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The Access–Enrollment Disconnect in Corequisite Math Reform: Causal Evidence and Stakeholder Perspectives from a Community College

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The Access–Enrollment Disconnect in Corequisite Math Reform:

Causal Evidence and Stakeholder Perspectives from a Community College

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Abstract

This study examines a statewide developmental education reform in Virginia that allows students who would have been placed in standalone remedial math to enroll directly in college-level math with corequisite support. Although corequisite support has been widely adopted and generally promising, less is known about how these reforms operate when expanded access does not always translate into actual enrollment. Focusing on the largest community college in Virginia, we use regression discontinuity (RD) analysis to evaluate policy impacts and follow up with interviews with students, advisors, and instructors to explain how implementation shaped the enrollment and completion patterns. We find that one-third of students did not enroll in recommended math courses. RD estimates show different impacts of corequisite placement for students with different levels of academic preparedness. For less-prepared students, corequisite placement increased gateway math enrollment and completion relative to prerequisite remediation, although completion gains were smaller than enrollment. For more-prepared students, corequisite placement reduced math enrollment substantially relative to placement into standalone gateway math, with no detectable overall effect on completion. Interviews suggest that the enrollment gap reflected logistical barriers to registration and scheduling, additional credit and financial burden, limited understanding of math sequences, and inadequate advisor communication. For the less pronounced impact on math completion, instructors described challenges sustaining engagement in corequisite support and teaching students with varying levels of preparation. These findings suggest that expanding access to college-level math is not sufficient on its own and highlight the importance of streamlined registration, clear advising, and effective instructional support.

Keywords: developmental education, corequisite support, math enrollment, community college, quasi-experimental design, implementation

Successful completion of gateway math—the first required college-level math—is a key step toward transfer or degree attainment at community colleges. However, many entering students are not adequately prepared for gateway math and are often placed into developmental math (Ogut et al., 2023). Over the past decade, corequisite support[1] has been widely adopted to address academic underpreparation and expand access to college-level coursework. Rather than placing students into standalone prerequisite math that does not count toward degree or transfer requirements, corequisite models allow underprepared students to enroll directly in college-level math while receiving concurrent support through a paired developmental course. The share of two-year public colleges offering corequisite support grew sharply from 28% in 2016 to 77% in 2023 (Litschwartz et al., 2023), and growing causal evidence indicates that corequisite math often increases students' likelihood of enrolling and completing gateway math relative to traditional prerequisite remediation (e.g., Austin et al., 2024; Logue et al., 2016; Meiselman & Schudde, 2022; Ran & Lin, 2022).

Despite the prevalence and promising evidence of corequisite support, less is known about how these reforms operate in practice when expanded access to college-level coursework does not consistently translate into actual enrollment in these courses. This question is especially important because corequisite support is implemented with considerable variation across institutional contexts. Much of the existing evidence comes from tightly controlled experiments or statewide mandates (e.g., Logue et al., 2016), where course-taking pathways may be more clearly structured. In settings without a mandate or strict experimental controls, implementation may become a central factor shaping reform outcomes. The gap between placement and actual

[1] This model has been referred to by various terms, including corequisite remediation, corequisite developmental education, and corequisite support. Corequisite support is our preferred term, but we use different terms to reflect its usage in the cited literature.

enrollment may therefore be especially consequential. Indeed, when scaling up corequisite support, colleges often enrolled fewer than half of the students referred to corequisite math, with take-up rates typically ranging from about 20% to 50% (see first-stage results in Austin et al., 2024; Meiselman & Schudde, 2022; Ran & Lin, 2022). This pattern suggests that students' course-taking decisions, along with the advising, registration, and instructional conditions surrounding those decisions, may meaningfully shape the observed impacts of reform. Similar gaps between placement and actual enrollment have long been documented in developmental education more broadly (Bailey et al., 2010), yet relatively little research captures students' perspectives on why these gaps emerge. Moreover, Schudde et al. (2025) highlight that faculty and advisors are central implementation actors whose practices may influence reform take-up. As more states and colleges adopt corequisite support, understanding how students, faculty, and advisors experience and navigate these reforms is critical for explaining variation in their realized effects.

Two additional questions also remain underexplored. First, existing literature primarily compares *corequisite support* with *prerequisite remediation*, with less evidence on how corequisite support compares with direct placement into *standalone gateway math* for students near the college-readiness cutoff. This comparison is policy relevant because, relative to standalone gateway math, the corequisite support model adds credits, costs, workload, and scheduling complexity—features that may shape students' course-taking decisions as well as increase institutional costs. Second, among quasi-experimental studies of developmental education, relatively little is known about students who are further below college-readiness thresholds. One reason is that many colleges have replaced prerequisite remediation with broader corequisite support, making it more difficult to isolate effects for students with the weakest prior preparation. Given the wide range of entering math skills and instructors' concerns that progressive reforms may not adequately serve students with the least academic preparation (Park-Gaghan et al., 2024), it is important to examine whether access to college-level coursework with concurrent support improves early gateway math outcomes for these students, or whether uncertainty about readiness, math anxiety, and the demands of paired enrollment limit take-up and success.

This study addresses these questions by examining a tiered corequisite support model at Northern Virginia Community College (NVCC). NVCC implemented Direct Enrollment reform in 2021 and has used a tiered model for math placement primarily based on students' overall high school GPA (HS GPA). Students with a HS GPA below 2.0 were placed in traditional prerequisite math, those with a HS GPA between 2.0 and 3.0 were placed into gateway math with corequisite support, and students with a HS GPA above 3.0 were placed directly into standalone gateway math. This policy setting provides a valuable opportunity to examine how tiered placement shaped students' early math enrollment and success.

Specifically, we adopt an explanatory sequential mixed-methods design, using qualitative data to follow up on and help explain the initial quantitative findings across our three research questions. First, what were students' math enrollment patterns during their initial year of enrollment following the Direct Enrollment reform? We address this question using descriptive analysis of transcript data. Second, what were the effects of assignment to corequisite support on gateway math enrollment and completion? More specifically, we compared placement into corequisite support to two alternatives: (1) placement into *standalone gateway math* and (2) placement into *traditional prerequisite models*. To identify the causal effects of the corequisite support placement, we adopted an RD design, comparing students above and below the 2.0 and

3.0 GPA thresholds. Third, how do students, advisors, and instructors understand the enrollment and completion patterns observed in the quantitative analyses? To address this question, we draw on semi-structured interviews and focus groups to examine how advising practices, instructional strategies, and student experiences may have shaped math enrollment and early course outcomes under the reform.

Our results show that, since the implementation of the Direct Enrollment reform at NVCC, up to one-third of students did not register for a math course aligned with placement based on HS GPA. Qualitative evidence suggests that this pattern may reflect students' math anxiety, limited awareness among both students and advisors about the importance of timely enrollment in gateway math, and logistical barriers such as additional financial costs, increased credit loads, and scheduling conflicts. Our RD analysis indicates that, for less-prepared students near the 2.0 GPA cutoff, placement into corequisite support increased both gateway math enrollment and completion relative to prerequisite remediation. By contrast, for more-prepared students near the 3.0 GPA cutoff, placement into corequisite support reduced gateway math enrollment relative to direct placement into gateway math without support, with no statistically significant effect on gateway math completion. Qualitative data from instructors further revealed difficulties in delivering corequisite instruction, particularly in fostering student engagement in support sections and managing the wide variation in student preparedness within these courses.

Literature on Developmental Education and Corequisite Models

Overall Effectiveness of Corequisite Models

A substantial body of research demonstrates that traditional developmental math education has not effectively prepared remedial students for college-level coursework (e.g., Boatman & Long, 2018; Xu & Dadgar, 2018). Most studies in this area have found null or negative effects of prerequisite math sequences on gateway math completion and student persistence. Several factors contribute to such results, including high attrition rates and a disconnect between remedial and college-level math content. The corequisite model has been developed to address these concerns by allowing students to directly enroll in college-level math courses while taking concurrent courses that provide "just-in-time" learning support tailored to the college-level course.

The majority of rigorous evidence on the corequisite model to date has focused on comparisons with the traditional prerequisite model. A randomized control trial (RCT) at The City University of New York (CUNY) showed that students assigned to corequisite statistics were 16 percentage points more likely to pass gateway math and thus accumulated more credits (Logue et al., 2016). Another RCT conducted in five Texas community colleges indicates that corequisite models enabled students to fit more college-level courses into their schedule and improved college-level credits accumulation within the first year (Miller et al., 2022). Quasi-experimental studies using data from community colleges in Texas and Tennessee found similar positive impacts on gateway math completion when corequisite models were scaled across entire systems (Meiselman & Schudde, 2022; Ran & Lin, 2022). Collectively, these studies suggest that, compared with the prerequisite model, the corequisite model is more effective at helping students successfully complete their first college-level math courses.

What remains less clear is the effectiveness of corequisite models compared with removing developmental education entirely, particularly for students near the college readiness threshold. To our knowledge, only two studies have conducted such a comparison (Austin et al., 2024; Ran & Lin, 2022). Using an RD approach, they found that students just below the college-level cutoff, who were placed in a paired corequisite support course, had gateway course completion rate similar to those just above the cutoff who took only gateway course, suggesting that students on the margin of college readiness threshold could succeed in gateway math without the concurrent support. Designing and implementing corequisite models requires significant effort from community colleges (Daugherty et al., 2018), it is critical to investigate whether these findings hold across state systems with varying corequisite models and approaches. Additionally, given that students entering community colleges with varying math skills and pre-college academic preparation is often stratified by socioeconomic status and race (Perna, 2006), it is essential to understand how developmental education affects students further from the college readiness threshold for addressing equity concerns. Prior studies have found mixed results and highlight the importance of further investigating the effectiveness of corequisite models for students far from college level (Boatman & Long, 2018; Ran & Lee, 2025).

