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Qualitative Analysis of Corequisite Instruction in a Quantitative Reasoning Course

Zachary Beamer
Piedmont Virginia Community College, zbeamer@pvcc.edu

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Cover Page Footnote

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In corequisite models of instruction, marginally prepared students are placed directly into college-level coursework, taught with a paired support course. Initial research suggests that such models yield significant improvements in the number of students passing credit-level mathematics when compared to previous models of prerequisite remediation. The present study employs qualitative methods to investigate methods of instruction at one community colleges to understand how instructors identify and respond to student needs. It concludes with recommendations for practice and highlights advantages of small format corequisite classes taught by the same instructor.

Many students starting post-secondary education are identified as underprepared for college mathematics. Between 2003 and 2009, 21% of students at 4-year schools and 59% of students at 2-year schools enrolled into developmental mathematics (Chen, 2016). Of those students, only 67% of students at 4-year schools and a mere 45% of those at 2-year schools earned college-level mathematics credit (Chen, 2016). In recent years, many scholars have come to question the value of placing students into prerequisite remedial courses. Quantitative quasi-experimental research studies estimating the impact of remediation on credits earned or degree attainment suggest that receiving remediation has minimal benefits (Calcagno & Long, 2008; Boatman & Long, 2010; Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2015; Xu & Dadgar, 2018). Few randomized control trials have explored the issue, but one by Moss, Yeaton and Lloyd (2014) conducted at a large community college is in line with the quasi-experimental results. In the study, marginally prepared students randomly assigned to a prerequisite developmental course outperformed their directly placed peers by merely *one-third* of a letter grade.

These unimpressive results have prompted many reforms over the past decade, with the corequisite showing some promising initial results. In the corequisite model of remediation, marginally prepared students are placed directly into a college-level course, accompanied by an additional support course (Adams et al., 2009; Daugherty et al., 2018). Though quantitative research into large-scale reforms is in its nascent stages, one study of Tennessee's 2015 reforms estimated that placing students into corequisite courses increased the number of students passing these courses by *15 percentage points* (Ran & Lin, 2019). While the initial quantitative evidence appears promising, the transition to new structures and pedagogies leaves unanswered questions about how to effectively implement corequisite models of developmental education. These gaps in the literature prompted the following research questions:

- What strategies do instructors use when teaching a corequisite course paired with a quantitative reasoning course?
- How do instructors inform their remediation practices in a corequisite course?

Literature Review

In recent years, many colleges and systems have opted to implement major reforms to their developmental programs for English and mathematics. This has included acceleration or compression (Venezia & Hughes, 2013) as well as mainstreaming, or increasing placement directly into gatekeeper credit-level courses. The practice of mainstreaming can include using measures other than placement tests such as high school GPA or previous mathematics coursework (Ngo & Kwon, 2015). Corequisite models are another instance of these reforms, in which students receive remediation in the same semester as credit-level mathematics; the co-requisite model is showing signs as a promising approach.

The articles forming the foundation of the research base for corequisites come from studies of the "Accelerated Learning Program" (ALP) (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 paired with a gatekeeper course – the first credit-level college course – and taught by the same faculty member during the same semester. The remediated students were a subgroup (8 of 20) of the whole class. Courses in the ALP format address sa combination of remedial and college-level content, with the overarching goal of in these ALP classes to increase students' prospects of succeeding in the paired gatekeeper course. In mathematics, what constitutes a gatekeeper course depends on the institution, and may include courses like quantitative reasoning (QR) or liberal arts mathematics, statistical reasoning (SR), intermediate algebra, or precalculus.

As corequisite reforms become more popular, they are being implemented in considerably different ways in other settings (Daugherty et al., 2018). These include 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 as the credit-level course. 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 (Belfield, Jenkins & Lahr, 2016) or reports available electronically on the websites of advocacy groups such as Complete College America (2018).

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. Between-course attrition, a problem documented in Bailey, Jeong, & Cho (2010), meant that around a quarter of the students who completed their course 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, only 29% of remedially-placed students made it through gatekeeper mathematics courses. However, this study was not been experimental in nature, which limits the generalizability of findings.

