Implementing the Corequisite Model of Developmental Mathematics Instruction at a Community College

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A Capstone Proposal

Presented to

The Faculty of the Curry School of Education

University of Virginia

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

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by
Zachary Beamer, B.S., M.A.
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Curriculum, Instruction, & Special Education
Curry School of Education
University of Virginia
Charlottesville, Virginia

APPROVAL OF THE CAPSTONE PROJECT

This capstone project, Implementing the Corequisite Model of Developmental Mathematics Instruction at a Community College, has been approved by the Graduate Faculty of the Curry School of Education in partial fulfillment of the requirements for the degree of Doctor of Education.

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Susan Mintz, co-chair

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Joe Garofalo, co-chair

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Jennifer Chiu

__________________________ Date

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I – EXECUTIVE SUMMARY

Co-Chairs – Joe Garofalo and Susan Mintz

Many students enter higher education with poor preparation for college mathematics courses. Often these students are placed through high-stakes placement testing into developmental mathematics courses that do not bear credit towards graduation. However, only a small minority of students who begin in developmental mathematics ever succeed in a college-level mathematics course. Recent scholarship estimating the impacts of developmental placement and coursework has cast doubt on the effectiveness of many remediation practices. Such scholarship has prompted major reform efforts across the nation, led by educational administrators as well as state legislators, particularly at the nation's community colleges.

One of these reforms that has seen dramatic impacts on several measures of student success is the practice of *corequisite remediation*. Traditional remediation practices require underprepared students to take foundational courses, often pre-algebra and algebra. These courses must be completed as a prerequisite to enrolling in a college mathematics course. By contrast, the corequisite instructional model places marginally prepared students directly into introductory-level college mathematics courses. These students receive just-in-time remediation through a required supplemental support course. Some states that have moved towards corequisite models of developmental education have seen astonishing improvements to student success. The rates of developmentally-placed students completing college-level mathematics have in several instances increased from 20% to 60% under the new corequisite model. These results have prompted systems of community colleges, including those of Virginia, to reduce traditional developmental offerings in favor of corequisite models.

Though many states are now implementing various models of corequisite support at their higher education institutions, there remains little qualitative research on the instructional practices within these courses. The present research study employed qualitative methods to explore corequisite reforms at one community college and the context in which they were implemented. The study used data from interviews with faculty, staff, and administrators, classroom observations with two full-time instructors, documents, and student surveys. The goals of this research were to identify the conditions for reforms to be successful and the mechanisms by which the corequisite instruction might improve student outcomes.

The four research questions explored (1) practitioners' goals and expectations for corequisite reforms, (2) the design details of the support course, (3) the instructional practices in the support course, and (4) student responses to the support course. Findings from interviews with practitioners revealed that, while a previous set of reforms had been unsuccessful, they nevertheless offered insights into the conditions under which current reforms would be successful. That is, corequisite remediation needed to address flawed placement measures, deliver relevant curriculum, and incorporate instructional methods that address gaps in student's understanding.

The two sections of corequisite courses observed in this research supported a transfer-level liberal arts course in Quantitative Reasoning. Observations revealed how instructors employed a combination of direct instruction, guided practice, and assignment support. Because the corequisite support class had no fixed curriculum itself, instructors had to gather information from a variety of sources to decide upon how to remediate their students. Despite this challenge, the instructors were able to target remediation to the individual needs of students, be they gaps in content or non-academic factors creating barriers to student success. Following preferences of students and insights from faculty, instruction tended to focus on credit-level content. Instructors discussed remedial topics in arithmetic and algebra only when needed and often within applied contexts. Students largely viewed the combination of additional instruction, practice, and help with graded assignments as beneficial. Thanks to the help of this course, students in the corequisite support class performed at similar levels to their peers who directly placed into the same course but did not receive support. The findings point to several recommendations, highlighted below.

1. The college should continue to offer the QR corequisite support course with additional structure and attendance enforcement, and should experiment with offering corequisite support for other courses.

2. The corequisite support course should continue to be a subgroup of eight to 12 students from the credit-level course, taught by the same instructor
3. Faculty teaching corequisite support courses should collaborate to share resources and instructional experiences.
4. Administrators should involve faculty in the creation of policies regarding corequisite support courses at the college and system level.

II – STUDY DESCRIPTION

This section of the research capstone is organized into four chapters. Chapter 1 (Problem of Practice) starts with a discussion of the impetus for developmental mathematics reforms and concludes the research questions in this particular study. Chapter 2 (Literature Review) overviews pertinent research on the teaching and learning of mathematics. It then summarizes research on the quantitative estimates of the impacts of approaches developmental mathematics on various student success outcomes. Finally, it concludes with research on the implementation of the corequisite model of developmental instruction and critiques of the scholarship on developmental education. Chapter 3 (Methodology) offers justification for use of qualitative research methods, along with the paradigmatic assumptions of such research. It also presents a description of site and participants, the process of data collection, and the methods used to analyze these data. Chapter 4 (Findings) presents a series of assertions addressing the research questions, with support from evidence gathered during the data collection process.

Chapter 1 - Problem of Practice

This first chapter introduces the nationwide context of the problem of practice – the low success rates of students placed into developmental mathematics – and then explores potential solutions to this problem of practice at a local level. It starts with an overview of what developmental mathematics is, its purpose, and how recent scholarship has challenged whether current practices are achieving this purpose. This research sets up a discussion of ongoing reform efforts to developmental practices across the nation. Instances of many of these reforms can be found taking place at colleges in the Virginia Community College System (VCCS). After summarizing two recent rounds of reform at the VCCS and estimates of their initial impact, the first chapter discusses in detail how these reforms are being implemented at one college in the VCCS. It concludes by focusing in on the curriculum and instruction issues surrounding one aspect of reforms, the corequisite model of remediation, and how it interacts with other reforms.

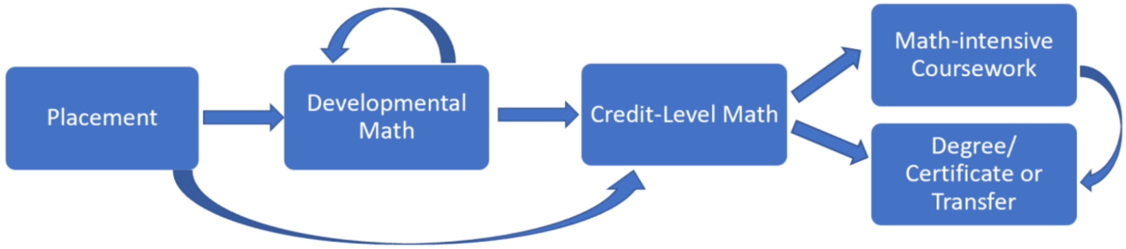
Background

Many students starting post-secondary education are assessed as insufficiently prepared for college mathematics, and despite remediation never complete a credit-level mathematics course. This problem is particularly acute at 2-year colleges, where 59% of students enroll into developmental mathematics (Chen, 2016). These developmental courses, also referred to as “remedial”, “precollegiate”, or “basic skills”, generally include prealgebra and introductory algebra up through intermediate algebra.

Unfortunately, upwards of half of students fail to complete their first developmental mathematics course (Bailey, Jeong, & Cho, 2010), a lower completion rate than developmental reading or writing (Bonham & Bailey, 2011). Judging based on student pass rates and retention, developmental mathematics is more often a roadblock than a bridge to credit-level mathematics. Nationwide, only 45% of students who enroll in developmental mathematics eventually earn college-level mathematics credits (Chen, 2016). Even among those who *complete* all developmental coursework, this figure is only 62% (Chen, 2016). With remedial courses comprising 10% of courses taken at community colleges, at an overall annual cost of upwards of four billion dollars (Scott-Clayton & Rodriguez, 2015), a growing body of research has come to question the value of traditional curricular and instructional models of developmental mathematics.

The traditional model of developmental education places students who do not demonstrate competency on a placement exam into remediation. Depending on their placement scores and eventual credit course, these students must complete between one and three (sometimes four) semesters of developmental coursework to become eligible to take credit-level mathematics. These credit-level courses themselves may be a prerequisite for other mathematics-intensive courses, or they may simply satisfy a degree requirement. A diagram illustrating the traditional pathway to credit-level mathematics is shown in Figure 1 below.

Figure 1. The Traditional Path Through Developmental Mathematics.



In the past decade, several researchers have employed experimental and quasi-experimental designs to rigorously estimate the impact that developmental mathematics has on student outcomes. These range from pass rates in entry-level college mathematics coursework to credits earned, graduation, and labor market outcomes (see Calcagno & Long, 2008; Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2015; Xu & Dadgar, 2018). Findings are mixed; some studies find that developmental mathematics increase performance in credit-level gatekeeper courses by a third of a letter grade, while others suggest that placement into developmental mathematics may have a negative impact on students' likelihood of persistence. Many studies identify no significant impact either way on a broad array of outcomes. Some statistical estimates (Scott-Clayton, Crosta, & Belfield, 2014; Scott-Clayton & Rodriguez, 2015) suggest that upwards of a quarter of students are unnecessarily assigned to remediation. As this growing number of studies are casting doubt on the value of existing practices of developmental education, many institutions across the country have begun piloting and implementing large-scale reforms to their developmental programs (see Bonham & Boylan, 2011). The Virginia Community College System (VCCS) offers an excellent example of many of the developmental reforms taking place across the nation.

Overview of Developmental Mathematics Reform Initiatives at the VCCS

For many years, the VCCS offered a sequence consisting of three levels of developmental mathematics. Edgecombe (2016) summarizes a recent round of reforms at the VCCS that led to major changes. The reform process began in 2008 with the organization of a VCCS Developmental Education Task Force that reviewed VCCS outcome data and approaches to the reform across the nation. Edgecombe does not detail the research informing the task force's decisions, but overviews how reforms began their implementation in 2011. At a VCCS level, the developmental mathematics curriculum was reorganized into nine modules, the "Math Essentials" sequence. While the curriculum itself did not undergo major modifications, reorganizing it had impacts for instructional and placement measures.

Placement into developmental mathematics was previously determined by a student's score on the COMPASS placement test. However, with the new curricular structure came a new placement test, the Virginia Placement Test (VPT). The test consists of two portions: one for modules 1 through 5 (covering, approximately, prealgebra and introductory algebra) and a second for modules 6 through 9 (covering intermediate algebra). Students who do not demonstrate proficiency on the first portion are subsequently diagnosed in detail on each of the first five modules. Students who are proficient on the first portion take the second portion, and either satisfy all modules or take a subsequent detailed diagnosis on the content from modules 6 through 9. In contrast with the previous developmental sequence, the modular curriculum was not entirely cumulative. That is, students could use the VPT to satisfy modules in non-sequential order; for instance, a student might satisfy modules 1 and 3, but not module 2. This is possible because of how these courses were organized, as their topics below show (a full course description from the VCCS Master Course File can be found at VCCS, 2018).

- Module 1: Operations with Positive Fractions
- Module 2: Operations with Positive Decimals and Percents
- Module 3: Algebra Basics
- Module 4: First Degree Equations and Inequalities in One Variable
- Module 5: Linear Equations, Inequalities, and Systems of Linear Equations in Two Variables
- Module 6: Exponents, Factoring, and Polynomial Equations
- Module 7: Rational Expressions and Equations
- Module 8: Rational Exponents and Radicals
- Module 9: Functions, Quadratic Equations, and Parabolas

As specified in requirements standardized across all colleges in the VCCS, each credit-level course required students to satisfy a certain number of modules as prerequisites, either through placement testing or coursework. The requirements for the minimal credit-level mathematics, part of some career and technical programs, was modules 1 through 3. To become eligible for credit-level courses that would satisfy general education requirements, students needed to satisfy the first five modules. Finally, to qualify for precalculus, the first credit-level mathematics course required in STEM-related transfer majors such as engineering and computer science, students needed to satisfy all nine modules. A detailed description of all credit-level courses and their prerequisites can be found in the VCCS course catalogue (VCCS, 2018).

The principle behind this modularization was to eliminate redundancy and accelerate students' progress into credit-level mathematics by identifying the specific skills and content areas in which each student required remediation (Edgecombe, 2016). Students weak in one area of prealgebra but not others could focus on only those skills they needed. These curriculum and placement reforms were the first steps towards a full implementation of the Emporium Model (EM). In the final step of implementing the EM, developmental mathematics instruction shifted into computer labs, with students completing one-credit modules using commercial instructional software to achieve mastery thresholds with assistance from instructors (see National Center for Academic Transformation, 2018; Twigg, 2011).

A VCCS (2014) report suggests that the first stages of modularization and placement led to improvements to the number of students passing credit-level mathematics. However, after only three years of full implementation of the computer-based instruction of the EM, some colleges within the VCCS are now beginning to abandon it. A second round of interconnected developmental reforms began in 2017-2018; these are outlined in the subsequent section.

The current initiatives are changing both who is assigned to developmental coursework and how these developmental courses are delivered. First, the VCCS is incorporating *multiple measures* placement across the system. This term refers to the practice of including measures other than standardized placement tests to determine eligibility for remedial or college-level coursework. At the VCCS, the new placement uses high school GPA in conjunction with the level of mathematics coursework taken in high school as an alternative to placement testing (see Osberger, 2017). Students above a certain GPA threshold that have taken certain mathematics coursework can enroll directly into credit-level mathematics without the need to take a placement test. For students with slightly less preparation, the second aspect of reforms is the model of *corequisite* instruction. Students at the margins of needing remediation (discussed later in detail) are now allowed to enroll directly into credit-level courses but are required to take a supplement *corequisite* course offering in-time remediation. Finally, some of these credit-level courses are changing as well, with a new course in Quantitative Reasoning (QR) offering a new alternative for students to satisfy general education requirements for mathematics.

Evaluating the Success of VCCS Reforms

There were four stated goals of the curricular and placement redesign, as reported in a VCCS review published shortly after their implementation:

1. Decrease the number of students enrolling in developmental education,

2. Increase the number of students completing developmental education requirements within one year,

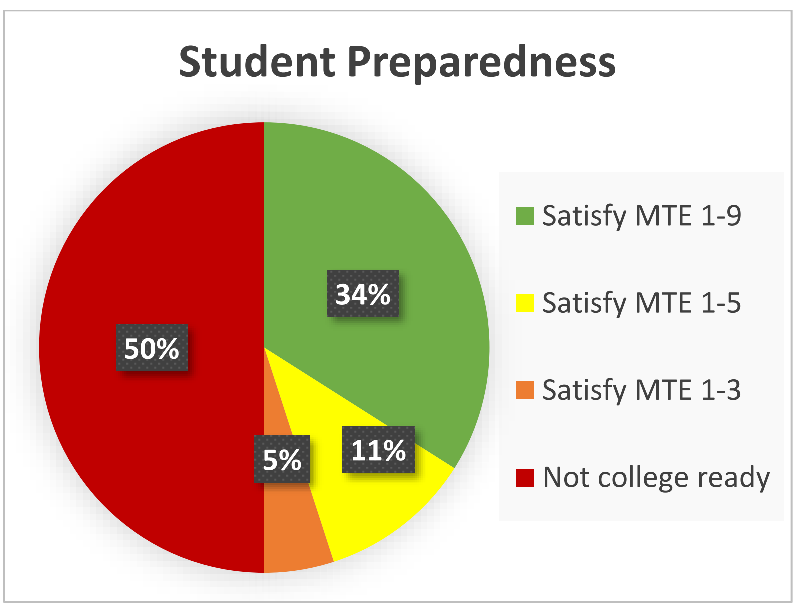
3. Increase the number of students successfully completing college-level math courses, and

4. Increase student success in terms of persistence, graduation, and transfer.

(VCCS Office of Institutional Research and Effectiveness, 2014, p. 1)

The report evaluates the success of these goals through the performance of “First Time in College” (FTIC) students in the VCCS, tracking data at each college and in aggregate. A full list of college-level results can be found in the appendices of the report (VCCS, 2014). Among the 29,583 in the fall 2012 VCCS cohort of FTIC students, 22,376 (76%) took the VPT-Math. The results for those tested are displayed in Figure 2 below.

Figure 2. VCCS Student Preparedness for College-level Mathematics



As can be seen in the figure, half of students failed to complete at least one of the first three modules. These students needed to complete at minimum one module before they could begin mathematics that would satisfy degree requirements, though these students could have needed as many as nine modules to progress towards their chosen degree.

According to the report, the modular system of placement partially satisfied the first VCCS goal, decreasing the placement of students into developmental mathematics as a percentage of total FTIC from 37% to 30% after the institution of the new placement test. As for the second goal, there was a slight increase in the percentage of program-placed students enrolling in college-level mathematics within a year, from roughly 35% in each of the three prior cohorts to 40% for the Fall 2012 cohort on average across the system. However, the report does not fully address whether the second goal was met. The authors of the report acknowledge that is methodologically difficult to assess whether a student completed all of their remedial requirements, since students could have decided to change to a less mathematically-intensive program after struggling in remedial coursework.

Regarding the third goal, despite an overall 5% decrease in enrollment after reforms were introduced, the number of students *attempting* and *succeeding* in credit level mathematics both increased by 2% in the two years following reforms. However, there was a slight dip in the success rates in both developmental (pass/fail) and credit-level courses (where passing counts as a grade of A, B, or C) of between 1 and 4 percentage points. The increase in students placed into credit-level mathematics may have included some students who would have otherwise passed a remedial course but failed the credit-level course they were assigned to. Without detailed statistical analysis, however, it is difficult to support such assertions.

Regarding the final goal, there appeared to be no change in fall-spring or fall-fall retention following the redesign. However, the percentage of students earning at least 12 credits in their first semester increased slightly, from 26% to an average of 30% after redesign. There are several limitations to the conclusions that can be drawn from the VCCS system data. First, the report is descriptive rather than inferential; it does not adjust for the impacts of covariates or identify whether year-to-year differences were statistically significant, either at the system level or the college level. The new implementation of a policy offers the opportunity for the use of a comparative interruptive time series, a quasi-experimental method that estimates the effect of a policy intervention, after adjusting for baseline trends (Angrist & Pischke, 2014). No such rigorous methodology was applied in this initial report.

However, the initial assessment of impacts took place prior to further instructional reforms that significantly changed the delivery of developmental education. As the report was released, several colleges were implementing the last stage of reforms by fully adopting the EM. In the years since the report, these goals have become even more concrete, taking the form of performance-based funding measures. By 2020, 20% of each college's funds will depend upon each college's performance, using a formula that includes placement figures into credit-level coursework, retention, and completion outcomes. The details of this initiative can be found at http://trcenter.vccs.edu/data/. One newer approach the VCCS is taking to achieve some of these goals systems-wide is a new set of placement measures.

Multiple Measures Placement

The VCCS instituted new multiple measures placement in 2017, effective for the 2017-2018 academic year (VCCS, 2017). This aligns with nationwide trends moving away from testing as the sole method of placement. The share of two-year colleges using measures other than standardized tests for assessment rose from 27% to 57% between 2011 and 2016 (Rutschow & Mayer, 2018). The VCCS measures use high school overall GPA and mathematics coursework as alternatives to placement testing, following recommendations from a study by Ngo and Kwon (2015) discussed in detail in the literature review.

The VCCS had already been using other standardized tests (SAT or ACT mathematics scores) to place students into college-level mathematics. The new system also allows students to place directly into college-level mathematics *without* any placement or standardized test results. While students may still take the VPT to satisfy developmental modules, students with a sufficiently high GPA and high school mathematics background can immediately enroll into credit-level mathematics. Students in a slightly lower GPA range qualify as “corequisite eligible”. These students can take certain credit-level mathematics courses if they simultaneously enroll in a corresponding corequisite course. The system of qualifying measures is shown in Table 1 below. In the table, "MTE satisfied" indicates competency on the selected numbered modules, which satisfy prerequisites for credit course eligibility.

Table 1. Multiple Measures Placement

Math Placement Measures	HSGPA or Score Range	Placement
HSGPA and Algebra II and One Algebra Intensive Course* * Trigonometry, Math Analysis, Pre-Calculus, Calculus, Algebra III	3.0 or higher 2.7 – 2.9	MTE 1 – 9 satisfied MTE 1 – 9 Co-requisite eligible
HSGPA and Algebra II	3.0 or higher 2.7 – 2.9	MTE 1 – 5 satisfied MTE 1 – 5 Co-requisite eligible
HSGPA and Algebra I	3.0 or higher 2.7 – 2.9	MTE 1 – 3 satisfied MTE 1 – 3 Co-requisite eligible
SAT - Math	530 or above 510 – 520	MTE 1 – 9 satisfied MTE 1 – 5 satisfied
ACT – Subject Area Test Math	22 or above 19 – 21 range	MTE 1 – 9 satisfied MTE 1 – 5 satisfied
GED - Math	165 or above 155-165 range	MTE 1 – 5 satisfied MTE 1 – 3 satisfied

The GPA value is computed from overall coursework, not specific to mathematics, and are valid up to *five years* past high school graduation, for those graduating 2017 or later. For example, a student with an overall high school GPA of 3.1 who took at most Algebra II would satisfy the first five modules. This is regardless of what grade this student earned in their mathematics coursework or when they took it. This student could then enroll directly into MTH 154 – Quantitative Reasoning, which requires competency in the first five modules. A student who had taken Algebra II but only had a GPA of 2.92 would be counted as corequisite eligible; he or she could enroll into QR but would be required to simultaneously enroll into the corequisite course. Student eligibility based on GPA criteria is manually coded into each a student databased shared across VCCS colleges, but the policy is a system-level and colleges are not offered the opportunity to override it.

Future longitudinal data may make it possible to rigorous evaluate the impact of this placement system using quasi-experimental methods. However, its complexity, coupled with its recency and the possibility for inconsistent implementation between colleges, mean that it would be difficult to produce rigorous estimates of its effects at this stage. Consequently, this present research does not seek to produce any such estimates but will consider the possible effects of placement on reforms locally at a mid-sized community college in the VCCS, Commonwealth Central Community College (CCCC; the name of the college and individuals in this study are pseudonyms).

Implementing Current VCCS Reforms at CCCC

As discussed, many of the reforms taking place at CCCC are statewide VCCS initiatives, including multiple measures placement and the courses that colleges are permitted to offer. The curricular structure of having nine modules with the VPT as placement test remains for the time being, though further changes may yet be in the works. Other aspects, such as which entry-level courses will be paired with corequisite courses and which will be taught using traditional models of developmental instruction, are left to the discretion of each college. Currently, these choices include the previous system of MTT courses (the EM-based courses), the new corequisite model, and new "bundled" developmental mathematics courses that effectively reverse the previous modularization. What colleges choose to offer may vary, and the additional placement measures will also provide alternative pathways by which students can demonstrate preparedness for college-level mathematics. While a study of the success of various approaches may offer insights into developmental offerings at the VCCS, for purposes of scope this current research will not explore these alternative pathways. It will instead focus on the details of the corequisite support course for the QR course as they are being implemented at CCCC.

Implementing Curriculum Modularization and the EM at CCCC

During the first stages of reform implementation in 2011-2012, developmental mathematics at CCCC was delivered through "Math Essentials" courses, each of which covered the topics in a single module. Each five-week course included a lecture component, plus computer-based homework and quizzes completed in the mathematics tutoring center. So, over the course of the fifteen-week fall semester, a student could enroll and complete in MTE 1 in September, MTE 2 by the end of October, and MTE 3 in December, all with the same faculty member in the same time slot. However, if this student failed her first MTE 1, she would need to transfer to a different instructor or time to retake MTE 1 in October. Particularly at smaller institutions, this posed challenges for scheduling, for students as well as the college.

In the spring of 2013, CCCC piloted a computer lab-based “MTT” course; the new name reflected the fact that these courses were technology-based. By the fall of 2014, CCCC fully implemented these courses, which followed the design elements of the EM. These MTT courses, still done in five-week segments, were much easier to schedule, since *all* developmental students could now enroll into any section of MTT, regardless of whatever modules they needed. That is, within the same section of 15-18 students, some students could be adding fractions while others worked on systems of equations or factoring polynomials. Each student would work at their own pace, though to count as successful completion for financial aid purposes students still needed to finish at least one module during a five-week block. Students could also complete work at a faster pace and fulfill requirements in an accelerated time frame.

According to the design principles of the EM, students complete modules by correctly answering a certain percentage on homework assignments, quizzes, and final exams. The National Center for Academic Transformation, a nonprofit advocating the EM, recommends setting these thresholds between 75% and 90% (National Center for Academic Transformation, 2013). At CCCC, students in MTT (computer-based) courses needed to earn an 80% on homework sections, for which students had unlimited attempts at each problem. After reaching this threshold for a required number of homework sections (around three to five), students would need to earn at least 80% on a quiz associated with this material. Once students finished three of these quizzes, they took a post-test (final exam), on which they needed to earn at least a 75%. On quizzes and the post-test, students were allowed two attempts. In instances where students did not pass after two attempts, a conference with the instructor was required.

After the first few years of implementation, the EM-based instructional reforms did not appear to significantly boost success rates of students in the MTT courses. In 2015 and 2016, according to internal data on CCCC's website, the pass rate in each semester for these developmental courses at CCCC was between 50% and 60%. This was no improvement upon or slightly worse than earlier iterations of developmental courses. What these pass rates mean and the reasons why these numbers did not improve are a matter taken up in greater detail in Chapter 4 (Findings).

Mathematics Pathways and Quantitative Reasoning

One aspect of current reforms taking place at CCCC is an example of what Hagedorn and Kuznetsova (2016) call a "curricular substitution": changing gatekeeper credit-level courses in ways that aim to improve student success. Perhaps the best known of these initiatives are the Statway® and Quantway® courses, collectively termed as Pathways. Both courses were developed in 2010 by the Carnegie Foundation for the Advancement of Teaching, which has since become operated by WestEd, another nonprofit educational advocacy group. The curricula and materials from the Carnegie Math Pathways are proprietary, but the Quantitative Reasoning and Statistical Reasoning classes developed during recent VCCS curriculum updates follow similar guidelines.

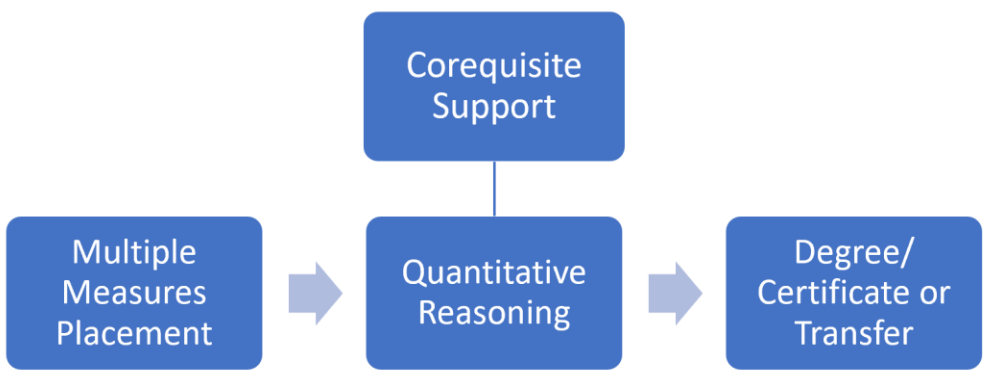
The move towards QR as the credit level mathematics reflects a move towards credit-level mathematics away from computation and algebra and towards reasoning skills. This can be seen in the major topics in the VCCS QR course include financial literacy, perspective (including ratios, proportions, and conversions), modeling, and validity studies (inferential logic and set theory). The course objectives emphasize the skills that students will be able to do, including communication, problem solving, reasoning, evaluation, and technology. These are much more reminiscent of the principles and standards outlined by the National Council of Teachers of Mathematics (NCTM; 2000) than they are of the procedural objectives outlined in previous remedial courses.

While the focus of this current research is on the corequisite model of instruction, part of the research will include exploring relevant details of the QR course. Previous remedial courses were self-contained courses that had established curriculum. However, as will be discussed in the next section, the corequisite support courses in the VCCS have no set curriculum, which means that remediation is now intricately linked to the entry-level course.

Corequisite Support

The final aspect of developmental mathematics reform at CCCC, the central topic of the problem of practice addressed in this research, is the new instructional and curricular model of developmental education. Under the previous model, students completed developmental prerequisites using instructional software in an instructor-supported computer lab. In the new model, students who qualify by multiple measures placement or are short at most two modules can enroll immediately into credit-level mathematics, provided that they also enroll in an accompanying corequisite course. For example, a student who demonstrated competency in any three of the first five modules (e.g., 1, 3 and 4) could then enroll into a corequisite-supported QR course. The VCCS has made it possible for colleges to create corequisite courses paired with statistical reasoning, QR, precalculus, and other courses. However, CCCC only offered corequisite support for the QR course. A visual representation of how the corequisite model of developmental instruction differs from the traditional model in Figure 1 is shown in Figure 3 below.