Implementation of Corequisite Support

Given the broadly positive evidence showing success of the corequisite model over the traditional prerequisite model, many states have initiated reforms to implement corequisites. An expanding literature has documented the challenges associated with implementing this model across various stakeholders (Beamer, 2019; Bickerstaff et al., 2022). These challenges include gaining faculty and staff buy-in and shifting long-standing mindsets from the prerequisite model (Schudde et al., 2025). Additionally, school systems need to adjust the course scheduling to offer corequisites and college-level courses simultaneously. For students to successfully enroll in appropriate developmental courses, community college advisors need awareness and a comprehensive understanding of the new policies, as they play a key role in helping students build their degree plans (Daugherty et al., 2018).

The transition process under a new policy reform can be complex, which can lead to information gaps and behavior barriers for students (Bailey et al., 2010; Schudde et al., 2021). The Direct Enrollment reform alters placement methods and requires paired course enrollment, which may potentially introduce additional steps and navigation challenges in enrolling in the appropriate math courses. Additionally, psychological barriers also play a role in this process. The well documented issue of math anxiety—a negative feeling while engaging with math—can further complicate the corequisite implementation (Beilock & Maloney, 2015; Luttenberger et al., 2018; Samuel & Warner, 2021). Students' math anxiety may be exacerbated by course-taking requirements under the reform. They must directly engage with college-level math while simultaneously managing an increased math workload, including college-level math and a corequisite support course. However, there is limited research on students' perceptions and experiences with corequisite reform. This study contributes to the literature by documenting and deepening our understanding of how different stakeholders perceive and experience the corequisite reform.

Conceptual Framework

To understand the effects of corequisite support models, we extend the conceptual framework by Scott-Clayton and Rodriguez (2015) and Kane et al. (2019). Their framework identifies three key mechanisms through which developmental education can impact students: *skill development*, which enhances academic readiness and performance in college-level courses; *delay or displacement*, which postpones or replaces enrollment in college-level courses with remedial coursework; and *diversion*, which separates remedial and college-ready students into distinct tracks, thereby reducing classroom heterogeneity. Below, we describe how this framework informs our analysis of corequisite models' effects compared to traditional prerequisite remediation and standalone gateway math.

In comparison to the traditional prerequisite model, corequisite support has the potential to reduce *delay or displacement* in college-level course enrollment by granting students immediate access to these courses. Consequently, it is expected to improve gateway math *enrollment rates*. However, implementation challenges such as course registration barriers and advising gaps may prevent corequisite support from eliminating delay (Daugherty et al., 2018). At the same time, the impact of corequisite support on student *performance (or completion rates)* in gateway math courses depends on its ability to provide sufficient *skill development* for underprepared students. Corequisite models approach skill development differently from traditional remediation. The "just-in-time" support structure allows students to immediately apply newly learned skills in their college-level coursework before these skills fade out. However, this approach often reduces the intensity of developmental support. For instance, Ran and Lee (2025) found that corequisite remediation nearly halved the total instruction time dedicated to developmental content for students at the lower end of the preparedness spectrum.

Compared to standalone gateway courses, corequisite support introduces potential benefits through skill development in concurrent learning support. However, it requires students to allocate time and resources to the non-credit-bearing corequisite sections, potentially displacing a credit-bearing college-level course in their schedule. Assuming students have a fixed capacity for coursework in their initial semester, the overall effect of corequisite support depends on whether the benefits of skill development outweigh the potential drawbacks of these displacement effects.

The *diversion* mechanism operates differently under the corequisite model, particularly for students with varying levels of academic preparedness. By mainstreaming students with diverse skill levels into the same gateway math courses, the corequisite model creates more heterogeneous classrooms. This change introduces effects that could be positive or negative. On one hand, lower-achieving students may benefit from their higher-achieving peers by gaining subject knowledge or general academic know-how (Griffith & Rask, 2014). On the other hand, the increased heterogeneity may pose challenges for instructors. If instructors focus more on students with mid- to high-level skills, those at the lower end of the achievement spectrum may struggle to develop the foundational skills necessary for success in college-level study. Conversely, if instructors prioritize students with lower levels of preparedness, it may become more difficult to engage higher-achieving students who seek advanced material and discussions (Ryu et al., 2022). The overall impact of the diversion mechanism ultimately depends on how these peer dynamics and instructional challenges play out.

Institutional Context and Policy Implementation in Northern Virginia Community College

Data for this study come from NVCC, the largest institution within the VCCS. In Fall 2023, NVCC enrolled 9,311 first-time-in-college (FTIC) students across five campuses offering math coursework, accounting for 35% of total VCCS enrollments. The college serves a diverse student body, with 62% identifying as underrepresented minority students and 20% receiving Pell Grants (VCCS, 2024).

NVCC started to implement the Direct Enrollment reform during the 2021-22 academic year, incorporating corequisite support model as a key component of its tiered developmental education structure. Since the reform, incoming students are required to self-report their HS GPA through the Direct Enrollment Survey to determine course placement[2]. Figure A1 in the Appendix displays how student placement into math developmental education and gateway math differ before and after the Direct Enrollment reform in NVCC. Before the reform, all students with HS GPA lower than 3.0 were placed into prerequisite remediation; after the reform, students with HS GPA lower than 3.0 were placed into two math tiers: students with a GPA between 2.0 and 3.0 were placed into gateway math with corequisite support, and students with a GPA below 2.0 were still referred to prerequisite remediation. NVCC offers three gateway college-level math based on programs of study: MTH 161 (Precalculus I), MTH 155 (Statistical Reasoning), and MTH 154 (Quantitative Reasoning).

Despite NVCC's large size, its five campuses coordinated the reform's implementation and featured several common elements, as reported on a survey administered by the research team and confirmed via interview with another administrator: Each corequisite support course was directly linked to a gateway course, with students simultaneously enrolling in both courses that took place over the same semester. Corequisite support courses were mostly offered in a face-to-face format with some synchronous online offerings. In most instances the same instructor taught both sections, and the department reported that instructors had considerable flexibility to adapt the course to individual student needs. Most corequisite sections were also supported by an embedded tutor, a staff member who provided additional instructional support during the corequisite support class.

[2] Although some VCCS documents suggest that placement decisions are based on multiple measures, including high school GPA, GED, SAT, and ACT scores, the Direct Enrollment Survey for official placement only collected student self-reported HS GPA. We believe this is the de facto placement criterion, as other measures are not systematically recorded.

Data and Method

Consistent with an explanatory sequential mixed-methods design, we first analyzed NVCC administrative data to examine students' math enrollment patterns and estimate the effects of corequisite placement under the Direct Enrollment reform. We began by describing overall patterns of math course enrollment and then applied a regression discontinuity design to estimate the effect of placement into corequisite support at two HS GPA cutoffs: the 2.0 cutoff (further below college readiness), where corequisite placement is compared with prerequisite remediation, and the 3.0 cutoff (closer to college readiness), where corequisite placement is compared with standalone gateway math without additional support.

The quantitative findings then informed the qualitative component of the study. Specifically, we developed the interview and focus group protocols to follow up on key patterns in the quantitative results, including students' low enrollment in recommended math courses and the observed effects of corequisite placement on gateway math completion. We then analyzed interviews and focus groups with students, instructors, and advisors to examine why and how these patterns emerged in practice. This qualitative evidence allowed us to contextualize the quantitative findings by identifying the advising, registration, and instructional processes through which stakeholders experienced and navigated the reform.

Quantitative data and analysis

College Administrative Data

The administrative data include student characteristics and transcript data that detail students' course enrollment and grades. Our full analytic sample includes three entering cohorts from 2021-22 to 2023-24[3]. This descriptive sample consists of 20,397 students, and their characteristics are presented in Table 1, column (1). We focused on two key outcomes: gateway math course enrollment and completion within one year of initial enrollment. Enrollment includes students who passed it, earned a failing grade, or withdrew after the add/drop period. Completion is defined as earning a grade of D or higher. Table 1, panel B, presents descriptive statistics for these outcomes across different analytic samples.

[Insert Table 1 here]

Regression Discontinuity: Effects of Developmental Course Placement

We used a Regression Discontinuity (RD) design and leveraged NVCC's tiered placement procedure, which is based on students' HS GPA (see its distribution in Figure 1), to estimate the effects of placement into corequisite support on student outcomes relative to two alternatives. First, we estimated the impact of placement into corequisite support versus *prerequisite remediation* by focusing on students near the *2.0* HS GPA threshold. Second, we compared placement into corequisite support versus *standalone gateway courses* for students near the *3.0* GPA threshold.

[Insert Figure 1 here]

Figure 2 provides visual evidence of discontinuities around these placement thresholds. The horizontal axis shows the distance between students' HS GPA and the cutoff used for placement into developmental courses; the vertical axis shows the average rate of participation in developmental courses; and the size of each circle indicates the number of students within each GPA bin. We present separate subfigures for the two cutoffs. Figure 2 shows substantial jumps

[3] The sample is restricted to students who graduated from high school within the preceding five years, as those who graduated more than five years earlier may self-place into gateway courses. We further restrict the sample to students who intend to pursue degrees that require completion of gateway math.

in developmental courses participation at the cutoff for both groups. This suggests that students with very similar HS GPAs were much more likely to be placed into different courses depending on which side of the threshold they fell on. We selected the optimal bandwidth following Calonico et al. (2014). Additional details on the RD validity tests are provided in Appendix A.

