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Embedded Remediation Is Not Necessarily a Pathway for Equitable Access to Quantitative Literacy and College Algebra: Results from a Pilot Study

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Abstract

Courses in developmental and introductory mathematics are changing. Because nearly all students need mathematics coursework to graduate from a postsecondary institution, yet institutions consistently struggle to ensure that students of all demographics succeed in credit-bearing mathematics courses, student success in such courses may be viewed as an issue of social justice. In particular, there is a need for institutions to provide pathways through college-level mathematics courses that meet the needs of students with a wide array of incoming mathematical knowledge and skills. In light of questions about pedagogy, pass rates, and effects on degree completion time, some institutions have moved away from requiring students to enroll in non-credit-bearing developmental mathematics courses. At Michigan State University, college-level courses in both Quantitative Literacy and College Algebra now directly enroll students who previously would have placed into Intermediate Algebra. Accompanying this shift in access are changes in course structure and content; during the 2017-2018 academic year, some course sections included an extra class meeting to help students bridge gaps in their requisite skills. While the corequisite model is an intuitive approach to supporting student learning, essentially increasing time on task and identifying needed requisite skills “just in time,” these quantitative analyses show little evidence for these course sections improving students’ course grades. In this context, the role and type of corequisite, supplemental instruction that best supports learning for a diverse group of students in introductory undergraduate mathematics courses remains in question. We discuss potential reasons for these results in light of existing reports on corequisite models and situate the results in the context of what social justice and equity might look like for corequisite models of introductory mathematics coursework.

Keywords

college algebra, developmental mathematics, embedded remediation, quantitative literacy, regression, social justice

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Cover Page Footnote

Rebecca L. Matz is an academic specialist in the Hub for Innovation in Learning and Technology at Michigan State University. Her research focuses on assessment and student success in introductory undergraduate STEM courses.

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Introduction

The profile of the “traditional” college student—regardless of how one defines the word—is changing. While the percentage of 18-24-year-olds enrolled in U.S. post-secondary institutions decreased by about 2% from 2010 to 2015, the overall percentage enrolled in 2015 was still much higher, at 41%, than its 1970 counterpart of 26% (U.S. Department of Education 2016). If we partition the 18-24-year-old population by demographic characteristics such as gender, underrepresented minority status, or first-generation status, we see similar increases, with notably higher percentage increases among Black and Hispanic individuals in comparison to white individuals—a reflection of the fact that Black and Hispanic populations enrolled in post-secondary institutions in 1970 at lower base percentages. Notwithstanding these statistics suggesting that access to higher education has increased over the past five decades, it would be misleading to rely on enrollment statistics alone as the sole measure of opportunity; that is, to borrow from Engstrom and Tinto (2008, 50), “access without support is not opportunity.” In the particular context of institutionally-required college mathematics courses, where it is well-documented (Jones and Herbel-Eisenmann 2015; Larnell 2016) that students of color often face myriad challenges in comparison to their white peers, it is especially important that attention be given to systematic patterns in the success rates of different demographic groups (with race being just one grouping characteristic). Doing so is one means of attending to opportunity beyond access.

While we do not seek to engage in gap gazing, or fetishizing achievement gaps between different demographic groups (Gutiérrez 2008), we believe it is important to be proactive in identifying and mitigating barriers to student success, particularly in first-year mathematics courses that serve as gatekeepers to specific majors and to nearly any college degree. Indeed, the unequal distribution of opportunity for success in such courses yields an unequal distribution of resources requisite to thriving as a U.S. citizen. In this sense, student success in first-year mathematics courses is an issue of social justice. As with many social justice issues, attention to causality and intentionality (e.g., Who caused this problem? Were the consequences intended?) is perhaps less pressing than work to improve the situations of those affected. Giving attention to student achievement as a proxy for access to college education and making changes based on the findings is one means of striving for social justice in postsecondary mathematics education.