One randomized control trial by Logue, Watanabe-Rose, and Douglas (2016) includes 907 students who were randomly assigned to one of three courses: traditional elementary algebra, elementary algebra supported by a one-credit support "workshop," or directly into a college-level SR course. Of the 907 students randomly assigned, 717 enrolled into their assigned course. Using statistical methods to adjust for the non-compliance of the other 190 students, the authors find that students placed into the SR course performed much better (56% pass rate) in their course than those students taking either elementary algebra with the workshop (45%) or without (39%).

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 measured success rates within the first course, whether that was algebra or the SR course. Given that the pass rate is *highest* for the SR course, this is less of a concern than some critics have expressed (e.g., Goudas, 2017; Goudas & Boylan, 2012). Indeed, these results indicate that students who might fail remedial algebra could pass a credit-level course when provided corequisite supports. When coupled with findings from Bailey, Jeong, and Cho (2010) that each additional prerequisite developmental course results in the attrition of nearly half of students, the corequisite-supported course represents a potentially significant improvement.

However, given the wide variety of methods of implementation, some scholars have been skeptical of the move towards unproven methods of developmental instruction. As Goudas (2017) notes, many of the aspects that may have been critical to the success of the ALP are absent from other models of corequisite education currently being debuted across the country. Reliable scholarly research on corequisite mathematics education is lacking. 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. The details of program implementation are confined to a paragraph. This brief description notes that the corequisite workshops followed a regular structure including reflection and practice on algebra topics necessary for understanding concepts within statistics.

A research brief by the Community College Research Center (Belfield, Jenkins, & Lahr, 2016) discusses initial findings from Tennessee's recent implementation of corequisite education. 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). The causal analysis by Ran and Lin (2019) that estimated an increase in pass rates in gatekeeper mathematics of 15 percentage points also noted some major limitations. The researchers lacked detailed information on the execution and structure of learning supports. Furthermore, they were unable to measure the quality of implementation or analyze its impact on student success. This gap in the literature prompted the following qualitative research design, discussed in the subsequent section.

Methods

This research employs interviews with practitioners as well as in-person observations of instruction to characterize elements of effective corequisite instruction. According to Denzin and Lincoln (2011), the use of multiple methods adds richness and depth to qualitative inquiry. The use of multiple methods of data during analysis contributes to the triangulation of findings, as described in Yin (2017) and Miles, Huberman, and Saldaña (2014). The current paper excerpts findings from a more comprehensive case study (Author, 2019).

Description of Site and Participants

The college in this study is a mid-sized community college in the Virginia Community College System (VCCS), Commonwealth Central Community College (CCCC; the name of the college and individuals in the study are pseudonyms). According to internal statistics reported by the institution from fall of 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 service region (69% white, 13% African-American, 7% Hispanic, 5% Asian, and 5% multiple race or other), with slightly more female students (58%) than male (42%).

Two instructors for corequisite courses were included in this study, Dr. Hall and Mr. Oates, both full-time faculty members. The corequisite courses, number MCR 4 were paired with a QR course, a transfer-level course aimed primarily at transfer students in general studies and liberal arts programs. The course itself had been recently developed through system-wide curriculum reforms, with the goal of increasing student success rates. As in the ALP, the corequisite course included a subgroup of eight to twelve students within a larger QR course of approximately twenty-five students.

Under the prior format of developmental instruction, students were required to take appropriate one-credit modules focusing on a developmental topic for which they had not earned credit when taking the Virginia Placement Test (VPT) (e.g., fractions). Previously, students would need to demonstrate competency on the first five modules to qualify for a standalone QR course. The corequisite reforms allowed students missing at most two of these modules to enroll into the corequisite-supported QR course. As part of the multiple measures reforms taking place in the

VCCS, detailed in Edgecombe (2016), the corequisite courses also included students with a high school GPA of between 2.7 and 3.0 who had taken Algebra II.

Observations

The principle method for addressing research questions relating to instruction in corequisite courses is 20 hours of classroom observations. These observations took place in two sections of MCR 4, each taught by a full-time mathematics faculty member. Each of the MCR 4 courses met twice weekly, for 50 minutes in length, scheduled either immediately before or after the paired QR course. Observations took place starting the fourth week of classes and continued regularly throughout the semester. 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 1.

Table 1. 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?