[Insert Figure 2 here]

Specifically, we estimated the impact of placement into corequisite support on student outcomes using the following model:

$$Y_{it} = \alpha_0 + \beta_1 BelowCutoff_{it} + \beta_2 HS\ GPA_{it} + \beta_3 (BelowCutoff_{it} * HS\ GPA_{it}) + \gamma X_{it} + \delta_t + \varepsilon_{it} \qquad (1)$$

In equation (1), Y_{it} represents the first-year outcomes—gateway math enrollment and completion—for student i in cohort t. The variable $BelowCutoff_{it}$ is defined as an indicator of whether student *i* is placed into particular developmental courses. For students near the 2.0 GPA cutoff, this indicates placement into *prerequisite remediation*. For those near the 3.0 GPA cutoff, it indicates placement into *corequisite support*. β_1 is the reduced-form estimate of the impact of placement into developmental courses on student outcomes. We allowed for differential correlations between students' HS GPA and outcomes above and below the threshold by controlling for HS GPA and its interaction with the threshold indicator. We also controlled for various students' background characteristics X_{it} including gender, race/ethnicity, age, Pell grant eligibility, years since high school graduation and GPA, and intended degree; ε_{it} represents the error term at the same level of the outcome variable. We also use equation (1) to estimate the impact of developmental courses placement on enrollment into these courses to better understand the level of compliance with the placement. Specifically, the outcome is student i's enrollment in the *developmental courses*, and the coefficient β_1 captures the proportion of students enrolled in the developmental course among those referred to these courses.

Qualitative data and analysis

Data Collection and Protocols

The research team conducted semi-structured interviews with math instructors and academic advisors, as well as focus groups with students. The protocols (see Appendix B) were tailored to each participant group while covering similar domains to better understand the processes underlying the observed quantitative patterns in math enrollment and student success. This design allowed us to compare how students, advisors, and instructors understood and navigated the same reform from different perspectives (Miles et al., 2014).

Specifically, advisor interviews focused on the roles advisors play in guiding students through the enrollment process, how they communicate information about corequisite support, and the common challenges students encounter in math enrollment. Students were organized into different focus groups based on whether they had enrolled in corequisite support courses or had deferred enrollment in a gateway course with corequisite support. Student questions focused on their math course experiences, the factors shaping their enrollment decisions, and their perceptions of the support available to them. Instructor interviews then focused on their perceptions of the challenges students face in corequisite support courses, the strategies they use to address variation in students' preparedness, and their views on the effectiveness of corequisite support in promoting student success. Additional information on the interview protocols is provided in Appendix B.

Sampling Scheme and Description of Sample

We used a maximum variation sampling strategy (Patton, 1990) to capture diverse perspectives across participant groups. To recruit participants, the research team administered a screening survey that collected information on respondents' demographic characteristics, campus affiliations, and math enrollment histories. Participants were selected based on their responses to include variation in different groups' experiences. Interviews and focus groups each lasted about one hour, and participants were compensated for their time.

The final sample includes five instructors and four advisors from different college campuses, including a mix of full- and part-time faculty with varying levels of experience teaching corequisite support courses. A total of ten students participated in three focus groups: six students across two groups had enrolled in corequisite support courses, while four students were in the no-math group.

Coding and Thematic Analysis

Interview and focus group data were audio-recorded and transcribed, and the resulting transcripts were coded in Dedoose. Three researchers independently conducted the initial coding. Codes were developed using a combination of inductive and deductive approaches (Miles et al., 2014), drawing on codes that emerged from the data and codes informed by prior literature. To improve consistency in coding, assignments were rotated so that each researcher reviewed the codes applied by others. Coding was refined over several iterations, and Fleiss' kappa indicated a moderate level of agreement. Discrepancies in coding were discussed and resolved collaboratively to ensure that multiple perspectives were incorporated into the analysis.

The research team then conducted thematic analysis to identify recurring patterns across the data. After initial coding, related codes were compared and grouped into broader themes. In developing these themes, we examined how students, advisors, and instructors described experiences and perceptions in math enrollment, corequisite support, and the institutional processes surrounding advising, registration, and instruction under the Direct Enrollment reform.

Quantitative Findings

The quantitative analyses reveal three central patterns. First, a substantial share of students did not enroll in the math course aligned with their placement. Second, placement into corequisite support had opposite effects on gateway math enrollment at the two HS GPA thresholds: it increased enrollment relative to prerequisite remediation near the 2.0 cutoff but reduced enrollment relative to standalone gateway math near the 3.0 cutoff. Third, placement into corequisite support increased gateway math completion at the 2.0 cutoff, though by less than it increased enrollment, indicating that expanded access translated only partially into successful completion. At the 3.0 cutoff, we do not detect an effect on completion, primarily due to the negative impact on enrollment.

Math Course Enrollment

To address our first research question, we analyzed transcript data to show students' math enrollment patterns during their first year under the Direct Enrollment reform. As shown in Table 2, more than one-third of students did not enroll in the math courses as recommended by the placement procedure. Of these students, over half did not enroll in any math courses, including developmental math. More than one-tenth enrolled in math courses above the recommended level; for example, students placed in prerequisite courses opted to enroll in corequisites instead. Around one-tenth enrolled in courses below the recommended level, such as students placed in corequisites choosing to enroll in prerequisite courses.

Although earlier NVCC cohorts also showed low college-level math enrollment rates, the cohorts under the Direct Enrollment reform exhibited an even lower rate, as shown in Appendix Figure A2. This pattern is central to interpreting the regression discontinuity results below. The ultimate effects of the reform depend not only on formal placement, but also on whether students follow through with that placement by enrolling in the designated math level. Understanding the reasons for this gap is important both for supporting students' academic progress towards their educational goals and for interpreting the reform's observed impacts. As the qualitative findings show, this gap between placement and enrollment reflected a combination of informational, logistical, and instructional frictions.

[Insert Table 2 here]

Positive Impact of Placement into Corequisite Support vs. Prerequisite Remediation for Students Near a 2.0 GPA

We next present the results for our second research question regarding the effects of placement into corequisite support on first-year math outcomes. Table 3 presents both first-stage and reduced-form estimates. Near the 2.0 GPA cutoff, the first stage results indicate students' compliance with math placement is low. Column (1) of Table 3 indicates that students below the 2.0 cutoff were 61 percentage points more likely to enroll in prerequisite remediation than those above the cutoff. This further validates that a substantial proportion of students do not enroll in the recommended math course during their first year of college, the expanded access to college-level math did not consistently translate into math enrollment.

The reduced form estimates (column 2 of Table 3) indicate that placement into corequisite support increased gateway math enrollment relative to placement into prerequisite remediation. Students just above the 2.0 cutoff were 35 percentage points more likely to enroll in gateway math within one year than students just below the cutoff.[4] This is a substantively large effect, suggesting that corequisite placement successfully expanded access to gateway math for students farther below college readiness.

[4] For consistency in comparing placement into corequisite support with other placement categories, we reverse the sign of the coefficient for students below the 2.0 GPA cutoff.

We also found that placement into corequisite support increases gateway math completion by 17 percentage points at this cutoff. Although this effect is statistically significant, it is about half the size of the effect on enrollment. This pattern suggests that, for students further from the college-readiness threshold, expanded access to college-level math and corequisite support helps students access college-level math earlier and produces meaningful improvements in completion, even if these gains do not fully match the increase in enrollment. As discussed in the qualitative findings, this attenuation may reflect pedagogical challenges within corequisite support courses given the wide range of students' academic preparedness, difficulties engaging students in those courses, and students' math anxiety.

[Insert Table 3 here]

Negative Impact of Placement into Corequisite Support vs. No Remediation (Standalone Gateway Math) for Students Near a 3.0 GPA

For students near the 3.0 GPA cutoff and closer to college readiness, the first stage estimates (see column (3) of Table 3) indicate that students below 3.0 cutoff were 30 percentage points more likely to enroll in corequisite courses than those above the cutoff. Relative to direct placement into standalone gateway math, placement into corequisite support has a statistically significant negative impact (12 percentage points) on enrollment in gateway math, but no significant difference in completion (see column (4) of Table 3).

Despite the significant negative effect on gateway math enrollment, we find null impact on gateway math completion. This pattern suggests that the lack of an overall effect on completion is driven primarily by the lower rate of gateway math enrollment among students assigned to corequisite support. However, when examining the subset of students who successfully enrolled in a gateway course, those below the cutoff had a higher completion rate by

14 percentage points (see column (4) of Table 3). Importantly, this conditional outcome should not be interpreted as a causal effect, as students who chose to enroll in gateway math may differ systematically from those who did not. Nevertheless, this pattern suggests that while the corequisite model potentially supports completion for those who enter the classroom, the reform's total impact is constrained by significant barriers to initial enrollment. Consistent with this interpretation, the qualitative findings point to several barriers that may have discouraged take-up of corequisite coursework, including the additional credit load and related financial burden, logistical challenges related to enrollment and scheduling, and limited understanding of math course sequencing.

Qualitative Findings

The quantitative results reveal that the effects of placement into corequisite support depended not only on formal placement, but also on whether students actually enrolled in the courses to which they were placed and how those courses were experienced for those who enrolled. We use the qualitative data to interpret two central patterns: the substantial gap between placement and math enrollment, and the limited evidence of completion gains under corequisite support. Across students, advisors, and instructors, participants described recurring informational, logistical, and instructional challenges that may help explain these quantitative patterns.

Main Theme 1: Information and Advising Gaps Delayed Enrollment

Consistent with the quantitative finding that formal placement did not always translate into actual math enrollment, many students were unaware of the importance of taking math in their first year, proper course sequencing, and transfer requirements, often because they had limited effective interaction with academic advisors. Incoming students at NVCC were not required to meet with an advisor prior to enrollment, and some students delayed math enrollment, unaware of its importance for future progression. As one advisor said: “[W]hen students aren’t forced to do advising before they can register, they’re just going to take what they want to take… They don’t understand the sequencing.” Advisors recounted other instances where students had delayed meeting with an advisor until their second year of study. These students discovered that they were not on track for transfer because they had not already completed credit-level mathematics courses as required by the transfer institution. Misconceptions about college-level math, such as assuming high school math fulfilled requirements, further compounded delays and misaligned expectations. As one advisor observed: “I think a lot of students come in unfamiliar with the fact that high school math does not replace college-level coursework. So they think, ‘Oh, I took pre-calc in high school, I can go right into calculus,’ which really isn’t the case…it’s a learning curve.”