Figure 3. The Pathway Through Corequisite-Supported QR



A corequisite workgroup produced a guide to implementation for colleges in the VCCS, which is discussed in greater detail in Chapter 4 (Findings). These findings ultimately led to the descriptions of the MCR courses that entered the VCCS course catalog. One noteworthy aspect is that the MCR course only describes its purpose simply as to “Provide instruction for students who require minimum preparation for college-level Quantitative Reasoning" (VCCS, 2018). By contrast, the course objectives for the previous modules indicated specific curricular objectives, such as "finding the equation of a line, graphing linear equations and inequalities in two variables…" as in MTE 5, for instance. The lack of a stated curriculum for the MCR courses leaves quite a bit open as to what may be taking place in these classes.

Regarding curricular materials that support the corequisite course, CCCC will be using an electronically-based textbook for the QR course. This curriculum is commercially available through a company Knewton, which packages open educational resources into a mastery-based adaptive learning platform. This software includes a curriculum for the QR course and an additional curriculum for the corequisite course, with sections covering topics in algebra. The details of this implementation and how they impact classroom practices is discussed in Chapter 4 (Findings).

Summary of Reforms at CCCC

To summarize the array of initiatives, the new multiple measures placement aims to identify students capable of success in credit-level mathematics or in need of minimal remediation. The students at the margins of remediation enroll in corequisite support courses in conjunction with their credit-level course. The ambition of these support courses is to reduce the attrition and failure in prerequisite systems of developmental mathematics. Finally, the gatekeeper course for students taking mathematics to satisfy general education requirements has been redesigned to make it more relevant and, perhaps, increase pass rates.

Much of how these reforms work is in a process of emerging. While the quantitative impacts of these reforms would be valuable knowledge, the interactions between each reform creates challenges for quantitative analysis. It remains to be seen whether how the changes to placement will affect the preparedness of students entering corequisite-supported QR courses. These QR courses themselves are also being piloted at CCCC, so practitioners will be addressing issues with credit-level courses at the same time that corequisite remediation is debuting.

Initial reports of the corequisite model at other community colleges suggest that its implementation can dramatically increase the number of students passing college-level mathematics, *doubling* or *tripling* success in entry-level courses in *half* the time (Complete College America, 2016). This research is discussed and critiqued in detail in the second chapter. However, several uncertainties and questions surround these reforms as they move into full implementation at CCCC. First, there is the question of what this newest series of reforms might accomplish and how practitioners perceive them. Next, there is the matter of how these new reforms are implemented, and the possibilities, challenges, and unintended consequences that arise during the transition. Finally, there is the matter of what happens in the corequisite classroom: how teachers prepare for the class, make instructional decisions, utilize resources, and interact with students, and how these students respond to the instructional format. As a faculty member involved in corequisite implementation at CCCC, I have a unique opportunity to record the trials and tribulations of these reforms as they are being debuted.

Summary of the Problem of Practice and its Importance

The central problem of practice can be understood on a macroscopic and microscopic level. On a broad scale, within traditional systems of developmental mathematics, a majority of students never reach success in college-level mathematics. This has prompted dramatic reforms across the country. However, in a rush to replicate the dramatic increases reported by some reform advocates, colleges may enact reforms that are ineffectual because they have been poorly executed or based on flawed research. Structural reforms imposed by administrators with the goal of increasing credits earned may neglect to address student learning outcomes, leaving instructors ill-prepared to substantively address student's knowledge gaps in ways that align with research on effective pedagogical practices.

At a local level, the VCCS has instituted a number of reforms to developmental education across its colleges. One such college, CCCC, has been in a continual process of reform for several years. The primary focus of the present research study is to examine one aspect of these reforms in detail: what corequisite instruction looks like in practice and how the successes and failures encountered during its implementation can improve upon practice.

With states like Virginia increasingly moving towards reducing or eliminating developmental education requirements, the stakes of the current reforms are considerable. If colleges in the VCCS continue to underperform expectations in assisting poorly prepared students for success in mathematics, they may suffer financial consequences. Administrators could impose further measures reducing the autonomy of academic departments to decide upon how they wish to place and educate students at the margins of preparedness for college. By observing these reforms as they take place, this present research will attempt to identify the context-specific conditions that promote or inhibit the success of reforms related to corequisite instruction. Because of the complex interplay of factors and the potential for variation across colleges in the VCCS, this research uses a qualitative single-case study approach to explore implementation at CCCC. This research begins by describing the structural details of recent and current reforms at the VCCS level. It then narrows the reforms into a study of implementation at a single college, identifying how implementation takes place and what corequisite instruction looks like.

Research Questions

This capstone project addresses the implementation of corequisite instruction within the context of reform efforts at CCCC. While multiple measures placement and the QR courses are relevant to understanding the context in which corequisite instruction is taking place, the discussion of these topics is limited to the extent of how their implementation impacts corequisite instruction. The research questions and a summary of the plan for data collection is overviewed in Table 2 below and detailed in subsequent sections.

Table 2. Research Questions and Data Collection Methods

Research Question	Data Collection Methods
1. What are practitioners' goals and expectations for corequisite reforms at CCCC?	15 hours of interviews with mathematics faculty members, administration, and staff
2. How does the design of corequisite courses reflect faculty and administrator goals?	Documentation on student learning objectives and syllabi; recorded interviews and informal conversations with administrators and faculty.
3. How do faculty teach and use instructional resources in QR corequisite support courses?	20 hours of classroom observations of corequisite-supported QR courses; two 30-60 minute interviews and informal conversations with corequisite instructors
4. How do students respond to corequisite instruction?	Closed-form and open-ended survey responses from students

Definition of Terms

Corequisite. A supplemental support class for students who are not eligible to enroll directly into credit-level mathematics based on placement measures.

Developmental mathematics. Mathematics coursework offered at higher education institutions for which credits do not count towards graduation, covering arithmetic and algebra content; this includes prerequisite and corequisite models and is used here interchangeably with "remedial mathematics" and is distinguished from mathematics taken for credit.

Emporium Model (EM). A system of instructional reforms, based on individualized computer-based mastery instruction taking place in computer labs supported by instructors and using a modularized curriculum.

Gatekeeper/Entry-level courses. The lowest level of mathematics courses that offer credits towards graduation; these vary by institution but include college algebra/precalculus, introductory statistics, and quantitative reasoning.

Multiple Measures. Placement measures that include factors other than placement test scores when determining the level of course a student is eligible to enroll in; may include high school GPA or high school coursework.

Quantitative Reasoning (QR). A first-year college-level course satisfying general education requirements oriented towards building conceptual understanding in mathematical topics practical for everyday use.

Chapter 2 - Literature Review

The following review of literature explores how the problem of practice at CCCC relates to the broader literature on developmental mathematics instruction and reforms. It begins with a selection of findings from the science of learning mathematics that have implications for developmental instruction. Next is a highlight of findings on the goals and challenges of developmental reform. This follows with a conceptual framework that establishes the relevant constructs for the present research.

Following the conceptual framework is a broader discussion of remediation at the community college: why remediation exists, who is being remediated, and what reforms such as the corequisite model might be able to accomplish. It follows with a critical review of recent quantitative studies estimating the impacts of developmental mathematics. Since the results of these studies have prompted many calls for reforms, it is necessary to investigate the extent to which the conclusions drawn by reform advocates are supported by the data. The subsequent section overviews the literature on the impacts of corequisite instruction and the details of its implementation in other studies. Finally, the review highlights some critiques of developmental education scholarship and in doing so provides some cautions for research on the reforms central to the problem of practice.

Research on Learning Mathematics and its Implications for Remediation

A considerable body of research on the science of learning has concluded that instruction and assessment must be in alignment and that students' prior understanding must be engaged if they are to develop transferrable skills. This issue is particularly central to the challenges of offering effective remedial mathematics instruction. Goldwasser, Martin, and Harris (2017) suggest that misalignment between remedial and credit-level coursework is one of the primary contributors to the failure of remedial programs to improve student outcomes.

The influential *How People Learn* by the National Resource Council (NRC; 2000) distills three principles from the science on learning. Since the focus of this present research project centers on the instructional approaches to the corequisite model of remediation, this literature review begins with a summary of the NRC's three principles, their implications for teaching developmental mathematics, and the specific lessons these principles have for developmental mathematics education.

Preconceptions, Misconceptions, and Conceptual Change

> Principle 1: Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, the may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom. (NRC, 2000, p. 14)

This recommendation by the NRC is echoed by the NCTM, which advocates in its *Principles to Actions* that "learners should have experiences that enable them to… connect new learning with prior knowledge and informal reasoning and, in the process, address preconceptions and misconceptions" (2014, p. 9). Misconceptions have long been a subject of research in mathematics education, particularly in remedial contexts, going back to Erlwanger's single-case study of a sixth-grader named Benny (Erlwanger, 1973). Benny's performance was better than many of his remedial peers, and he followed procedures with remarkable consistency. Benny developed these procedures as he submitted his work to an aide, who then returned these exercises with the correct answers. Benny would refine his approach based on these corrections. Through this process, Benny "developed consistent methods for different operations, which he [could] explain and justify to his own satisfaction" (1973, p. 51). These approaches yielded correct answers ($0.5 \times 0.7 = 0.35$) as well as incorrect answers ($0.3 + 0.4 = 0.07$) but did not correspond to the meaning behind the arithmetic algorithms. Benny did not view these rules as supported by reason or logic but was nevertheless confident in his responses and apparently unaware of his errors.

Benny's idiosyncratic views of mathematics offer insights into the discrepancy between correct answers and correct reasoning. In a larger scale, the case of Benny serves as a caution to behaviorist approaches to mathematics. Ideas from *conceptual change theory* (see Ozdemir & Clark, 2007) can provide insights into the purpose of developmental mathematics. According to one perspective from conceptual change theory, knowledge can be thought of as elements that are highly dependent on the context in which the learner is instructed and assessed. Because of this dependence on context, students who learn remedial skills solely as procedures (e.g., adding decimals) may fail to transfer those skills when being asked a question that applies those concepts (e.g., an application that requires decimal arithmetic).

Recent research on the impact of learning these procedural skills indeed appears to indicate that the procedural emphasis commonplace in remedial coursework offers limited benefits to students as they transition to credit-level coursework. A study by Quarles and Davis (2017) finds that remedial mathematics coursework does lead to slight improvements to procedural algebra skills. However, after controlling for students' grades in previous courses, these procedural skills were not associated with higher grades in credit-level mathematics. This is partly a problem of transferability but also a problem of memory. The authors not that almost half of the procedural skills students possess by the end of intermediate algebra decay within four months to a year after taking the course. By removing the delay between remediation and credit-level coursework, corequisite instruction may address the loss of skills over time, while also providing the immediate context in which a skill must be applied. Quarles and Davis also note that conceptual skills are much slower to decay. However, courses in intermediate algebra such as the one they studied have a much heavier emphasis on procedural knowledge on specific tasks, rather than a broader understanding of how concepts are interconnected. This points to the next principle from the NRC on the importance of a strong conceptual foundation.

Foundations and Frameworks for Knowledge

> Principle 2: To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. (NRC, 2000, p. 16)

This second principle notes that one distinguishing factor between experts and novices in any area of inquiry is the fluency with which experts can identify patterns and relationships in their domains of mastery. This ability comes from a deep level of conceptual understanding in which facts are interconnected. A highly organized structure of knowledge allows experts to extract more meaning from each point of data to build on what they already know and facilitates more efficient retrieval. One example of this fluency in elementary mathematics is the mastery of multiplication facts (Kling & Bay-Williams, 2015). While students can memorize each multiplication fact independent of others, fluency requires students to build knowledge in stages. This starts with understanding the interpretation of multiplication as repeated addition, then learning to multiply by 2, 5, and 10, perhaps by using skip counting (e.g., 5, 10, 15, etc.). Next, students build on these strategies to multiply by other numbers; for instance, multiplying by 4 is doubling twice, while multiplying a number by 9 can be done by multiplying by 10 and then subtracting that number (e.g., $6 \times 9 = 6 \times 10 - 6 = 60 - 6 = 54$). At the final stage of fact fluency, students understand how to use multiple strategies to derive each fact.

Developing fluency is critical because these strategies help learners build skills as they are used by experts. Unfortunately, the concepts that students learn in classrooms do not always correspond to how communities of experts in the discipline use them (Brown, Collins, and Duguid, 1989). Often, classroom knowledge fails to reflect the fact that the meaning of conceptual tools is the product of the wisdom and negotiation of a community whose members share culture and values. However, students are frequently asked to take up the tools of the discipline before they are familiar with its culture. This can lead to the classroom practice of providing students with inauthentic tasks or solution methods only appropriate to artificial scenarios. When students are assessed in remedial mathematics classes on their ability to complete exercises in a narrow range of tasks, they may fail to transfer these skills to credit courses. This may particularly be the case if credit-level courses require a problem-solving approach that is more open-ended than remedial coursework. An emphasis on problem solving and metacognition is taken up in the last principle from the NRC.

Metacognition and Problem Solving

> Principle 3: A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them. (NRC, 2000, p. 18)

The NRC's definition of metacognition relates to the NCTM and its definition of problem solving. The NCTM defines problem solving as "engaging in a task for which the solution method is not known in advance" (NCTM, 2000, p. 52), and has argued for the importance of doing problem solving in classrooms since its *Agenda for Action* (NCTM, 1980). Giving students well-defined yet unfamiliar scenarios that require mathematics provides the opportunity to develop strategic thinking. The emphasis on strategic thinking as part of mathematics education goes back to Polya's foundational text in mathematical pedagogy, *How to Solve It* (1945/2014). This text discusses mathematics teaching and learning through *heuristics*, approaches to forming problem solving strategies. Since Polya, the educational research community has begun to explore ways that instruction can emphasize *metacognition*, "one's knowledge concerning one's own cognitive processes and products" (Flavell, 1976, p. 232). Shortly after the concept of metacognition was introduced, researchers began to note a link between metacognition and mathematical performance (Garofalo & Lester, 1985). More recent research estimates that metacognitive knowledge accounts for approximately 17% of variation in math scores on the PISA assessment (Schneider & Artelt, 2010).

The ability to monitor and regulation one's cognitive processes is essential during the problem-solving process, which has been characterized as having stages (Polya, 1942/2014; Schoenfeld, 1992). Schoenfeld notes that a major factor that distinguishes novices from experts in mathematics is how they advance through these stages. Novices put limited effort into making sense of a problem, spending little time reading the problem statement before attempting a solution, and often neglect to check if their solution is reasonable (Schoenfeld, 1992). Their approaches often follow inductively rather than deductively, without a clear plan. By contrast, experienced mathematicians spend more time reading and analyzing the problem before methodically carrying out a plan and making revisions as needed (Schoenfeld, 1992). As the NCTM puts it: “Effective problem solvers constantly monitor and adjust what they are doing. They make sure they understand the problem” (2000, p.54).

The NCTM advocates integrating problem solving and tasks that facilitate metacognition into all content areas of mathematics, noting that problem solving skills prepare students for unfamiliar situations. Proper assessments are a crucial aspect of this integration. Testing students solely on procedural skills separated from meaningful context can send an unintended message that the purpose of mathematics is to memorizing facts and follow rote procedures. Instruction that does not emphasize connection between concepts misses out on opportunities to apply content from a mathematics course to science courses or practical scenarios such as personal finance or statistical reasoning. Problem solving is important not only because it enriches the study of procedural and conceptual skills and connects them to broader mathematical practice, but because the skill of problem solving applies well beyond the mathematical classroom. Developing the confidence and mental habits to respond to new challenges with methodical approaches has broad transferability (NCTM, 2000). This may potentially be another area in which corequisite instruction could improve upon traditional practices of remediation. The next section addresses lessons that have been learned from colleges that have begun to implement this format of instruction.

Research on Corequisite Reform Implementation Challenges

A recent report by the RAND corporation (Daugherty et al., 2018) uses interviews with administrators and faculty involved in corequisite implementation across community colleges in Texas. The report identifies four challenges to implementation and successful strategies for overcoming them. First, limited buy-in among faculty, advisors, and students posed a significant challenge at many of the institutions. This was particularly the case among developmental education faculty, many of whom perceived the corequisite movement as an incremental approach to eliminating developmental education entirely. Second, the transition to the new corequisite model created problems for scheduling and advising. Third, faculty experienced limited preparation and support during the design and implementation of their courses. Finally, about half of institutions in the study reported that the speed and uncertainty surrounding state policymaking efforts were a cause for concern. Some interviewees expressed frustration about the pace and limited ability of colleges to fully implement the new policies.

There are multiple potential explanations for why developmental reforms may or may not lead to improvements in the desired outcomes being measured. While the flexible nature of the corequisite model means that it can be adapted to a variety of circumstances and systems, the different approaches may yield drastically different rates of success. Other unforeseen difficulties in the process of change and transition may also contribute to a mismatch of expectations and reality. It could also be that faculty resistance to current reforms could limit their potentially positive impact. Or, CCCC may struggle to duplicate the success of other initiatives that had better access to resources. While the focus of this present research is on the character of instructional support provided in corequisite courses, this research also recognizes that some practical design impacts may have consequences on how corequisite courses are taught. The interacting effects of these are explored in the conceptual framework, discussed below.

Conceptual Framework

The conceptual framework outlined below is a response to several critiques and recommendations made by those evaluating the effectiveness of developmental education and how to improve it through reforms. Xu and Dadgar (2018), whose quantitative research is discussed later, note that premise that remedial mathematics increases preparedness for college-level coursework depends on several as-yet-unverified assumptions. First, the curriculum in remedial mathematics must be well-defined and contribute to preparedness in college-level coursework. Second, remedial placement needs to correctly identify those who would benefit from studying remedial content. Third, the potential benefits of remediation must outweigh potential negative effects of placement into remedial coursework.

Logue, Watanabe-Rose, and Douglas, whose 2016 study on corequisite instruction is also discussed in subsequent detail, summarize three theories as to why corequisite implementation represents an improvement upon traditional remedial coursework. First, placement measures may inaccurately identify students as needing remediation. Second, assignment to remediation may have negative impacts on student affect, due to the stigma attached to remediation or negative associations with similar coursework in high school. Third, the authors note that it may be easier for some students to pass college-level courses than remedial algebra courses, as such courses may be presented in more concrete and applicable contexts.

The conceptual framework that guides the data collection process in this present research responds to these suggestions. It also incorporates some recommendations on assessing developmental education programs from Goldwasser, Martin, and Harris (2017) and the challenges to implementing corequisite reforms identified in Daugherty et al. (2018). A visual of the conceptual framework is shown in Figure 4 below.

Figure 4. A Conceptual Framework for Studying Corequisite Instructional Practices

To briefly explain the conceptual framework, a number of anticipated factors will contribute to successful corequisite instruction, as understood to be student success in their paired entry-level course. First, placement measures must accurately identify students for whom the corequisite course might be beneficial: if students are highly underprepared, the corequisite course may provide insufficient assistance. Advising serves to assist placement by ensuring that placement measures appropriately identify students' level of preparation.

The next aspect regards the curriculum of corequisite courses; namely, the content of such courses must be directly aligned with the credit-level content for such remediation to be effective. Connecting with this aspect, teaching and learning resources ought to facilitate this connection and build foundation skills. As the research on learning mathematics discussed above indicates, a foundational base of knowledge is critical for students to successfully transfer content. To build this foundation, instructors must address students' prior conceptions and misconceptions and build skills that are conceptual and metacognitive, in addition to procedural.

The implementation challenges highlighted by Daugherty et al. (2018) indicate the need to gauge the extent to which students, instructors, and administrative staff believe in the potential effectiveness of the corequisite model. Consequently, beliefs form one aspect of the conceptual framework, following back to research by Garofalo (1989) establishing a link between beliefs and mathematical performance. Finally, collaboration and reflection among corequisite instructors, with administrative supports, may increase the effectiveness of instructional practices and encourage buy-in among those teaching in this new model of support.

Before discussing the detail on corequisite-related reforms in the lens of this conceptual framework, it is worthwhile to reflect more carefully upon what these reforms are replacing. To unpack the construct of “accurate placement”, it is worth delving into the quantitative studies on who has been assigned to remediation and what has happened to those students at the margins of remediation. The corequisite model, as stated in the VCCS course description, is suitable for students at *minimum preparation* for credit-level coursework. In order to contextualize this research, it is worthwhile to look at how recent research has looked at what it means to be a marginally prepared student and what has traditionally happened to those students who may now be placed into corequisite support classes. A careful reflection upon the quantitative literature reveals that the question of whether developmental education practices are effective cannot be separated from the question of *which* students they may be effective for. Finally, this review of the quantitative literature also provides insights on why corequisite support may not be able to completely replace traditional practices of remediation.

Traditional Remediation Practices: Placement and Performance

While many higher education institutions face the problem of underprepared students, remediation is considerably more common among students attending two-year colleges than four-year colleges. According to the most recent nationwide longitudinal data from the National Center for Education Statistics (NCES), students entering two-year public colleges in 2003-2004 were almost twice as likely to enroll into developmental mathematics than their four-year peers (59% versus 33%; Chen, 2016). While some students enroll into developmental mathematics by choice, most enrollees would be ineligible to directly enroll into credit-level mathematics.

The higher rate of developmental placement at two-year colleges reflects multiple factors. The principle of open access is embodied in the mission of many community colleges, which were created to extend educational opportunities to those who may not otherwise have them. However, by offering open access to all students, two-year colleges give up their ability to filter out the least prepared students in the way that selective four-year institutions do. Two-year colleges also may have higher rates of adult students returning to school after years or decades outside of the classroom, during which time their skills have atrophied. Many students in two-year colleges are also taking classes part-time, due to external family or work obligations or the lack of financial resources to pursue education full-time.

Of course, these high levels of remedial placement also reflect major issues with K-12 instruction. Ideally, a well-functioning K-12 educational system would prepare students with the skills deemed essential for success in college-level coursework. Were this the case, the need for remediation would be minimal. Though a detailed discussion of the failures of mathematics instruction at many K-12 institutions is outside of the scope of the present review, there are unquestionably many institutions that do not adequately prepare many of their students for college-level mathematics. As is widely documented in educational literature, such inadequate preparation is more often encountered in school districts with high poverty rates and high rates of minority populations. Unsurprisingly as a result, students beginning remediation are disproportionately more likely to be black, Hispanic, low-income, and the first of their family in college (Chen, 2016). Addressing this disparity has been an explicit target of some reforms to developmental education (e.g., Ngo & Kwon, 2015; Twigg, 2005).

Once students begin remediation, it may be some time before they begin credit-level coursework. Developmentally-placed students complete at two-year colleges complete an average of 2.9 remedial courses (including all remedial coursework), with 48% of students taking at least two remedial classes (Chen, 2016). The NCES data analyzes remedial students into those who complete all assigned remedial coursework, those who complete some, and those who do not complete any. Descriptive data shows that those who complete all remedial requirements perform at comparable levels to nonremedial students, with roughly 40% of students in each category successfully transferring or attaining a degree/certificate within six years. Those who complete some or no remediation fare worse along all observed outcomes. This NCES data, however, fails to account for how the *amount* of remediation a student is assigned to may relate to their chances of passing their gatekeeper mathematics courses or persisting in college.

In recent years, research and reports from scholars and administrators at community colleges have begun to look at remediation more as a *process*, one that starts with placement and (sometimes) ends in degree completion. An influential study by Bailey, Jeong and Cho (2010) addresses this question using longitudinal data from 250,000 students in the Achieving the Dream dataset, which includes 57 two-year schools in seven states. Like the NCES figures, 59% of students in their data set were assigned to mathematics remediation (typically by commercial placement tests such as COMPASS); this includes 24% of students needing one level of remediation, 16% needing two, and 19% needing three or more. The more remediation students required, the less likely they were to make it through their remedial sequence. While this result itself may be unsurprising, the magnitude of the cumulative effect of additional remediation is dramatic. For students needing one, two, and three or more levels of remediation, the percentages who complete all remedial requirements are 44%, 29%, and 16%, respectively. Effectively, each additional level of remediation required cuts the overall likelihood of completing credit-level mathematics in half. With such an alarming number of students failing to even make it out of remediation, one might question whether placing students into long remedial sequences is beneficial to these students.

Though the 2010 report by Bailey et al. is widely cited, these figures may not be generalizable to community college populations because the sample of data is in many ways not representative. Over 80% of the students in the data set were in urban locations, with considerably higher minority populations than national rates. The colleges in the study also had lower instructional expenditures per student; though the authors do not report the full range of data, the average was approximately two-thirds that of the average across two-year colleges. Indeed, the Achieving the Dream initiative explicitly sought to address the achievement gaps facing students of color and low-income students (Hagedorn & Kuznetsova, 2016). Because their data set may not be representative, Bailey et al. compare their results to data from the National Education Longitudinal Study (NELS) of 1998. They estimate that the cumulative effects of multiple rounds of remediation have similar negative impacts nationwide. The levels of completion for students assigned to one, two or three levels in that data set is 65%, 24%, and 10% respectively. However, because the authors did not have data on remedial referrals for these students, these are not actual figures from the NELS. Instead, the authors estimate these figures based on individuals' 12th grade math test scores, assuming a correspondence between referral to remediation and enrollment in remediation. A further limitation is that the NELS remediation sequences included different courses: algebra, geometry, and algebra II. Consequently, these estimates from NELS data may not accurately capture current impacts of remediation.

However, even if there is some inaccuracy in these figures, any substantial rate of withdrawal or failure in sequences of remediation would result in large levels of student attrition. Even if only a quarter of students failed to complete each next course, only 56% would make it through two courses and 42% would make it through three.

Such research has even prompted some scholars to explore the hypothesis that the poor outcomes of developmentally-placed students are *caused* by remedial placement itself (Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2015). According to this line of reasoning, placement into remediation sends a signal that a student is unprepared for college, leading the student to feel stigmatized. This discouragement is amplified by the fact that these students' first experience with mathematics in college is much the same curriculum that they struggled to master in high school. Furthermore, since remediation effectively sets students back a semester or more, being assigned to remediation delays the return on a college education, as transfer or degree attainment becomes a semester or more out of reach. The long remediation sequences described by Bailey, Jeong, and Cho (2010) offer plenty of off-ramps for struggling students. Finally, if developmental education is ineffective and poorly aligned with college-level learning objectives, the minimal gains may not justify the costs in time and money to students or colleges. However, assessing whether developmental placement causes poor student outcomes, rather than being merely correlated with them, requires more robust methods when analyzing data on a large scale.

Quantitative Estimates of Developmental Mathematics on Student Outcomes

While research into its impacts goes back to the 1990s, Martorell and McFarlin note that "early studies of the effect of remediation suffer from serious methodological and data limitations" (2011, p. 438). Many such studies fail to address underlying differences that contribute to placement outcomes. That is, a direct comparison of remediate and non-remediated fails to account for how these two populations may differ across aspects that could drive variation in student outcomes (e.g., academic preparation, commitment to education, ability to navigate placement procedures). One statistical technique that attempts to remove observable sources of bias is the use of ordinary least squares (OLS) regressions. For instance, the aforementioned study by Quarles and Mr. Green employed OLS regression to conclude that gains in procedural algebra skills were not associated with higher grades in credit-level mathematics.

Such studies utilizing OLS regression can provide insights into how observed variables such as demographic factors, socioeconomic status, standardized test scores, and GPA covary with measured outcomes. However, while regression studies control for the effects of covariates, they may suffer from selection bias. That is, the mechanism that assigns individuals to treatment (developmental coursework) is non-random. Consequently, the observed differences between treatment groups may be driven by unobserved factors (e.g., student motivation, familiarity with institutional practices), rather than the treatment itself. Furthermore, no amount of additional control variables can guarantee that selection bias has been eliminated in OLS regression (Angrist & Pischke, 2014). As a result, the method of OLS regression does not provide *causal* effects of treatment, but rather an estimate of how effects *correlate* with treatment by adjusting for the impacts of other predictive factors.

Quasi-Experimental Estimates of Traditional Developmental Education

Given the limitations of OLS regression, researchers in the past decade have increasingly employed quasi-experimental methods such as regression discontinuity (RD) designs and instrumental variables (IV) to estimate the causal effect of developmental education on student outcomes. RD designs, like all quantitative research, are an attempt to address the *fundamental problem of causal inference* (Holland, 1986). That is, for any given individual, it is impossible to observe both the effects of receiving treatment and not receiving treatment. In this case, an individual is either assigned to receive remediation or not, and there is no data on the counterfactual scenario in which the individual receives the opposite assignment. Experimental research addresses this problem using randomization to achieve statistically equivalent groups. Quasi-experimental research uses statistical techniques to overcome potential bias of the naïve estimate of treatment – the difference in outcomes between treated and nontreated groups.

The way that RD designs overcome this bias is to utilize score cutoffs that determine treatment assignment. Colleges that make placement decisions based on whether a student receives above or below a given score on a placement test are an excellent opportunity to estimate treatment effects using an RD. In these scenarios, the measurement error of standardized tests is a boon to researchers, since the individuals clustered near the cut score are effectively sorted randomly to one side or another. That is, an individual avoiding remedial placement by a single point could have by chance missed one additional question and been placed into developmental coursework instead. This means that the students immediately above and below the cutoff differ on little other than their assignment to treatment. When placement test score is included along with other covariates, the difference in outcomes predicted by regression curves at either side of the cutoff can be interpreted as the effect of treatment (Jacob et al., 2012) – that is, provided that endogenous variation (such as manipulation) does not drive placement to one side of the cut score or another.