Interviews

Interviews supplemented observational data and offered the opportunity for instructors to reflect upon their experiences. 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). Instructors participated in two one-hour interviews, one midway through observation and another at the conclusion of observation, which were recorded and transcribed. Other informal encounters with instructors were recorded in field notes.

Data Analysis

Following Erickson's (1986) framework for qualitative research methods, the data were coded inductively; the process of data analysis was informed by the open-coding techniques outlined in Corbin and Strauss (2008). Emphasis was placed on using *in vivo* codes that use the language of participants. Miles, Huberman, and Saldaña (2014) recommend in vivo codes because they "prioritize and honor the participant's voice" (p. 74) and offer good leads into identifying patterns. After initial coding, preliminary findings coalesced 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*, these assertions and findings were revised to match the ongoing process of data collection. Finally, in the process of *member sharing* (Yin, 2017), participants in the study were provided with initial findings, and their reactions helped ensure that research findings accurately captured the voice and experience of participants.

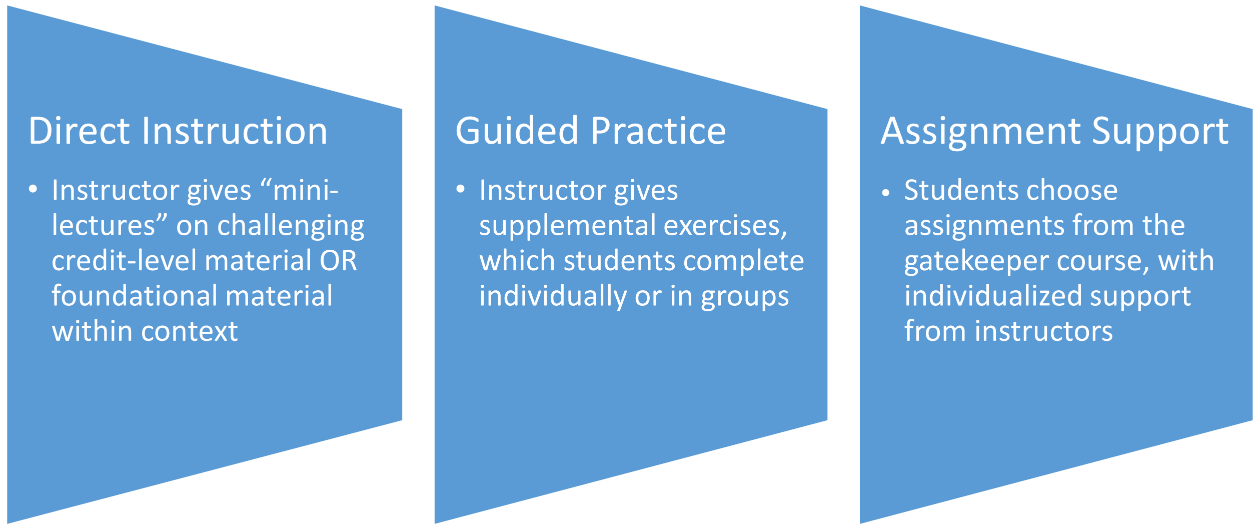
Findings

The findings below are categorized into three assertions. The first assertion describes the nature of instruction observed within the corequisite courses. The second assertion characterizes how instructors chose to utilize their instructional time for the corequisite courses. The third assertion describes some of the gaps in knowledge and other issues that students faced that instructors sought to address in the corequisite course.

Assertion 1: Faculty employed a combination of direct instruction, guided practice, and assignment support to respond to the needs of individual students

The MCR 4 corequisite course did not include its own set of curricular or instructional guidelines for the corequisite support course, a notable departure from previous methods of developmental education. Consequently, faculty in the study were free to choose the topics they remediated, as well as the instructional approach they saw fit for a particular circumstance. 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. Each of these categories is visualized in Figure 1 below.

Figure 1. Instructional Methods in the Corequisite Course



Direct Instruction. The first category of classroom activity was for the instructor to utilize the MCR class time to present that day's QR 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. Oates would re-open presentation slides from the lecture for the day's class to revisit material. 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. Hall and Mr. Oates taught their support classes immediately after their paired QR course, so this offered a natural segue to review that day's material in the smaller format of the corequisite course. For instance, Dr. Hall began one class by summarizing an assignment the students just completed during QR. 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 QR class, Dr. Hall 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 QR course, faculty would also use the direct instruction in MCR 4 to extend these concepts or present them in alternative ways. Dr. Hall 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. Oates emphasized the importance of not simply re-teaching the same material but using the support class to further explore 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 QR 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 QR 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 QR students.