Yet limited advisor contact was only part of the problem. Even when students did seek advising, the quality and specificity of the guidance they received varied considerably. One student described receiving helpful advice to avoid online enrollment based on their previous struggles with that modality, while another remarked that the advice they received was generic and less helpful than information they could find from friends or the college website. One student reflected, “She [the advisor] made some suggestions of classes to take, asked me about my goals for the upcoming semester, how many credits I wanted to take. She made a face when she saw how many withdrawals and failures I had in previous attempts.” Some advisors concurred that not all of their colleagues provided strong recommendations to take mathematics early.

At the same time, some students preferred to seek information about course prerequisites and transfer requirements independently through college websites or advising sheets rather than consult advisors directly. However, both the Direct Enrollment Survey and the college website offered relatively minimal information on what the corequisite support course was, so students did not always understand why they had been assigned this additional course or its purpose. As one student remarked: "I only found out what [the corequisite course] was when I was on Rate My Professors. I wanted to take a specific math professor, and when I tried to enroll, it said I had to also take MDE (remedial math). So then I looked up what that [MDE 61] was and then took it."

Taken together, these findings suggest that low take-up of assigned math courses reflected not only students' own preferences, but also uneven access to effective advising and limited institutional communication about math sequencing, corequisite support, and placement. These qualitative findings help explain the overall low rate of math enrollment and why formal placement under Direct Enrollment did not consistently translate into actual enrollment. They also highlight the importance of clearly communicating reform-related information to students through multiple channels.

Main Theme 2: Structural Burdens Discouraged Enrollment in Corequisite Support

In addition to information and advising gaps, the structural burdens associated with the corequisite support model—such as financial costs, increased credit load, and scheduling difficulties—may also help explain why many students avoid taking their required math courses. For students assigned to corequisite support, enrolling in math often meant taking on extra costs and navigating a more restrictive registration process than students in standalone courses. As one student put it, bluntly: "Personally, I don't care about corequisites because I just want to get through the [gateway] class and not pay extra." Some advisors surmised that students might be waiting for some kind of policy change or exemption to bypass their assigned remedial coursework.

These challenges were compounded by the complexity of the enrollment process itself. At NVCC, students were required to enroll into a pair of linked corequisite and gateway course sections; choosing a course without its appropriate pair would yield an error message. An advisor put it as follows:

> *[Some] students have no idea what a prerequisite is and have no idea what a corequisite is, because those are words that they have never heard. So then the system doesn't let you [enroll]. Let's say they registered for mismatching sections of MTH 161 and MDE 61. And the system gives them X's that says that the sections don't match, then they're like, 'Okay, I can't take this class this semester, let me move down the list.'*

While it is unclear how often this happened, advisors and students shared instances where a small process error as shown above could easily lead to delayed enrollment or create confusion about placement and eligibility.

In addition to the logistical issues, students often found it challenging to add another three credits of developmental mathematics into their schedule. Students had less flexibility given the requirement to enroll in a pair of gateway and corequisite course sections. Scheduling challenges were exacerbated by the fact that students below a 3.0 GPA, by Direct Enrollment policy, were also directed to take another three-credit corequisite course paired with their gateway English course. The additional credit burden required students to choose between overloading their workload to try and graduate on schedule or postpone enrollment into required coursework.

These financial, administrative, and scheduling burdens further illuminate the low rate of math enrollment. Their effects were compounded by the information and advising gaps described in the prior theme, which left many students to navigate a complex enrollment process on their own. Together, these findings underscore the importance of streamlining the enrollment process and providing additional support to help students manage the demands of the corequisite model.

Main Theme 3: Math Anxiety Contributed to Enrollment Delays and Coincided with Limited Engagement in Corequisite Support

As students navigate their math requirements, math anxiety shaped both whether they enrolled in their required math courses and the extent to which they engage in corequisite support once enrolled. Anxiety about mathematics was a common theme among students placed into corequisite support. This was evident in the students' own estimations, with one student reporting that "I avoided mentioning my issues with math because I was worried [the advisors] would recommend a remedial math course. I hoped to figure it out on my own." The interviews did not provide clear evidence that assignment to a corequisite support course itself carried the same stigma as assignment to prerequisite remediation, especially given students' limited awareness of the course. However, advisors noted that students often viewed math as difficult, which may have contributed to delayed enrollment.

This anxiety also appeared in the classroom, shaping both students' participation and instructors' approaches to teaching corequisite support courses. Instructors noted that many students in their corequisite courses lack confidence in their abilities, which impacts their willingness to engage in classroom activities. According to one instructor, "[Students] don't have confidence in what they're saying or doing. However, when we work in small groups… with me offering encouragement, it helps build their self-esteem… but it takes a lot of small steps to get there." This evidence suggests that math anxiety shaped not only students' decisions to delay or avoid enrollment, but also their ability to participate meaningfully in corequisite support once they entered the classroom. These patterns may also help explain the limited evidence of an effect on gateway math completion and highlight the importance of instructional design in corequisite support.

Main Theme 4: Low-Stakes Course Design and Wide Gaps in Student Preparation Limited the Benefits of Corequisite Support

Even when students enrolled in corequisite support, the low-stakes course design and students' varying levels of math preparation may have limited its potential benefits. Because the corequisite support course did not count toward students' college GPA, and performance in the course did not directly affect the grade earned in the paired credit-level course, instructors noted that students often had limited incentive to engage fully.

Students also pointed to instructional practices that may have contributed to disengagement, describing classes as tending toward lecture with limited opportunities for interactive engagement. These instructional patterns partly reflected the wide variation in students' incoming preparation. Instructors often had to revisit basic mathematical principles to ensure that all students had the necessary skills to progress, particularly during the first few weeks of the corequisite courses, where significant time needed to be spent on reviewing the sort of basic concepts typically covered in prerequisite remedial coursework. As a result, the "just-in-time" learning support that supported the credit-level gateway math could be difficult to put into practice. As one instructor explained:

> *Prerequisite knowledge is definitely an issue with the MDE class. The MDE component is not really meant to be a time to relearn old material, but I have found myself, especially*

early on, spending a lot of time on prerequisite content. For example, we might spend an entire class on fractions and percentages, scientific notation, or just the basics of exponents, multiplication, and division. It's important to note that this isn't what the MDE component is meant for; it's supposed to support the material that students are currently learning. However, without a placement test, many students come in without the proper prerequisite knowledge to even begin engaging with the new material. I know that many of my colleagues feel similarly obligated to spend significant time on foundational material. And then, as we get deeper into the course, we just review it as needed. But often, with only three hours a week, it feels like there isn't enough time to cover everything thoroughly.

Another instructor noted that when substantial class time was devoted to repeated review of basic skills, the course may have been less responsive to the needs of students closer to college readiness, which could have limited their opportunities to master credit-level material and reduced their engagement. Peer environments may also have shaped students' experiences differently depending on their level of math preparedness. Instructors noted that under the cohort model, in which the same group of students enrolled in both the corequisite support course and the paired credit-level course, students just below the 3.0 GPA threshold were often among the best prepared in their class, limiting their opportunities to benefit from gateway courses with more college-ready peers. These dynamics may help explain the difficulty of designing engaging corequisite courses for students from different math preparedness levels that produce positive effects on student outcomes.

Discussion and Conclusion

Summary of Key Findings and Connections with the Existing Literature

Our study highlights critical insights into the challenges and opportunities associated with gateway math enrollment and the implementation of corequisite support in the Virginia Community College System. Despite college-level math being a requirement for most degrees and credentials, our findings reveal that a significant number of students did not follow the recommended math courses or did not enroll in any math courses during their first year. This low enrollment rate poses risks for academic progression. Students who delayed enrollment often faced barriers such as inadequate advising, logistical challenges, and math anxiety, underscoring the need for more structured and proactive support systems (Bailey et al., 2015).

Qualitative evidence helps explain why students delayed or bypassed math. Student interviews indicate that information gaps around math course sequencing and program requirements often contributed to delayed enrollment. In addition to information gaps, students also identified logistical challenges as significant barriers to corequisite enrollment. The additional credit load, financial costs, and scheduling difficulties associated with corequisite courses were common roadblocks. For many students, these practical challenges outweighed any possible academic benefits of enrolling in corequisite support courses, leading them to either delay or bypass the math courses altogether. These findings are consistent with prior research showing that both financial constraints and scheduling challenges are key determinants of student course enrollment decisions (e.g. Goldrick-Rab, 2016). Math anxiety also emerged as an important factor contributing to delayed enrollment, with many students deliberately postponing math courses due to apprehension about the subject. This anxiety, combined with limited interactions with academic advisors, further exacerbated delays.

In terms of the impact of placement into corequisite support on student outcomes, our study highlights important distinctions in how different groups of students respond to the placement. A key contribution of our study is its focus on students at the lower end of the GPA distribution, a population often overlooked in prior research. We found that students placed in corequisite support were more likely to enroll in and complete gateway math within the first year compared to those with similar levels of academic preparation but were placed in traditional prerequisite remedial sequences. This finding suggests that for academically underprepared students, the corequisite model offers a more efficient pathway than the prerequisite model. At the same time, the smaller positive impact on gateway math completion than enrollment suggests that increased access to gateway math may not fully translate into successful completion without sufficient academic support. These findings echo prior evidence that corequisite models can improve access to and completion of gateway math compared with traditional prerequisite remediation among students closer to the college-readiness threshold (Meiselman & Schudde, 2022; Ran & Lin, 2022). Our study extends this literature by showing that a similar pattern also holds for students further from the college-readiness threshold.