Using an RD, Scott-Clayton and Rodriguez (2015) find no impact, either positive or negative, of assignment to developmental mathematics on overall degree completion, credits earned, or grades in subsequent mathematics coursework. However, some individuals do not receive their assigned treatment, starting in developmental mathematics despite placement into credit-level or vice versa. When individuals do not receive the treatment assigned, a problem known as *crossover*, an RD gives effects of *assignment to* treatment, which may not correspond to the treatment itself (Jacob et al., 2012).

Other researchers have dealt with this problem of crossover by using a "fuzzy" RD, also known as an RD-IV design. Such studies combine RD with instrumental variables. Instrumental variables use a two-stage least squares regression to predict the likelihood of taking up treatment based on an instrument (often the assignment to treatment). When certain assumptions are satisfied, instrumental variables produce *treatment on treated* effects: the effect that a treatment has on the group who take it up, known as *compliers* (Imbens & Lemieux, 2008; Jacob et al., 2012). When coupled with an RD, instrumental variables can remove the bias on effect estimates introduced by individuals who choose not to take remediation when it is assigned, or who enroll into remedial coursework despite qualifying into higher mathematics.

Calcagno and Long (2008) use an RD-IV and find that students receiving math remediation were two to four percentage points more likely to persist from fall-to-fall, but no more likely to pass their first college-level algebra course, earn a certificate or associate's degree, or transfer. Boatman and Long (2010) find negative but statistically insignificant results of developmental math on year-to-year retention, passing college-level mathematics, and college credits completed within three years. Another RD-IV by Martorell and McFarlin (2011) finds that requiring remediation in any subject reduces the number of academic credits attempted in a student's first year. The authors also find negative impacts on labor market outcomes, though not enough to be statistically significant. A more recent RD-IV study used data from colleges in the 2004 cohort of the VCCS, Xu and Dadgar (2018) examine the effects of the lowest level of remediation, prealgebra, with the middle level of remediation, basic algebra. The authors find negative but statistically insignificant effects of receiving remediation in prealgebra on receiving credentials within four years or passing the first credit-level mathematics course.

Limitations of Regression Discontinuity Designs

Overall estimates from RD designs show mixed results on the impact of mathematics remediation on student outcomes. However, some degree of caution is needed when interpreting these estimates due to the limitations and assumptions of such designs. First, an RD gives local area treatment effects, meaning that the population of causal inference for an RD is only those individuals scoring near the cutoff (Imbens & Lemieux, 2008; Jacob et al. 2012). In this case, these estimates apply to students who might plausibly place into either remedial or college-level coursework, according to wherever the cut scores have been set. There is no fixed interpretation in RD research for what exactly it means to be "near" the cutoff (Jacob et al., 2012), but the effect is certainly not internally valid for the entire population of study. Goudas and Boylan (2012) claim that such research has been misinterpreted to characterize developmental education as a failing enterprise. In a direct response, Bailey, Jaggars, and Scott-Clayton (2013) point out that different studies using RDs have looked at colleges using the same placement test (COMPASS) but different thresholds for the cut score. These scores, ranging from 27 through 81, represent a significant number of the scores (out of a possible 1 to 99). Consequently, they argue, when these RDs are taken together, they provide evidence that these effect sizes apply to a rather broad range of students.

A second caution about RD designs is that they measure the effects of treatment on the treated. That is, the effects represent the impacts on students receiving remediation, not the impacts that remediation *would* have had on students who *did not* receive it. To explore that possibility among students scoring just above these score cutoffs, Moss, Yeaton, and Lloyd (2014) used a randomized experiment embedded within an RD. The authors imposed two separate score cutoffs, with the lowest scores assigned to developmental, the highest to credit-level, and finally a middle score range within which individuals were randomly assigned to either developmental or credit-level mathematics. The authors find that those students in the middle group who were randomly assigned to developmental mathematics performed approximately one-third of a letter grade better in their first credit-level mathematics course than those directly placed into credit-level coursework.

Another pair of considerations regarding RD research relate to potential issues regarding placement. The first issue is the uncertainty about whether the score threshold for placement into remediation is chosen in a way that accurate identifies those who would benefit from it. If the cut score were too high, the placement test might inaccurately place well-prepared students into a developmental mathematics they do not need. Were this the case, an RD comparing performance at the two sides of the cutoff would suggest that remediation was not beneficial. However, it would be more accurate to infer that remediation practices misidentified the potential beneficiaries. While these RDs do not provide an indication as to whether the cut score is chosen accurately, research from Scott-Clayton, Crosta, and Belfield (2014) and Scott-Clayton and Rodriguez (2015) suggests that placement testing may indeed be unnecessarily assigning some students to remediation. Both studies estimate that upwards of one quarter of students assigned to developmental mathematics could have otherwise earned a B or better in a gatekeeper mathematics course, based on statistical analysis of factors predictive of success.

The second issue with placement has to do with the methodological assumption required for RD of the *exogeneity of discontinuity*. This holds that there is not some non-random mechanism that is endogenously (non-randomly) sorting individuals to one side of the score cutoff or another. For instance, the practice of allowing students the opportunity to retake a placement test after being assigned to remediation (as in some colleges in Xu & Dadgar, 2018) could result in endogenous variation. That is, if more motivated students were more likely to retake the test, the populations at either side of the cutoff would differ along characteristics predictive of outcomes. Xu and Dadgar's (2018) estimates did not significantly change when they removed colleges whose data suggested they allowed students to retake placement tests. Nevertheless, variation in the specific placement practices of institutions may threaten this assumption.

A final issue with these quasi-experimental estimates is depend upon the untestable assumption referred to as the *stable unit treatment value assumption* (Angrist, Imbens, & Rubin, 1996). This assumption holds that an individual's outcome is not dependent on the treatment status of other individuals. However, other research (e.g., Carrell, Fullerton, & West, 2009) notes that placing underprepared students into college-level mathematics can have negative peer effects, lowering the achievement of better-prepared students. Scott-Clayton and Rodriguez (2015) discuss three potential purposes of remediation: *development*, *discouragement*, or *diversion*. As discussed, their findings suggest that remediation does not significant develop skills, nor discourage students from enrolling or persisting. Nevertheless, they argue that developmental courses could still serve the function of diverting less-prepared students away from credit-level courses. Estimating the extent to which reforms placing more students into credit-level mathematics impact better prepared students poses methodological challenges. However, some of these reforms do appear to be successful for certain groups of students.

Assessing Impacts of Alternative Placement Measures

To estimate the impacts of not receiving remediation, Ngo and Kwon (2015) look at the implementation of MM placement in nine community colleges in California between 2005-06 and 2007-08. These measures were in response to statewide policies that prohibited the use of single assessment instruments. However, regulations did not specify *what* alternative measures needed to be included, and consequently there were variations across the colleges in what measures to incorporate. These included academic factors (receipt of a high school diploma, prior mathematics coursework, and self-reported high school GPA) as well as college plans and motivational aspects. Based on their responses, students could receive additional points to a raw ACCUPLACER test score. Among the students in the study, 4.2% were boosted into the next level course. The authors use this boost, a binary outcome, as their treatment variable in a linear OLS regression. Within the model they also include multiple measures points, test score, and a vector of individual characteristics.

The authors limit their analysis to two of the nine colleges, one that used only mathematics background and one that used only high school GPA. The authors decide to only include enrolled students, noting that placement itself is not likely to drive differences in enrollment given statistically comparable enrollment rates among both groups. The school that used prior mathematics in their placement measures gave point boosts for successful completion of trigonometry and algebra, number of years of mathematics taken, and length of time since last mathematics course. At this school, students who receive a boost and those who do not were just as likely to pass the first course they enrolled in. However, boosted students were 8 percentage points less likely to pass a course than other students in their same course. This decrease is presumably because the boosted students were less prepared than those traditionally placed into non-remedial courses. In the long run, receiving a boost had no statistical impact on number of credits earned. When data were pooled with another college using slightly different mathematics background placement measures, the effects were similar. That is, the results reported by the authors at the one college were not likely anomalous.

At the college that used self-reported high school GPA, boosted students were statistically equally likely as non-boosted students to pass their first mathematics class. The authors also report the unexpected result that students placed into higher courses through this boost were 6 percentage points *more* likely to pass than students placing into the same courses through placement test score alone. Ngo and Kwon offer these results as evidence that incorporating prior mathematics background and high school GPA into placement decisions can correct for measurement error in high-stakes placement tests. However, in addition to the previously discussed caveats of OLS regression to support causal inferences, these findings are specific to the placement measures as practiced at these colleges. Only a small percentage of students were boosted, meaning that broader placement measures could inappropriately boost underprepared students.

Quantitative Estimates of Corequisite-Supported Instruction

As an alternative or supplement to the practice of simply mainstreaming students into credit-level mathematics, some colleges are beginning “corequisite” models of instruction. These courses provide remediation in the same semester as credit-level mathematics, under various structures discussed later in the literature review. Research into the effects of placing students into these corequisite-supported courses shows some promise towards improving student success rates. Royer and Baker (2018) report the success of such initiatives at Ivy Tech in Indiana. They report that, over the first four semesters of implementation, between 58% and 64% of students in the corequisite-supported QR course successfully completed their remedial and gatekeeper mathematics courses (though the authors do not indicate what is meant by successful completion). Under the previous model of remediation, only 49% of students passed remedial algebra. Echoing the results of Bailey et al. (2010), about a quarter of the students who passed remedial algebra neglected to enroll into gatekeeper mathematics. As a result, only 36% of the original group made it into credit-level mathematics. Though most of these students who enrolled into their gatekeeper course passed it, the cumulative effects of attrition meant that only 29% of remedial-placed students made it through gatekeeper mathematics courses.

Many similar findings are reported by Complete College America, a nonprofit group advocating for corequisite instruction models alongside other reforms (2018). States such as Georgia, Tennessee, West Virginia, and Colorado have seen success rates between 61 and 64% in corequisite gateway credit courses, comparing this to only 22% of students nationally enrolled in remediation who pass gateway courses within 2 years. However, none of these studies are based on randomized control trials or include rigorous analysis that controls for the impacts of other policies or covariates.

Another study by Kashyap and Mathew (2017) uses a combination of experimental and non-experimental methods to examine the impact of assigning remedial students to corequisite models of instruction. Students scoring above a certain threshold could enroll in the QR course, while students below the threshold were randomly assigned either to a prerequisite or corequisite model for a 1-credit course in arithmetic and elementary algebra. The authors find the corequisite-supported QR course had a mean grade equal to the QR course and higher than the prerequisite group. The overall success rate was actually *highest* in the corequisite course, with 49% receiving at least a B- and 79% earning at least a C-. These compared to 43% and 70%

for the standalone QR course and only 26% and 50% for the prerequisite-supported course.

However, several internal validity threats significantly limit the scholarly value of Kashyap and Mathew (2017). With only 155 students in the entire study, there are several plausible rival explanations that may account for these findings. The authors report that six sections were offered, taught by three different instructors, but only report aggregate data. However, without reporting *which* professor taught each class, there is the possibility that these results simply reflect instructor effects; while grade computations and assignments were identical, grading leniency as well as instructional quality could account for observed differences. The authors also do not report the *size* of each class section, leaving that as another possible explanatory factor. Finally, the grading procedure for the prerequisite course is unclear. The authors report grades on all 46 students randomly assigned to the prerequisite model. This would appear to imply that all 46 students who began the prerequisite course were included in final grade computations. If there indeed was no attrition, this would be somewhat surprising given the findings from other scholarship, since it would imply that 100% of students made it through the remedial coursework *and* enrolled in the subsequent course. This leaves the possibility that there were no enforced requirements in the prerequisite course, yet another possible explanation for the authors' results.

The best evidence comes from a randomized control trial by Logue, Watanabe-Rose, and Douglas (2016). This is the only such study to date, though others are forthcoming (see Daugherty et al., 2018). The Logue et al. study includes 907 students who were assigned to treatment, of which 717 enrolled into their assigned course. The student participants assessed as needing remedial algebra were randomly assigned to one of three groups: traditional elementary algebra, elementary algebra supported by a one-credit support "workshop", or directly into college-level statistics (the Statway® course from the Carnegie Foundation, discussed in a later section) with a one-credit support "workshop".

Differential rates of attrition from the study complicate the analysis, as more students assigned to the elementary algebra with workshop class did not enroll into the course they were randomly assigned (27% versus 17%). The authors do not report findings on those who did not enroll into their assigned course. However, the authors incorporate multiple statistics methods to add rigor to their findings. First, the authors include multiple model specifications, including the effects of covariates (algebra placement test score, gender, high school GPA, number of days to consent, and controls for missing values). Second, they use an instrumental variables approach to adjust for the attrition and produce estimates of the effect of treatment on the treated. In this case, the treatment effects are the difference between groups on the percentage who pass their assigned course.

The first outcome variable they explore is the total credits earned a year later. They find no significant difference between two treatment groups assigned to remedial algebra with or without support, but that students assigned to statistics earned four to six credits more than the two groups assigned to algebra. Since the authors report *college-level* credits, it is perhaps expected that those starting in credit-bearing coursework might accumulate more credits. However, the authors' estimates of credits *other* than those earned in statistics suggest that credit-placed students earned approximately three or four total credits more than either group of remedial-placed students. The second outcome was the students' success in the course they were assigned. They find that students placed into the statistics course performed much better (56% pass rate) in their course than those students taking either elementary algebra with the workshop (45%) or without (39%). These findings are robust to different model specifications, producing point estimates that varied slightly but coincided on significance.

One major limitation of the interpretation of these findings is that the outcome variable of *pass rates* is not the same among treatment and control groups. While other studies (e.g., Moss et al., 2014) have looked at *eventual* performance in credit-level mathematics, Logue et al. (2016) only measure success rates within the first course, whether that is algebra of the statistical reasoning course. However, given that the pass rate is *highest* for the statistical reasoning course, this is less a concern than some critics have expressed (e.g., Goudas, 2017). Indeed, these results are perhaps the most compelling evidence that students who might fail remedial algebra could pass a credit-level course when provided corequisite supports. When coupled with the findings from Bailey et al. (2010) that perhaps only half of those who complete their developmental mathematics requirements, the corequisite-supported course represents a potentially enormous improvement. If nearly 60% of students could pass the corequisite-supported course, while perhaps only half of the 40% remedial algebra completers successfully pass their credit-level course, this would represent a three-fold increase in the number of students passing credit-level mathematics.

Summary of Quantitative Literature

The quantitative literature, taken together, suggest that there is the potential for alternative approaches to improve the dismal success rates of developmentally-placed students. Overall, the RD studies appear to indicate that students at the margins of remediation may be just as well off in the short-run and long-term by starting in credit-level mathematics. The methodological limitations of RDs mean that similar conclusions are not supported for all students, and therefore that remediation may still be needed as an option for the least prepared of students. However, the multiple measures study by Ngo and Kwon identifies actionable measures that students can take to identify which students are marginally prepared. Lastly, if the findings from Logue et al. (2016) can be replicated and generalized, the corequisite model of instruction may produce striking increases to the number of students passing gatekeeper mathematics.

Literature on Corequisite Implementation

The articles forming the foundation of the research base for corequisites come from studies of the "Accelerated Learning Program" (ALP; see Adams et al., 2009, Cho, et al., 2012; Jenkins et al., 2010), an initiative for *English* remediation. In the ALP, the supplemental three-credit corequisite course was taught by the same faculty member as the credit-level course. The students were a subgroup (8 of 20) of the whole class. Corequisite courses in the ALP format may address some combination of remedial and college-level content; the overarching goal of in these ALP classes is to increase students' prospects of succeeding in college-level coursework. While the reforms at CCCC follow many similarities to those in the ALP, corequisite instruction is being implemented in considerably different ways in other states (see Daugherty et al., 2018). Whether the variation in implementation reflects a strength of the flexibility of corequisite education or a lack of caution amongst its adopters, however, has been the subject of considerable scholarly debate.

There are multiple models of corequisite support. These courses can take the form of a technology-based lab, additional academic support, extended instructional time, or a paired remedial course taken at an accelerated rate with the same student cohort. The literature on corequisite instruction offers some discussion into the possible structures of corequisite education. Many of the guides to implementations are in the form of research briefs by institutions such as the Community College Research Center (see Belfield, Jenkins & Lahr, 2016) or reports available electronically on the websites of advocacy groups such as Complete College America (2018).

As Goudas (2017) notes, many of the aspects that may have been critical to the success of the ALP are not present in all models of corequisite education currently being debuted across the country. At this point, the scholarly research on the impacts of corequisite instruction paired with mathematics courses is sparse. Much of it, discussed in a prior section of this literature review, emphasizes the statistical findings, with an almost sole emphasis on pass rates. Because relatively few models have been explored in the literature, there is relatively little information on what measures and design aspects facilitate student learning. The study by Logue et al. (2016) mostly explores the statistical analysis of results, with scant details on implementation of corequisite support into the statistics class. The excerpt below shows the extent to which implementation is discussed in the article:

> If students in statistics sections needed to review certain algebra concepts to understand a particular statistics topic, such as using variables in equations and different types of graphs, the workshop [corequisite course] leader would cover that topic in the workshop…. All workshops occurred weekly, lasted 2 hours each, and had the same structure: 10 to 15 minutes of reflection by students on what they had learned recently in class and what they had found difficult, then approximately 100 minutes of individual and group work on topics students had found difficult, and a final five minutes of reflection by students on the workshop's activities and whether the student's difficulties had been addressed. (Logue et al., 2016, pp. 584 - 585)

Though this description gives some indication as to the function of such courses, it does not give a rich description of what this group work consisted in or what other efforts the instructor may have taken to prepare the course.

The study by Kashyap and Matthew (2017) includes slightly more practical details of implementing a corequisite course. The authors provide four concrete examples on how the corequisite is used to supplement content in the QR course. This included an application of exponential decay to calculate the presence of an antibiotic after an injection of a drug. The authors discuss how instructors would review the prerequisite skills – exponent notation and computation with exponents – during the supplemental session, solving problems and asking students to complete similar exercises in groupwork. They state that their goal was to use these supplemental sessions to build skills as students were encountering the applied problem in the QR course. This approach could help address the problem discussed in Quarles & Davis (2017) of students in remedial algebra courses building algebra skills only to forget them by the time they reach credit-level coursework.

Another report of corequisite education, a research brief by the Community College Research Center (Belfield, Jenkins, & Lahr, 2016) discusses initial findings from Tennessee's recent implementation of corequisite education. While the report emphasizes the cost-savings under a set of assumptions about retention and corequisite-supported pass rates, it also briefly discusses some ways in which these courses have been offered. Among three community colleges discussed, two used the EM to teach both the credit-level courses and the supplemental course. Another college employed two versions, one in which students were paired with an accelerated 7-week remedial course followed by an accelerated 7-week credit-level course and another in which students took the corequisite course and credit-level course simultaneously as 15-week courses, each taught by the same instructor.

While the report optimistically reports that “students are likely to be much better off under a corequisite system” (2016, p. 6), there are caveats and unknowns. They note that “it is not clear to what extent the outcomes we observe, such as the higher college-level pass rates, were due to corequisite remediation per se…. The corequisite model has not yet been subjected to rigorous evaluation” (2016, p. 8). As with CCCC, during this time advisors at Tennessee were also directing more students to take courses *other* than algebra. They go on to note that during the period data were drawn from, Tennessee was undergoing other major reforms, including the Tennessee Promise initiative that offered scholarships for tuition-free attendance to two-year schools. The authors also note that “even to the extent that corequisite remediation is effective, it is *not clear precisely what practices work best* for different subject areas and students” (2016, p. 10, italics added). Furthermore, only 51% of students at the Tennessee colleges passed their corequisite-support credit-level course. For the nearly half of students that fail their corequisite-supported class, “why this is the case and what approaches can work for these students are questions for further experimentation and research” (2016, p. 10).

However, of the research thus far conducted on corequisite instruction, the authors of the first ALP program have offered some suggestions explaining why corequisite instruction works. Because the reform efforts at CCCC share many similar aspects to the early ALP study (Adams et al., 2009), and the ALP study has received considerable praise from advocates and skeptics of corequisite instruction alike (Goudas, 2017; Daugherty et al., 2018), this study may offer insights into the present research on *how* the details of corequisite instruction facilitate improvements to student outcomes.

Mainstreaming. Adams et al. (2009) argue that placing students at the margins of remediation directly into credit-bearing coursework has a positive psychological impact. Offering students an opportunity to immediately earn credits may boost their motivation and assist the transition into become college learners. This represents an improvement upon the potentially stigmatizing impact of requiring students to repeat material they struggled to master in high school; this reason is echoed by Logue et al. (2016) in their study applying the ALP to mathematics instruction.

Cohort Learning. Part of the ALP design borrows from the concept of learning communities by offering a small group of students the opportunity to bond through shared experiences and community. In the ALP in Adams et al. (2009), the eight students were in classes for a combined six hours per week. They argue that these facilitated opportunities for students to form a network of mutual support outside of the classroom on academic and non-academic issues.

Small Class Size. The authors hypothesize that the small group size limited behavioral issues and increased students' opportunity to form bonds. Furthermore, in a small class, students are more likely to have their individual questions addressed, essential to having the course serve its function of remediation.

Contextual Learning. By pairing remediation with college-level content, the remediation immediately becomes more meaningful. This contrasts with remedial courses, which may ask students to master procedural skills devoid of a context in which the skills are applicable. The opportunity to create meaningful contexts is facilitated by using the same instructor for credit-level and remedial coursework. Logue et al. (2016) theorize that the meaningful context offered by credit-level courses may actually make the material easier as well, by avoiding the purely abstract reasoning and procedural skills often emphasized in remedial algebra.

Acceleration. Many students fail to make it through the developmental pipeline due to the large number of courses students need to complete. The corequisite model aims to increase student success by reducing attrition, due to students failing standalone remedial courses or neglecting to enroll in credit-level coursework even after completing remediation.

Heterogenous Grouping. Adams et al. (2009) note that one issue with early mainstreaming models is that entire sections only included remedial students. By contrast, the ALP courses were comprised of 40% developmental and 60% non-developmental students. This ratio is expected to be comparable at the QR courses at CCCC. Adams et al. (2009) speculate that better prepared students, those not taking the support course, can act as role models, generating positive peer effects for marginally prepared students.

Attention to Non-Academic Issues. This last aspect combines two ideas discussed in Adams et al. (2009), attention to behavioral issues and attention to life problems. The designers of the ALP consciously worked in study skills and required students to make detailed plans of their study habits. Furthermore, they encouraged ALP instructors to acknowledge and work with the non-academic concerns of developmental students that may interfere with their academics. The small class size and existing network of relations between developmental educators and support staff at CCCC means that this aspect of the ALP framework, along with the others, might translate into a successful instructional transition at CCCC. The extent to which this is the case is discussed in chapter 4.

Critiques of the Scholarship on Reform Efforts

Not all scholars believe that reforms placing greater numbers of students into credit-level coursework are supported by rigorous research. Saxon et al. (2018) argue that it is a misinterpretation of the data to conclude that developmental education practices are failing. For instance, among those who fail to complete their first developmental course in Bailey, Jeong, and Cho (2010), 30% *do not even enroll*; given that placement into developmental does not appear to have an impact on whether students enroll (Scott-Clayton & Rodriguez, 2015), these students presumably would have “failed” regardless of their placement. Saxon et al. (2018) claim that the characterization of developmental education as failing can be self-perpetuating, as administrators create unreasonable sets of expectations to measure the success of those least prepared for college. Saxon et al. (2018) speculate about how reform efforts to accelerate students into credit-level mathematics are principally about costs, rather than student success. Financers of higher education could be looking to reduce the investment into developmental education, as in the case of Florida's reforms that were accompanied by a $30 million cut to the community college budget. On the other side, nonprofit organizations such as Complete College America or the National Center for Academic Transformation that advocate reforms could be exploiting the status of developmental education as failing as a pretense to pursue 501c3 funding.

Goudas describes sending inquiries to Complete College America to view the underlying data in their reports, requests that were responded to with documents no more detailed than the pass rates and graduation rates available from their website. Goudas draws the conclusion that their data "is not quality research and analysis into the effectiveness of corequisites" (2017). From his (highly critical) review of the literature, Goudas concludes that only the ALP efficacy studies (Cho et al., 2010; Jenkins et al., 2012) and the study by Logue et al. (2016) provide accurate and reliable analysis of corequisite remediation.

There is some evidence that advocates of corequisite instruction like Complete College America is overstating the success of corequisite reform efforts in its reports. The glossy infographic-laden but self-published *Spanning the Completion Divide* (2018) on its website presents outcomes but offers few citations. For instance, it reports that 64% of Indiana students passed gatekeeper mathematics after corequisite implementation. If these numbers are the same as those reported by Royer and Baker (2018), it should be noted that the 64% in the first semester of implementation was the *highest*. Later, these pass rates dipped slightly to 61%, 61%, and 58% in the subsequent three semesters.

The fact that a new round of reforms is occurring at all points to a disappointing impact of the previous reforms. The dramatic student improvements reported in some research on the EM (see Twigg, 2005; 2007; 2011) apparently did not materialize at colleges in the VCCS. This positive research, however, was put out by the NCAT, the same nonprofit group advocating the widespread adoption of the model. Research by Webel, Krupa, and McManus (2017), scholars unaffiliated with the nonprofit, note that in the NCAT's reported findings, the results from some colleges were excluded for unclear purposes. Their own research produces more reserved conclusions about the effectiveness of EM. They note that the EM was beneficial for certain students, notably those with higher levels of preparation. These findings have been echoed in prior research done at a VCCS college (Dass, 2011). This research, conducted as part of a pilot of the instructional software in an unpublished capstone noted that computer-based mastery learning provides benefits to some students, those comfortable working with the software. However, among its recommendations were the students be given multiple options to satisfy developmental requirements, and that the method of computer-based developmental instruction may not ideally serve all students.

Certainly, skepticism is needed when those advocating reforms claim to offer the “silver bullet for higher education” (Twigg, 2011), as was the case for the last set of developmental reforms within the VCCS. A qualitative study by Carafella (2016) points out that dramatic improvements in selected studies can lead some administrators to approach redesign with excessively optimistic expectations. Perhaps such expectations were partially responsible for CCCC phasing out the EM, the last attempt at reforming developmental mathematics instruction.

Summary of Literature

The quantitative estimates from the past decade of literature call the traditional practices of developmental mathematics into question. At best, it would appear that sending students to remedial algebra prior to taking college coursework results in slightly better course grades in subsequent gatekeeper mathematics and higher retention in the first year of enrollment. At worst, students who may have been able to otherwise pass credit-level mathematics are delayed or even discouraged from completing their degree. Upwards of 40% of students fail each course, and when students must take multiple remediation courses, this has a negative cumulative effect. Even among those who complete remediation, 40% do not successfully complete credit-level mathematics, either because they do not enroll or because they fail credit-level courses even after receiving remediation.

Meanwhile, colleges experimenting with alternative methods of developmental delivery have seen sizeable improvements to the percentage of incoming students passing credit level mathematics within the first two years. Offering corequisite remediation at the same time as a college-level QR course appears to yield increases in student pass rates, while also reducing the time required to complete remediation. In some research, pass rates of these credit-level courses exceed those of the remedial algebra courses themselves, undermining the idea that such courses are a necessary foundation for credit-level mathematics. However, with the literature on the corequisite model of developmental mathematics still in its nascent stages, there remains much that is unknown. Improvements demonstrated by scholarship on previous reforms to developmental mathematics have not always produced similar improvements to other contexts. Furthermore, there remains the question of *how* corequisite instruction occurs in practice, *whether* this reform will improve student success at each college implementing it, and *why* a particular implementation does or does not improve student outcomes. This case study offers an excellent potential to identify potential pitfalls that may interfere with implementation and provide insights into the conditions required for success. The methods for this case study are overviewed in the next chapter.

Chapter 3 - Methodology

This chapter connects the findings and recommendations from the literature to the problem of practice, establishing the course of action taken in the present research study. As discussed in the first chapter, CCCC is undergoing several reforms to curriculum and instruction and began implementation of a corequisite support course for Quantitative Reasoning in Fall 2018. From the second chapter, much remains unknown about the processes by which students fail or succeed in developmental education in general, and corequisite models of instruction in particular.

This chapter on methodology begins with a rationale for the use of qualitative methods to assess the impact of corequisite instruction. It follows with a statement of paradigm assumptions and a discussion of the researcher as instrument. After describing the rationale for choosing the site and participants, the chapter overviews prior exploratory research that informed the choice of research topic. Next, the methodology section includes a process for data collection and the role that each method of collection contributes to the study. The chapter ends with the data collection procedures and method of data analysis.