The direct instruction was well-suited in instances when a concept from the QR course was particularly challenging and many students shared common confusions. Since both instructors taught the MCR 4 course after their QR 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. Hall and Mr. Oates expressed a hesitancy towards using the small format lecturing, particularly on remedial topics. When Mr. Oates was asked about which 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 more often used 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 such topics were relevant, but often addressed material identical to that of the QR course. Sometimes, instructors would take examples directly from the 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 QR class as a whole, but which the faculty did not have time to go over in the QR class. This included test review documents developed by the QR faculty that contained a large list of exercises on each test. In the week before the test, Mr. Oates would often direct students to work on these exercises. Mr. Oates 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. Oates 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 that they thought might benefit the class at large. For example, Mr. Oates chose to have all 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 set of problems was that instructors could easily transition between directing students to work in groups, individually, or as a class. Though instructors could occasionally plan out the topics in advance, in multiple instances they found that the anticipated topics students would struggle in were not the ones that vexed students. 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 QR course. Both Dr. Hall and Mr. Oates offered students time for their students, though each instructor adopted different instructional practices to incorporate assignment support. For Dr. Hall, who had a slightly larger class, assignment support was a regular fixture of the course that would occur after opportunities for direct instruction or guided practice. By contrast, Mr. Oates would spend most classes using a combination of instruction and guided practice. However, on days when he did not a specific topic that he or the students thought necessary to cover, he would dedicate an occasional class period towards providing assignment support.

During assignment support, faculty would allow students to choose which of their QR assignments they wanted to work on. In most instances they work on regular homework assignments, though at points the students also completed "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, open-ended, and often 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 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 circulate around the class and monitor the work that students were completing.

Offering assignment support had the advantage of being flexible to student needs. Not all students needed direct instruction or guided practice on a particular topic. Furthermore, some students were further ahead than others, making it more challenging to find a topic that all students were simultaneously struggling on. Working on an individual basis also allowed faculty to see precisely what students struggled in. However, offering support on assignments had its drawbacks as well. It was challenging for instructors to provide one-on-one support for all of their students. Dr. Hall remarked that some of the students, if they had their way, would work with her one-on-one for the entire duration. Since some material was a common struggle among students, reviewing concepts individually was not always the most effective use of time. Unlike guided practice in which 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. At the end of the semester, Dr. Hall expressed regret at allowing too much time on assignment support, because some students came to expect that they would be able to get their assignments done within the corequisite course.

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

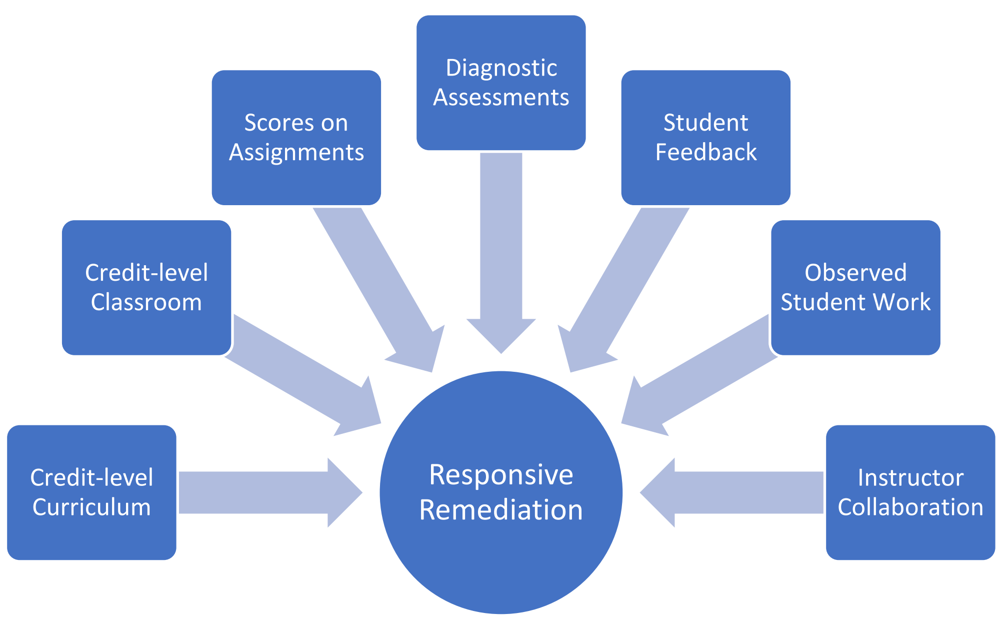
> Sometimes I am just pulling some problems from the homework, and I've done that a time or two. I've looked at the first test with them. I've done some of the "backfilling" material . I've done just more examples from a worksheet in class where we didn't get to all of the examples. I think that a little 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. Oates 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 a unit on logical reasoning included many concepts such as truth values of statements that did not directly address content from any prerequisite developmental course. Because there was no one-size-fits-all set of topics to cover, instructors had to constantly gather information to determine how to effectively use class time.