In contrast, for students on the margin of college readiness, the benefits of corequisite support courses were more limited. Corequisite support placement was associated with a significantly lower likelihood of gateway math enrollment. However, we observe no negative impact on gateway math completion. This result may be driven primarily by reduced enrollment, as among students who enrolled in gateway math, those assigned to corequisite support had a higher completion rate. These findings add nuance to prior evidence comparing corequisite support with direct placement into standalone college-level math for students near the college-readiness threshold. Prior studies have generally found that corequisite support improves gateway course completion for students near the cutoff (Austin et al., 2024; Ran & Lin, 2022). In contrast, our results suggest that these benefits may depend on whether placement into corequisite support successfully translates into initial gateway math enrollment. For academically stronger students, the main challenge may be encouraging enrollment when corequisite support adds coursework beyond standalone gateway math. At the same time, favorable completion patterns among enrolled students suggest that corequisite support may still benefit those who participate.

Finally, the qualitative findings shed light on instructional challenges within corequisite courses. Instructors reported that many students did not actively engage with corequisite support courses, particularly when they perceived the additional coursework as redundant or unnecessary. Additionally, instructors noted that the wide variation in student preparedness made it difficult to effectively tailor instruction, often leading them to focus more on students with the greatest academic struggles. This uneven distribution of instructional attention may have contributed to disengagement among students closer to the college-readiness threshold, who might have benefited from a different type of support structure. Math anxiety further contributed to disengagement, as students who lacked confidence in their mathematical abilities were hesitant to seek help or fully engage with course materials. These findings extend prior research on developmental education by suggesting that discouragement effects may operate not only in prerequisite remediation, as theorized by Scott-Clayton and Rodriguez (2015), but also in corequisite models when additional support requirements create burdens or appear misaligned with students' academic needs.

Implications for Policy and Practice

These findings offer several important implications for policy and practice. First, given the low enrollment rates in math coursework, colleges should provide more proactive guidance about math course sequencing and the importance of completing gateway math early in students' academic careers. To better support students in making informed academic plans, colleges may consider integrating mandatory advising with orientation programs, which ensures that all students, especially those who might not actively seek out academic support, understand the importance of enrolling in essential courses like math early in their academic careers. For instance, some community colleges implemented a model where students are required to attend a mandatory orientation that includes detailed academic advising focused on math and English course enrollment during their first semester (Cho & Karp, 2013). This early emphasis on math placement ensures that students understand the need to take math as soon as possible and has been linked to improved first-year course completion rates.

Second, the benefits of corequisite courses may depend heavily on whether placement actually translates into gateway math enrollment. Institutions should therefore address the financial and logistical barriers that can accompany corequisite reform and discourage students from enrolling, including additional credit loads, costs, and scheduling difficulties. Colleges could mitigate financial barriers by offering targeted support, such as tuition waivers or dedicated aid for students enrolled in corequisite courses, and by ensuring that corequisite support courses align with financial aid eligibility requirements. They could also reduce informational and logistical barriers by making relevant information more accessible through clearer enrollment systems (e.g., paired enrollment in corequisite and gateway math courses at the same time) and more structured advising that helps students understand how corequisite courses fit into their academic plans.

Finally, our findings suggest that institutions should consider differentiating corequisite support based on students' level of academic preparation. For students further from college readiness, corequisite placement may offer a more efficient pathway than traditional prerequisite remediation by allowing them to enter college-level math more quickly. However, the smaller positive effect on completion relative to enrollment suggests that access to gateway math alone may not be sufficient. These students may need additional, targeted support within corequisite courses such as embedded tutoring to more robustly support student learning (e.g., Duffy & Burkander, 2024). For students closer to college-readiness, institutions may need to address both enrollment friction and support fit. Some academically stronger students may perceive full corequisite support as unnecessary or redundant. For these students, more flexible or lower-intensity options such as targeted workshops or optional supplemental instruction may reduce enrollment deterrents while preserving access to academic support.

Limitations and Future Research

There are several limitations associated with our study that must be acknowledged. First, although the study was conducted at the largest institution in the state community college system, the findings still reflect a single institutional context, which may limit the generalizability of our findings to other institutions. In a similar vein, the sample size of respondents for our qualitative component was small. While the insights gathered from student, advisor, and instructor interviews provide valuable context, the experiences captured may not fully represent those at other institutions or within other student populations. Future research should expand to include multiple institutions across diverse settings.

Second, our study does not explore in detail which specific methods of delivering corequisite courses are most effective (such as discussed in Bahr et al., 2022). Corequisite models can vary widely in terms of instructional practices, course structure, and contextual factors. Understanding which instructional strategies are optimal for different student populations or settings remains an open question.

Third, our study focused primarily on short-term outcomes, such as gateway course enrollment and completion within one year. While these are important measures of immediate success, they do not capture long-term outcomes like persistence, success in subsequent coursework, transfer to a four-year college, and associate or bachelor's attainment. Understanding how corequisite models affect students' broader academic trajectories and labor market outcomes would provide a more comprehensive picture of their long-term impact.

Despite these limitations, our study makes an important contribution to the literature on promoting successful completion of gateway math by shedding light on both the advantages and challenges of the increasingly popular corequisite developmental education model. Through an in-depth exploration of student experiences and institutional practices, our research highlights the complexities involved in effectively implementing corequisite courses. The findings pave the way for future research to further refine corequisite models and adapt them to effectively serve a wider range of students.

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Table 1 Student Descriptive Statistics

	(1)	(2)	(3)
		Analytic sample	
Student characteristics and outcomes	Full sample	Corequisite vs. Prerequisite remediation (Students Near a 2.0 GPA)	Corequisite vs. No remediation (Students Near a 3.0 GPA)
Panel A. Background variables			
Female	48%	41%	45%
Race/ethnicity			
White	25%	16%	25%
Black	16%	23%	16%
Hispanic	38%	47%	41%
Asian	16%	10%	13%
Other race	5%	4%	5%
Age at entry term	18.83	18.77	18.73
	(1.52)	(1.13)	(1.23)
Pell Grant eligible	45%	52%	45%
Average High school GPA	3.01	2.05	3.00
	(0.64)	(0.16)	(0.16)
Associate's degree intent			
Associate of Arts	4%	3%	4%
Associate of Applied Arts	0%	0%	0%
Associate of Applied Science	17%	22%	16%
Associate of Fine Arts	3%	3%	3%
Associate of Science	76%	72%	77%
Years since high school graduation	0.49	0.45	0.41
	(1.01)	(0.92)	(0.92)
Cohort			
2021-22	30%	27%	32%
2022-23	35%	35%	33%
2023-24	35%	39%	35%
Entry Term			
Spring	14%	14%	12%
Summer	4%	2%	4%
Fall	82%	84%	84%
Panel B. Outcome variables			
Gateway math			
Enrollment by end of year 1	52%	34%	59%
Completion by end of year 1	35%	16%	38%
N	20,397	1,252	4,268

Note. Standard deviations are in parentheses for continuous variables. The full student sample comprises students from the 2021-22 to 2023-24 cohorts who have non-missing high-school GPAs and who pursue degrees that require gateway math. Gateway math includes Quantitative Reasoning, Statistical Reasoning, and PreCalculus I. Based on optimal bandwidth estimates, column (2) includes students with GPAs from 1.701 to 2.239 (excluding 2.0), column (3) from 2.725 to 3.275 (excluding 3.0).

Table 2 Math Course Enrollment During Students' First Year of College

	Total	Percentage
Total number of students required to take a college-level math	20,397	100%
Students who enrolled in recommended math courses	12,172	60%
Students who did not enroll in recommended math courses	8,225	40%
No math course enrollment (including math remediation)	6,194	30%
Enrolled in math at levels above recommendation	1,253	6%
Enrolled in math at levels below recommendation	778	4%

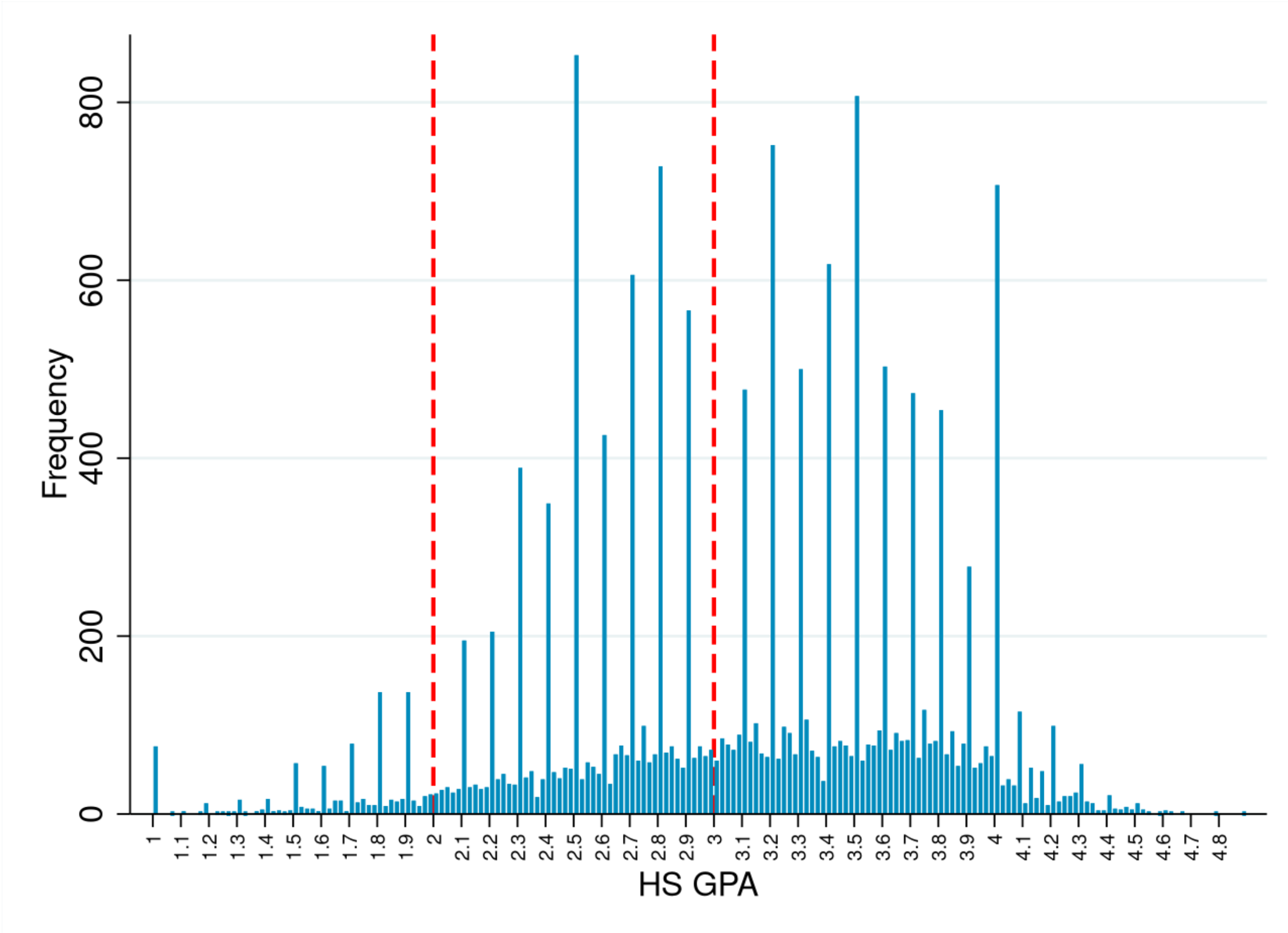
Note. The student sample in this table matches the full sample in Column (1) of Table 1. College-level math includes math courses numbered 150 or above, including gateway math.