Rationale for Qualitative Case Study Research

As introduced in the first chapter, the interaction of multiple simultaneous reforms makes it challenging to evaluate the impact of any one individual reform. Looking only at those measurable outcomes stated by the VCCS can provide estimates of overall reform efforts, but not specific measures. For example, the use of MM placement could continue the trends observed in the VCCS' modularization efforts, with a higher *number* of students passing, but lower *rates* of passing courses. Given that placement measures now use an interaction of GPA and high school coursework, on top of other measures such as ACT/SAT scores and placement testing, it is difficult to even assessment the impacts of placement measures themselves. Another challenge of using quasi-experimental methods is that they often require large data sets to produce statistically significant results (Angrist & Pischke, 2014). However, the fact that implementation details may vary by college complicates the use of such methods when using a dataset including multiple colleges.

Furthermore, focusing solely upon the student outcome goals outlined by the VCCS does not capture the process by which a new developmental mathematics program may change student outcomes. Some quantitative studies specifically refer to the need for qualitative research in their discussions; Xu and Dadgar note that "qualitative analysis is thus needed to provide more information about the specific mechanisms that contribute to the success or failure of remedial education" (2018, p. 78).

According to Gerring (2004), while quantitative methods are useful for providing estimates of *causal effects* of treatment, case studies are better suited to identifying *causal mechanisms* – *how* and *why* causal effects come about. Merriam (2002) discusses how a problem is suited to qualitative research if aims to form an *in-depth understanding* of a research phenomenon and the processes by which humans act and make meaning. In this research, case study methodology provides the opportunity to explore how the corequisite model of instruction may address issues existing in the prior model of developmental instruction and how practitioners choose to teach within the new format. Finally, Erickson notes that situations "when one needs to [know] more about… [t]he specific structure of occurrences rather than their general character and overall distribution" (1986, p. 121) are well-suited to the use of *interpretive* qualitative research.

Paradigm Assumptions

I approached this research study with an interpretivist paradigm. Following Lincoln and Guba, I believe that there are "multiple, apprehendable, and sometimes conflicting social realities that are the products of human intellects" (1994, p. 111) and that these realities are subject to processes of revision. Consequently, this research presents my understanding of the constructed realities of instructors, administrators, and students as they navigated the corequisite model of instruction within the new system of reforms. My paradigmatic assumptions reflect my constructivist approach to teaching and my belief that meaning is co-constructed in interactions between teacher and student, or in this case, between researcher and participants. Furthermore, I believe that mathematics is a human social endeavor whose practices reflect the values and culture of its members (discussed in Lave, 1988). Following Schoenfeld (1992) and Garofalo (1989), I contend that the beliefs of students and teachers regarding the nature of mathematics shape their classroom practices, and that classroom practices lead students and teachers to form beliefs about learning mathematics.

My interpretivist paradigm assumption is further reflected in my beliefs on how educational research can be valuable and useful. The goals of my research are informed by Flyvbjerg's (2001) recommendation that social science research should build practical wisdom. Or, as Schwarz-Shea and Yanow (2012) put it, interpretive research "bear[s] on action as well as understanding" (p. xii). Following Guba and Lincoln (1985), I contend that one aspect of conducting interpretive qualitative research is to deal with the fact that both theories and facts are value-laden. Also, following Flyvbjerg (2001), I believe that these research findings are sensitive to context, including the role that power relations and values play in social interactions and structures. Consequently, the recommendations provided by this research acknowledge the role of values and power and how my position as researcher may impact my research. This issue is elaborated upon in the following section.

Reflexive Statement

I have worked as a full-time faculty member at CCCC for the past six years. During that time, I have formed my own professional relationships with colleagues and understandings of organizational structures and department policies and practices. I also taught a section of corequisite-supported QR course during the period of data collection. To avoid ethical concerns that arise with having power over one's research subjects (Miles, Huberman, and Saldaña, 2014), I did include any of my own students within the research. However, my own experiences teaching this format of class informed my data collection procedures and provided insights during analysis of the data. My experience with planning and teaching the QR course also prepared me to distinguish between content that was remedial for the QR course and content that was covered as part of course objectives.

In addition to my role as faculty member teaching one of these corequisite courses, in fall of 2018 I began a two-year term as the chair of the department of mathematics at CCCC. My primary duty as departmental chair has been to serve as a liaison between the administration of the larger academic unit (the Department of Business, Mathematics, and Technology) and the mathematics faculty. This includes organizing and leading regular departmental meetings in which administrative policies and practices are communicated to full-time and adjunct faculty. I have also been responsible for communicating the concerns, suggestions, and uncertainties to administration and participating in dialogues in situations of conflict. As part of additional duties, I have been involved in the scheduling process and ensuring that course sections are appropriately staffed.

The first anticipated impact of my unique role within the institution is on the access to research participants. Since the department chair is jointly responsible with the academic unit for staffing decisions, this may disincentivize faculty participation. This could particularly be so among adjuncts who may interpret my role as *evaluator*, rather than researcher. Consequently, I strived to minimize any concerns of power imbalance by regularly stressing the voluntary aspect of participation in research throughout the project. Additionally, in communications with administrators and gatekeepers I emphasized that the goal of observations and interviews was to address the problem of practice as identified in this study. To minimize the potential for ethical concerns, I did *not* include adjunct faculty in this research. Instead, I only observed full-time faculty, over whom I hold no authority regarding pay, contracts, tenure, promotions, or any other financial considerations. As department chair, I have no authority to require or prohibit full-time faculty from engaging in any activities related to their employment. Because scheduling decisions regarding full-time faculty are based on seniority, this minimizes the ethical concerns of conducting research with full-time faculty.

In sum, this position has offered an excellent opportunity to access pertinent information concerning the problem of practice. To address the impact that serving simultaneous roles as instructor, administrator, colleague, and researcher, I tracked methodological decisions and inspirations in a methodological journal. According to Lincoln and Guba (1985), reflexive journaling offers an opportunity for the researcher to acknowledge sources of personal bias and prior conceptions. The decision to include value decisions in the reflexive journal also reflects my paradigm assumptions that the researcher should strive to acknowledge his or her own subjectivity. Within this reflexive journal, I have taken care to note instances that may have impacted my research and data collection process to the best of my ability.

I began this journal in January 2018 when I began considering this capstone topic. As Yin (2017) notes, case studies are by their nature bounded, but these bounds are not initially precise. The early portion of my journal discusses influential readings, online resources, interpersonal communications, and previous research that has informed my capstone research decision-making process. It also charts my decisions for gathering data as part of a course in case study methodology that informed this research and is discussed in a subsequent section. The methodological journal also recorded instances in which my role as department chair may have impacted data collection. It also records instances of meetings with faculty and administrators that impacted data collection.

Sampling Rationale

Stake (2004) draws a distinction between the purpose of case studies as *instrumental* versus *intrinsic.* A case study is instrumental in the extent to which it seeks to illustrate some general concept, comparable to Yin's (2017) notion of a *theory testing*. By contrast, a case study follows intrinsic purposes if it is conducted primarily in pursuit of studying a phenomenon *for its own sake*. This present research is driven primarily by intrinsic interest in the problem of practice of corequisite instruction and its intersection with other simultaneous reforms. As discussed previously, the choice to study CCCC reflects my interest in improving implementation at my own institution. This is particularly true because, as the department chair, I have been involved in the implementation of corequisite instruction. The recommendations of this research study will be specific to the context of CCCC. However, they may offer lessons to the broader research community, particularly those considering implementing corequisite models of developmental mathematics instruction.

Description of Site

The college in this study is a mid-sized community college in the VCCS. According to internal statistics reported by the institutional research department from fall 2017, 78% of students are part-time and 22% are enrolled full-time, making for the equivalent of approximately 3000 full-time students. The student body is broadly reflective of the counties served by the college (69% white, 13% African-American, 7% Hispanic, 5% Asian, and 5% multiple race or other), with slightly more female students (58%) than male (42%). The performance of the college on the measures discussed in the 2014 VCCS report discussed in the first chapter is quite comparable to the overall system performance.

There are several academic support resources available at no cost to all students at CCCC. First, there is a mathematics tutoring center in which students can receive individual assistance. The tutoring center is staffed by wage staff peer tutors, ranging in education from current students to bachelor's degree recipients. Second, students have access to academic coaching through the college's writing center. Third, a student success office at CCCC reaches out to students flagged as struggling through the college's early alert system. Finally, each degree program at CCCC requires a 1-credit SDV course; this course, which is required to be taken early in a student's academic career, introduces the student to these resources and others available through the college library and academic advising and financial aid offices. While these services are not a major focus of the present research, they are one aspect of the context required to understand the role of corequisite support as one of multiple support services offered by the college.

Access and Role Chosen

As a faculty member and incoming department chair at CCCC, I have what Adler and Adler (1987) term "complete membership" within the institution. Lofland et al. (2004) note that such insider status comes with the advantage of knowledge of the institution and relevant individuals. Furthermore, having conducted prior research at CCCC, many of the potential participants had already been acquainted with some of my research interests, which assisted in the process of recruiting participants.

Because part of my task as mathematics department chair is to oversee the implementation of corequisite instruction and identify challenges in real-time, I held the dual role of participant-observer. According to Yin (2017), there are trade-offs to conducting participant-observer research as a decision-maker within an organizational setting. On one hand, having an insider position allows the research to render a potentially more accurate representation, and provides opportunities to access or influence the phenomenon being studied. This status does however come with a greater potential for bias, as my familiarity with colleagues may have impacted how I came to understand corequisite instruction. While this could limit the generalizability of my findings, this role was nevertheless suited to the goals of this research of solving a problem of practice within the specified context.

Participants

The participants of this study include practitioners serving various roles at the college, including faculty, administrators, and support staff. The faculty I chose to observe and interview were selected based on schedule availability and their willingness to participate. Other practitioners were identified using purposeful sampling based on my familiarity with their involvement in matters concerning developmental education. The table below gives a role-ordered matrix of participants who participated in interviews and a brief description of how they are involved with relevant reforms. The two instructors whose courses I observed, Mr. Bridges and Dr. Heyward, are described in subsequent detail.

Table 3. Role-ordered Matrix of Faculty & Administrator Participants

Role		Relevant roles at CCCC
Mathematics Faculty	Mr. Bridges	• Teaches credit-level & developmental mathematics courses • Taught a pilot corequisite course for precalculus in Spring 2018 • Taught MTH 154 & MCR 4 in fall 2018
Mathematics Faculty	Dr. Heyward	• Teaches credit-level & developmental mathematics courses • Former mathematics department chair • Taught MTH 154 & MCR 4 in fall 2018
Mathematics Faculty	Ms. Miller	• Teaches precalculus & calculus courses, and MTH 9 • Co-designed MTH 9

Mathematics Faculty	Ms. Underwood	• Teaches a variety of credit-level and developmental mathematics courses • Co-designed MTH 9
VP – Institutional Effectiveness	Dr. Lamb	• Compiles data on institutional performance measures • Writes and delivers reports on program performance
VP – Instruction & Student Services	Dr. Smith	• Supervisor to academic division deans • Facilitates implementation of matters relevant to curriculum, instruction, and student concerns • Communicates VCCS policy to faculty
Division Dean (Left this role in summer 2018)	Dr. Fisk	• Academic dean overseeing administration of mathematics and other departments • Creates schedules, resolves academic issues
Director of Enrollment Management (Interim Division Dean starting summer 2018)	Dr. Wainwright	• Coordinates placement and advising measures with local high schools • Leads recruitment efforts with local schools
Lead advisor	Mr. Irons	• Coordinates academic advisors • Advises students • Trains faculty on advising policies
Student Success Coordinator	Mr. Green	• Oversees support staff reaching out to struggling students

Mr. Bridges is a full-time instructor at CCCC in his fourth year of teaching at CCCC. He teaches a wide variety of courses, from developmental courses to precalculus, calculus, statistics, and discrete mathematics. He has a master's degree in Mathematics Education and over a decade of teaching experience at multiple K-12 institutions. Dr.

Heyward has been a full-time instructor at CCCC for over a decade and has completed a Doctorate of Education in Curriculum & Instruction. She teaches developmental mathematics and several credit-level courses, including finite mathematics, precalculus, and calculus I, II and III. She has previously served as department chair at CCCC at the time when EM reforms were being introduced. She also helped design the curriculum objectives for the MTH 154 course at the VCCS level and implement the course at CCCC.

Prior Exploratory Research

This present research study is informed by two prior studies I conducted exploring the developmental mathematics program at PVCC. Though the primary focus of the present research is to study the corequisite model of instruction, these previous studies included a total of 15 hours of observational data on the EM and 15 hours of interviews relating to issues faced by practitioners involving developmental mathematics. All studies received an exemption from the University of Virginia's Institutional Review Board and approval from the relevant authorities at CCCC. The first study explored the computer-based format of instruction at the college and faculty members' responses. The findings from this initial research, reported in Beamer (submitted for publication), are supported by 15 hours of observational research and 5 hours of interviews with faculty who taught in the EM. The instruction, technology, policy, and assessment issues that emerged inspired a second study investigating practitioner perspectives towards the goals of reforms generally.

This second study followed what Yin (2017) describes as an *exploratory* purpose. During this phase, I conducted 10 hours of semi-structured interviews with practitioners on the topic of what contributions educational research can bring to developmental mathematics at the college. All of the participants involved were involved in one interview. The interview questions explored topics around developmental mathematics generally, following the prompts below:

- How does your work at the college involve developmental mathematics?
- How do you think developmental mathematics instruction is going at PVCC?
- What are the challenges to implementing a successful developmental mathematics program?
- What is your understanding of how the developmental mathematics initiatives fit together?
- What is purpose of developmental mathematics?
- If you could design the developmental mathematics program, what would it look like?
- Where do you see developmental mathematics instruction heading in the future?

Initial analysis of the data revealed that there was considerable uncertainty regarding the implementation of the corequisite model for the new QR course. These interviews serve as a primary source of data to addressing the first research question on the goals and expectations of the corequisite implementation and its interaction with other reforms. Furthermore, the findings presented in Beamer (submitted for publication) themselves provide insights into the first research question in this research capstone.

One topic discussed within Chapter 4 of this research capstone concerns the findings regarding the EM and their implications for corequisite reforms.

Data Collection

In this research study, I employed four methods of data collection: observations, interviews, documents, and surveys. According to Denzin and Lincoln (2011), the use of multiple methods adds richness and depth to qualitative inquiry. Furthermore, a plurality of methods in interpretive case study research helps the research to achieve a *crystallization* of findings (see Ellingson, 2009), analogous to the goal of triangulation as described in Yin (2017) and Miles, Huberman, and Saldaña (2014). These data were collected after receiving consent forms from instructors (see Appendix B).

Observations

The principle method for addressing research questions relating to instruction in corequisite courses is 20 hours of classroom observations. Based on schedule availability and their willingness to participate, these observations took place in two sections of MCR 4, each taught by a full-time mathematics faculty member. One other section of MCR 4 was taught by a full-time faculty member who was not included because the section was added as the semester was beginning. Finally, two other sections of MCR 4 were taught by adjunct faculty. However, these faculty were excluded from research to avoid potential ethical dilemmas of conducting research on adjunct faculty while serving as department chair. Each of the MCR 4 courses met twice weekly, for 50 minutes in length, scheduled either immediately before or after the paired MTH 154 course. Observations took place starting the fourth week of classes, following approval from IRB and the capstone committee. Observations continued regularly throughout the semester, and I tracked the decisions behind which days to observe in my methodological journal.

These observations explored the patterns of interaction between instructor and student and the daily rhythms of the MCR 4 course. The observations were guided by a Protocol informed by the constructs established in the conceptual framework. The protocol is shown below in Table 4.

Table 4. Observation Protocol for Corequisite Support Classes

Aspect	**Focus**	**Question**
Class structure	*Instructor activities*	What activities does the instructor engage students in (e.g., lectures, worksheets, assisted independent work with computers)
	Student engagement	To what extent are students actively participating in class activities?
Curriculum	*Remediating & re-teaching*	To what extent does instruction re-teach QR topics versus teach remedial content (i.e., content not explicitly tested in QR coursework)
	Integration	How are discussions of remedial content embedded into QR content?
Resources & Materials	*Teaching resources*	How does the instructor use prepared materials during instruction?
	Learning resources	How do students use learning resources during class?
Instruction	*Misconceptions*	How do instructors identify and address individual students' prior knowledge and misconceptions?
	Skills-building	To what extent does instruction focus on building procedural skills versus conceptual understanding or metacognitive skills?

During observations, I recorded the activities that the instructor engages in, the resources used, and the apparent function, in terms of how it serves a remedial or supportive function. Whenever possible, I asked instructors immediately before and after their course what they had planned for the course, and how the class went. For days when I did not observe classes, I had brief, informal discussions with faculty in which I asked them to summarize the day's class. Though I was teaching another section of these support courses, I did not gather observational data from my own students out of practical and ethical concerns that arise one studying individuals over which one has authority (in this case, grading authority). However, at some points, my interactions with my own students had impacts on my data collection and analysis. I logged these instances and other factors that may have informed data collection in my methodological journal.

In addition to observing classrooms, as an insider of the institution under study, I have had access to what Lofland et al. (2004) term private settings. These include *departmental meetings* and *informal conversations* with faculty and administrators. Lofland et al. (2004) note the ethical as well as practical considerations when conducting research in public or private spaces, emphasizing the need to consider potential risks and benefits. At points I encountered such situations that offered valuable insights into addressing the research questions, and to the best of my ability I let members of these discussions know that their comments may provide theoretical insights to my research. Lofland et al. (2004) point out that no research can be entirely candid with their research intentions. This is especially so in case study research in which one's precise research interests may evolve.

Interviews

Interviews formed the primary source of data collection in this study for addressing the research questions regarding practitioner goals, expectations, and evaluations of the corequisite courses. These interviews were invaluable to answering these research questions because of their ability to provide insights into participant perspectives and explanations of events (Yin, 2017). As mentioned, 15 hours of interviews with practitioners had already been conducted in spring 2018. Many of these interviews explored topics in addition to the corequisite reforms. Excerpts from these interviews are included within this capstone as they provide information on the landscape of reforms at CCCC.

Following the advice of Kvale (2007), I began each interview with a briefing, in which I introduced my purpose for conducting research and concluded with a debriefing in which I offered participants the opportunity to ask questions. These interviews followed a semi-structured format, with a focus on exploring themes rather than participants' responses to a particular wording or ordering of questions. The first interview with faculty regarding the corequisite instruction was conducted approximately halfway through the fall 2018 semester. Following the responses of instructors, I wrote up a second set of follow-up questions to pose at the end of the semester. These questions are given in Appendix A.

Since many of the participants in my case study are colleagues, I already had established relationships with them. Seidman (2006) discusses how relationships between interviewer and participant are central to a researcher's ability to generate useful data from interviews. My established rapport with participants may have increased the likelihood that participants were open to sharing their experiences. However, as Seidman (2006) notes, establishing the right level of rapport is essential to accurately represent the experiences of participants. Consequently, I strived to maintain a greater level of formality with colleagues during the interview process than I might otherwise have in other collegial interactions. Throughout my interviews, I reflexively considered the role that my status as insider had on the responses of participants. Following Seidman (2006), I took care to limit my own interaction by sharing my experiences only occasionally and avoiding reinforcing participant responses. Given my additional role as department chair involved in conversations with faculty as well as administration, there were many times I found myself experiencing similar pressures and frustrations to those I was interviewing. Though my familiarity with issues may have made me highly sympathetic to practitioner concerns, my multiple roles at the institution exposed me to a variety of perspectives.

Documents & Artifacts

Yin (2017) remarks that documentation has multiple strengths as a method of data collection in case study research. Documents, including curricular objectives, emails, meeting agendas, and administrative memoranda, have the advantages of being stable and unobtrusive. However, because my insider status can create potential ethical dilemmas (Lofland et al., 2005; Miles, Huberman & Saldaña, 2014), I did not report any private information that I had access to (e.g., emails) without the expressed consent of those involved in the creation of the documents. However, these sources of data did at points provide valuable insights into the rationale behind implementation decisions and the difficulties and concerns encountered as they are put to practice. As Yin notes, documents are valuable as they offer specific details that corroborate information from other sources. The main documents I used during this research were the VCCS policies and reports along with instructional materials used during MCR instruction.

Finally, to provide insights into how students regard these corequisite courses, I gathered aggregated, anonymous data on course grades for students in the MTH 154 course. This data allows for a comparison between students enrolled into the support course and those placed directly into the QR course. To limit the effects of variation across instructors, this data only captures the grades of those students who were enrolled in a face-to-face MTH 154 class with the instructors involved in this study.

Surveys

The final source of data was surveys gathering information pertaining to RQ 4, on student responses to corequisite instruction. I developed these surveys in response to themes developed during observations and interviews with faculty. I shared these surveys with the two instructors teaching these courses to elicit their feedback and make corresponding adjustments. These surveys and the full student responses to them are included as Appendix C.

Data Analysis

Following Erickson (1986), I used an inductive approach to coding sources of data, informed by the open-coding techniques outlined in Corbin and Strauss (2008). My emphasis was on using *in vivo* codes that use the language of participants. Miles, Huberman, and Saldaña recommend in vivo codes because they “prioritize and honor the participant’s voice” (2014, p. 74) and offer good leads into identifying patterns. Furthermore, the use of in vivo codes aligns with my interpretivist paradigm by capturing the meaning-making of individual participants.

After initial coding, I synthesized preliminary findings in the form of *assertions* in *analytic memos*, as described in Erickson (1986) and Miles, Huberman, and Saldaña (2014). Through a process of seeking confirming and disconfirming evidence, or what Erickson (1986) describes as *analytic induction*, I revised these assertions and findings as needed to match the data. These assertions also informed my process of data collection at various points, logged in the methodological journal (Appendix A). Finally, I used *member checking*, sharing initial findings with participants to ensure that research findings accurately captured the voice and experience of participants (Yin, 2017). The process of sharing findings with practitioners also has the added benefit of creating solutions to the problem of practice in real time.

The assertions in the research findings are also accompanied by *analytic vignettes*, after Erickson (1986). These vignettes are a *composite* of multiple observations, interviews, and descriptions in journals into a coherent narrative synthesis. Finally, I also utilize *visual displays* of data, such as role-ordered matrices, as recommended by Miles, Huberman, and Saldaña (2014). In addition to presenting data in ways that assist the reader to make sense of results, the use of these diagrams is "itself a focusing and forcing device that propels further analysis" (p. 118).

Chapter 4 – Findings

This fourth chapter presents how the corequisite support classes were implemented in reference to the four research questions stated at the end of the first chapter. Findings are organized thematically by research question, presented in the format of Erickson's assertions with supporting quotations, observational data, documents, and surveys. This thematic ordering also follows a roughly chronological order, beginning with the lessons learned from the last EM-based reforms that modularized the developmental curriculum and led to computer-based instruction. The findings follow with how the corequisite support courses were planned and what took place within these classes from instructor and student perspectives.

RQ 1: What are practitioners' goals and expectations for corequisite reforms at CCCC?

The first research question investigates how the corequisite reforms changed upon prior practices at CCCC and the perspectives of those involved in the reform process. The interviews capture perspectives of various practitioners in the spring prior to reforms and those of two faculty teaching these courses as they learned lessons in their first semester. These perspectives are presented to offer additional insights into the ways in which these practices and beliefs impacted the rollout of reforms. Following initial data analysis, the scope of this question expanded to address the matter of the conditions under which these corequisite reforms might be successful. The assertions addressing this research question begin with how lessons from the previous reforms impacted the implementation of the new reforms. They conclude with the agreements and disagreements among practitioners regarding their support of the corequisite reforms and their outlook for the future landscape of developmental education at CCCC.

Assertion 1: The EM reforms at CCCC were broadly viewed as unsuccessful both for their low pass rates and their failure to prepare students for credit-level mathematics

The faculty, support staff, and administration involved in the study were all united in a sense of disappointment about the how the implementation of the EM had gone. The original decision to adopt the EM was led by administrators at CCCC, as was the decision to phase out the EM when it was clear to them that it was not working. Three participants in this study were administrators at the time of interviews in spring of 2018. The Role-ordered matrix below includes a brief quote from each administrator on their perspective on the need to move away from the EM.

Table 5. Role-Ordered Matrix: Administrator Perspectives on the EM

Dr. Lamb (VP – Institutional Research)	"Based on the data, we're not getting students to the finish line… students passing [developmental math] is 55%... versus [developmental English] which is 76%."
Dr. Smith (VP – Instruction & Student Services)	"We've had some successes, I can't say that it's been an abject failure. But we don't see the needle moving enough to say, 'Oh my God, we found the cure!'…. We implement something at a scale and it doesn't work when we think it's going to work. And so we keep on that cycle."
Dr. Fisk (Dean of Business, Mathematics, & Technology)	"The [EM] program we have right now stinks. It's not a personnel issue… it's that we never thought about *instruction*; we thought about *structure*…. We don't ever take a step back and say, 'Wait a minute, how does developmental prepare them for success?'"

During interviews, each of these three administrators emphasized three primary measures by which they evaluated the success of the college's developmental education practices. These measures, in alignment with the VCCS reform objectives mentioned in the discussion of the Problem of Practice, were: (1) developmental completion rates, (2) rates of success in subsequent college level mathematics course, and (3) year-to-year student retention rates. Though each administrator admitted that these measures had their limitations, they nevertheless cited them as evidence that the EM reforms had not worked at CCCC. Simply put, the dramatic successes reported in research by the NCAT (e.g., Twigg, 2005; 2007; 2011) failed to materialize at CCCC. This was despite faculty reports of attempting to adjust instructional practices, policies, and software.

The EM was not without some apparent successes. As has been identified in other research on the EM (e.g., Webel et al., 2017), a handful of students at CCCC appeared to thrive in this model. Each faculty in this study who taught one of these courses over the past two years shared an experience of working with a student who excelled in the EM. The self-paced format of the EM allowed students to complete the developmental sequences at an accelerated rate, provided they had the skills to self-remediate. Dr. Heyward, for example, identified an instance of one student who completed four modules in a single five-week session, and other faculty shared similar anecdotes. Under this positive interpretation of the EM, the self-paced format gave an opportunity for students who had not received adequate preparation or had been out of school for some time to brush up on skills and prepare for later coursework.

However, for every student completing these courses at an accelerated rate, there were many others who struggled to complete a single module in a five-week session or even an entire semester. A prior research study at a VCCS college had anticipated that some students might struggle with a self-directed computer-based instructional software and had recommended that instructional delivery be differentiated to respond to student needs (Dass, 2011). However, this format was the only one available at CCCC. Some faculty saw the few students who made progress in the self-paced format not as a success of the EM, but rather as evidence that some self-driven students would thrive under virtually any instructional model. By this alternative interpretation, such students may simply have been unnecessarily assigned to remediation; their accelerated rate of completion may instead have been evidence that they had little to learn in these developmental courses.

While the administrators were mainly bothered by the lack of improvement in pass rates following EM reforms, faculty were primarily concerned about the pedagogy and student learning taking place in the computer-based instruction of the EM, discussed in detail in the next assertion. The mathematics faculty as a whole had never been enthusiastic about adopting EM in the first place. A few of the faculty opinions are highlighted in Table 6 below.

Table 6. Faculty Perspectives Towards EM Reforms

Mr. Bridges	"It's a drill and kill, memorization, pass the quiz, pass the test, [and] move on…. The questions end up so similar from the homework to the quiz to the test, it's like, 'Oh, I got this question wrong on the quiz last time, so let me just do the other thing this time'. And they don't know why, they just got it wrong, so they'll try this other thing that seems to work."
Dr. Heyward	"I don't like that we keep switching every two years to trying a different implementation instead of just picking something [and] try to make it the best it can be. I don't think we are really getting a chance to do that because we keep modulating."
Ms. Miller	"[The MTTs on the computer] in my opinion are what I call a 'monkey with a stick' process. This is a sample problem, you get to look at how this is all worked out, so if you learn it looks like this, you're supposed to do this. If I push the stick on this button, food comes out the slot."
Ms. Underwood	"[Students in MTT courses] are trying to devise a way [to get the right answer] without actually understanding it. All the effort that you've put into devising how do you get the right answer, you could have learned how to do it with the same amount of effort."

The quotes suggest that many faculty did not see the instructional format as producing the desired learning outcomes. All of these faculty taught gatekeeper courses and all but Ms. Miller had taught the MTT courses and thus had personal experience, both with what was expected in credit courses and the work that students in MTT courses were producing. Ms. Miller, the longest-serving mathematics faculty at CCCC, thought that the instructional software encouraged to learn by imitation, a step in the wrong direction from the developmental courses that existed prior. From her anecdotal experience, students entering courses like precalculus after taking MTT courses were less prepared than those who finished previous developmental sequences.

At the same time, some faculty expressed frustration that the administration had not given them adequate time to improve instructional practices and policies in the EM. Faculty had tried two alternative instructional software systems and were still experimenting with policies on how to keep students on pace to complete their courses as scheduled. A team of three full-time faculty, including Dr. Heyward, regularly met to discuss policy and communicate decisions to adjunct faculty teaching developmental courses. They shared concerns that the transition to MCR courses might encounter similar growing pains and end up being judged as a failure before they are given adequate time. These concerns echo those brought up by Saxon et al. (2018) on the self-perpetuating cycle of developmental reform. In that cycle, models of developmental education are judged as failing, rejected, and hastily replaced by an alternative model. When the implementation is poorly executed, it may fail to replicate any improvements noted in successful reforms documented in the literature.