A useful metaphor to adopt in thinking about barriers to opportunity comes from the story of “low bridges” built in New York City in the early twentieth century. The story centers around Robert Moses, a prominent public figure at the time, known in particular for his work in engineering many of the city’s bridges, parkways, and parks. Some scholars have argued that Moses intentionally ordered some bridges to be built low to prevent buses with poor individuals and individuals

of color from accessing roads to public beaches (Caro 1974). In the decades following the building of those bridges, a task for individuals involved in city planning has been to work within and around the given structures to ensure that individuals who might ride such buses still have access to favored places in the state. Without considering Moses's intentionality, or even the veracity of the claim itself (cf. Woolgar and Cooper 1999), the story adapts well as a metaphor to mathematics courses in the post-secondary context.

Here, we position completion of a university mathematics graduation requirement as a potential barrier to opportunity for students, or a "low bridge" according to the metaphor; students must fulfill the mathematics requirement by taking or placing out of the equivalent of two credit-bearing mathematics courses. The bridge is not necessarily a barrier in and of itself but, depending on the resources of those encountering the bridge, it can be problematic for access to what lies on the other side. That is, those encountering Robert Moses' low bridges were resourced with public buses, and the conflict between the low bridge and the public bus engenders the problem. Students encountering the university mathematics graduation requirement given their resources—in some cases, low mathematics placement scores and room for improvement in their mathematical knowledge and skills—have a similar problem of access.

At the land-grant institution of Michigan State University (MSU), students are required to take or place out of the equivalent of two credit-bearing mathematics courses. A founding directive of MSU is that Michigan citizens have access to higher education, so it is critical that we be aware of remnants of the past that limit the opportunities of underrepresented groups to this day. Innovations in mathematics education at MSU (and elsewhere), such as the enhanced course sections described in this paper, are one means of finding a route around, over, under, or through the low bridge. While the University has made efforts over the past decade (Tunstall et al. 2016) to create meaningful alternatives to and supports for college algebra, work remains to be done to meet students where they are with respect to their mathematics preparation levels.

Following suit with many institutions across the U.S. (Gaze 2018), various units and individuals across MSU have made it a priority to address gaps in incoming students' knowledge that inhibit their success in credit-bearing, first-year mathematics courses, specifically Quantitative Literacy 1 and 2 and College Algebra (hereafter referred to as QL1, QL2, and CA, respectively). Students intending to major in STEM disciplines and other fields that require calculus tend to enroll in CA and Calculus to complete their mathematics requirement, whereas students in other fields (e.g., Political Science) are encouraged to enroll in QL1 and QL2 to complete their requirement. Both groups contain students for whom the courses QL1, QL2, and CA were not sufficiently supportive. Rather than placing students with certain performance metrics in developmental mathematics courses,

which often bear no credit, increase time-to-degree, and are generally associated with high failure rates (Bonham and Boylan 2011), MSU piloted sections of QL1, QL2, and CA in 2017-2018 that included embedded remediation in an additional weekly class meeting for students. The premise underlying the embedded remediation was that an additional period would allow students time to practice foundational skills “just in time” for when they would be useful in class (Perez et al. 2018).

Though this premise is plausible, plausibility alone is not sufficient to justify long-term changes to courses that enroll thousands of students each year, and for this reason we find it important to examine effects of this embedded remediation pilot. In this paper, we present a quantitative analysis of success rates from these pilots, paying attention to the interactions between various demographic characteristics and student success as measured through final course grades and DFW rate (referring to D-grades, F-grades, and withdrawals together). The two research questions guiding this study were: RQ1) What were the final grade and DFW rate outcomes in embedded remediation course sections for students who otherwise would have placed into developmental mathematics? and RQ2) What impact did the course sections with embedded remediation have on final grades and DFW rates compared to course sections without embedded remediation, and how do these differences covary with various predictor variables?