Table 3 Effects of Math Remediation Placement on Remedial Course Enrollment, Gateway Math Enrollment and Completion

	(1)	(2)	(3)	(4)
	Prerequisite vs. Corequisite remediation placement (Students Near a 2.0 HS GPA)		Corequisite vs. No remediation placement (Students Near a 3.0 HS GPA)	
Outcomes	First stage	Reduced form	First stage	Reduced form
Panel A. Remedial Course Outcome				
Math remediation enrollment by end of year 1	0.611***		0.303***	
	(0.043)		(0.027)	
F-statistics	200		130	
N	1,252		4,268	
Panel B. Gateway Math Course Outcomes				
Gateway math enrollment by end of year 1		-0.354***		-0.117***
		(0.060)		(0.036)
Gateway math completion by end of year 1		-0.170***		0.007
		(0.049)		(0.036)
Gateway math completion by end of year 1 (conditional on gateway math enrollment)[a]		0.023		0.142***
		(0.174)		(0.046)
N		1,252		4,268

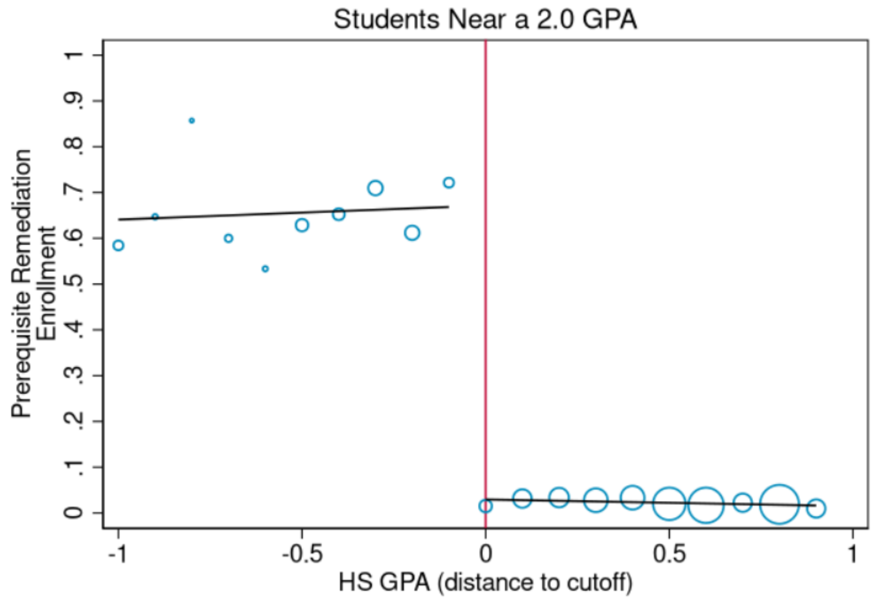
Note. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are in the parentheses. All models controlled for HS GPA, interaction of HS GPA and placement, sex, race/ethnicity, age, Pell Grant eligibility, years since high school graduation, intended award, cohort, and entry term (spring, summer, fall). Gateway math includes Quantitative Reasoning, Statistical Reasoning, and PreCalculus I. Based on optimal bandwidth estimates, column (1) and (2) includes students with GPAs from 1.701 to 2.239 (excluding 2.0), column (3) and (4) from 2.725 to 3.275 (excluding 3.0). For the first stage results, the outcome is prerequisite enrollment for column (1), and corequisite enrollment for column (3). [a]The conditional outcome is less relevant for column (2) because students below the cutoff were placed into prerequisite courses and thus are less likely to enroll in gateway math; the conditional outcome sample includes 420 observations in column (2) and 2,509 observations in column (4).

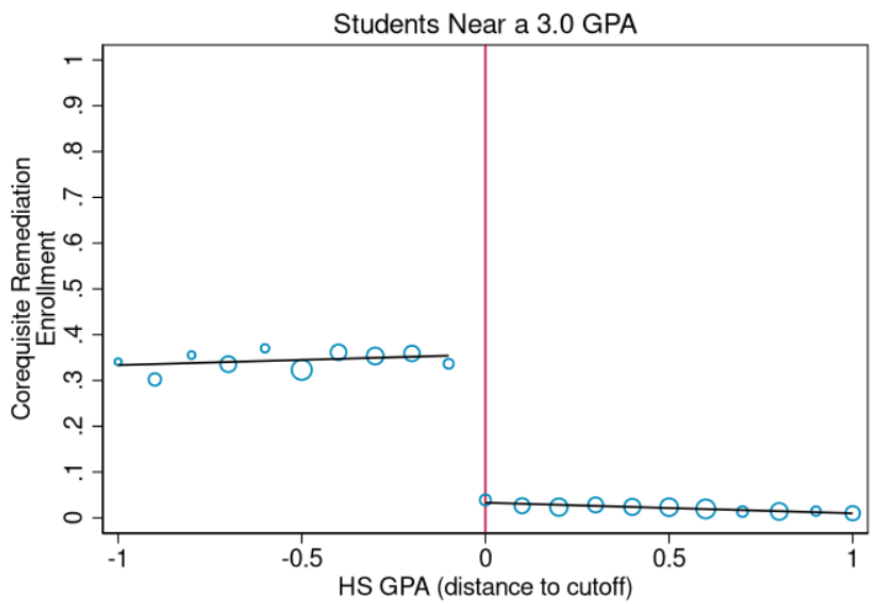
Figure 1 Distribution of Running Variable HS GPA



Note. The red lines indicate the two developmental math placement thresholds at GPAs of 2.0 and 3.0.

Figure 2 Math Remediation Enrollment by HS GPA: Students Near a 2.0 GPA and Students Near a 3.0 GPA





Note. The horizontal axis shows the distance between students' HS GPA and the cutoff for placement. The vertical axis displays the average math remediation enrollment rate. Each circle's size corresponds to the number of students in each HS GPA range.

Appendix

Table A1 Covariates Balance Test

	(1)	(2)
Covariates	Prerequisite vs. Corequisite remediation placement (Students Near a 2.0 HS GPA)	Corequisite vs. No remediation placement (Students Near a 3.0 HS GPA)
Female	-0.050	-0.004
	(0.068)	(0.038)
Race/ethnicity		
White	0.074	-0.037
	(0.050)	(0.033)
Black	-0.008	0.024
	(0.058)	(0.028)
Hispanic	-0.028	-0.031
	(0.068)	(0.037)
Asian	-0.015	0.023
	(0.041)	(0.026)
Other race	-0.023	0.022
	(0.062)	(0.029)
Age at entry term	0.088	0.152
	(0.155)	(0.093)
Pell Grant eligible	-0.106	0.002
	(0.068)	(0.038)
Associate's degree intent		
Associate of Arts	-0.021	-0.020
	(0.023)	(0.014)
Associate of Applied Arts	0.005	0.001
	(0.004)	(0.002)
Associate of Applied Science	0.068	-0.008
	(0.057)	(0.028)
Associate of Fine Arts	0.017	-0.011
	(0.023)	(0.013)
Associate of Science	-0.069	0.037
	(0.061)	(0.032)
Years since high school graduation	0.041	0.179**
	(0.125)	(0.070)
Cohort		
2021-22	0.019	0.029
	(0.061)	(0.035)
2022-23	0.038	-0.040
	(0.065)	(0.036)
2023-24	-0.057	0.011
	(0.067)	(0.036)
Entry Term		
Spring	-0.037	0.030
	(0.048)	(0.025)
Summer	-0.002	0.022
	(0.018)	(0.015)
Fall	0.039	-0.052*
	(0.050)	(0.028)
N	1,252	4,268

Note. The coefficient is the estimate of the below-cutoff indicator on each covariate. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are in the parentheses. Based on optimal bandwidth estimates, column (1) includes students with GPAs from 1.701 to 2.239 (excluding 2.0), column (2) from 2.725 to 3.275 (excluding 3.0). All models controlled for HS GPA and the interaction of HS GPA and placement indicator.

Table A2 Effects of Remedial Placement on Math Enrollment and Completion: Manipulation Robust Estimates

	(1)	(2)
	Prerequisite vs. Corequisite remediation placement (Students Near a 2.0 HS GPA)	Corequisite vs. No remediation placement (Students Near a 3.0 HS GPA)
	Point estimate	Point estimate
Gateway math enrollment by end of year 1	-0.322	-0.086
Gateway math completion by end of year 1	-0.131	0.005
N	1,252	4,268

Note. The bounding analysis does not detect manipulation, based on an estimated proportion of "always-assigned" students of zero, so the lower and upper bounds of the estimates equal the point estimates. To keep the analysis transparent, we report the point estimates from this analysis for both models. These models do not include covariates due to methodological constraints. Gateway math includes Quantitative Reasoning, Statistical Reasoning, and PreCalculus I. Based on optimal bandwidth estimates, column (1) includes students with GPAs from 1.701 to 2.239 (excluding 2.0), column (2) from 2.725 to 3.275 (excluding 3.0).