The faculty teaching these developmental courses were bothered by the low pass rates and the number of students who completed only one or two modules in a fifteen-week block when they were enrolled in three of these courses. For faculty teaching credit-level mathematics as well, their major concern was that the instruction in these courses was not adequately preparing students for their subsequent coursework. With the exception of some students who needed to satisfy modules as a program prerequisite, such as for nursing, most needed these courses to qualify for gatekeeper mathematics. When asked about the purpose of developmental mathematics, interviewed practitioners all described its function to build a mathematical foundation or increase student success in college mathematics. The two are certainly related, though faculty emphasized the former while administrators and support staff the latter. Faculty were curious and somewhat skeptical about the longitudinal success rates of MTT-completing students. Ms. Miller was perhaps the most critical among the faculty about the ability of the computer-based instruction to prepare students for credit-level mathematics, particularly for precalculus.

> The whole point of developmental [education] is to help them learn those foundations that they don't have… It's there to help strengthen their skills so they can go on confidently. If [students who complete MTT courses] come to us in precalculus and are confident, they're delusional, mostly.

I originally thought about exploring the longitudinal outcomes of these students in the present research. However, the decision to abandon the EM format meant that this question was no longer as relevant for addressing the problem of practice. The hunch of the faculty was that the students who completed developmental coursework in the EM were less successful in subsequent coursework than those who went through an earlier developmental system, perhaps indicating that they had not formed a strong foundation.

Many of the faculty based their judgments on their anecdotal experiences rather than a detailed exploration of data. There are assuredly many more lessons that could have been learned about the EM, the outcomes that it produced, and what CCCC could have done better. However, by the fall of 2018, CCCC began phasing out these classes, with the last planned MTT courses scheduled for spring of 2019. The demand for such courses was already being reduced by Multiple Measures placement, along with the corequisite courses and other developmental alternatives. In the 2018-2019 academic year, CCCC also began to offer “bundled” developmental courses that grouped together multiple modules into a single course. These effectively reversed the curriculum modularization and computer-based instruction of the EM. While a detailed exploration of these “bundled” courses is outside of the scope of the present study, the move to replace MTT courses with a more traditional instructional format is further evidence of the failure of the EM at CCCC. As CCCC transitions away from the EM, it is worth reflecting upon its flaws in greater detail and their implications for the current reforms.

Assertion 2: The failures of the previous reforms indicated that corequisite reforms needed to address issues with placement, curriculum, and instruction to yield improved student outcomes

During interviews in the spring of 2018, members of the faculty and administration speculated a variety of reasons *why* the previous developmental reforms had been unsuccessful. A list of some of these reasons are outlined in Table 7 below and discussed in further detail below.

Table 7. Reasons for Poor Developmental Mathematics Outcomes at CCCC

Placement Issues • Placement test validity concerns • Psychological effects of high-stakes placement • Delays caused by developmental placement
Curricular Issues • Decontextualized curriculum • Lack of connection between skills • Irrelevant developmental curriculum
Instructional Issues • Emphasis on procedural skills • Limited opportunities for individualized instruction

Placement. Not long after the VPT entered usage, the faculty began to question its validity. Ms. Miller, the most vocal opponent among the faculty to the VPT, described it as "a poor test" that was written by a company that "didn't know anything about writing tests". She and other faculty suggested that major design flaws allowed students to correctly guess the right answer and demonstrate competency on skills they lacked. One example of this was the existence of multiple students who used the VPT to demonstrate competency on module 7, but not module 6. Ms. Miller noted this as a particularly peculiar oddity:

> You could fail the one on factoring, but you could pass the one that came after it that was rational expressions. How could you pass rational expressions, which theoretically involves an awful lot of factoring, if you couldn't pass the factoring one?

Her implication in this quote is that some students may have been somehow able to make correct guesses on the VPT. These correct guesses may have allowed them to satisfy module 7 despite lacking skills that should have been prerequisite to this module. Though I did not collect any detailed data of how often this occurred, the fact that faculty identified it as being possible was some evidence that the placement test may not have accurately been gauging students' skills.

Faculty also lamented that the VPT was a "black box", that they could not see a student's actual performance, how they scored, or the placement cut scores. All the test showed was whether each student qualified as demonstrating competency on each module. Ms. Miller mentioned that efforts were underway to make changes to the VPT, though the potential impacts of such changes were unclear. A detailed study of this placement test could offer additional insights into the landscape of developmental education at the VCCS. This however is not included in the present study for reasons of scope. Nevertheless, the faculty expressed a common concern that the test was setting up a large number of students up for failure by allowing these students to enroll in courses they were unprepared for.

By contrast, administrators and support staff at CCCC were far more concerned about other impacts of high-stakes placement testing. Academic support staff like Dr. Wainwright and Mr. Green both pointed out how content knowledge was merely one of several predictive factors for success in college. Administrators saw the questionable validity of placement tests as a barrier that reduced the potential number of students completing their college-level mathematics requirements. Dr. Smith and Dr. Lamb further suggested that placement into developmental education had a negative psychological impact on students, as evidenced in the following quote from Dr. Smith:

> I think that [high-stakes placement testing] sets people up for failure…. If you don't succeed, you end up in developmental… we have now validated to you that you're a bad student and you say to yourself, "You know, I knew I wasn't good at math". And now we're going to put you in these [developmental] courses that… [have] no connection whatsoever to what you're doing…

This perspective can also be found in the literature, for instance in the hypothesis expressed by Scott-Clayton and Rodriguez (2015) that developmental education actually serves as *discouragement*. Dr. Smith went on to note that the corequisite model had potential to address this stigma and that, while it may not be a panacea, this would lead to improved student outcomes. That is, he hypothesized that the additional study session would not be perceived by students in the same negative way that being placed into remedial coursework had. The positive psychological impacts of mainstreaming were one of the explanatory mechanisms suggested by Adams et al. (2009) in the original ALP study for the success of in-time remediation. However, this claim was largely speculative and could have been better supported by direct evidence. All that was suggested by the authors was that, "We think mainstreaming has a powerful psychological effect for basic writers" (p. 60).

At CCCC, placement into developmental mathematics also had practical implications that could have a demotivating consequence regardless of whatever stigma students attached to it. Starting in not-for-credit developmental courses delayed a student's enrollment in courses that would fulfill degree requirements. Given that the community college population includes so many students with part-time schedules and family and work obligations, it was all too common for developmentally-placed students to stop before they had made significant progress. Data gathered by Dr. Lamb indicated that only 16% of developmentally-placed students at CCCC starting in fall of 2016 had completed a credit-level mathematics course by the end of spring 2018.

Beyond any demotivating factors that might be addressed, the corequisite model had the potential to correct for the inaccuracy of placement measures. That is, the in-time remediation of the corequisite model (if properly implemented) could be flexible and responsive to student's needs and misconceptions. By contrast, the structure of the developmental modules left few opportunities to respond and adjust to individual student needs. If a student had been marked, either through placement or coursework, as having completed one of the modules, instructors did not have an enforcement mechanism to require students to return to concepts in prior modules. This exemplifies yet another flaw in the execution of curriculum modularization as previously discussed. Indeed, Dr. Fisk was highly skeptical that satisfaction of the modules provided any valuable information about the skills a student possessed. He is quoted at length below.

> We have this misconception in developmental math that it's a conveyor belt deficit model where you move with your shopping cart and the boxes that are empty get filled and the boxes that are filled get ignored. We think that if we

just dump enough in, by the time you get to the end of developmental math… we have filled your tank to full. And now we're going to totally switch you into credit level math, which isn't a *deficit-model* program, it's a *skills-acquisition* program. And we're going to say OK, now we're ready to put you into this pipeline even though we never asked you to actualize any of that information… we just said "Hey, you're not any good at fractions. Pass this quiz on fractions and let's move on."

Dr. Fisk's concerns also pointed to the structural issues of the developmental mathematics curriculum, which are turned to next.

Curriculum. The second issue with the EM as implemented at CCCC was one that other scholars (Hagedorn & Kuznetsova, 2016) have identified as one of the major reasons for the failure of developmental programs. That is, in several ways, there was a misalignment between the developmental and credit-level mathematics coursework. The above quote from Dr. Fisk exemplifies the perspective of some practitioners that the developmental curriculum was backwards-facing; the curriculum reviewed procedural competencies that students either had failed to acquire or had forgotten since learning it in middle or high school. For some students at the community college, it may have been decades since their last mathematics course.

Proponents at CCCC of in-time remediation saw it as preferable precisely because it situated foundational content within the credit-level curriculum. Mr. Bridges put it as follows: "I think that getting that help to the student when it's needed is way more beneficial to the student than trying to store it all up like you're trying to hibernate for the winter or something." Scholarship discussed earlier from Quarles and Davis (2017) corroborates this point. In that study, many of the procedural gains that students made during their developmental coursework had evaporated by the time they had enrolled into subsequent credit-level courses.

Faculty also expressed concerns about the byproducts of modularization. As they saw it, separating developmental mathematics into the nine modules limited the opportunities for students to develop a strong mathematical foundation. Ms. Underwood put it that "everything… was encapsulated into these separate little concepts and there isn't time [for students] to make connections." As discussed in the literature review, two principles that were key to facilitating student learning were that teachers engage prior conceptions and help learners build an interconnected framework of knowledge that facilitates retrieval of facts (NCR, 2000). However, faculty saw the procedural outcomes of the modularized curriculum as too narrow. They contrasted this with prior developmental courses, sharing the opinion that these earlier courses offered a better format to take a spiral approach to instruction, revisiting and reinforcing earlier skills.

Some faculty also had concerns that the corequisite model would not represent an improvement. Some of them preferred to return to teaching face-to-face developmental courses more like those that preceded the EM. They anticipated that many students would lack enough of a mathematical foundation for the corequisite course to provide sufficient supports, and that students would falter and fail as a result. This corresponds to a critique of the corequisite model expressed in Daugherty et al. (2018) that upwards of half of students placed directly into these courses ended up failing, and that there was no alternative support system for these students.

One last misalignment identified by faculty who taught both developmental and credit-level mathematics was that in some instances the developmental curriculum included skills that were not needed for subsequent coursework. For instance, modules 1 through 5 were required for both general education mathematics courses, MTH 154 (QR) and MTH 155 (Statistical Reasoning). Mr. Bridges and Ms. Underwood both identified module 5 as being particularly challenging to students, as it was the most algebraically intensive. The curriculum of module 5 covered slope, equations of lines, and systems of linear equations. However, Ms. Underwood, who had taught elementary statistics class as well MTT courses, noted that a fair amount of this curriculum was not applied in the elementary statistics course. That is, while students needed to understand concepts like slope and equations of lines to understand linear regression, the content on systems of linear equations was not needed in later coursework. So, even if developmental instruction were improved upon, the developmental curriculum may still not be entirely aligned with gatekeeper courses.

The idea that developmental mathematics set up an unnecessary barrier for students was a major concern among administrators. Though none of the administrators had a background teaching mathematics, some wondered about the precise function of the developmental prerequisites. Dr. Wainwright pointed out this dual nature of developmental prerequisites during an interview in spring 2018, when he was Director of Enrollment Management (he has since taken a role as Interim Division Dean). He noted that in many instances, prerequisites were obviously necessary. For example, calculus was required for engineering courses that employ methods of calculus. In other instances, he surmised that prerequisites appeared to serve as a hurdle, ensuring that the students who enrolled in certain credit-level courses would be more mature and generally competent. This second function resonates with the hypothesis of Scott-Clayton and Rodriguez (2015) that, in practice, developmental education most often had the impact of *diversion*, filtering out the less prepared and mature among students.

Dr. Wainwright went on to make the point that the move towards corequisite instruction seemed to have an impact of undermining the notion that the prerequisites were absolutely necessary.

> We're saying if you're missing two of those [modules] you can also do [MTH] 154, as long as you spend some extra time doing this MCR 4. And so are we saying that the MCR 4 is going to, while they're learning the college level [mathematics], is going to beef up the sort of missing parts that these students are coming in with in terms of their math foundation? …. So, is the co-req designed to help them fill in those gaps or are we just saying "Eh, to heck with the gaps, let's just try to get them successful right now in the here and now"?

> And if that's the case then why is it that we think a student needs to have MTE one through five in order to be successful in the course in the first place?

Dr. Wainwright's response pointed to a common uncertainty about the curricular objectives of the corequisite course. The potential shift in curriculum also required a rethink of developmental instruction and what this instruction was meant to accomplish.

Instruction. When combined with the challenges concerning placement and curriculum, the issues with instruction in the EM were a major contributor to its failed implementation at CCCC. In Chapter 3 (Methodology), I noted that my research interest in the developmental mathematics program at CCCC was inspired by observational research done of these EM courses. A detailed report of this findings is currently under review for publication (Beamer, under review). The observational research in the report documents first-hand much of what led faculty to their frustration with the EM. The following paragraphs briefly summarize some of the most major issues based on the report along with subsequent interviews conducted with faculty in the spring of 2018.

A cascade of factors limited the instructional quality of the EM courses. First, each section of the MTT courses was open to all developmental students, regardless of which modules they needed. When combined with the self-paced nature of the class, this made it rare for more than a handful of students to be working on the same material at the same time. As a result, faculty could only work with students individually and had few chances to work with larger groups of students. Some students, left having to self-remediate, relied heavily upon the help features of the instructional software. In some instances, documented in Beamer (under review), students simply tried to reverse engineer the correct answer, a common complaint mentioned previously in Table X. To the extent that students were doing so, taking such an approach runs counter to research on how mathematical learning occurs (NRC, 2000). Perhaps this was due to a lack of metacognitive awareness of appropriate study strategies, a lack of intrinsic or extrinsic motivation to complete the largely procedural exercises, or some combination of those. Whatever the case may be, the end result was often the same: many students would then fail multiple attempts and reattempts at quizzes, fall behind, and then fail or withdraw. Others managed to learn enough to scrape through quizzes on their second, third, or fourth attempt after instructor intervention. Given the methods some students used, there were obvious shortcomings of the instruction in the EM that were clear to the faculty teaching these courses.

There was less agreement on the extent to which the corequisite model would improve upon instructional methods or the way it might achieve gains in student learning or performance. Faculty had yet to see whether marginally prepared students would succeed despite foundational gaps or become overwhelmed by higher-level tasks. Even Dr. Smith who was optimistic about the transition expressed his uncertainty bluntly, wondering “what the heck are we doing with coreqs?” He anticipated that instructors might run the small-format corequisite course more like a seminar, and that this would involve aspects of coaching. One major agreement between proponents like

Dr. Smith and skeptics like Ms. Miller was that it was crucial to staff these corequisite courses with faculty who agreed with the instructional philosophy behind them. That is, the faculty teaching corequisite support courses should believe that the method of in-time remediation could assist students at marginal levels of preparation. Faculty like Mr. Bridges agreed with this sentiment, while others scoffed at the notion that students would be likely to succeed in credit-level mathematics without a solid foundation in algebra and arithmetic. However, given the literature already discussed on the apparently minimal impacts of developmental coursework (e.g., Quarles & Davis, 2017; Scott-Clayton & Rodriguez, 2015), the beliefs of faculty may not have been in line with research. The conflicting priorities and preferences of faculty and other practitioners at the college are unpacked further in the next assertion.

Assertion 3: The corequisite reforms highlighted tensions between faculty and administration and uncertainties about the future of developmental education

Faculty, administration, and academic support staff all shared two basic sentiments: (1) developmental education at CCCC could benefit from reforms, and (2) these reforms had their limitations. Some practitioners, like the Student Success Coordinator, Mr. Green, saw that the need for reforms extended far beyond whatever changes that were being made to placement, curriculum, and instruction.

> We all know developmental math is the gorilla in the room, and it is nationally not just at [the college]…. My belief is that until we change the way we address the factors that come about, why students have not been successful in school to

> begin with, we are not going to help students get anywhere with mastery in the developmental math content. I don't care what the delivery method looks like.

All interviewees offered their own perspectives on the causes that contributed to the low success rate of developmentally-placed students. Mr. Green emphasized the role of structural social inequalities that led the existence of underserved educational communities. Mathematics faculty, several of whom had K-12 teaching experience, often blamed instructional practices in elementary and secondary education that made it possible for students to graduate without basic arithmetic and algebra skills. They also expressed they idea that it was socially and culturally acceptable to be bad at mathematics in a way that was unlike other academic disciplines.

In fact, many among the mathematics faculty felt that administrators at the college held negative attitudes towards mathematics given the way they talked about the function of mathematics. Faculty often expressed resentment at how upper administration described developmental mathematics as a *barrier* (a term that Dr. Smith used seven times in a one-hour interview when discussing the function of developmental prerequisites). This resentment among faculty was worsened by the hangover from EM reforms, which two faculty described as being "forced" on them. Faculty felt they were unfairly being held accountable for the failures of a model they had never wanted. Another aspect of this resentment was that mathematics faculty perceived administrators and other faculty at the college as not understanding the challenges they faced. In the fall as the QR courses began implementation, faculty recounted multiple instances of working with students in the course who did not know how many pennies were in a dollar. They exasperatedly wondered at how they were supposed to teach these students how to compute the payment for an auto loan. As Ms. Underwood put it, “If you can’t do some basic math, I don’t know how you can move forward.”

Some faculty, like Ms. Miller, who had been the longest serving full-time faculty, characterized the corequisite reforms as “pretty much doomed”. She anticipated that it would be overwhelming to students to simultaneously catch up on foundational content while also trying to learn concepts that employed this foundational content. She characterized constant push for reforms oriented towards achieving higher pass rates in conflict with their role as educators. During an interview, she quipped: “The whole objective [of reforms] was to *get them through***;** it was never *help them learn*”. The underlying conflict is perhaps best understood through the terminology that faculty and administrators would use to describe developmental mathematics. Faculty frequently described developmental mathematics as a foundation, while administrators characterized it more as a support. Dr. Smith used language like “floatation device” to describe the potential role of the corequisite courses. This evocative description calls up the following metaphor: faculty wanted students to learn to swim, administrators wanted students not to drown.

Dr. Wainwright used a similar metaphor to justify the need to completely rethink the approach to doing developmental mathematics.

> I would say the task being asked of developmental mathematics is one that I'm not sure could be done in a way that many people would consider successful…. The idea that in a few short months an instructor can help a student achieve things in math that that student maybe hasn't been able to achieve in 12 full years I think is a pretty difficult task… You kind of try to hold back the sea. There's only so much you can do and even if you're doing a great job, I don't know that realistically you're going to see tons of movement for those students that really struggle with math.

Here once again members of the faculty and administration held opposing viewpoints regarding their priorities. The faculty wanted developmental mathematics to increase access to higher education, by setting up paths for whatever incoming students to pursue whatever program of study they wished. Administrators, who were more attuned to the long-term success rates of developmentally-placed students, saw how dismal the prospects were for students placing at the lowest levels of developmental. They questioned the wisdom of allowing students with weak mathematical backgrounds to pursue a program of study like engineering. As discussed in the previous assertion, administrators like Dr. Fisk doubted the value of developmental mathematics education, at least as it was being practiced. He expressed his preference as follows: "I'd rather have a student take a credit class twice and fail it the first time than have a student sit in developmental because I believe that our developmental program is not preparatory for our credit program".

Dr. Fisk's view was apparently shared by members of the VCCS administration, which had already imposed the Multiple Measures placement as a method of bypassing placement measures. While many practitioners at CCCC agreed with the philosophy of finding more accurate placement measures, many also questioned its implementation. Dr. Wainwright said that when he talked about the 3.0 GPA eligibility for credit-level mathematics at one school he coordinated with, "a high school guidance counselor started laughing and she says, 'At this school everyone has a 3.0 – it's grade inflation'".

Dr. Heyward, who as department chair had pushed against the EM reforms prior to their implementation, characterized that administrators at CCCC "wanted to get rid of developmental math". Some of the faculty feared that corequisites were one step in the direction of completely eliminating developmental education requirements, as had taken place in other states like Florida. The apprehensions came in one of two forms. First was the concern that corequisite supports would be inadequate for the least prepared students, and that they would no longer be able to serve all incoming students. Second was the frustration that allowing less-prepared students into credit-level courses would inevitably lower the level of discourse in these courses, as faculty dreaded dedicating more class time to discussing rudimentary material. Many of the faculty prided themselves on CCCC's reputation as a high-quality college in the VCCS, one that sent many transfer students to prestigious universities across Virginia. Some worried that an influx of poorly prepared students into credit-level courses would force them to "dumb down" their courses. This was coupled with worries that this would eventually lead to challenges for students to transfer their mathematical coursework to four-year schools.

As it would turn out, much of the uncertainty around the future of developmental education proved to be well-founded. In fall 2018, the VCCS formed an initiative, at first called “Direct Placement” and subsequently renamed “Placement for Success”. Dr. Wainwright and Dr. Smith served as CCCC’s two representatives for the committee, which consisted primarily of Presidents and VPs from across the system. At a full-time faculty meeting in November, the two shared the goal of the committee, which was to find how to implement successful attempts to reform developmental mathematics from other states. Notably, the discussion centered on how only 16% of developmentally placed students at CCCC completed a credit-level mathematics course. They also shared data on the effect of implementation of corequisite courses from other states, such as Tennessee, on pass rates.

Members of the mathematics faculty, particularly Dr. Heyward and Ms. Miller, were outspoken and defensive at the meeting, critiquing the use of the 16% pass figure proffered by Dr. Lamb and the administration. They noted how it included students in some programs such as nursing who had to complete developmental prerequisites to qualify into their program but were never required to complete a credit-level mathematics course. In response to the concerns of the mathematics faculty that the least prepared students would not receive sufficient supports, Dr. Smith responded with the admission that “we’re not going to get everybody”. Following the ambitions of upper administration at the VCCS, Dr. Smith claimed to the faculty at the meeting that "in three to five years there will be no placement testing." While no details on implementation from the Placement for Success initiative had been shared at that point, as Dr. Smith put it, "the train has left the station". The administrators made it clear that corequisite courses would soon play a significantly larger role at the college. The next section of this chapter looks at how these corequisite courses were implemented in their first semester at CCCC.

RQ 2: How does the design of corequisite courses reflect faculty and administrator goals?

As discussed in the prior assertion, the shift to corequisite courses represented an opportunity to reconsider the purpose of developmental education. The mathematics faculty came together with administration to talk about their visions and decide upon how the MCR 4 course should be implemented. As the incoming department chair, I was involved in many of these discussions, which provided me with many opportunities to understand the rationales behind implementation. I documented minutes from discussions with administrators when possible to represent these rationales as accurately as possible. The assertions below focus, first, on what the implementation of MCR courses at CCCC sought to accomplish and, second, on the variety of practical challenges that arose during implementation.

Assertion 4: The design of the MCR 4 course, in terms of grading and attendance policy, reflected the goal of increasing students' chances of success in the paired MTH 154 course

In fall of 2016, a VCCS workgroup as part of a larger curriculum redesign initiative produced a series of requirements and suggestions for the 23 VCCS colleges to implement corequisite courses. The stated goal of these courses is to enable qualified students to enter into credit-bearing courses with equal or better success than those students who already meet prerequisite requirements. The language that ultimately made it into the policy in the VCCS course document reflects this goal, emphasizing only the role of the course as a support for the other course.

> **MCR 4 – Learning Support for Quant Reasoning**
>
> Provides instruction for students who require minimal preparation for college-level Quantitative Reasoning. Students in this course will be co-enrolled in MTH 154. Credits are not applicable toward graduation and do not replace MTE courses waived. Successful completion of Quantitative Reasoning results in the prerequisite MTE modules [1-5] being satisfied. Lecture: 1-2 hours. Total: 1-2 hours per week.

The guidelines elaborate upon the course description above noted that colleges could take creative approaches to scheduling, staffing, and grading. Regarding instructional approaches, the document suggests four basic instructional objectives: (1) covering foundational content in anticipation of future content, (2) reviewing credit material, (3) offering support for assignments, and (4) developing student skills (outside of content knowledge).

Without a specified curriculum, the MCR course was left open to be responsive to student needs, as judged by the instructor. Like other developmental courses, the MCR classes were stipulated to be on a pass/fail basis, with the results not impacting GPA. Though there was some initial confusion about how to handle grading policy for the MCR course, ultimately the administration and faculty (which included myself) decided upon a policy that passing the MCR course would be based upon student attendance and participation. The rationale was that passing the MCR course did not satisfy prerequisites. So, a student who failed MTH 154 would need to retake the course with MCR 4 again, regardless of whether they passed the MCR course. However, since a fail grade in the MCR course could have financial aid impacts, faculty saw no need to give a student a failing grade when that student had been attending and putting forth effort. Whether this policy was uniformly observed by all MCR instructors was not explored in this study.

However, faculty and administration planning the MCR course anticipated that there might be some mechanism to enforce student buy-in. What was agreed upon was to enforce an attendance policy. Instructors could withdraw students from the MCR course if they missed 5 or more days of class. Because eligibility in MTH 154 was contingent on enrollment in MCR 4, this would have the effect of withdrawing the student from MTH 154 as well. The policy aligned with a college-wide attendance policy but provided faculty with a concrete way of requiring that students attend the MCR course.

As to the possibility that MTH 154 students *not* needing the MCR course could enroll, administrators suggested that the course align with the college's policy for auditing. That is, they discouraged allowing students into the MCR course without officially enrolling into the course. The rationale here was that this would prevent class size from swelling. However, in practice, Dr. Heyward did allow one student to attend the MCR course despite not enrolling. She thought that doing so did not hinder the effectiveness of her course.

The faculty and administrators next decided that students in the MCR 4 course would not have to complete any assignments outside of those required for MTH 154. Additionally, MCR 4 students would be graded in MTH 154 according to exactly the same criteria as other students in MTH 154. That is, there would not be any portion of their grade in MTH 154 that depended on assignments other than those required in MTH 154. The rationale here was that it would not place MCR 4 students at any advantage or disadvantage relative to other students in MTH 154. Since the MCR course was implemented to be responsive to the curriculum in MTH 154, the learning objectives from the MTH 154 syllabus are included as Appendix D to this study. The next assertion turns to some of the practical issues that interfered with successful implementation of the plan for the support courses.

Assertion 5: Implementation issues in scheduling, new curriculum, and instructional resources limited the effectiveness of the corequisite support course during the first semester

In its first semester at CCCC, the MCR 4 course ran into a number of issues. Similar issues from navigating new scheduling and policies have shown up elsewhere in the scholarship (see Daugherty et al., 2018). This assertion overviews some of the challenges to provide further context for the instructional practices within the MCR 4 courses. However, since the focus of the present research is on the corequisite course itself, not the piloting of the MTH 154 course itself, these are overviewed only briefly.

The scheduling issue arose from how the MTH 154 and MCR 4 courses were encoded in to the enrollment management system. While each MCR 4 instructor taught a class that was paired with a MTH 154 course, it was possible for students to not be in both paired courses with the same instructor. A few students ended up enrolling into an MCR 4 section not taught by their MTH 154 instructor because the MCR 4 section conflicted with another class in their schedule. Some other students enrolled into a section of MTH 154 that did not have a paired MCR 4 course. However, because they required MCR 4 to enroll into MTH 154, they ended up enrolling into

In Dr. Heyward's section of MCR, this posed relatively minor issues, because all of her MCR students belonged to one her two MTH 154 sections (one section in the morning, and one in the afternoon). Dr. Heyward found that it was easier for the students from the same 154 section to build rapport with one another. However, since she knew exactly what her students were covering in their 154 course, having multiple sections did not interfere with her ability to interact with students or know their performance in MTH 154. Mr. Bridges encountered other challenges, as one of his MCR 4 students belonged to a section of MTH 154 with another instructor. Though the MTH 154 sections shared the same curriculum and resources, the week to week schedules varied. As a result, there were points when Mr. Bridges was discussing material in MTH 154 that was review for his students but which the student from another section had yet to encounter.

A host of other issues arose simply because the QR course itself was a new course. The faculty teaching MCR 4 found themselves having to figure out how to help underprepared students prepare for a course without the experience of having already taught that course. Dr. Heyward noted this difficulty during an interview: “If I was [teaching] calculus, I would know what mistake they’re going to make before they make it.” To add to this, faculty were still working on finalizing exactly how to cover the student learning objectives for MTH 154 in terms of breadth and depth. The full-time and adjunct faculty teaching MTH 154 met regularly to discuss these issues and share assignments. They also decided collectively to cut some material that had originally been scheduled when classes began to run behind or material in the instructional resources proved to be more challenging.

The inexperience with the instructional resources also proved another challenge, as faculty experienced multiple setbacks with the resources they were using in the course. Dr. Heyward, who had been jointly responsible with another faculty member for designing the QR course at CCCC, decided to utilize a company called Knewton for the instructional software platform. Dr. Heyward explained that she chose this platform for three main reasons: (1) the course used open educational resources, rather than publisher materials, and hence was more affordable than many publisher-based alternatives; (2) unlike some other QR textbooks, it covered all of the learning objectives specified in the VCCS MTH 154 curriculum; (3) The online homework platform was designed as an adaptive mastery-based learning platform, which would diagnose gaps in student understanding and redirect struggling students to remedial topics.