Assertion 2: Faculty leveraged a variety of data sources from the curriculum, credit-level classroom, and student feedback to inform their instruction in the support course

Because the MCR course had no curriculum aside from supporting whatever was taking place in the QR course, faculty often devised and revised their plans for the MCR course on short notice. Dr. Hall 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 prove challenging. She and Mr. Oates 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 2 below.

Figure 2. Sources of Information for Responsive 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 QR, 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 financial mathematics formulas. Sometimes, in anticipation of these challenges, the instructors would create targeted exercises, like a worksheet on computing annual percentage yield. However, as Dr. Hall 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.

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. Hall discussed the value of these classes to bring to light and then address unexpected challenges. She actually taught multiple sections of the QR 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 QR 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 instructional software would send regular reports to faculty noting the sections of homework on which students were struggling. Mr. Oates used this in part when deciding to review direct and inverse variation during the chapter on ratios and proportional reasoning. Dr. Hall also would check each of her MCR students' scores on assignments and take time to remind them of the assignments when they ran behind. The small format of the MCR course facilitated this high level of involvement and accountability.

Diagnostic Assessments. During one of his first classes, Mr. Oates 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 observed 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. Hall gave the same quiz to her students a week later, she 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. Mr. Oates 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. Mr. Oates 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 how faculty leveraged the students own perceptions of their strengths and weakness to inform their classroom practices. From Mr. Oates' perspective, this approach of asking students was actually the most valuable, one that is facilitated by a strong rapport with students and the class as a whole. However, both he and Dr. Hall acknowledged that students at times lacked the metacognition to accurately report the nature of their struggles.

Dr. Hall also relied upon student input and began class by eliciting questions from students on recent material from the QR 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. In her assessment, many of her students were eager to spend the support course working on their assignments. However, the assignment support itself was also a valuable source for choosing remediation strategies.

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. Hall 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. Hall'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. Hall 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 regular implementation meetings between instructors teaching the QR course, they 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.

Whereas previous prerequisite models employed at CCCC had a fixed curriculum on topics in fractions, decimals, and basic algebra that students needed to demonstrate competency on, 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 QR 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 3: Students displayed a wide variety of foundational content gaps and study skills; faculty used the support course to respond to these student needs

Dr. Hall observed that the multiple measures by which students could qualify for the corequisite course led to some instructional challenges. She 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 contributed to some amount of reluctance to provide students with exercises focused solely on remedial content. It is important to acknowledge the previous format of developmental instruction at CCCC required students to focus on one remedial content area at a time but did not always adequately prepare students for college-level mathematics (see Beamer, 2020).

In contrast with the previous model of developmental mathematics, lessons in the support course tended to focus on topics from the QR content. However, 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.

Arithmetic Issues. Of these, Mr. Oates highlighted fractions 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 QR 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. Instructors leveraged the applied context to provide students a meaningful way to check their answer. Instructors would often emphasize the importance of checking the reasonableness of an answer in an applied context. This contextualization of foundational skills was critical because the foundational prerequisite skills were rarely tested in the QR course outside of a particular application.