Our intention in completing and writing about these analyses is to contribute to the ongoing conversation about practices that foster student success in undergraduate mathematics courses—especially those that serve as gateways to graduation or to specific majors. Here, we report three key results, namely that: 1) For QL1 and CA, final grades were lower and DFW rates were higher for students who had developmental mathematics preparation than for those who had developmental mathematics waived and then immediately took the course; 2) comparable students in enhanced embedded remediation sections of QL1, QL2, and CA performed worse overall than those who enrolled in non-enhanced sections of the courses; and 3), in relation to 2), statistical predictors of success for these students in QL1 and QL2 include prior mathematics GPA, ACT mathematics component score, and students’ race. We begin with a brief review of the landscape of post-secondary developmental mathematics, and then discuss the specific context of the MSU courses.

Getting to and through College Mathematics

A variety of trajectories and models exist for students who place into developmental mathematics courses. One model that has gained notoriety in recent decades requires that students pass one or more prerequisite developmental courses before being allowed to take a course such as statistics or college algebra for college credit.

For many students, such a path devolves into a cycle of floundering within the courses and even dropping out from postsecondary pursuits altogether, especially when students must take two or more courses before being allowed in a credit-bearing course (Bonham and Boylan 2011). While it is easy to critique such a sequence for its effects on students and their timelines to graduation, creating alternatives is challenging, as it requires meticulous attention to what mathematics students need for success in the diverse courses students might encounter subsequently in fulfilling their institution's mathematics requirement (Gaze 2018). Furthermore, implementing alternatives is a multilateral endeavor, given that multiple parties at the institutional and supra-institutional levels need to be aware of and "on board with" the changes in order for their implementation to be effective. Two broad options beyond this model have emerged in recent years: a modified sequence for credit-bearing mathematics, and corequisite options for a single semester of credit-bearing mathematics. These options are not mutually exclusive.

In relation to the former category, one promising strategy is the notion of pathways as exemplified by the Charles A. Dana Center at the University of Texas-Austin (Zachry Rutschow and Diamond 2015) and the Carnegie Math Pathways initiative in association with WestEd (Hoang, Huang, Sulcer, and Yesilyurt 2017). Aimed at community colleges but available for various types of institutions, both models support condensing the developmental mathematics sequence into a single course that precedes the mathematics courses students take to fulfill their mathematics requirement, whether such a course is statistics, quantitative reasoning, or college algebra. This abridged version of developmental mathematics includes only the content that students will need to be successful in later coursework, jettisoning other topics (e.g., polynomial long division) that tend to hinder student success and that bear little import for students' future coursework or careers. Both models aim to meet the needs of an increasingly diverse college student body.

Differentiation in these models begins at the first stage—the developmental mathematics course—and not at the second stage, where students take a course specific to their goals or major. This differentiation changes developmental mathematics from a series of multiple courses to a "one-stop shop" developmental experience. This switch in timing facilitates the compression of the developmental mathematics topics into those that students actually need for the following credit-bearing course(s). In relation to these models, implementation data from the organizing groups (e.g., Sowers and Yamada 2015; Zachry Rutschow and Diamond 2015; Hoang, Huang, Sulcer, and Yesilyurt 2017) and from researchers and faculty involved in implementation (e.g., Howington, Hartfield, and Hillyard 2015) indicate that the approach benefits students' affect in relation to mathematics, timeline to graduation, and required mathematical skills.

Pathways are not the only means of accelerating students through mathematics requirements. An optional component of pathways is the corequisite model, wherein students complete credit-bearing mathematics in a single semester while simultaneously having additional supports, whether in the credit-bearing course itself, or alongside it. Understandably, the corequisite model has gained traction for its alluring removal of the necessity of multiple semesters for students. This model has been successfully implemented in several states, including California, Colorado, Georgia, Indiana, and Tennessee (Complete College America 2018); in California, new legislation (bill AB 705) now requires community colleges to aim to maximize the likelihood that students can successfully complete transfer-level mathematics (and English) coursework within one year. Indeed, beginning in Fall 2018, the Carnegie Math Pathways project will include Quantway and Statway corequisite models. Similarly, the approach now in place at MSU is that of removing developmental courses altogether and instead embedding support as needed within credit-bearing mathematics courses, generally referred to as “zero entry” mathematics at MSU. As noted by Burn, Baer, and Wenner (2013, 23), “the embedded approach removes mental, fiscal, and temporal barriers created by corequisite courses”—a point that we believe readily applies to prerequisite courses as well.