The hope with the Knewton software was that it could be beneficial for diagnosing and remediating students on an individual basis, redirecting them as needed to foundational content. While the faculty reported some positive impressions about the software and positive responses from students, they also noted several issues that made it difficult for students and instructors to use. One issue was that the instructor interface allowed for the removal of learning objectives, but not individual questions. The terminology Knewton used for “learning objectives” may be more appropriately thought of as skill proficiencies. They included, for example, finding truth tables involving conjunctions and negation, solving proportions involving similar triangles, computing income tax, or relating the annual percentage rate (APR) with the annual percentage yield (APY). However, the problems within a single learning objective could vary significantly in their difficulty and the amount of algebra required. For example, computing the APY given the APR was a straightforward application of addition, multiplication, and exponents. The reverse direction required using radicals, an algebraic technique that a number of students struggled with. In several instances during observations, faculty identified issues with the software only after seeing students in the MCR course experience such challenges. Exploring students' experiences with these adaptive learning software platforms could certainly offer further insights. However, this would require methods beyond those used in this study. Instead, this research capstone turns to address the third research question on the instructional approaches employed in the support course.

RQ 3: How do faculty teach and use instructional resources in QR corequisite support courses?

The assertions in response to this research question address the ways in which instructors utilized the support course their reflections upon their pedagogical practices. The instructors' role in the support class is explored along several dimensions: what instructional activities they engaged in, how they employed formative assessment and other strategies to inform their remediation practices, and what content and skills they addressed with their instruction. The last assertion in response to this question addresses the instructors' own experiences of the MCR course and the potential avenues for improvement. As an introduction to these assertions, this section begins with an analytic vignette of a typical day in Mr. Bridges MCR course.

Analytic Vignette: Mr. Bridges' MCR class

As the fifteen-minute break between his MTH 154 and MCR 4 course nears an end, Mr. Bridges reiterates to his students the practical importance of the assignment they've just completed. In it, they used Excel to determine the amount of time and total interest paid when making minimum payments to a credit card. Mr. Bridges tells them, "You know, those people who are going to be financially successful in life are going to have interest working in their favor." Looking at the clock, Mr. Bridges claps his hands together as a signal that class has officially started, saying to himself and the class: "Oh man, I have so many things we can go over".

On the board behind him is already a list of topics already written up from the MTH 154 course in anticipation of the next test on financial mathematics. The list is extensive: simple and compound interest, income and sales taxes, present and future value of annuities, APY, loans, amortization schedules, and credit cards. Sitting casually with one leg folded over another on his desk at the front of the room, wearing a plaid shirt with a black skinny tie, he poses a question to his students: "Looking at the list of broad topics, what scares you the most?"

One of his students, Lloyd, a bespectacled young man in a hooded sweatshirt and baseball cap, volunteers a suggestion: "I was looking at the homework on annuities and I was really struggling". Mr. Bridges remarks that he is not surprised to hear that annuities were giving them difficulties, based on how not yet half of the MTH 154 class had completed the homework assignment. He walks to his work bag, noting that anther *instructor had fortunately already written up some practice problems on this very subject. He encourages his five students to gather around one table and then opens the classroom computer to his lecture slides. On the whiteboard on the front wall, the projector displays the formula for the future value of an annuity.*

$$FV = \frac{d[(1 + r/m)^{mt} - 1]}{r/m}$$

"Now I know this is a complicated formula," he says, seeing a furrowed brow on one of his students, "but remember, you're going to have this on a formula sheet for the test, so you do not need to memorize it". As he hands out copies of the practice problems on annuities, he verbally summarizes the first exercise on the page: "So you are trying to save up one million dollars for retirement. You assume that you earn a rate of 5% in returns after inflation on money you deposit in an investment account that is compounded monthly. You want to know how much you need to save every month over 40 years to get there. Let's start with this: where does the number 1,000,000 go in the formula?"

One of the students suggests that it would replace FV, the future value, in the formula. "Up top", Mr. Bridges responds, holding up an upstretched palm in the student's direction for a high five. Mr. Bridges continues, "Now since d is the only other variable that indicates an amount of money, that must be your unknown". This is followed by an audible "Aah…" from one of his students, who follows up by noting that m, the compounding frequency, must be 12, and that r would be 0.05.

Mr. Bridges gives the students a few moments to start evaluating the formula with the numbers they have collectively arrived at. He circulates to each student, glancing briefly at the work each of them is writing down on their paper. After a moment, Bella, a student with her long black hair in a ponytail, looks quizzically at her paper. "My answer does not look right," she says. Mr. Bridges, with a slight smile on his face after hearing his student reflect upon whether her answer seemed plausible, comes over to inspect. After a moment, he finds a potential issue, and then walks over to the board to explain.

"Sometimes I find that students not knowing fraction facts will really get in the way of using these formulas. Let's take a moment to look at how this works with something simpler." On the board, he writes the following:

$$\frac{x \cdot 3}{5} = x \cdot \frac{3}{5} = \frac{3}{5}x$$

"You see," he explains, "there are a lot of ways to write the same thing. In all of these forms, I'm multiplying x by 3 and dividing it by 5, but I can carry that out in any of these orders. You might remember that is called the commutative property of multiplication." He directs a request at Bella, "Now, could you write up on the board what you had right after you simplified your numerator and denominator?" Bella comes up to the board and writes the following:

$$1000000 = \frac{d(6.358)}{0.00417}$$

"That's great up to that point," he says, as Bella returns to her seat. "Note that what we have on the right side looks a whole like what we were just talking about with multiplying by fractions. We have a few options, but one approach we could take would be to divide those two numbers on the right side. What do we get if we do that?" A student with a backwards hat on and a goatee, looking at his graphing calculator, offers an answer of 1526. Mr. Bridges writes a simplified version of the equation, $1000000 = d(1526)$*, and then asks for the next step. A student with her dyed-red hair in a colorful headband asks the next question: "So do we divide by 1526?" After receiving an affirmative response from Mr. Bridges, she follows with another question, "Then how many decimals do you use in your calculator?"*

Mr. Bridges walks over to the student. "What you want to do is use the numbers stored in your calculator. That way you'll have the exact value stored and you will not lose any accuracy that might happen if you round too early. You can do 1 million divided by…" His hands hover over her calculator, and he says aloud as he gestures towards the buttons: ***2nd****, then* ***Answer****. Somewhat awestruck after getting that to work, she exclaims, "Oh, I did not know you could do that!" Mr. Bridges asks Lloyd what he wound up getting for the answer, and Lloyd replies with $655.30. "Hah!" laughs Mr. Bridges, "And you told me you were having trouble with annuities!"*

The preceding analytic vignette illustrates some of the strategies Mr. Bridges would frequently use the support class. Mr. Bridges began the lesson grounded in the practical skills emphasized in the MTH 154 course. He provided students with the opportunity to lead the class according to their self-identified needs, within a selection of options. The lesson itself was collaborative in nature, moving freely between instructor-led direct instruction, individual additional practice, and student-led discussions. He continually assessed whether students were following along and provided encouragement along the way. The methods by which he did so are the subject of a later assertion. The next assertion delves into the matter of the classroom activities taking place in Mr. Bridges' and Dr. Heyward's classes, and what the faculty intended to accomplish with these activities.

Assertion 6: Faculty employed a combination of direct instruction, guided practice, and assignment support to respond to the needs of individual students

Without a specific set of curricular or instructional guidelines for the corequisite support course, faculty were free to choose what topics they remediated as well as the instructional approach they saw fit for a particular circumstance. As the semester went on, both Mr. Bridges and Dr. Heyward settled into their own rhythms and patterns of interaction. Much of this rhythm was dictated by the classroom activities the instructors chose to offer students. This assertion overviews the various ways that faculty regularly utilized class time and what these various activities accomplished. Broadly, classroom activities fell into three categories: direct instruction, guided practice, and assignment support.

Direct Instruction. The first category of classroom activity was for the instructor to utilize the MCR class time to present that day's MTH 154 material again or clarify concepts that students found to be confusing. Direct instruction was more frequently the first activity that took place and took the form of a lecture format with interactive components. Instructors would discuss examples they might not have had time to present in the larger class or re-explain examples they thought deserved revisiting. Usually the direct instruction portion was brief, around five or ten minutes, and would consist in off-the-cuff discussions of concepts, skills, or formulas. Sometimes, Mr. Bridges would re-open the slides from the lecture for the day's class and present one or two slides again. During interviews he described this practice as giving "mini lessons" to the students. This direct instruction most often covered the same sections and material from the course that immediately preceded it. At times though, such as before the test or as the final exam approached, instructors reviewed topics from earlier in the unit or earlier in the semester.

Both Dr. Heyward and Mr. Bridges taught their support classes immediately after their paired MTH 154 course, and so this offered a natural segue to review that day's material in the smaller format of the corequisite course. For instance, Dr. Heyward began one class by summarizing an assignment the students just completed during MTH 154. The assignment directed students to make a spreadsheet in Excel that would compute their grade in the course, based on the weights of each category of assignment and the scores the student had received. While teaching the MTH 154 class, Dr. Heyward found that students struggled to set up the computation for the weighted average. So, at the beginning of the support class, she presented this computation a second time, working with the students step-by-step to arrive once more at the formula.

In addition to revisiting what they had just gone over in the MTH 154 course, faculty would also use the direct instruction in MCR 4 to extend these concepts or present them in alternative ways. Dr. Heyward followed the Excel example by asking students about what would happen to their grade if the course were weighted differently, eliciting the idea that the weights had to collectively add to 100% for the process as outlined to make sense. During interviews, Mr. Bridges emphasized the importance of not simply re-teaching the same material but using the support class to more thoroughly explore the class concepts. As an example of this from an observation, he started one class by reviewing direct variation, a topic that students had found challenging during the MTH 154 course. He presented direct variation in a slightly different way, discussing how the equation of direct variation implied that a ratio between two variable quantities was constant. This strengthened the connections of the concept of direct variation to the other topics in the unit on ratios and proportional reasoning. At some points, these explorations inspired him to bring back ideas into the MTH 154 classroom. For example, after he found his MCR students connecting with this alternative explanation of direct variation, he reported taking this explanation back to the rest of his MTH 154 students.

The direct instruction was well-suited particularly in instances when a concept from the MTH 154 course was particularly challenging and many students shared common confusions. Since both instructors taught the MCR 4 course after their MTH 154 course, it was natural for them to begin the class by going over concepts they or their students felt they needed to spend additional time on. However, because of the various strengths and weaknesses of the students, instructors typically refrained from spending more than five or ten minutes at a stretch doing direct instruction. Both Dr. Heyward and Mr. Bridges expressed a hesitancy towards using the small format lecturing, particularly on remedial topics. When Mr. Bridges was asked about approaches he thought were not useful, he responded that when he taught these remedial topics “like a regular lesson” that it did not offer enough practice for the students. In such instances, he was more often to use class time to provide guided practice for students, which is discussed next.

Guided Practice. The second way instructors utilized class time was to give students suggested exercises to work on individually or in groups. Guided practice included remedial topics at times when it was logical to introduce them and material from MTH 154 at other points. Sometimes, instructors would take examples directly from the Knewton instructional software and have the students collectively work on these exercises. At other times, these suggested exercises were reviewed in a worksheet prepared in advance when instructors anticipated students might struggle in a certain topic. At several points during the semester, instructors would share resources they developed specifically for the MCR course with one another. These review materials were also sometimes exercises that were given to the MTH 154 class as a whole, but which the faculty did not have time to go over in the MTH 154 class. This included test review documents developed by the MTH 154 faculty that contained a large list of exercises on each test. In the week before the test, Mr. Bridges would often direct students to work on these exercises. Mr. Bridges also would revisit tests his students had already completed to give them the opportunity to revisit concepts they struggled with on their first attempt.

The instructors offered multiple formats for guided practice. In one class at the beginning of the unit on ratios and proportional reasoning, Mr. Bridges wrote up ten problems on the board on fraction operations. He had each of his five students complete two exercises on the board and then explain their work to the rest of the class. In many instances, the instructors did not even need to ask some students to explain their work; many of them developed some enthusiasm about sharing their successful methods with other students. Getting students to teach one another was made possible by having students all working on the same or similar content. It also made it easier for the instructor to provide individual support to those who needed it most and to leverage the skills of their better-prepared students to assist with remediation.

At many points, instructors would use the guided practice exercises to launch into direct instruction when they encountered a topic or example they thought might benefit the class at large. The earlier vignette demonstrates an example of how the two activities of direct instruction and guided practice each supported one another. In the vignette, Mr. Bridges chose to have the students each work on the same exercise, one that involved a complicated formula with many potential pitfalls. An advantage of guided practice on the same problem was that instructors could easily transition between directing students to work in groups, individually, or as a class. However, guided support required the instructors to come prepared with some selection of activities they wanted to work on, or else have to concoct examples for the whole class on the spot. When instructors did not have a particular topic they wanted to review, they instead used the support class as a format for providing assignment support.

Assignment Support. The third category of classroom activity was for the instructor to allow students to use MCR class time to complete their assignments for the MTH 154 course. This instructional format was not entirely dissimilar from the MTT courses in that students were self-directed but given support from the instructor. Both Mr. Bridges and Dr. Heyward offered students time for their students, though they took different approaches. For Dr. Heyward, assignment support was a regular part for most classes, which came after she had taken the opportunity for direct instruction or guided practice. By contrast, Mr. Bridges would spend most classes using a combination of instruction and guided practice. However, he would dedicate some entire class periods to giving assignment support, allowing the students to work on what they saw fit. This occurred on days when he did not have a specific topic he thought it necessary to review with the class.

During assignment support, faculty would allow students to choose which of their MTH 154 assignments they wanted to work on. In most instances this was on the regular homework assignments, though at points the students also chose on "lab" assignments that would apply course concepts within structured scenarios. These lab assignments included, for example, having students compute the amount one would need to pay on taxes under a given scenario. This included sales tax on food, personal property tax (on vehicles), real estate tax, and income tax. The lab assignments also included Excel-based work, such as creating a gradebook they could use to calculate their course grade or constructing a payment schedule for a credit card with a specified balance, as were mentioned earlier. Finally, instructors also allowed students to work on projects, which were broader, more open-ended, and usually group-based. One of these projects had students research prices for a new and a used car and then compute their monthly payments, amortization schedule, and depreciated value under a particular set of scenarios for financing options.

What typically took place during assignment support was that instructors would circulate throughout the classroom as students worked on their chosen assignments. Some students gravitated to working in groups, while others preferred to work by themselves. Sometimes students would request assistance by raising hands or calling for the instructor. When instructors were not responding to one of these help requests, they would simply circulate around the class and monitor the work that students were completing. Sometimes this included making sure that students were on task and completing MTH 154 assignments.

There were several advantages to utilizing class time in this way. For one, any assignments that the students completed would contribute to their grade in MTH 154. Each student had the opportunity to select what they thought they might need support on. Both instructors mentioned that one aspect that made them reluctant to review remedial topics with the entire MCR class was that some students were perfectly capable of carrying out fraction addition or isolating a variable in an equation. They worried that by doing direct instruction with the entire class on these topics, they would lose the interest of some of their students, and that the course would not provide the sort of support these students might benefit from. This was evidenced at multiple points during observations. At times when the instructor was offering direct instruction or guided practice, some of the students had their computers open to their assignments already. In some cases, their computers were open to material not relevant to the MTH 154 course, either working on another class or spending time on a social media website. While students also engaged in these off-task behaviors during assignment support time as well, instructors were regularly checking in and trying to make sure that students were making some sort of progress.

Offering assignment support was also highly flexible to student needs. Not all students needed direct instruction or guided practice on a particular topic. It was not uncommon for students in the same section to be perhaps one or two sections ahead of one another, based on the rate at which they were completing assignments. Consequently, faculty could not be sure that all of their students were working through the same material, which may be one reason why students did not always follow along with direct instruction or guided practice. Also, as mentioned in Assertion 5, students had occasionally frustrating experiences with the instructional software. Taking time to let students complete assignments offered opportunities to catch these issues and prevent students from getting frustrated. On occasion, Dr. Heyward would use a problem that a student was struggling on as an example to go over as guided practice with the entire class. Perhaps most importantly, working on an individual basis, though not unique to giving assignment support, allowed faculty to see precisely what students struggled in. The nature of what students struggled on is taken up in a later assertion.

However, offering support on assignments had its drawbacks as well. Since providing assignment support to students completing assignments on computers was similar to the EM, this approach shared similar issues. It was challenging for instructors to provide one-on-one support for all of their students, particularly for Dr. Heyward who had to rotate between about 10 students. The college had chosen a cap of 12 for these classes, so this was on the higher end of what was thought to be acceptable. She remarked that some of the students, if they had their way, would work with her one-on-one for the entire duration. In this class size, this would of course be impractical. Since some concepts, usually material from MTH 154, were a common struggle among students, going over the same issues on an individual basis was not always the most effective use of time. Unlike in guided practice when instructors prepared examples ahead of time, assignment support required instructors to work out the problems on the spot, so it was more laborious to verify answers.

The guidelines from the VCCS corequisite work group discouraged instructors from utilizing the entire class time for assignment support, noting that the corequisite model was not intended to replace a tutoring center or model a homework help lab. When Dr. Heyward or Mr. Bridges did not come to class with a particular topic to cover with the entire class through supplement instruction or guided practice, offering assignment support was one way to ensure that class time was of some value to students. The progress, at least as measured by student completion on assignments, was readily apparent, and thereby impacted grades in a much more direct manner than, for instance, covering remedial topics with the entire class. However, there is also the possibility that the option to offer students extra work to direct themselves may have disincentivized faculty from preparing more material for guided practice in advance. So for both faculty and students, simply working on assignments and offering support was a time savings, since it required less preparation for instructors and meant that students did not have to complete all of their assignments outside of class time.

Both instructors developed their own balance of the three approaches, as Mr. Bridges discusses in the following excerpt:

> Sometimes I am just pulling some problems from the homework, and I've done that a time or two. I've looked at the first test with them. I've done some of the

> “backfilling” material. I’ve done just more examples from a worksheet in class where we didn’t get to all of the examples. I think that a little bit of all of those to meet their needs from lesson to lesson depending on how that lesson went over for them is probably what I would continue to do and I think probably is the best.

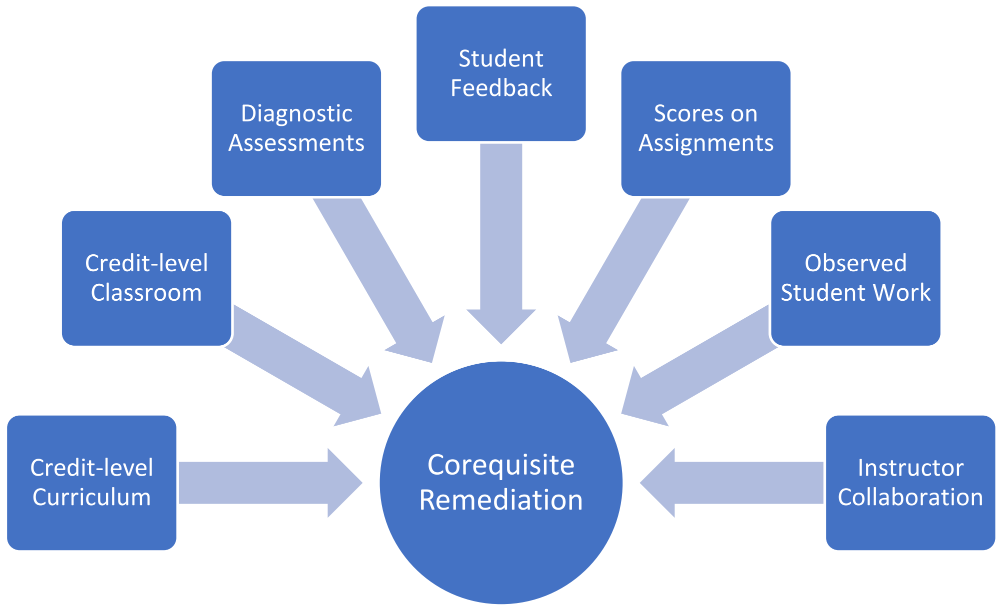
The “backfilling” Mr. Bridges is referring to is the practice of reviewing prerequisite content necessary for success in the credit-level mathematics course. Not every unit required reviewing prerequisite material, for instance the unit on logical reasoning included many concepts such as truth values of statements that did not build on developmental module content. However, the units on ratios and proportional reasoning, financial mathematics, and modeling required more foundational skills, a point addressed in Assertion 8. Covering prerequisite content in preparation of credit-level content was one activity suggested in the recommendations in the VCCS guidelines for corequisite courses. In practice, the instructors would typically revisit prerequisite material only after it became clear to them that the lack of these skills was preventing students from succeeding with credit-level content. Mr. Bridges did some of this with the whole class and some of this individually, while Dr. Heyward mostly reserved discussing remedial topics on an individual basis when students were getting caught because of foundational gaps.

The rationale for this is discussed in more detail in Assertion 8, but one reason for the emphasis on credit-level content was that some of the MTH 154 content required little or no remedial content – that is, content discussed in the first five developmental modules. This was particularly true for the first unit on logical reasoning, which covered truth values of statements, logical connectives, arguments, and fallacies. In other units when the credit-level content built on remedial skills, both instructors usually revisited remedial topics only after introducing them in an applied context from MTH 154. This can be seen, for example, in the analytic vignette on how Mr. Bridges discussed fraction concepts because they were necessary to make sense of a financial formula. Ultimately, the needs that Mr. Bridges discussed in the previous excerpt varied across units, lessons, and students. How he and Dr. Heyward chose which topics to remediate is discussed next.

Assertion 7: Faculty leveraged a variety of data sources from the curriculum, MTH 154 classroom, and student feedback to inform their instruction in the support course

As discussed in Assertion 6, faculty spent the time in the MCR courses using a combination of direct instruction, guided practice, and assignment support. Because the MCR course had no curriculum aside from supporting whatever was taking place in the MTH 154 course, faculty often devised and revised their plans for the MCR course on short notice. Dr. Heyward noted that she planned for the course by "picking out things that [the students] have struggled with or I foresee they're going to struggle with, but sometimes it's a last-minute change." This referred both to the prerequisite foundational gaps students would arrive to class with, as well as the credit-level material that might provide greater challenges. She and Mr. Bridges both incorporated information from a variety of sources to decide upon what material to cover and how. This variety of data sources is visualized in Figure X below.

Figure 5. Sources of Information for Remediation



Credit-level Curriculum. The first source of information that inspired activities in the MCR course was the QR curriculum itself. When faculty were preparing their lessons for MTH 154, they would often anticipate areas in which students would struggle, either because they perceived a new concept as challenging or because it required competency in prerequisite skills. For example, faculty anticipated that students might struggle when working on truth tables, given that it was likely to be a new concept for many students. They also thought the same for more computationally intensive topics, like the formulas in the financial mathematics chapter. Sometimes in anticipation of these challenges the instructors would devise additional practice on exercises, for instance, a worksheet on computing APY. However, as Dr. Heyward noted, she did not always accurately predict which concepts the students ultimately found challenging. Consequently, she supplemented these expectations with her experiences from the QR class itself offered further insights.

Credit-level classroom. Because the MCR course was scheduled after the QR course that each instructor taught, they had the opportunities to build from their experiences in the classroom. Dr. Heyward discussed the value of these classes to bring to light and then address unexpected challenges. She actually taught multiple sections of the MTH 154 course, one several hours before her MCR course, and noted how that "luxury" gave her more opportunities to plan for student difficulties. For example, on one day she shared that her students in MTH 154 were struggling to solve equations where two ratios were set equal to one another, a topic she had not anticipated as a difficult one. In response, she wrote up a series of exercises to lead students in guided practice in the MCR class later that day.

Scores on Assignments. A related item of student feedback was student performance on assignments, on an individual and a group level. The Knewton instructional software would send regular reports to faculty noting the sections of homework on which students were struggling. Mr. Bridges used this in part when deciding to review direct and inverse variation during the chapter on ratios and proportional reasoning. Dr. Heyward also would check each of her MCR students' scores on assignments and take time in the MCR course to remind them of the assignments when they ran behind. The small format of the MCR course facilitated this high level of involvement and meant that it was easy for instructors to enforce additional accountability for the students in the MCR course.

Diagnostic Assessments. During one of his first classes, Mr. Bridges gave his students a self-developed diagnostic “quiz” which included a sample of skills on developmental material. This included exercises on fraction arithmetic, evaluating expressions, and solving linear equations. He saw that they performed poorly on it, particularly on the exercises involving fractions. This prompted him to dedicate some of the instructional time early in the course to lessons on fractions. This was the only instance of a diagnostic assessment in the MCR course, and both instructors noted that they did not seem to find it particularly helpful. When Dr. Heyward gave the same quiz to her students a week later, she later reported that she thought it was not very useful. She felt that giving the students this assignment just upset them, because many of them seemed to already be aware that they struggled on these skills. Interestingly enough, though placement data was available on how students placed into the MCR course, neither instructor reported using this data to supplement their remediation practices. Instead, this much more often took the form of simply asking the students themselves.

Student Feedback. One valuable source of information for instructors, particularly for Mr. Bridges, was eliciting suggestions from students. He would typically begin his MCR classes by presenting students with three or four options for direct instruction or guided practice. The students would then choose, as a group or individually, which of these options they wanted to take. They typically expressed preferences towards credit-level content rather than review more basic prerequisite material, though future research could help better identify student preferences on a week-by-week basis. Mr. Bridges explained why eliciting student feedback was important relative to some of the other sources of information.

> I try to predict, but much more important than predicting is being comfortable enough with them and them being comfortable enough with you that you can have candid conversations about it. So instead of me trying to predict I'm really trying to get input from them.

The excerpt above demonstrates that faculty leveraged the students own perceptions of their strengths and weakness to inform their classroom practices. From Mr. Bridges' perspective, this approach of asking students was actually the most valuable and the one he would encourage other faculty teaching a corequisite course to take. While he and Dr. Heyward acknowledged that students did not always have the metacognition to accurately assess what they did or did not struggle with, this information went a long way to informing instructional interventions. As Mr. Bridges remarked, having a strong rapport with students facilitated this open communication.

Dr. Heyward also relied upon student input and began class by eliciting questions from students on recent material from the MTH 154 course. At some points, she would come prepared with a particular topic she wanted to revisit because she thought the class as a whole would benefit from additional instruction. At other points, students would offer some suggestions for her to go over. However, in her assessment, many of her students were eager to spend the support course working on their assignments, and so usually after a few minutes of group review she would let them begin work on their homework or other assignments. However, this student work was itself a valuable source of information.

Observed Student Work. Circulating around the room and observing students as they worked individually or in groups had a major impact on how instructors chose the topics to remediate. Sometimes students would raise hands to get attention, other times faculty would walk around and monitor students' progress and intervene when they struggled. Because the instructional software offered two attempts to receive a correct answer on open-ended calculation questions, getting the first attempt wrong frequently provided an opportunity for instructor intervention. This was one apparent advantage of the instructional software, that it was impossible for students to simply request a new version of an exercises and thereby it was in their interest to ensure they received assistance. The design of the software meant that getting an answer wrong could increase the number of correct answers required to complete the assignment. This offered an incentive for students to ensure they arrived at a correct answer, preventing some kinds of "gaming" that the instructors had noted existed with previous systems.

Dr. Heyward noted that these individual interactions, typically in the context of assignment support, was the primary way she identified and addressed student misconceptions: "I think it is mostly from working with them individually, that is where I am seeing the deficiencies. I can tell you who in that class knows how to do those things and who doesn't". Indeed, the majority of Dr. Heyward's time in the MCR course was spent bouncing from student to student as they ran into issues they were unable to resolve themselves. Dr. Heyward would ask these students to explain how they were approaching the exercise, making sure that they were following the appropriate steps by hand on paper and ensuring that they were following along at each step. These individual interactions were a frequent way that instructors identified the specific misconceptions and struggles held by each student that served as a barrier to their success in the credit-level course.

Instructor Collaboration. One last source of information came from the collaborative practices of instructors who shared information with one another. During the regular implementation meetings that took place for the QR course, instructors also shared tips and suggestions for what approaches seemed to be effective in their corequisite class. Sometimes faculty would create in-class exercises for their MCR students and would share these resources with other instructors. This sharing was helpful because the instructors often had little time to respond with prepared activities to the confusions and challenges students faced in real-time, making it harder to arrive to the MCR course with appropriate guided practice activities.

In sum, the planning and preparation that went into the corequisite support class made it considerably more flexible and open-ended than the MTT developmental courses that preceded it. While these MTT courses had a very fixed curriculum, the

MCR courses could cover whatever instructors or students saw fit. Instructors ended up gathering data to inform their remedial practices from the curriculum, but largely from the students themselves. This included everything from the issues revealed while teaching the MTH 154 class as a whole to the performance and suggestions of individual students within the MCR 4 course. Each piece of information helped to paint a fuller picture of the particular guidance that each student needed.