Figure A1 Student Placement into Developmental and Gateway Math before and after the Direct Enrollment Policy in NVCC

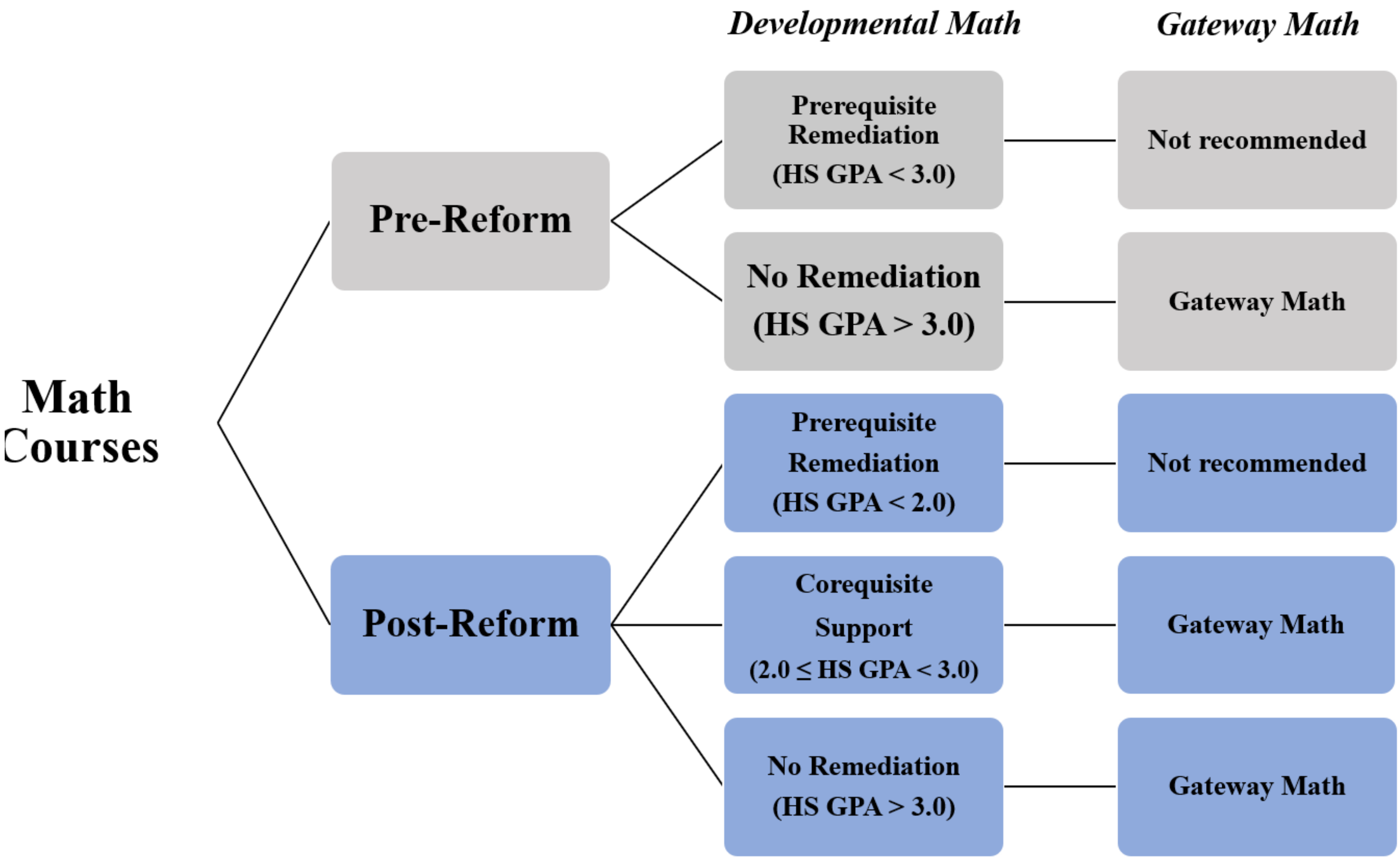
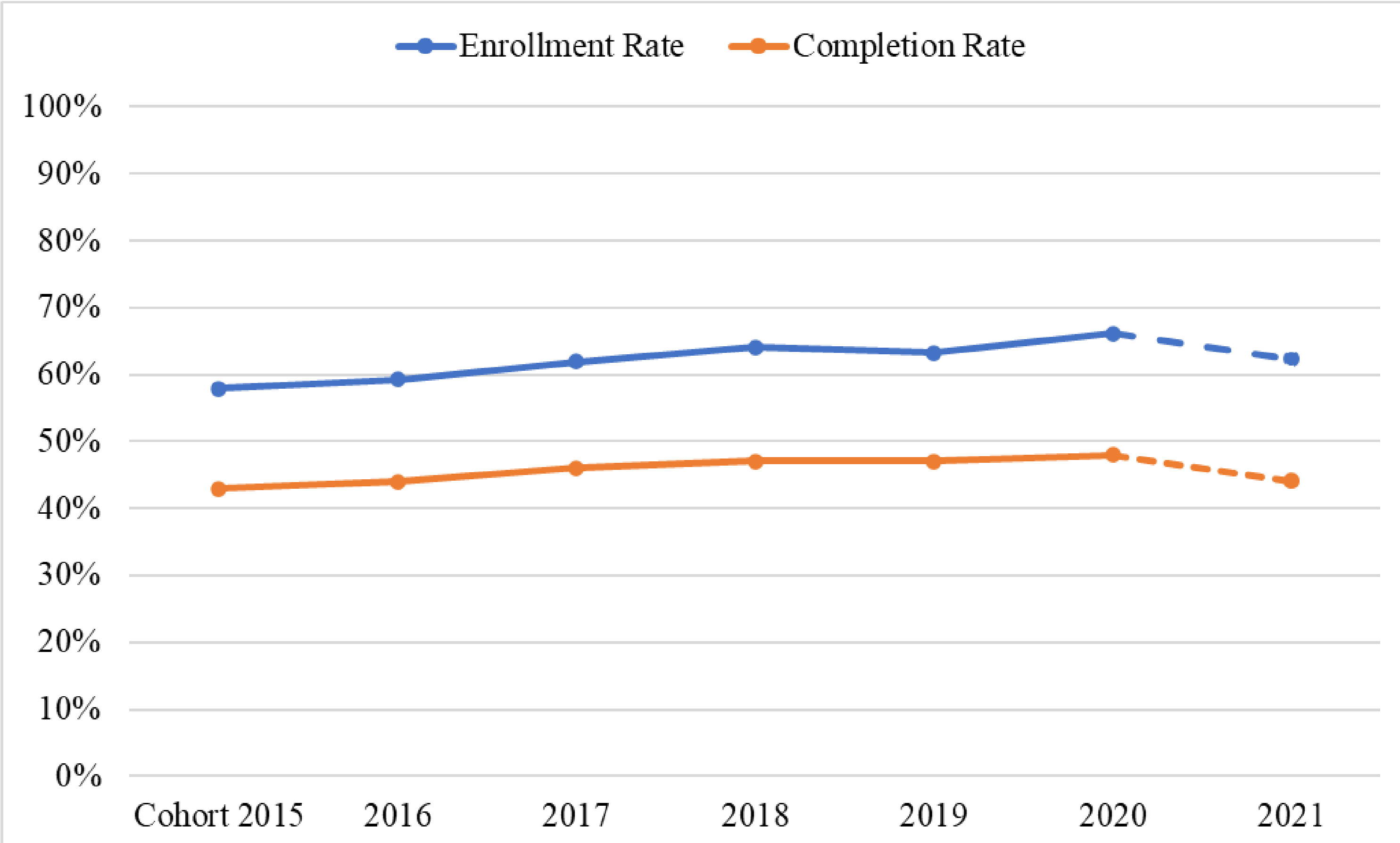


Figure A2 College-Level Math: One-Year Enrollment Rate and Completion Rate by Cohort



Appendix A

Validity of RD Model

A key assumption for the validity of RD estimates is that observable and unobservable student characteristics were comparable above and below the HS GPA cutoffs for developmental course placement. This ensures that any differences in first-year gateway math outcomes are attributable to developmental course placement rather than confounded by individual characteristics. We tested this assumption by checking whether the density of students' HS GPA was smooth across the 2.0 and 3.0 cutoffs. We observed significant heaping in the distribution of HS GPAs, with a disproportionate number of students reporting GPAs of 2.0 and 3.0.

This heaping may result from two primary factors. First, the developmental education reform asks students to self-report their HS GPA, potentially leading to manipulation. Students who are aware of placement policies or other relevant considerations, such as financial aid eligibility, might inflate their GPA to meet certain cutoffs. Second, individuals may naturally round their HS GPA to the nearest integer or the first decimal place, a behavior documented in previous literature (Scott-Clayton & Schudde, 2016); indeed, the Direct Enrollment Survey includes rounded examples in its explanation, for example noting that students who received "mostly B's" should enter 3.0. The first scenario raises concerns about systematic bias in the estimation, as students with greater resources and knowledge of institutional policies or higher motivation to meet degree requirements might be more likely to manipulate their GPA to waive the remediation requirement. This could result in non-comparable student groups around the cutoff, undermining the validity of the RD approach.