Of course, it is relatively easy to place students into a course with embedded remediation; the more difficult problem is ensuring that the course is designed to support student learning and success. Reporting on a multi-year, multi-site pilot of corequisite model implementation in select Louisiana community colleges, Campbell and Cintron (2018) found that students who would have otherwise placed into developmental mathematics, but who instead took a corequisite pilot course, achieved credit in college-level mathematics courses at statistically similar rates to students who remained in developmental mathematics and later took the credit-bearing mathematics course. The authors noted that student buy-in to the nature of the corequisite model—including its time commitment and purpose—was important in order for them to take the corequisite model seriously; in relation, where students did not succeed in the corequisite model, the authors cited attendance as a major issue. Moreover, though Campbell and Cintron did not provide data on the topic, they remarked that schools using adaptive learning technologies without actually monitoring student progress regularly reported little value in the programs. We discuss the relationship between that implementation and the one at MSU at the end of this article.

Before transitioning to specific details about embedded remediation at MSU, we believe it is important to note that neither the pathways nor the embedded remediation approach inherently leads to socially just outcomes. If we substitute the word *pathways* for *tracks*, for example, this point becomes salient. Indeed, K-12 education scholars have for decades documented the ways in which *tracking*, or

the placement of students into various tracks based on their needs (whether self-stated or imposed), reinforces and compounds existing societal inequalities (Willis 1978; Gamoran and Mare 1989; Lucas 2001; DiPrete and Eirich 2006; Larnell 2016). Even with embedded remediation, students are tracked into “appropriate” courses before calculus based on metrics like placement scores. All of this is to say that many of the students whom we work with and discuss in this paper arrive with cumulative disadvantages that no special program can remove altogether. The embedded remediation approach at MSU is one means of attempting to work around an existing low bridge—it does not remove the road prior, nor the bridge itself.

Context

The QL courses at MSU are offered in a format with two 80-minute class meetings per week, the first in a large lecture hall with an instructor and the second in smaller recitation sections with a graduate student teaching assistant (TA) or undergraduate learning assistant (LA) who has experience facilitating class discussions and collaborative activities. In addition to this format, pilot “enhanced” sections of these courses were offered in the 2017–2018 academic year,¹ incorporating a second small-enrollment 50-minute class meeting each week with an LA. Both the TAs and LAs were specifically chosen for their demonstrated capabilities with students struggling in mathematics courses (e.g., through exemplary work in the Math Learning Center, a source for centralized tutoring support). Given the large size of the courses, multiple TAs and LAs were involved in each course. Neither students nor the TAs nor the LAs were provided an orientation that specifically discussed expectations for how the additional meeting time would contribute to student success, and it is difficult to know if students in the enhanced sections ever fully “bought in” to the idea of the corequisite model—an important consideration brought up by Campbell and Cintron (2018). Assessments were common across both formats.

For QL, the enhanced class meetings were scheduled after the lecture and before the recitation. These sessions provided students opportunities to practice skills introduced in the lecture session in preparation for more contextualized group “laboratory” activities in the recitation sections, and LAs could work with students on more foundational ideas as needed. The laboratory activities were designed to be the centerpiece of the course, insofar as the constraints of large lectures do not usually permit the nuanced explorations and subsequent class discussions that a small class size can more readily support. The goal of both QL1 and QL2 is to help

¹ These enhanced course sections are no longer offered as of the 2018–2019 academic year. The current curricular model is a subject of ongoing study.

students learn to use and communicate about numbers in contextualized and applied situations; the courses differ in the contexts covered. QL1 centers on numbers in the media, understanding global trends (e.g., using Gapminder), and health and risk; QL2 centers on the contexts of voting and politics, finance and economics, and other topics (e.g., social justice and mathematics). The initial design of these courses was described previously (Tunstall et al. 2016). Both courses have increased in size every year, with current figures (2018–2019) at approximately 1,100 annual enrollments in each course.