The student difficulties with arithmetic operations pointed more generally to the weak numeracy skills of some MCR students. Some struggled with even more foundational concepts of place value – Dr. Hall recounted an example of a student who struggled to understand why 0.35 + 1 was not 0.351. In multiple observed instances, students appeared to be confused by directions asking to round to the nearest tenth or hundredth, or to the nearest cent. Ability to perform arithmetic operations was critical for the QR course, for example, converting between decimals and percentages when interpreting interest rates. However, a major difference between corequisite instruction and the previous developmental modules was that there were no restrictions in QR on students using calculators. In fact, a scientific calculator was required, and some students chose to use graphing calculators to compute answers or convert between various numerical forms (decimals, fractions, and percentages). Observations revealed that some MCR students were able to successfully complete assignments in QR, even though they turned to calculators for rudimentary computations such as single-digit multiplication or fraction arithmetic. This indicates one other potential reason why more students may be finding success in these supported QR courses: some of these students may be able to do computations with the assistance of a calculator but struggle to do so by hand.

Algebra Issues. However, there were also skills covered in the developmental modules embedded within the QR 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 unit on mathematical modeling. As Dr. Hall 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.

Issues with Technology. Even when students did understand arithmetic and algebraic principles, some struggled to utilize their technology appropriately. For example, instructors found that students would miss their first attempt on a question because rounded incorrectly. Either students would use a calculator at each step and round mid-way through their solution process, leading to inaccuracies, or students would truncate decimal expressions rather than round. Because the instructional software had little error tolerance for answers, an improperly rounded answer was a frequent source of error. Other students had difficulty using their scientific calculators to properly enter order of operations.

Study Skills. Many students from the MCR courses indeed did struggle with the remedial content as covered in previous developmental structures. However, instructors did not solely focus on building content mastery in the MCR courses. Dr. Hall 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 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.

In other instances, the one-on-one instructional format would reveal unexpected roadblocks – for example, a student who was struggling in part because she had strong enough arithmetic skills to solve some proportions 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. Hall's intervention allowed the student to help refocus her energy, and it provided Dr. Hall with an opportunity to force additional accountability on her students. Dr. Hall noted that, over the course of the semester, many of her MCR students became more willing to come to office hours when they struggled.

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. Hall and Mr. Oates admitted that there were ways they could improve, they saw the MCR courses as successful in these ways.

Conclusion

The purpose of this qualitative research design was to analyze instruction within two sections of a corequisite course in order to understand what pedagogical approaches were valuable and why. The research here presents a description of the mechanisms by which instructors within this particular model of corequisite instruction were able to support marginally prepared students. As with the original ALP study in Adams et al. (2009), having a small class format taught by the same instructor and with a subgroup of students appeared to facilitate a number of positive effects. While this present research study cannot offer comparisons between the effectiveness of multiple methods of corequisite instruction, it offers some potential strategies for instructors and valuable elements of corequisite models similar to the ALP.

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 QR. 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 QR 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 QR class. Ultimately, the aggregate course grades of the MCR students in this study were slightly lower than those of their directly-placed peers, but two-thirds of the MCR students received a grade of C or better in their credit-level course (see table 1 below).

Table 1. Grade Distribution in MTH 154 among Non-MCR and MCR students

Grade	Non-MCR students	MCR students
A	11 (17.2%)	1 (5.6%)
B	22 (34.4%)	5 (27.8%)
C	17 (26.6%)	6 (33.3%)
D	7 (10.9%)	2 (11.1%)
F	7 (10.9%)	4 (22.2%)

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. For more detailed analysis and findings, refer to Beamer (2019).

Future Directions. There are several future directions for research on the implementation of corequisite courses. First, because corequisite remediation is dependent on credit-level context, further research is needed into the necessary skills for other gatekeeper courses such as SR or precalculus. Additionally, longitudinal research, particularly for students beginning in algebraically-intensive programs of study, will provide insights into whether students starting in corequisite instruction are able to be successful beyond their gatekeeper course. Finally, more large-scale quantitative analysis comparing the effectiveness of various implementation practices is merited. Such research would be beneficial for comparing the effect of alternative models, such as having larger corequisite classes, separate instructors, online models, alternate placement measures, the impact of corequisite models on disadvantaged groups, and so on. Carrying out this research is critical to understanding how to successfully implement corequisite solutions to challenges that have plagued developmental education for decades.

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