntington, WV, USA. (August 11, 2017).

Workshop, "Workshop on Co-Requisite Mathematics," The West Virginia Higher Education Policy Commission and the Community and Technical College System of West Virginia in collaboration with The Charles A. Dana Center, Huntington, WV, USA. (May 16, 2017 - May 17, 2017).

Conference Attendance, "Redesign: Technology and Innovation in Mathematics and English," Hawkes Learning, Charleston, SC, USA. (March 4, 2016 - March 5, 2016).

Workshop, "Hawkes Learning Training for Faculty," Marshall University Mathematics Department, Huntington, West Virginia, USA. (August 19, 2015 - August 20, 2015).

Training and Conference, "Quantway Summer Institute," Carnegie-Center for the Advancement of Teaching, Santa Cruz, California, United States. (July 19, 2013 - July 21, 2013).

Conference Attendance, "Quantway Summer Conference," Carnegie Institute, Denver, Colorado, USA. (June 2013).

Training and Conference, "Kaleidoscope Institute," Lumen Foundation, Denver, Colorado, United States. (June 5, 2013 - June 9, 2013).

Workshop, "Kaleidoscope Training," Lumen Foundation, Huntington, West Virginia, United States. (March 7, 2013 - March 8, 2013).

Training and Conference, "Quantway Winter Institute," Carnegie-Center for the Advancement of Teaching, San Francisco, California, United States. (January 8, 2013 - January 10, 2013).

TEACHING

Teaching Experience

Marshall University
MTH 102, Prep for College Math B, 5 courses.
MTH 102B, Abr Prep for College Math B, 6 courses.
MTH 121, Concepts and Applications (CT), 5 courses.
MTH 121B, Cncpts & Apps-Expanded (CT), 16 courses.
MTH 122, Plane Trigonometry, 2 courses.
MTH 127, College Algebra Expanded, 13 courses.
MTH 130, College Algebra, 11 courses.
MTH 132, Precalculus with Sci Applica, 1 course.
MTH 98, Mathematics Skills I, 3 courses.
MTH 99, Mathematics Skills II, 4 courses.
STA 150B, Foundations of Statistics Expanded, 2 courses.
STA 225, Introductory Statistics (CT), 1 course.

Non-Credit Instruction

Workshop, Mathematics Department, and WV Science Adventures with College of Science, 100 participants. (June 2016 - February 2020).

Workshop, Academic Affairs and University College, 88 participants. (July 2017 - August 2017).

Workshop, Academic Affairs and University College, 88 participants. (July 2016 - August 2016).

Workshop, Academic Affairs and University College, 88 participants. (July 20, 2015 - August 7, 2015).

Workshop, Academic Affairs and University College, 83 participants. (July 2014 - August 2014).

Workshop, Academic Affairs and University College, 100 participants. (June 2013 - July 2013).

Awards and Honors

Council of Chairs Award for Excellence in Teaching Winner, Center for Teaching and Learning, Teaching, University. (October 15, 2020).

Council of Chairs Award for Excellence in Teaching Nomination, Center for Teaching and Learning, Teaching, University. (October 15, 2018).

Council of Chairs Award for Excellence in Teaching Nomination, Center or Teaching, and Learning, Teaching, University. (October 15, 2016).

Council of Chairs Award for Excellence in Teaching Nomination, Center for Teaching and Learning, Teaching, University. (October 15, 2015).

RESEARCH

Presentations Given

Miller-Mace, S. N. (Presenter & Author), Cartwright, T. J. (Coordinator/Organizer), Welch, M. J. (Presenter & Author), Stapleton, L. L. (Presenter & Author), Goodman, A. B. (Presenter & Author), iPed 2020: Student Success: The Education Imperative, "Metacognition and Mindset," Center for Teaching and Learning, Huntington, WV. (May 2020).

Miller-Mace, S. N. (Panelist), Regional Meeting of Ohio MAA, "My Experience Teaching a Co-requisite Course," Mathematical Association of America, Shawnee State. (October 2019).

Miller-Mace, S. N., First in the Family – First-Generation Students at MU. (2018).

Miller-Mace, S. N., Welch, M. J. (Presenter & Author), iPed 2018: Advancing a Growth Mindset, "Threshold Concepts and Transformative Learning," Center for Teaching and Learning, Huntington, WV. (August 2018).

Miller, S. N., New Student Orientation: First in the Family/First-Generation Students, Academic Affairs, Huntington, WV. (July 2018).

Miller-Mace, S. N. (Author Only), iPed 2017: Teaching and Learning for a Civil Society, "Voting Power - Equality versus Representation," Center for Teaching and Learning, Huntington, WV. (August 2017).

Miller, S. N., Advisor to Advisor Chat. (2016).

Miller, S. N., iPed 2016: Inquiring Pedagogies, "When will I use this?" – Discovering Meaning and Connection across Disciplines: A Summative Project," Center for Teaching and Learning, Huntington, WV. (August 2016).

Intellectual Contributions in Submission

Other

Miller-Mace, S., Crytzer, M., Mace, R.-R., Marsh, T., Stapleton, L. *Summer Bridge 2015*.

Miller-Mace, S., Crytzer, M., Stapleton, L., Wright, D. *Summer Bridge 2014*.

Miller-Mace, S., Crytzer, M., Marsh, T., Stapleton, L., Wright, D. *Summer Bridge 2013*.

SERVICE

Department Service

Attendee, Meeting, Math Faculty Committee. (August 2006 - Present).

Committee Chair, E-Course Committee. (January 2019 - December 2019).

Committee Member, E-Course Committee. (January 2017 - December 2018).

Committee Member, 100/102/121. (October 2015 - May 2016).

Committee Member, 098/099 Committee. (August 2010 - May 2015).

College Service

Faculty Advisor, Pi Mu Epsilon. (August 17, 2011 - August 2014).

University Service

Committee Member, TECI Advisory Board. (January 2019 - December 2019).

Consulting

Government, Higher Education Policy Commission - Math Task Force, Charleston, WV. (October 2017 - November 2019).

Government, West Virginia Department of Education - SAT Exam Review, Charleston, WV. (June 2018).