Our third course of interest, CA, is a college algebra course focusing primarily on functions, exponents and logarithms, and systems of equations, among other topics. The course sections consist of two 50-minute lectures per week with an instructor plus one small-enrollment 50-minute recitation with a TA. Given the central nature of algebra as a prerequisite for calculus and statistics, this course serves an enormous number of students every year, with annual enrollments usually greater than 3,500 students. The enhanced course sections of CA offered in 2017–2018 incorporated two additional 50-minute course meetings per week and again, assessments were common across both formats. We note that the enhanced section of CA offered in one of MSU's residential colleges (a living and learning community focused on students with STEM interests) was excluded from these analyses and that, for both the QL courses and CA, the authors were not involved in the design of the enhanced course sections.

Students who enter the University with mathematics placement levels below QL1, QL2, and CA have generally had an array of instructional options from which to choose in order to complete the developmental instruction requirement. One former option was a formal, one-semester developmental mathematics course largely offered online. This course was recently jettisoned in favor of credit-bearing alternatives (such as the enhanced sections described herein), though it is relevant to introduce because many students in the data analyzed here had enrolled in this course. MSU also regularly offers several summer experiences for matriculating students with various career interests (e.g., engineering and medicine) or other characteristics. As a part of these programs, students often have access to mathematics instruction that, though not part of a formal course, still prepares them adequately for QL1, QL2, or CA. These programs vary widely in their goals and mechanisms (e.g., residential, online, or hybrid), and it is beyond the scope of this paper to describe them fully. Of course, these are usually referred to as bridge programs; in the context of the “low bridges” metaphor, the bridge programs are one way over the existing low bridge. For the sake of simplicity, throughout we refer to all of these options, including the formal course, as developmental mathematics.

In 2017–2018, the developmental mathematics instructional requirement as a formal prerequisite was waived for a subset of students by virtue of their

participation in a broader first-year cohort program—a Common Intellectual Experience (CIE) as defined by Kuh (2008). This CIE program at MSU was designed to foster learning communities, with two cohorts of approximately 250 freshman students each enrolled in four common courses throughout their first year on campus, and all the courses broadly focused on a theme of social justice and the environment. CIE students did not necessarily live together, and there were few non-academic activities for the cohort. Still, there is some evidence (not shown) for positive impacts on student help-seeking behaviors and other non-cognitive outcomes.

As part of the CIE program, two different sets of four courses were offered, one set including QL1 and primarily for humanities and some social science degree programs, and the other set including CA and primarily for STEM degree programs. A subset of the QL1 and CA course sections in Fall 2017 were thus enhanced with the extra one or two class meetings per week and designated for students in the CIE program, though students outside the CIE program were allowed to enroll in the enhanced courses as well. (That is, some sections mixed both students in need of developmental mathematics and those not in need of developmental mathematics.) QL2 was not officially involved in the CIE program, so we are not able to examine final grade and DFW rate outcomes in QL2 for students who otherwise would have placed into developmental mathematics. In other words, the student population necessary to address RQ1 exists only for QL1 and CA.

Methods

Data Collection

Following the end of the Spring 2018 semester, we collected information about students and their QL1, QL2, and CA course enrollments from relevant University systems. Data collection was limited to information about QL1 and CA enrollments in Fall 2017 and QL2 enrollments in Spring 2018 because these were the course/term combinations during which enhanced course sections were offered. The information collected about each student enrollment included section type (enhanced or non-enhanced) and final course grade (measured on a 4.0 scale). The student demographic data collected included gender, race, ACT and SAT mathematics component scores, MSU mathematics placement exam score (< 10 indicating a need for developmental mathematics), a normalized version of high school grade point average (GPA), financial aid need level, and whether the student was associated with the CIE program, among other variables (e.g., degree program and college). We note that the course instructor was the same for all QL1 and QL2 students included in these analyses, and the enhanced sections of CA were taught by a single instructor. This data collection and the following analyses were exempt from review by our Institutional Review Board.