Assertion 8: Students displayed a wide variety of foundational content gaps and study skills; faculty used the support course to respond to these student needs

As discussed in the first chapter, students could place into the MTH 154 course with corequisite support through one of three measures: completing algebra II with a high school GPA of between 2.7 and 3.0, satisfying three of the developmental modules 1-5 on the placement test, or completing MTT developmental courses. Practitioners like Dr. Wainwright who coordinated with local high schools noted that the same GPA could mean very different things at different high schools in the area. When coupled with the instructional issues of the MTT courses discussed in the first two assertions, there was a wide range of ability levels among students placed into the corequisite support course. Faculty had few guarantees about what their incoming students did or did not know.

Dr. Heyward described this experience of having to address a wide variety of gaps and deficiencies as "frustrating", both for herself and for students.

> Some of them cannot solve linear equations; some of them cannot simplify fractions. But it's frustrating, because some of them can, and can do it very well.

> I feel bad for them when I spend time on that because they're like, "Yeah this is boring, I know how to do that", because their deficiencies are in different areas and some of them are very different in their abilities.

The different ability levels likely contributed to why instructors in the corequisite course largely avoided discussions or exercises focused solely on remedial content (from the first five developmental modules). Instead, their lessons in the support course tended to focus on topics from the MTH 154 content. Unsurprisingly though, given the instructional and placement issues already discussed, many students had gaps in their understanding of the content covered in the developmental modules. As revealed during observations and instructor interviews, these gaps included fraction arithmetic, decimals and place value, exponents, order of operations, solving linear equations, and equations of lines.

Of these, Mr. Bridges highlighted fractions, the content of module 1, as a primary "sticking point" for many of his students. It was the only remedial topic he reported spending a significant amount of dedicated instructional time towards in the corequisite course. Fractions were embedded throughout the MTH 154 curriculum, when working with ratios and proportions, slope, and many of the financial formulas. As part of these problems, students needed to simplify fractions, do arithmetic operations on fractions, and convert between improper fractions and mixed numbers in the context of various applied problems. While these applied questions had a greater complexity than many of the procedural sorts of questions common to the MTT courses, instructors leveraged the applied context to provide students a meaningful way to check their answer. As illustrated in the analytic vignette, instructors would often emphasize the importance of checking the reasonableness of an answer in an applied context. On relatively few occasions were students in MTH 154 asked to solve algebra or arithmetic problems outside of some application.

The content from modules 2 and 3, on decimals, percentages, and operations with real numbers, was also a challenge for many students. Dr. Heyward recounted dumbfoundedly an example of a student who struggled to understand why 0.35 + 1 was not 0.351. The skills discussed within these modules were also present throughout almost all of the MTH 154 curriculum, particularly on the financial mathematics unit. In it, students needed to evaluate complex formulas involving exponents and order of operations. They also needed to accurately convert between decimals and percentages when interpreting interest rates. Instructors often found that students would miss their first attempt on a question because they rounded incorrectly. Either students would round mid-way through their solution process, leading to inaccuracies, or students would truncate decimal expressions rather than round. In multiple instances, students appeared to be confused by directions asking to round to the nearest tenth or hundredth, or to the nearest cent. Because the instructional software had little error tolerance for answers, an improperly rounded answer was a frequent source of error and frustration.

The student difficulties with arithmetic operations pointed more generally to the weak numeracy skills of some MCR students. During observations I encountered numerous instances of students using a calculator to conduct single-digit multiplication or basic operations on fractions, such as $1 - \frac{1}{4}$. However, another major difference from the developmental modules was that there were no restrictions in MTH 154 on students using calculators. In fact, a scientific calculator was required, and some students had graphing calculators that enabled them to convert between decimals and fractions, allowing them to avoid many computations by hand (such as fraction arithmetic). By contrast, in the first five developmental modules, students were required to complete quizzes and tests without the assistance of a calculator. Observations revealed that some MCR students were able to successfully complete assignments in MTH 154, even though they turned to calculators for very rudimentary computations. This indicates one other potential reason why more students may be finding success in these supported QR courses. That is, some of these students may be able to do computations with the assistance of a calculator but struggle to do so by hand.

However, there were also skills covered in the developmental modules embedded within the MTH 154 material that could not be done with a calculator. Linear equations (e.g., $3x + 7 = 12$) showed up throughout the curriculum, when dealing with proportions, financial formulas, and modeling with lines. Students were often required to solve linear equations within an applied context, such as finding the rate of interest on a loan using the simple interest formula. Many students were also rather unfamiliar with the meaning of slope and working with equations of lines, which were required in the last unit on mathematical modeling. As Dr. Heyward noted in the earlier quote, these basic algebra skills were a large hurdle for some students. Some of them did not know that dividing by a fraction was equivalent to multiplying by its reciprocal. Though a calculator could help students avoid issues with arithmetic, they were less well-suited to compensating for poor algebra skills.

To sum up the above points, many students from the MCR courses indeed did struggle with content from the first five modules, and instructors had to identify and address these issues. However, instructors did not solely focus on building content mastery in the MCR courses. In many instances, instructors utilized a one-on-one instructional format to coach students through difficulties they encountered. As discussed in Assertion 5, one of the design aspects of the Knewton instructional software was that it was responsive to student work. One challenge of this that impacted the MCR course was that when students received wrong answers on multiple questions when using the software, they could *lose* progress on their assignment, and then lengthen the amount of time required to finish. This feature, which was not adjustable by instructors, discouraged students from guessing on problems, but also led to frustrating experiences. Dr. Heyward took some of the instructional time to help students avoid this frustration. An example of this takes place in the following note from this next analytic vignette, written from a combination of fieldnotes and informal conversations with Dr. Heyward.

As usual, Dr. Heyward is circulating about the class, stopping with each student for a moment to check on their progress and answer questions. Maggie, a student in a yellow sweater raises her hand, exhaling with frustration. She lowers her hand briefly, opening up Facebook on her computer and idly clicking around while Dr. Heyward looks over another student's work. She raises her hand again once she sees Dr. Heyward finish her conversation. Dr. Heyward comes over and sees that Maggie has missed her first attempt on a problem involving direct variation. Maggie is starting to get visibly emotional. Dr. Heyward, spotting that Maggie is not writing down anything while working on the instructional software, leans in and asks her to show what progress she has been able to make. This is not the first time Dr. Heyward has gently prodded Maggie into getting her to write on paper to work out the mathematics. Maggie reaches into her backpack to get some out, then starts choking back tears.

Dr. Heyward, unphased, attempts to calm Maggie, telling her, "part of your trouble is that you are getting frustrated. Let's take a break from it. Is it just material you're having trouble with or is something else going on?" Maggie, through sniffles, talks about an upcoming job interview that is stressing her out. Dr. Heyward, standing back straight and taking an encouraging tone, tries to refocus Maggie on the larger picture.

"This one section is not going to make or break you. Do you have time to work on this later today? It might make more sense for you to work on the next sections on unit conversion. That material is not dependent on what we are doing with variation."

Maggie replies about how she could work with ratios and proportions in her head, but that she was not good with solving equations. Dr. Heyward agrees with Maggie's self-assessment, and she reiterates the need to write down steps when completing these exercises. She asks Maggie about her next few days, and after some amount of prodding, gets Maggie to find a time to meet her during office hours.

The vignette above illustrates how students struggled not simply because of their algebra or arithmetic skills, but because of issues outside of the class, challenges with the software, and lack of study skills including metacognition. Indeed, the student in the example was struggling in part because she had reasonably strong arithmetic skills that made it possible for her to solve some ratio and proportion problems in her head. When this approach failed to help her on more complex exercises, she became frustrated as she had not developed the skills to work these by hand. Dr. Heyward's intervention allowed the student to help refocus her energy, and it provided Dr. Heyward with an opportunity to force additional accountability on her students. Dr. Heyward noted that many of her MCR students became more willing, over the course of the semester, to come to office hours when they struggled. She also noted how she had to have heart-to-heart discussions with students like Maggie who engaged in off-task activities. She reported that she worked with Maggie in the corequisite course and succeeded in getting her to regularly attend office hours.

Dr. Heyward spent most of her time supporting students on an individual basis, and frequently took time to address matters not directly related to content knowledge.

For instance, many of her students tended to use the calculators on their computers or phones, rather than the scientific or graphing calculators that were perhaps better suited to the task. Some students would avoid using pencil and paper, and it took instructor intervention to ensure that students were modeling appropriate solution techniques. As in the earlier vignette from Mr. Bridges' class, the instructors would in some cases spend time making sure that students were familiar with how to use their calculators. Both instructors also used the MCR course to reiterate course expectations. For example, they would remind students about the assignment schedule or topics required for upcoming tests. Throughout their interactions, they also built rapport with the students, engaging in small talk and banter.

The findings in this assertion connect back to those expressed in Assertion 2 and the expectations among practitioners that it might be possible for these corequisite courses to represent an improvement. To do so, the format needed to be responsive to whatever needs students have, and these were not solely gaps in foundational reasoning. Observational data indicated that faculty spent time coaching and working with students on an individual basis. Given the considerable variation in student ability, this was to some extent necessary. While both Dr. Heyward and Mr. Bridges admitted that there were ways they could improve, they saw the MCR courses as successful in these ways. This point is the focus of the last assertion responding to the third research question.

Assertion 9: Faculty saw the MCR 4 course as being more beneficial than the MTT courses, but saw further opportunities for improvement in terms of additional structure and improved placement mechanisms

One of the implementation issues for the corequisite model noted in Daugherty et al. (2018) was that of a lack of faculty buy-in. Given some of the skepticism towards reforms among faculty noted in earlier assertions, it is certainly possible that corequisite implementation at CCCC may have gone poorly for precisely this reason. However, at least in the case of the faculty observed, there did appear to be faculty buy-in. Both Dr. Heyward and Mr. Bridges had experience teaching the MTT courses, and both expressed a strong preference for the MCR corequisite support format over the MTT courses. That is, many of the conditions that needed to be improved mentioned in Assertions 1 and 2 did seem to take place with the new corequisite reforms. Dr. Heyward elaborated on the comparison between the two models:

> It's very similar to how I do my MTT. But it's better than the MTT, *so* much better, because you're all on the same page. You're all on the same thing. While their deficiencies may be in different areas we're still working on the same content. And in the MTTs we weren't, so… you could never do a classroom discussion on a topic because everyone's on a different topic.

Dr. Heyward's comments also corroborate findings from Assertion 2, noting the instructional issues with the EM, and Assertion 6, that the corequisite format enabled a flexible instructional approach.

Another way in which Dr. Heyward saw the MCR class as being beneficial was that the format facilitated stronger interpersonal connections between students and faculty and among students. Dr. Heyward described her MCR course as having formed a “mandated sort of cohort”, noting that her students “developed a lot of strong working relationships with each other”. Without having to direct them, her students would routinely help one another out and explain concepts to one another during class. They also took these relationships beyond the MCR course, working with each other on group assignments in the MTH 154 class. In some cases these relationships extended beyond academic collaboration. Dr. Heyward remarked how she overheard students arranging to give each other rides to school. In one instance, one student even bought the instructional software for another student. Dr. Heyward was struck by the level of camaraderie and the willingness of her students to work together. While she suspected that the strength of peer effects may have been specific to this particular group of students, she was nevertheless impressed by its apparent impact. Mr. Bridges did not express the same sort of effects in his own class, and noted that the fact that perhaps only four or five students were in regular attendance limited the impact of working in groups.

Along with the accountability from peers exhibited in Dr. Heyward’s class, the MCR course facilitated more accountability from the instructor. Even though students had access to a variety of help services, having a mandatory support course meant that many of these students may have been getting help they would not otherwise have received. With the exception of perhaps one or two of her students, everyone in the MCR course would ask questions, and a few of them regularly attended office hours. She compared this to how other students in the MTH 154 class might not reach out in the same way.

> When I'm teaching a [MTH 154] class, I can see, "Oh, this person needs help with that". But the chances that they come in to my office and actually get to work on that are slim. Now I got them [in the MCR] and I'm going to work on that with them. Because they are in there for an hour with me and so if I see that you don't know how to do something then I'm going to come and work on it with you.

Dr. Heyward noted with humor how some students would at one moment express that they did not need the MCR course, and then the next moment run into difficulties and ask questions. From her perspective, it was ultimately this combination of accountability, peer effects, and opportunities to ask questions that made the MCR course valuable.

Mr. Bridges, who described himself as "80% satisfied" with the MCR course, offered his own reasons for why he saw the MCR course as preferable to the MTT courses.

> My gut [reaction] having experienced both of them is that the coreq is more beneficial to students [than the MTTs], because any backfill information they're getting in the context of… some application. So, I believe that it sticks a bit more

> when we see it in the applications… We have a lot that are word problem-based, problem solving instead of 6x + 2 = 59.

The point Mr. Bridges makes here also connects back to the instructional issues of the EM discussed in Assertions 1 and 2. The previous dean, Dr. Fisk, had before characterized the developmental courses as having a backward-facing remediation objective rather than provide the necessary remediation at the time it is needed. Mr. Bridges' comments suggest that he shared a similar outlook.

Mr. Bridges and Dr. Heyward both noted that working with their same students in the smaller class format contributed to the value of the course. They both suggested that it would be difficult to offer the same variety of instructional approaches when working with more than 10 or perhaps 12 students. This certainly had been a challenge in the MTT courses that held upwards of 15-18 students. Also, both instructors saw the rapport they had with students as essential. Having that rapport facilitated an environment where students were comfortable bringing their questions and honestly sharing what difficulties they were having. Both faculty thought that having a separate instructor teach the MCR course would lose much of the value generated by the personal connections they formed with their students. Furthermore, working in the small format allowed instructors additional opportunities to learn how to effectively teach the MTH 154 material. Mr. Bridges also shared that there were four or five times when he stumbled upon an explanation in MCR 4 that "seem[ed] to be a light bulb". For Dr. Heyward as well, there were moments when her work in MCR 4 inspired her to bring an alternative explanation to the MTH 154 course. Both faculty also saw opportunities to improve upon the MCR courses in the future, and these suggestions are discussed below.

Additional Structure. During an exit interview, Dr. Heyward expressed some dissatisfaction about how she led the course, believing that she allowed the students to run the class too much. She surmised that her students saw completing the assignments as their priority and was unhappy that she allowed their preferences to dictate too much what went on in the class. In the future, she thought that it would be necessary to add more structure to her class and set clear expectations for the daily rhythm of the MCR class. She wanted to spend more time at the beginning doing direct instruction and guided practice before doing assignment support. She thought that establishing firmer expectations for the daily rhythm of class might help to avoid some student's desire to immediately begin working on assignments when class began. Mr. Bridges also thought that some of the "mini lessons" he gave during direct instruction were not particularly beneficial to students. In the future, he wanted to identify which topics or lessons appeared to be particularly useful and avoid offering those that did not appear to benefit students. He also had other ideas for adding regular structure, such as beginning each class with warm-up exercises on common struggles, such as fractions operations.

Regular Opportunities for Assignment Practice. While Dr. Heyward thought she had given too many opportunities for students to work on their assignments, Mr.

Bridges expressed somewhat the opposite during an exit interview, noting that he wished he had given more time for students to work on their assignments. He thought there had been other scenarios, such as a lesson he gave on fraction operations, that were less effective, and that the students would have benefitted instead from additional practice. As mentioned earlier, Mr. Bridges used assignment support fairly sparingly, and generally dedicated an entire day to it when he used it. He thought that giving students time to work on their homework on a more regular basis would be beneficial in the future.

Enforced Attendance. Both instructors expressed that they wanted to adhere more closely to the attendance policy. Neither of them ended up withdrawing any MCR students for non-attendance, though some students missed classes repeatedly. Mr. Bridges reported that in one case he did in one case take steps to talk to a student who regularly left class after MTH 154 and did not attend the MCR 4 course. Dr. Heyward also thought that she needed to keep better records and follow up when students began missing classes. As will be discussed in the next assertion, most of the students in the MCR course who were not successful in MTH 154 were those who struggled with attendance. Consequently, doing more to encourage and enforce attendance might help avoid failure by attrition.

Addressing Placement Issues. Unsurprisingly given the issues brought up in earlier assertions, one last area that faculty saw for potential improvement was the placement procedures for the MCR course. In a couple of instances, Dr. Heyward and

Mr. Bridges identified a couple of MCR students who seemed like they were able to be successful without the additional supports. However, they did not consider these cases to be of particular concern. They were more worried about underprepared students placed directly into MTH 154 courses and not required to take the corequisite support class. Because of the multiple measures placement and issues with developmental instruction already mentioned, some of the MTH 154 students who were not in the MCR course nevertheless struggled with the same issues mentioned in Assertion 8. Dr. Heyward thought it might be beneficial to create some sort of diagnostic assessment to give her whole MTH 154 class to identify students who struggled with foundational issues and might benefit from corequisite support. Mr. Bridges was less certain that this would be an effective use of time. He noted that some of the students who struggled did not begin to struggle until well into the semester and so an initial assessment might not be an accurate predictor of performance. The success rates and responses of these students to the corequisite format are turned to next in response to the fourth research question.

RQ 4: How do students respond to corequisite instruction?

The last research question turns from how the instructor utilized the MCR course to the impact it had upon the students enrolled in the corequisite course and how these students perceived the utility of the course. The first assertion explores the success rates of students in the MCR courses that were observed and compares these to the success rates of non-MCR students in MTH 154. It also explores some potential reasons for those students who were unsuccessful. The second assertion uses data from observations and surveys to explain how students perceived the effectiveness of the MCR course and what instructional approaches they found helpful.

Assertion 10: Students in the MCR course performed almost as well as their directly-placed peers the MTH 154 course

As discussed in the literature review, a number of states moving towards corequisite support models of developmental mathematics education have seen impressive increases in the number of students succeeding in their credit-level mathematics courses. Indeed, students in both MCR courses in this study performed at roughly comparable rates to their directly-placed peers. The table below shows the final overall course grades in MTH 154 of Dr. Heyward's classes, broken up by section. These grades were computed by a weighted average of final exam, test grades, in-class group assignments, projects, and homework. The first two columns show the performance of her students in her two sections, excluding those students enrolled in the corequisite support course. Two of her MCR students were enrolled in Section 1, and the remaining nine were enrolled in Section 2. The grades of the classes are shown in Tables 8 and 9.

Table 8. Dr. Heyward's Grade Distribution

Grade	Section 1 (non-MCR)	Section 2 (non-MCR)	MCR Students
A	5 (18.5%)	4 (21.1%)	0 (0%)
B	11 (40.7%)	7 (36.8%)	4 (36.4%)
C	7 (25.9%)	5 (26.3%)	5 (45.5%)
D	3 (11.1%)	2 (10.5%)	1 (9.1%)
F	1 (3.7%)	1 (5.3%)	1 (9.1%)

As can be seen in the table, Dr. Heyward's MCR students performed nearly as well as her other students in the section. Perhaps unsurprisingly given their identification as marginally prepared, the grade distribution among MCR students included considerably more C grades and no A grades, but only two MCR students performed worse than a C. Dr. Heyward reported that her student who failed MTH 154 from her MCR course struggled with attendance for both courses, and ultimately failed the MTH 154 course even though she did take the final exam. One of her students who failed from the other sections did not take the final exam. Dr. Heyward commented that the other student who received a failing grade, as well as several of the students who received Ds, would likely have benefitted from the additional support offered by the MCR course. These results are somewhat more favorable than those in Mr. Bridges' class, which are reported in Table 9 below.

Table 9. Mr. Bridges' Grade Distribution

Grade	Non-MCR Students	MCR Students
A	2 (11.1%)	1 (14.3%)
B	4 (22.2%)	1 (14.3%)
C	5 (27.8%)	1 (14.3%)
D	2 (11.1%)	1 (14.3%)
F	5 (27.8%)	3 (42.9%)

The success rates in Mr. Bridges' courses were considerably lower, among both MCR and non-MCR students. Mr. Bridges had several more students that, for whatever reason, stopped attending and subsequently received grades of F. This included two of the F grades among MCR students and three of the F grades among non-MCR students. When ignoring these students who failed as a result of not attending, only one of the MCR students ended up failing despite putting in effort. As noted before, one of Mr. Bridges' students was enrolled in another instructor's MTH 154 course, and that student ended up getting an A. Mr. Bridges surmised that this student probably would have performed reasonably well in the course even without the support of the MCR course, but he did express the belief that the MCR course was on the whole helpful.

As can be seen in the tables above, the MCR students succeeded at similar rates to her students in the MTH 154 course who were not receiving corequisite support. Of the 18 students in MCR, 12 earned a C or above, and two additional students earned a D. Though this is a rather small sample size, it provides some indication that many students who may have otherwise been placed into remedial prerequisite courses can indeed succeed in credit-level mathematics when given appropriate support. Of course, there are differential success rates among instructors, which may reflect some combination of instructor grading practices, student performance, and the effectiveness of different instructional practices in the MCR course. It cannot be entirely ruled out that instructors may have differed slightly in their grading practices when grading their corequisite students on MTH 154 assignments. It may be that the additional rapport and knowledge of the students may have made them more lenient. However, given that MCR students did not have separate assignments from the other MTH 154 students, it seems implausible that instructors would have a systematic bias in favor of all of their MCR students that would have a major impact on final grades.

Because the placement mechanism is not random assignment, and there is a limited pool of data, no detailed statistical analysis is included in this capstone. And of course, because of the fundamental problem of causal inference, there is no way of knowing how the MCR students would have performed had they been required to complete MTT courses, or if they would have been directly assigned into MTH 154. Nonetheless, this snapshot of data shows some amount of consistency with the findings in Logue et al. (2016). That is, many of the students who under the previous system would have started in remedial coursework were able to successfully pass their credit-level course when enrolled in the paired corequisite support course. The last assertion explores why this may be the case, from the perspective of students in the study.

Assertion 11: Many of the students agreed the MCR course enhanced their performance in MTH 154, but differed on their preferences towards direct instruction, guided practice, or assignment support

As noted in the methodology section, students were given two surveys eliciting their feedback, which both included Likert-type items and open-ended questions. The first survey was made available approximately halfway through the semester and the second was made available during the last week of classes. These surveys were completed independently by students outside of class, without any incentives provided for completion. The full responses are aggregated in Appendix C. This assertion begins by highlighting selected student responses to the mid-semester and end-of-semester surveys. It concludes by synthesizing these findings with observational data.

Mid-semester Survey. The first mid-semester survey, developed with the input of Dr. Heyward and Mr. Bridges, largely focused on identifying student preferences for the use of class time. This included preferences for content discussed (MTH 154 content or foundational content) and preferences for activities (e.g., small group exercises, working on homework, direct instruction). Four of seven (57%) of Mr. Bridges' students, and seven of 11 (64%) of Dr. Heyward's, responded to the mid-semester survey. The first major point to note on the mid-semester survey is that, among those students who responded, most of them agreed that the MCR course was beneficial. The average response on a 1-5 Likert scale to the survey item "I find that the time spent in MCR improves my preparation in MTH 154" was a 4.75 in Mr. Bridges's class and a 4.29 in Dr. Heyward's class. No response was lower than "Neutral (3)" on this item.

To the second point in the assertion, students expressed various preferences about how the instructor could best utilize the support course. Confirming the conclusion expressed earlier by instructors, many students did not want the course to focus on remediating basic skills, but not all students. Two of 11 respondents either agreed or strongly agreed that more instructional time should be spent reviewing algebra or foundational material, while two students disagreed and three students strongly disagreed. The average response to this item was lowest among various suggested instructional activities for both sections. Students in both sections expressed higher preferences for more time to spend working on Knewton (assignment support) and more time reviewing concepts from MTH 154 (direct instruction).

These preferences can also be seen in the student responses to the open-ended survey items in the mid-semester survey. One open-ended item from the survey asked students to give a short answer response to: “What have you found to be the most helpful use of time in MCR 4 this semester?” Of six students in Dr. Heyward’s class who responded to this item, five of them said something to the effect that having additional time to work on the assignments with instructor assistance was the most valuable. The other response suggested that going over confusing problems was the most beneficial. Of four students in Mr. Bridges’ class who responded to this item, two gave a similar response, that reviewing the challenging concepts from the class was the most helpful. The third student responded with “going over our tests”. Only one student identified “going over the basics in order to gain a better understanding of the more difficult concepts” as the most helpful use of time. One student in Mr. Bridges’ class offered a suggestion for improvement, noting that spending more time discussing the instructional software would help students make better sense of the question format.

End-of-semester Survey. The second survey was made available to students during the last two weeks of the course. This survey, also designed with the input of faculty, asked students about whether they thought the MCR course improved their grade in MTH 154 and what aspects of the class they believed to have an impact on their performance. Like the mid-semester survey, the results are given in Appendix C. For whatever reasons, the response rate for the end-of-semester survey was lower than the mid-semester survey. Five of 11 (36%) of Dr. Heyward's students responded to the end of semester survey, along with only one of Mr. Bridges' students. Because of the small number of responses, these six are aggregated together in the appendix.

Beginning with student responses to the effectiveness of the MCR course, the average response to the item "Overall, I think I received a better grade in MTH 154 because of my attendance in MCR 4" was a 4.50. Some students agreed with statements that they would want to spend more time in the MCR course, or that they would have participated even had the course not been required, though responses to these items varied between "Neutral" and "Strongly Agree". In terms of which aspects of the course had the largest perceived impact, completing assignments on schedule and understanding the Knewton instructional software had the highest responses (4.67). The average response was at least a 4.00 for each suggested factor (see Appendix C for greater detail).

In terms of open-ended responses, only three of Dr. Heyward's students offered feedback, plus the one of Mr. Bridges. When asked about what they thought to be most helpful, all of Dr. Heyward's responding students replied with something to the effect that the additional one-on-one help on homework was the most helpful. No students in either class had any particular suggestions for activities they thought were not helpful. Regarding what would have been more helpful, one student suggested that "[Dr Heyward] needs to teach more". Another offered the recommendation to "Maybe have set assignments to help understanding of certain units". So, while many students did indeed think that having one-on-one support on assignments was helpful, some also had the desire for a more structured course that featured direct instruction as a larger component.

Limitations of Survey Data. Several obvious limitations arise when considering these survey results. Not all students in the corequisite course responded to the survey. Those who responded may have been more enthusiastic about the course than other students who did not or may have alternative preferences for class activities. Even had all the students responded, the sample size was still rather small in these corequisite courses. At the very least, these surveys provide an indication that at least some of the students found the MCR sessions to be of value. Also, students agreed that there were a variety of activities, from one-on-one homework assistance to guided practice in groups and direct instruction, that were perceived as helpful. There were also material factors that made Mr. Bridges and Dr. Heyward's classes different, such as the class size, time of day, or individual personalities of students that may have affected how other students responded to the survey.

Synthesis with Observational and Interview Data. Many of the responses on the survey are supported by instances in interviews and instructor reports in informal conversations and interviews. Dr. Heyward agreed with the notion that many of her students were willing and eager to participate. In some cases she saw this willingness as going beyond her own requirements or expectations. She noted that many of her students would want to begin the MCR session immediately after her MTH 154 class ended, even though the MCR class was scheduled to begin 15 minutes after the end of her first course. On multiple occasions, some students in her class would ask if they could stay late to continue working in the classroom after the scheduled end of class. During one observation, Dr. Heyward found herself completed surrounded by four students who continued to pepper her with questions for several minutes after the scheduled class period ended. Dr. Heyward also noted that there were instances of some class days when she had planned on cancelling the MCR class. For instance, she anticipated that students would not be interested in attending the MCR course on the day of a test. She expressed surprise however when students asked to meet with her to continue working and asking questions to make sure they had understood the content from that unit, and she obliged.

However, the enthusiasm for the MCR course was not shared among all students. Dr. Heyward described some students as wanting to "blow it off" and noted that certain students asked to leave class early several times. On multiple occasions in Mr. Bridges's class, some students would attend the MTH 154 class and then fail to show up for the MCR course that immediately followed. Despite having seven enrolled in the MCR course at the beginning, Mr. Bridges would often only have between three and five attending on any given day. Dr. Heyward tended to see better attendance, but as previous mentioned, she did not strictly enforce the attendance policy. Again, because the surveys were voluntary and several students did not respond, the scores are likely biased upwards.

One enduring challenge for the faculty when teaching in the support course was balancing the conflicting needs and preferences of their various students. For example, many of the students in Dr. Heyward's course expressed a clear preference for assignment support. Dr. Heyward shared the impression that a handful of her students would have been content if she had spent the entire time working one-on-one with them as they completed their assignments. Most of her students thought that spending time working on the homework in Knewton was the most helpful use of time. Responses to her mid-semester survey were broadly positive, though by the end of the semester two students suggested that more direct instruction would have been valuable.

It is perhaps noteworthy that the student preferences for the use of time largely reflected how each instructor chose to utilize the time in their class. That is, Dr. Heyward's students expressed a stronger preference for assignment support, and most of the class time was dedicated to this purpose. By contrast, most of Mr. Bridges' students preferred to review concepts from MTH 154, either through direct instruction or guided practice. The extent to which these student preferences influenced the instructor's decision on how to use time and how much instructor decisions impact student preferences remains difficult to ascertain.