To address this potential manipulation, we applied the "donut-RD" method as outlined by Barreca et al. (2016), excluding observations with GPAs of exactly 2.0 and 3.0 from the RD analysis. This allows us to focus on the remaining student samples that are around the cutoff but are less likely to involve systematic manipulation. Figure 1 presents the distribution of student HS GPAs, with the red lines indicating the placement cutoffs. In the next section, we discuss the McCrary density test (Cattaneo et al., 2018, 2020; McCrary, 2008), sorting test, and the manipulation-robust estimations (Gerard et al., 2020).

Density Check, Sorting Test, and Bounding Analysis

After excluding cases at the cutoff that cause heaping, the distribution appears relatively comparable on either side of the cutoffs, as shown in Figure 1. We further assess the continuity of the running variable using formal density tests. Following McCrary (2008) and Cattaneo et al. (2018, 2020), we first use local-polynomial density tests to examine manipulation across the cutoff designed for continuous running variables. Using the optimal bandwidths, these tests reject continuity at both the 2.0 GPA cutoff ($t = 4.00$, $p < 0.001$) and the 3.0 GPA cutoff ($t = 2.71$, $p < 0.01$).

However, we interpret these results cautiously because HS GPA is reported to the nearest 0.01 (as shown in Figure 1) and creates discrete mass points throughout the distribution. Consistent with this concern, the density tests also reject continuity at placebo cutoffs that do not determine placement such as 3.1 and 3.2. This pattern suggests that the continuous-density tests may not be suitable in this setting because the running variable is discrete rather than truly continuous. We therefore conduct an additional density test designed for discrete running variables following Frandsen (2017). Using the Stata command rddisttestk, we set the value of k based on the optimal bandwidth. The discrete density test suggests no evidence of manipulation at the 3.0 GPA cutoff, but it does indicate potential manipulation at the 2.0 GPA cutoff ($p < .05$).

In addition, Appendix Table A1 presents covariate balance tests around both cutoffs. No observable characteristics are significantly associated with placement below the 2.0 cutoff. However, students just below the 3.0 cutoff have a longer gap between high school graduation and college entry and are less likely to have entered VCCS in the fall semester, suggesting some imbalance around the 3.0 GPA placement threshold.

Appendix Table A2 presents manipulation-robust estimates. The estimated proportion of "always-assigned" students is zero at both GPA cutoffs, suggesting that this method does not detect evidence of manipulation at either cutoff. As a result, the upper and lower bounds coincide with the point estimates, reinforcing the findings from Table 3. For students around the 2.0 GPA cutoff, the bounding analysis estimates the impact of prerequisite placement on gateway math enrollment at -0.322, compared with the reduced-form estimate of -0.354 in Table 3. For gateway math completion, the corresponding estimate is -0.131, compared with -0.170 in Table 3. For students around the 3.0 GPA cutoff, the coefficients are also comparable. The manipulation-robust estimates are -0.086 for gateway math enrollment and 0.005 for gateway math completion, compared with the reduced-form estimates of -0.117 and 0.005, respectively. Differences in magnitude may arise from the absence of covariates in the bounding analysis, as this method requires a substantially larger sample size to include the same set of covariates. Overall, the consistency in the direction and magnitude of most estimates provides further support for the validity of the reduced-form estimates reported in Table 3.

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Appendix B

Semi-structured Interview Questions for Advisors and Data Analysis Plan

Data Source: Interview Questions	Rationale	Analysis
• How long have you been an advisor at NOVA? • Could you talk a little about your roles and responsibilities? • Could you share a memorable experience that had a positive impact on you as an advisor?	These questions aim to establish context about the advisor's professional background and their experiences in advising.	Identify common themes in advisors' professional experiences and memorable moments.
• Could you share if students have assigned advisors? • Are students required to meet with advisors to register for courses or can they self-register? • How do you facilitate your interactions with students?	These questions explore how students interact with advisors and the structures in place for guidance.	Analyze patterns in advising processes and how they impact students' enrollment decisions.
• Let's imagine a new student comes in who is a recent high school graduate. Could you please walk me through how you would work with them to determine their mathematics enrollment? • Is it the same process for returning adult students?	These questions focus on understanding how advising practices differ for various student demographics (e.g., new vs. returning, STEM vs. liberal arts).	Highlight differences in advising approaches for different student groups.
• What types of questions or concerns do you hear from students about their math requirements? • What are some reasons that students have given for delaying enrollment into	These questions aim to identify common student concerns and factors influencing their course enrollment decisions.	Code recurring themes to understand barriers to timely math enrollment.

math courses in their first year?		
• How do you explain corequisites to students? • What kinds of questions do students have about corequisite courses? • How do students perceive the guidance or advice given regarding corequisite math courses?	These questions help evaluate students' understanding and perceptions of corequisite courses.	Assess feedback on advising effectiveness and identify gaps in student understanding.
• Next, I'd like to discuss only those students who have taken Algebra II in high school. What would you say are the most significant challenges associated with corequisite courses for these students? • If the student is exempt, will the GPA be recorded into the system? What does the exemption procedure look like?	These questions aim to explore the challenges faced by students with prior math experience and how exemptions are handled.	Analyze the alignment between student preparation and course placement.
• What are the math requirements for returning adult students? • What advising do they receive in terms of course enrollment?	These questions examine the unique advising needs of returning adult students and their decision-making process.	Identify patterns in returning students' enrollment behaviors and advising needs.

Semi-structured Interview Questions for Instructors and Data Analysis Plan

Data Source: Interview Questions	Rationale	Analysis

• How long have you been an instructor at NOVA? • Do you have any other forms of employment? • What courses are you teaching this semester? • Have you taught any developmental courses before? Have you ever taught both corequisite courses and gateway courses simultaneously?	These questions aim to gather background information about the instructor's teaching experience and personal reflections on their teaching role.	Analyze themes related to the instructor's teaching experiences, including memorable moments that influence their approach to instruction.
• In your experience, how useful and effective do you find the co-requisite classes in helping students succeed in their gateway courses?	This question is intended to understand the instructor's perception of the value and effectiveness of co-requisite courses.	Look for insights into the perceived strengths and areas for improvement in co-requisite instruction.
• From your perspective, what are the most significant challenges or difficulties you encounter when teaching co-requisite courses, and how do you typically address or overcome them? • Probe: Are there particular aspects or concepts within corequisite courses that you find particularly challenging to teach?	These questions explore the challenges instructors face and their strategies for addressing those challenges.	Identify common difficulties and teaching practices that instructors use to manage corequisite course demands.

• How do you approach teaching in a corequisite setting, where students may have varying levels of preparedness? • Probe: How do you distinguish between students who benefit from corequisite classes versus those who seem overwhelmed in corequisite classes? • Probe: How do you tailor your support strategies for individual students who may face specific challenges in corequisite courses?	These questions aim to understand how instructors scaffold learning and provide differentiated support for students with diverse needs.	Analyze strategies for scaffolding and identify best practices for tailoring instruction to individual students.
• Can you please share any reasons that explain why students enrolling in corequisite courses are less likely to complete gateway courses? • Probe: From your perspective, what are some common challenges that students face in corequisite courses? • Probe: Can you provide specific examples or instances where you observed these challenges in your corequisite courses? • How do you typically address or mitigate challenges to support student success in corequisite courses? • Probe: Can you describe an unconventional approach that you found particularly effective in enhancing student success?	These questions investigate the challenges students face and how instructors perceive and address these barriers.	Identify themes related to student struggles and effective teaching strategies for overcoming barriers to success in corequisite courses.

Sample Semi-Structured Interview Questions for Students and Analysis Plan

Data Source: Interview Questions	Rationale	Analysis

• How long have you been enrolled at NOVA? • Have you selected a major? • What courses are you taking this semester?	These questions aim to gather background information about the students’ academic journey and current status at NOVA.	Analyze patterns in students’ enrollment status and course selections to identify common academic paths.
• What resources of information did you use when deciding which courses to enroll in at NOVA? • Were there specific tools or platforms at NOVA you found particularly helpful? • How did your family members or peers contribute to your decision-making process?	These questions explore the role of institutional tools and personal networks in students' course selection.	Identify key resources and influences that guide students' enrollment decisions.
• Could you describe your interaction with your advisors? What matters do you typically discuss? • When do you get to interact with your advisors? What do you talk about? • Could you share what academic matters or topics you discussed with them? • Have there been specific academic issues or concerns that prompted you to seek advice from your advisors? • In terms of math courses, how frequently did you seek advice from advisors? What methods did you use?	These questions aim to understand the nature and frequency of students’ interactions with advisors.	Analyze patterns in advisor-student interactions and their impact on academic decision-making.

• What factors did you consider when enrolling for any math courses in your first year? • What personal experiences affected your decision to not enroll or not enroll in math courses during your first year? • Why do you think students delay enrolling in math courses during their first year?	These questions aim to explore the considerations and barriers affecting students' decisions about math course enrollment.	Identify common factors influencing students' math enrollment behaviors, including personal experiences.
• Have you heard of corequisite learning support courses such as MDE 54, MDE 55, MDE 61 at NOVA? If so, could you share what you know about them? • How did you learn about corequisite math courses? What information did your advisors provide? • How do you feel about the guidance or advice you were given regarding corequisite math courses?	These questions aim to assess students' awareness and understanding of corequisite courses and the role of advisors in disseminating information.	Identify gaps in students' understanding of corequisite courses and evaluate the effectiveness of guidance provided.
• How would you characterize your experiences in corequisite math courses? • In terms of peer interaction, how frequently do you engage with your classmates? • Regarding the course content, how would you assess its difficulty level? • Could you share your perspective on the supportiveness of your teacher?	These questions aim to capture students' experiences in corequisite courses, including peer and teacher interactions.	Analyze student feedback to identify strengths and areas for improvement in the corequisite course structure.

• What would you say are the most significant challenges associated with math corequisite courses? • How helpful have the instructional supports been in addressing these challenges? • What supports that are currently NOT provided do you think would be helpful?	These questions explore the challenges students face and the adequacy of existing support systems.	Identify common challenges and gaps in support to suggest actionable improvements for corequisite courses.