Data Analysis

We imported, formatted, and processed the data using IBM SPSS Statistics (version 24). Within the course/term combinations noted above, we focused on two quantitative outcomes: final course grades and the D-grade, F-grade, and withdrawal (DFW) rate. We made two sets of comparisons: the first (RQ1) focusing on students for whom the developmental mathematics requirement was waived, and the second (RQ2) focusing on differences in outcomes between students in the enhanced and non-enhanced course sections. Following descriptive statistics for RQ2, we report the results of listwise regression analyses that model the impact of the course section type (enhanced or non-enhanced), alongside other important variables, on final course grades and DFW rate.

Additional regression predictor variables we used included: 1) gender (male or female) and race, with American Indian/Alaskan Native, Black, Hawaiian/Pacific Islander, Hispanic, and Multiracial students coded as underrepresented minority groups—Asian students are not included because they attain bachelor's degrees at a rate comparable to that of White students (U.S. Department of Education 2016); 2) academic background variables including normalized high school GPA, ACT mathematics component score (converting from SAT scores when necessary using The College Board concordance table), MSU mathematics placement exam score, and MSU prior mathematics course GPA; 3) class level (freshman, sophomore, etc.) and freshman or transfer status at entry; and 4) financial aid need level, coded as high (akin to eligibility for the federal Pell Grant subsidy), moderate, low, or none. When a student had enrolled in the same prior mathematics course multiple times, we considered only the most recent enrollment in calculating the prior mathematics course GPA.

Limitations

Here we report a quantitative analysis of predictors—within a dataset—of students' success in the QL and CA courses including demographic factors and information about their course section. These variables are not completely independent from one another and, regardless of the covariance of individual variables, it is important to remember that social identities are based on interactions between multiple variables that uniquely contribute to educational experiences in mathematics (Riegle-Crumb and Humphries 2012). Further, these data come from one semester of each course, so we make no claims about what might happen in future semesters given that many factors change from term to term. While readers will recognize that the term prediction here is being used in a statistical sense, we emphasize that these analyses do not suggest that course placement or specific demographic characteristics like race determine students' success in the courses. Instead, based

on our analyses, we intend to bring to the fore systematic patterns that manifest from the data.

Additionally, we note that in refining our data to be suitable for analysis, we encountered limitations in ascribing to students their placement into some categories. For example, as we created the binary race category denoting underrepresented minority students for the regression analyses, we had to make decisions about what groups would be categorized as underrepresented minorities given the dataset available to us. Multiracial students were categorized as an underrepresented minority group, but we could not check with students to see if they would agree with such placement, undoubtedly introducing some error. A similar limitation applies to gender, which notably falls into only two categories within University records.

Results

We organize the results of our analysis according to the research questions: RQ1) What were the final grade and DFW rate outcomes in embedded remediation course sections for students who otherwise would have placed into developmental mathematics? and RQ2) What impact did the enhanced course sections with embedded remediation have on final grades and DFW rates compared to non-enhanced course sections, and how do these differences covary with various predictor variables? Hereafter, we refer to students who are in four different groups (A, B, C, and D) based on three relevant variables: mathematics placement score, if developmental mathematics was required, and the course section type. The following list provides a succinct description of each group as a guide for the reader:

- Group A: *Low* placement score, developmental math *not required*, *enhanced* section
- Group B: *High* placement score, developmental math *not required*, *enhanced* section
- Group C: *Low* placement score, developmental math *required*, *enhanced* section
- Group D: *Low* placement score, developmental math *required*, *non-enhanced* section

RQ1: Outcomes for Students Who Had Developmental Mathematics Waived

Defining the Student Groups. There were 56 students (out of 379 total) in the Fall 2017 QL1 course who otherwise would have been required to pass developmental mathematics; however, this requirement was waived because of their participation in the CIE program and instead they were allowed to enroll in enhanced sections of QL1. Those involved in developing this curricular intervention hypothesized that these students, in comparison to others enrolled in QL1, would need additional support in the course and so it was required that they enroll in the enhanced sections. To clarify, every other student in QL1 during the same term had either already

completed and passed developmental mathematics (and in some cases had taken additional mathematics courses), or they had placed directly into QL1 based on a higher mathematics placement score.