Overall, while the response rate to surveys leaves the possibility that some unenthusiastic students saw limited value in the course, there was certainly a sizeable group of students in both courses who saw the MCR course as beneficial. The student responses also show that, contrary to Dr. Heyward's expectation that students simply wanted time to do their homework, many students did see a review of MTH 154 content as a valuable use of the support course. There was also no single activity among direct instruction, guided practice, or assignment support that was universally viewed as the most helpful. These results again reinforce the point that a combination of direct instruction, guided practice, and assignment support allows the corequisite instructor to reach a wide audience and address a variety of student needs.

Summary of Findings and Directions for Future Research

As noted in the first two chapters, other colleges that have piloted corequisite models have seen dramatic increases in the number of students passing credit-level mathematics. Scholars using quantitative methods have noted already that attrition (Bailey et al., 2010) and skill atrophy between developmental and credit-level mathematics (Quarles & Davis, 2017) partially explain the poor longitudinal performance of students in traditional formats of developmental mathematics. One goal of the present research study was to examine *how* the corequisite course itself might provide support to students in ways that improve student outcomes. The findings discussed in this chapter point to several additional mechanisms within the support classes themselves that may be responsible.

Responsive Instruction. First, the support that instructors provided responded to the needs of individual students. The small-class format and rapport between student and instructors created an environment in the support class where many students were comfortable with asking their questions. Instructors used the guidance of students to help direct the course in productive ways. In some instances, this meant following student suggestions when choosing topics to review as a class. In other cases, it meant providing suggested exercises on common student struggles, or allowing students time complete assignments in a supported environment. Rather than using placement measures as a proxy of student knowledge, instructors employed their expertise to find and target specific misconceptions and gaps. This dialogic approach ensured an alignment between the developmental support course and the credit-level course, an issue that limited the effectiveness of the previous format. Furthermore, instructors had the opportunity in the support course to address not only content gaps but poor study skills and technology skills.

Integration with Credit-Level Curriculum. One aspect of achieving student buy-in among students was that the activities of the support class directly benefitted their progress in MTH 154. One aspect of this was the fact that remediation was largely embedded within the curriculum of the QR course. Rather than require students to master procedural skills (e.g., fraction arithmetic and solving linear equations) *prior* to encountering a useful application, instructors let the QR content lead students back into foundational skills when necessary. Because this curriculum focused upon solving applied problems, the relevant of these foundational skills was considerably more evident to students. When necessary, instructors would dedicate time to “backfill” these various foundational gaps. Giving students guided practice and assignment support allowed instructors to identify what these specific gaps were.

Accountability and Rapport. Finally, the corequisite course format provided additional accountability to students. This came in multiple forms. At the most basic level, students were required to dedicate at least two hours outside of the MTH 154 class to working with the course material. Though these students may have sought out assistance without the class, having the support course lowered the barriers to ask for help. Within the support course, students had opportunities to ask questions and try to explain their reasoning with the instructor and their peers. In some instances, the small format encouraged a certain amount of camaraderie and solidarity among peers. It also made it easy for instructors to follow up with students and ensure their individual needs were being met. The rapport and individual attention were made possible by the small class sizes and by working with the same instructor as the MTH 154 class. Thanks to the assistance of this support course, the students in the MCR support course ended up performing similarly to their directly-placed counterparts. The findings point to the conclusion that, in these two cases, the support course was an effective form of remediation that enabled marginally prepared students to succeed in credit-level mathematics.

Future Directions. There are several future directions for research on the implementation of corequisite courses, particularly given the potential that the VCCS may expand upon these course offerings in the future. First are potential changes that may occur at CCCC in the future. In future semesters the college might expand their corequisite offerings for courses such as MTH 161 (Precalculus). Given that this course may be used as an entry into mathematics-intensive programs of study, the approach in such a course may need to be considerably different than simply ensuring that students successfully complete their mathematics requirement. In the event that future scheduling and staffing needs demand alternative course structures, such as having non-paired students in the same corequisite class, or increasing the maximum class size, the effectiveness of these alternatives should be explored.

Finally, future research is needed to investigating differing corequisite instructional practices at colleges across the VCCS and the nation. Doing so may provide recommendations to the system as a whole on how these programs ought or ought not to be implemented at a large scale. Finally, because placement practices throughout the VCCS may change again, this may have considerable impacts on who gets into these corequisite courses and what adjustments instructors will need to make to ensure that corequisite remediation provides students with the supports they need to succeed.

III – POSITION PAPER

The overarching goal of this research capstone was to explore how the corequisite model of mathematics instruction was implemented at one college in the Virginia Community College System. Given the rapid expansion of corequisite remediation programs across the nation and the limited body of research, there is a demonstrated need for qualitative research on how these reforms ought to be implemented. This research study explored implementation from several angles in response to four research questions. These research questions began with practitioner perspectives towards these reforms. They followed with implementation details and additional contextual factors that impacted implementation. Lastly, the research questions asked about how faculty and students utilized the instructional time in the support course and what they thought of it. This element of the research capstone overviews a series of recommendations for improving the implementation of corequisite courses. These recommendations are specific to the institution under study but may provide insights for other institutions implementing similar models.

Recommendation 1: The college should continue to offer the QR corequisite support course with additional structure and attendance enforcement, and should experiment with offering corequisite support for other courses

Judging from the perspectives of instructors and students and the performance of students in the MCR course, the corequisite format appeared to be successful. The instructors teaching in the format believed it to be an improvement upon the prior format of developmental instruction. Instructors had more opportunities to target remediation to the needs of individuals and ensure that whatever remediation they covered was directly applicable to the paired credit-level course. The flexible format of the class allowed instructors to utilize a combination of direct instruction, guided practice, and assignment support based on what they judged to be most valuable within a given context. Because there were not a separate set of corequisite course objectives or required assignments other than those of the credit-level course, this format ensured that class time was not spent on concepts or skills that were unnecessary for student success. The students also viewed the corequisite class favorably and saw it as improving their performance in QR. These perspectives were corroborated by student performance, as the large majority of students in the MCR class were successful. Their overall performance was close to students placed directly into the QR course.

A few minor adjustments to the corequisite courses might further yield further improvements towards its capacity to help students. Of students who failed the QR course despite being enrolled in the corequisite support class, many of them struggled with attendance in the support course. Ensuring that faculty take regular attendance, follow up with non-attending students, and remind students of the consequences of missing the support class may help avoid failure as a result of attrition. The other major avenue for improvement according to faculty and student perspectives is creating additional structure for the use of class time. This should include some balance of direct instruction, guided practice, and assignment support, informed by the credit-level curriculum and the desires of students.

Given the success of students in this first semester, CCCC should pilot the corequisite format for other gatekeeper mathematics courses. One such course would be MTH 161 (Precalculus I). This course at CCCC currently has rather high failure rates, with upwards of half of students withdrawing or failing the course. Offering the corequisite course could represent an improvement on the remedial format currently offered, since instructors could tie in remediation on an as-needed basis. The college should explore ways to encourage marginally prepared students who place directly into gatekeeper mathematics courses to take the corequisite support class, even if they are not required to do so by current policy. Having this mandated support may encourage students to ask for help when they may not otherwise seek it out.

Given that the VCCS may be enacting additional policies that lead to increased corequisite offerings, and decreased offerings of traditional developmental mathematics, CCCC and other colleges may likely benefit by trying to identify valuable and successful corequisite practices. Because placement into QR courses may change in the future, the practices that appear to be successful in the current system may need to be revisited in the future. The uncertainty around policy complicates the process of identifying successful practices and policies. Even so, it would be beneficial to continue experimenting with the corequisite format in other courses such as Precalculus or Statistical Reasoning with piloted courses.

Recommendation 2: The corequisite support course should continue to be a subgroup of eight to 12 students from the credit-level course, taught by the same instructor

This recommendation aligns directly with the findings from the original ALP study (Adams et al., 2009), since the current format facilitates success for a number of reasons. First, a class size no larger than 10 or 12 allows faculty to be flexible with their instructional approach. Faculty can address common misconceptions using the corequisite course for direct instruction on topics informed by the instructor's judgment and informed by student feedback. Alternatively, faculty can provide guided practice or assignment support to address misconceptions on an individual basis. Were the class much larger, it would limit the ability of faculty to give each student individual attention.

Second, having the students be part of the same MTH 154 course provides additional opportunities for positive interactions among students and between students and faculty. When students are more familiar with their instructor and classmates, they may be more willing to ask questions to faculty or peers. The smaller format may also make for a less intimidating environment for students to share explanations with one another. Beyond the benefits of improved rapport, working with the same students also allows faculty to have a better sense of the student's performance in the credit-level course and understand exactly what assignments the student needs to complete and what topics each individual student struggles on. Working with the same section of students also avoids potential schedule misalignment issues that make it more complicated to identify topics to cover as a group when working with students from multiple sections.

VCCS policy allows these corequisite courses to be implemented according to the staffing and scheduling needs of individual colleges. Because these courses are listed as non-credit level, they may be taught by faculty qualified to teach developmental mathematics. At the VCCS, these courses can be taught by instructors with a bachelor's degree or higher in mathematics, while credit-level courses must be taught by a recipient of a master's degree with at least 18 graduate credits in mathematics. Though it may simplify scheduling and staffing to assign these courses to a separate developmental instructor, and to gather students from multiple sections, doing so may lose significant benefits of the support format. Unlike the previous developmental instruction, which only required faculty to teach concepts from arithmetic and basic algebra, the faculty teaching these corequisite support courses will need to be prepared to teach the exact same concepts from the credit-level course. Consequently, whenever staffing resources are available, they should have the same minimum qualifications as those teaching the paired credit-level course. Allowing the corequisite courses to respond to the needs of students means that the faculty teaching them must be adequately skilled to be able to teach all of the concepts in the credit-level course, in addition to remedial skills. Without investing sufficient resources in these corequisite classes by keeping enrollment small and staffing them with trained faculty, students will likely not receive the same benefits out of their support courses.

Recommendation 3: Faculty teaching corequisite support courses should collaborate across CCCC, the state, and the country

Teaching corequisite support courses poses a different set of challenges than does teaching remedial algebra, one that must be more flexible and responsive to student needs. Instructors in corequisite classes should come prepared with multiple options for additional practice on any given day. An instructor may run into unanticipated foundational gaps. Alternatively, they may find only a small number of students struggle on a particular remedial concept, such as operations with fractions or solving basic linear equations. The open-ended nature of the course and lack of a set of defined objectives can present challenges for instructors to prepare for these courses.

One aspect of addressing this challenge is to have faculty at CCCC collaborate and share resources they use in the corequisite support course with one another. This may include remedial topics one instructor has found particularly useful or a set of exercises on problems taken from the credit-level course. Given that instructors may not anticipate student requests, it is helpful for corequisite instructors to come prepared with more possibilities than they could expect to get to during the time period. However, preparing this amount of options by oneself can be time-consuming. Though faculty may be tempted to simply offer up most of the time for assignment support, some students prefer to have more direct instruction or guided practice.

Faculty should collectively compile a list of remedial topics that students struggle in and where and how to incorporate these into credit-level content. This could include a bank of practice problems on fraction operations, working with percentages and decimals, evaluating order of operations, and solving basic linear equations. These resources could be made even more useful to new corequisite instructors by mapping the credit-level curriculum to foundational topics. Doing so may help ensure that less-prepared students have adequate opportunities to practice whichever skills are preventing them from being successful. Instructors could also collaborate to create activities that address other student needs, such as working with calculators or appropriately utilizing paper and pencil when working on assignments. One way to organize this in a helpful way would be for instructors working on MTH 154 and MCR 4 at the college to create a repository of activities linked to learning objectives and sections. This way it would be easy for the instructors to respond as needed to whatever issues came up without having to prepare on the fly.

Ultimately, the exact approach a corequisite support instructor should take depends upon the needs of students and the demands of the credit-level curriculum. Because these support courses are small, faculty should anticipate that each course will have a different dynamic. Students may be enthusiastic to work with one another and gravitate towards working in groups, or they may prefer to work individually. Faculty should share their perspectives on how to balance the needs of the group as a whole with the needs of the least prepared among their students. Especially because this format is new, instructors ought to collaborate to identify what practices are valuable and in what contexts, as well as share experiences of their unsuccessful attempts to assist students. Compiling these experiences at CCCC can also provide insights that can inform policy decisions at the college.

Finally, the collaboration should extend beyond CCCC and include fellow colleges across the VCCS. The administration should provide resources for faculty to visit and learn from sister schools across the state and to share lessons learned from successes and challenges at the college. Given that other states such as Tennessee have already had multiple years to employ this format, CCCC would likely benefit by providing opportunities for its faculty to visit colleges with more experience in the format. Finally, faculty should share the details and results of their corequisite experiences at with the practitioner and scholar community through conferences and publications.

Recommendation 4: Administrators should involve faculty in the creation of policies regarding corequisite support courses at the college and system level

There are many reasons why educational reforms may be unsuccessful, and the EM-based reforms that preceding the corequisite model offered an example of the limitations of such efforts. Poor implementation or ill-founded reforms can lead to resentment and fatigue among the faculty and skepticism towards future initiatives. One part of ensuring faculty buy-in is making sure that faculty believe their expertise is valued and their voices are heard. Administrators may be more aware of broader reform efforts and initiate changes that are supported by certain findings in the literature. However, without the buy-in of faculty, such reforms may be ineffectual, and this can certainly be the case with corequisite reforms. Administrators should anticipate resistance to change among faculty and should make a good-faith effort to acknowledge and address their concerns so as to avoid negative sentiments.

To facilitate buy-in among faculty, administrators should provide clear rationales on why a transition to the corequisite model is beneficial. These appeals should not be limited to the impacts on success rates at other colleges. Rather, they should include some discussion of the mechanisms that enable corequisite courses to improve upon existing developmental education models. These explanations should also recognize and admit the flaws of previous models. In doing so, this may help administrators and faculty identify pathways for improving systems to prepare students for success in their college mathematics coursework.

Ultimately, the success of the corequisite models depend upon how faculty employ their instructional time and whether students actively utilize the course in ways that facilitate their success. Administrators should attempt to provide stability and freedom to instructors in these courses to allow time for faculty to experiment with instructional formats. Leaving expectations unclear or instituting programmatic changes without the input and guidance of instructors can be a recipe for creating resentment among faculty. Instead, administrators and faculty should collaborate to identify effective ways to institute and improve upon course policies.

For example, faculty should work with administrators to address the imperfections of the current placement system. This could include providing formalized measures for additional students to be recommended or required to take the support course. These measures could include diagnostic assessments given at the beginning of the credit-level course to gauge student preparedness. By tracking the success of students and comparing it to performance on a diagnostic assessment, faculty could ensure that all those who need extra assistance are benefiting by it.   Given that the VCCS is already in the process of embarking upon additional reforms, this is a crucial moment. Individual colleges at the VCCS and across the nation are finding themselves needing to respond to policies instituted from above. Corequisite support courses offer an opportunity to increase success for incoming college students. However, it will require faculty and administration to work together to lend their expertise and implement feasible and effective solutions.

IV – ACTION COMMUNICATIONS

From: Zachary M. Beamer
Doctoral Candidate
University of Virginia
405 Emmet St. S
Charlottesville, VA 22903

Dear Members of Administration,

I am writing to report findings and recommendations for the college based on a qualitative case study on the implementation of the corequisite model of developmental mathematics education. States that have recently adopted corequisite models of remediation have seen dramatic improvements to the number of students successfully completing credit-level mathematics. However, few studies have employed qualitative methods to investigate the causal mechanisms by which these support courses contribute to improved student outcomes.

The purpose of this study was to understand practitioner perspectives towards the corequisite model and how the corequisite course design impacted student success. It also explored what instructional practices took place within the support course and how students responded to the corequisite courses. These findings follow from 20 hours of classroom observation, 10 hours with each of two sections of the MCR 4 support course, 14 hours of interviews with faculty, administration, and staff, document analysis, and surveys administered to students at the midpoint and end of the semester.

The primary findings of this study are as follows:

1. Understanding the failures of the previous VCCS reforms to developmental mathematics in terms of placement, curriculum, and instruction offers crucial insights into what is required for corequisite reforms to improve student outcomes.
2. Faculty teaching the MCR support course addressed student misconceptions on an individual basis using additional lecture, guided practice in groups, student-led discussions, and supervised assignment support.
3. Faculty used the MCR support course to assist student in content gaps as well as provide coaching to address study skills and non-academic issues.
4. Faculty participants who taught the MCR 4 course favored it over the previous MTT courses as a means for ensuring student success.
5. Students in the MCR course performed comparably to their directly placed peers in the MTH 154 course.
6. Students largely agreed that the MCR course improved their preparation for MTH 154 but expressed varying preferences for the use of instructional time.

Given the findings of this study, I would recommend that the college take the following steps to improve the implementation of corequisite mathematics courses in the future.

1. The college should continue to offer the QR corequisite support course with additional structure and attendance enforcement and should experiment with offering corequisite support for other courses.
2. The corequisite support course should continue to be a subgroup of eight to 12 students from the credit-level course, taught by the same instructor.
3. Faculty teaching corequisite support courses should collaborate to share resources and instructional experiences.
4. Administrators should involve faculty in the creation of policies regarding corequisite support courses at the college and system level.

I look forward to reviewing your response to these recommendations. Should you have questions or comments, I invite you to email me at zbeamer@pvcc.edu.

Sincerely,

Zack Beamer
Assistant Professor and Mathematics Department Chair
Piedmont Virginia Community College

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APPENDICES

Appendix A - Instructor Interview Questions

Mid-Semester

- What is your impression of how the corequisite support class is going?
- What happens in a typical day of your corequisite class?
- How do you plan for the corequisite class?
- How do you decide what to do during the corequisite class?
- How does instruction in the corequisite class compare to instruction in other formats of developmental mathematics?
- What challenges have you encountered as you have been teaching the corequisite class?
- What approaches have you found that have been particularly useful?
- What approaches have you found that have not seemed useful?
- What would you recommend to other faculty teaching a corequisite course?

End-of-Semester

- How satisfied are you with how the MCR 4 course went?
- What is one thing you'd continue to do if you taught MCR 4 again?
- What is one thing that you would change if you taught MCR 4 again?
- How valuable would you saw that the MCR 4 course was for students?
- What about the MCR 4 course had the largest impact on students?
- How much did you find yourself enforcing the attendance policy?
- What should be done to improve MCR 4 courses at the college or in the VCCS?

Appendix B – Informed Consent Agreement

Please read this consent agreement carefully before you decide to participate in the study.

Purpose of the research study: The purpose of the study is to explore instruction and classroom interactions in MCR 4: Corequisite Support for Quantitative Reasoning. Research suggests that similar course formats may result in more students passing credit-level mathematics. However, researchers have yet to identify why courses like MCR 4 improve student success. Using classroom observations, this research study will identify instructional best practices and student responses to this instructional format. This research may help inform instruction policy at the college and contribute to educational scholarship.

What you will do in the study: This research will include regular classroom observations, during which the researcher may take notes. No video, audio, or photographic recordings will be taken. At points which do not interrupt instruction, you may be asked about your rationale for your instructional decisions. Your decision to participate or not participate in this research will have no impact on your employment or standing at the college.

As part of research, you will be asked to document your experiences in the course in an instructional journal. In this journal, you are encouraged to record the successes and challenges encountered while teaching MCR 4.

At a minimum of two points during the semester, you will be asked to participate in an interview regarding the corequisite instruction at the college. These semi-structured interviews will explore themes discovered during observation relating to corequisite instruction. These interviews will be scheduled at a time and place convenient to you. You are free to refuse to respond to any interview question and there are no consequences to doing so. You may terminate the interview at any time.

Time required: The research will take place during your Fall 2018 corequisite-supported QR course. The interviews will each take at most one hour, with a total time commitment outside of class of a maximum of five hours.

Risks: It may be possible that your actions or comments recorded in the study could be traced back to you. The researcher cannot guarantee whether individuals reading the study may use the recorded findings as a basis for administrative decisions. To minimize any risks associated with this loss of confidentiality, all findings will be reported using pseudonyms. You may inform the researcher to not report on any matters that you deem to be potentially sensitive.

Benefits: There are no direct benefits to you for participating in this research study. The study may help us understand the conditions under which corequisite support leads to improved student outcomes in gatekeeper mathematics courses.

Confidentiality: Because of the nature of the data, I cannot guarantee your data will be confidential and it may be possible that others will know what you have reported.

Voluntary participation: Your participation in the study is completely voluntary. Opting out of the study will not affect your employment or standing at the institution. You may change your mind and stop participating if you wish to at any point in the study.

Right to withdraw from the study: You have the right to withdraw from the study at any time without penalty.

How to withdraw from the study: If you want to withdraw from the study, tell the researcher to stop recording notes. There is no penalty for withdrawing.

Payment: You will receive no payment for participating in the study.

If you have questions about the study, contact:
Zachary Beamer
1006 Blenheim Ave
Charlottesville, VA 22902
zbeamer@pvcc.edu
Phone: (434) 961-5345

Faculty Advisor:
Joe Garofalo
P.O. Box 400273
University of Virginia, Charlottesville, VA 22904
jg2e@virginia.edu
Phone: (434) 924-0845

To obtain more information about the study, ask questions about the research procedures, express concerns about your participation, or report illness, injury or other problems, please contact:
Tonya R. Moon, Ph.D.
Chair, Institutional Review Board for the Social and Behavioral Sciences
One Morton Dr Suite 500
University of Virginia, P.O. Box 800392
Charlottesville, VA 22908-0392
Telephone: (434) 924-5999
Email: irbsbshelp@virginia.edu
Website: www.virginia.edu/vpr/irb/sbs

Agreement:
I agree to participate in the research study described above.

Signature: ____ Date: _____________

You will receive a copy of this form for your records.

Appendix C – Student responses to mid-semester and end-of-semester surveys

Table 10. Student Responses to Mid-Semester Survey Likert Items

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Question Item	Mr. Bridges' average student response (reported with standard deviation, *N = 4*)	Dr. Heyward's average student response (reported with standard deviation, *N = 7*)
I would like the instructor to spend more time in MCR 4 reviewing what we covered in MTH 154.	3.75 (0.50)	3.28 (0.95)
I would like the instructor to spend more time in MCR 4 reviewing material from algebra and foundational courses.	2.75 (1.71)	2.43 (1.13)
I would like more time in MCR 4 to ask questions about topics I am struggling in.	2.75 (0.96)	3.57 (0.98)
I would like to spend more time in MCR 4 practicing exercises in small groups.	3.25 (0.96)	2.43 (0.98)
I would like the instructor to offer assessments that identify foundational topics I need additional practice in.	3.50 (1.29)	2.71 (0.76)
I would like to spend more time in MCR 4 working in Knewton on my assignments for MTH 154.	3.50 (1.73)	3.86 (1.07)
I would like to spend more time reviewing graded assignments from MTH 154.	3.50 (0.58)	2.71 (0.95)
I find that the time spent in MCR 4 improves my preparation in MTH 154.	4.75 (0.5)	4.28 (0.95)

Table 11. Student Responses to Mid-Semester Survey Open-Ended Items

Open-ended question	Mr. Bridges' student responses (five students responding)	Dr. Heyward's student responses (six students responding)
What have you found to be the most helpful use of time in MCR 4 this semester?	S1: extra time for homework S2: Going over anything that might have been confusing in class S3: Review after we had the class. S4: Going over the basics in order to gain a better understanding of the more difficult concepts. S5: going over our tests	S1: Have the ability to do my Knewton work and recieve assistance on it. S2: The practice S3: Assistance in homework S4: Homework S5: going over certain problems S6: Practicing problems from MTH 154 with Instructor
What activity or activities would you prefer that we would spend more time on during the MCR 4 class?	S1: things we covered in MTH S2: I like using the extra time to go over anything I didn't understand in class S5: im pretty content with what we do	S1: Help understand what we do in the MTH 154 course, and help better our skills at that work. S2: Just Knewton S3: I think what we have been doing so far is comfortable/fine with me. S4: Homework S5: working on confusion S6: Working on difficult problems from MTH154
Please offer any additional suggestions for ways in which class time could be better spent to help you succeed in MTH 154	S5: A little more time on knewton so I understand their format sometimes	S2: Its very helpful and the teacher is great. so there is nothing else needed. S3: No suggestions to offer. S5: i don't know any S6: The class is already good with how the Instructor performs and helps

Table 12. Student Responses to End-of-Semester Survey Likert Items

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

(Note: These responses include one student from Mr. Bridges' class and five from Dr. Heyward's)

Question Item	Average student response (reported with standard deviation, *N = 6*)
The MCR 4 class helped me complete assignments on schedule.	4.67 (0.52)
The MCR 4 class helped me understand the Knewton instructional software better.	4.67 (0.52)
The MCR 4 class helped me avoid getting frustrated when completing assignments.	4.00 (1.10)
The MCR 4 class helped clarify concepts from class.	4.33 (1.03)
The MCR 4 class helped me prepare for tests.	4.33 (1.03)
The MCR 4 class helped me understand what I did wrong on tests.	4.00 (1.10)
One-on-one instruction in the MCR 4 course improved my performance in MTH 154.	4.50 (0.84)
Working with peers in the MCR 4 course improved my performance in MTH 154.	4.33 (1.21)
I would have attended the MCR 4 course even if attendance were not required.	4.00 (0.63)
I would have liked to spend more time in MCR 4 per week.	3.83 (0.75)
Overall, I think I received a better grade in MTH 154 because of my attendance in MCR 4.	4.50 (0.84)

Table 13. Student Responses to End-of-Semester Survey Open-Ended Items

Open-ended question	Student responses (Note: S1 – S3 are Dr. Heyward's students, S4 is Mr. Bridges' student)
What did you find to be the most helpful use of time in MCR 4 this semester?	S1: The help with work S2: The additional help; 1-on-1 help S3: Homework time S4: Reviewing material that was difficult to understand in class
Describe any activities in MCR 4 that you thought were not helpful	S1: Nothing S2: N/A S3: None S4: N/A
Please offer any additional suggestions for how MCR 4 can be improved for future semesters.	S1: [Dr. Heyward] needs to teach more S2: Maybe have set assignments to help understanding of certain units S4: I'm not really sure

Appendix D – MTH 154 Student Learning Objectives (per VCCS curriculum)

Upon completion of MTH 154, the student should be able to, with at least 70% accuracy:

1. Solve real-life problems requiring interpretation and comparison of complex numeric summaries which extend beyond simple measures of center.
2. Solve real-life problems requiring interpretation and comparison of various representations of ratios (i.e., fractions, decimals, rates, and percentages).
3. Distinguish between proportional and non-proportional situations and, when appropriate, apply proportional reasoning. Recognize when proportional techniques do not apply.[3]
4. Solve real-life problems requiring conversion of units using dimensional analysis, including ordering real-life data written in scientific notation.
5. Apply scale factors to perform indirect measurements (e.g., maps, blueprints, concentrations, dosages, and densities).
6. Identify logical fallacies in popular culture: political speeches, advertisements, and other attempts to persuade
7. Relate the concept of a "statement" to the notion of Truth Value. Identify statements and non-statements
8. Describe the differences between verbal expression of truth and mathematical expression of truth. Discuss the usefulness of symbolic representation of statements. Discuss the 2-valued nature of mathematical truth value, relate this to real world examples.
9. Determine the logical equivalence between two different verbal statements (simple and compound) in real-world context and relate the language of conditionals to the language of quantified statements
10. Explore the relationship between quantified statements and conditional statements (e.g., "all scientists are educated" is equivalent to "if she is a scientist then she is educated.")
11. Apply concepts of symbolic logic and set theory to examine compound statements and apply that to decision making of real-world applications.
12. Use simple interest and compound interest formulas to analyze financial issues
13. Describe how compound interest differs from simple interest and show the difference between compound interest and simple interest using a table or graph.
14. Compute payments and charges associated with loans, evaluate the costs of buying items on credit, and identify the true cost of a loan by computing APR. Compare loans of varying lengths and interest rates.
15. Calculate the future value of an investment and analyze future value and present value of annuities (Take into consideration possible changes in rate, time, and money.)

16. Calculate profit from a sale of an investment and compare various investment options and understand when it is appropriate utilize them
17. Through an examination of examples, develop an ability to study physical systems in the real world by using abstract mathematical equations or computer programs. Make measurements of physical systems, assemble them (tables, charts, etc.), and relate them to the input values for functions or programs.
18. Quantitatively compare linear and non-linear (exponential). Identify and distinguish linear and non-linear data sets arrayed in graphs. Identify when a linear or non-linear model or trend is reasonable for given data or context.
19. Correctly associate a linear equation in two variables with its graph on a numerically accurate set of axes and numerically distinguish which one of a set of linear equations is modeled by a given set of (x,y) data points
20. Using measurements (or other data) gathered, and a computer program (spreadsheet or GDC) to create different regressions (linear and non-linear), determine the best model, and use the model to estimate future values.