In other words, MSU was not attempting to conduct a randomized controlled trial—such as that reported by Perez et al. (2018)—and there is no truly comparable control group of students in these data that has similar characteristics to these 56 sampled students yet enrolled in a non-enhanced course section. Therefore, in Table 1 we report final grade and DFW outcomes for the 56 students of interest (Group A) alongside the two most reasonable comparison groups: 1) students who earned a higher score on the mathematics placement exam but had no prior mathematics instruction at MSU (Group B), and 2) students who earned a similar score (< 10) on the mathematics placement exam but had passed developmental mathematics and perhaps taken one or more prior mathematics courses (Group C).

Table 1
Characteristics of Comparison Groups

		A	B	C	D
Mathematics placement score		< 10	≥ 10	< 10	< 10
Developmental mathematics required?*		No	n/a**	Yes	Yes
Course section type		Enhanced	Enhanced	Enhanced	Non-Enhanced
QL1 Fall '17	Total N	56	52	108	52
	DFW N (%)***	5 (9%)	0 (0%)	28 (26%)	3 (6%)
QL2 Spring '18	Total N	n/a	n/a	119	32
	DFW N (%)***	n/a	n/a	38 (32%)	5 (16%)
CA Fall '17	Total N	68	45	29	445
	DFW N (%)***	21 (31%)	5 (11%)	13 (45%)	165 (37%)

*Students in Groups C and D may have also taken one or more mathematics courses beyond developmental mathematics prior to our QL1, QL2, or CA enrollment of interest.

**Based on their mathematics placement scores, developmental mathematics was not required for these students.

***DFW includes students who earned grades less than 2.0 (D grades and F grades) and those who withdrew from the course. No numeric grade is reported for students who withdrew.

QL1 Grades and DFW Rate. Among these three groups, we might reasonably expect Group A students to show the lowest final grades as well as the lowest rate of passing the course with a C grade or better. After all, Group B and C students have all demonstrated some prior success in mathematics that they might build on (either via the placement exam or having passed developmental mathematics), though this expectation hinges on all the students having similar underlying characteristics. We indeed found that Group A students earned lower final course grades and had a higher DFW rate than Group B students. However, contrary to our expectation, Group C students earned the lowest overall course grades (Figs. 1a and 1b) and had the highest DFW rate (Table 1) among these three groups. Testing via Analysis of Variance (ANOVA) shows a statistically significant relationship between the comparison group and final course grades (Welch's $F(2, 130) = 20.6$, $p < 0.001$, $\omega^2 = 0.15$), representing a large effect size (Kirk 1996). Welch's F is reported because the homogeneity of variance assumption was violated. The *post hoc* Games-Howell procedure shows that all possible differences in mean final course grade between the comparison groups are significant ($p < 0.05$).

QL1 Grades vs. Term of First Math Instruction. Group C students had a range of experiences in MSU mathematics courses prior to enrolling in QL1 in Fall 2017. Most students had enrolled in the formal developmental mathematics course within the prior three semesters (i.e., Fall 2016 or later), and roughly half of students had taken an additional mathematics course at least once. (Recall that two college-level mathematics courses, or the equivalent, are required for students to fulfill MSU's mathematics graduation requirement.) Student trajectories here are varied and greatly complicated by the plethora of summer bridge options available to students, different mathematics pathways required for different degree programs, and the relatively high rate at which lower-division students switch majors.

Regardless, given the observed results for QL1 in Figures 1a and 1b, we also investigated the relationship between the earned final grade in our QL1 term of interest, and the number of terms since the students' first mathematics course at MSU (Fig. 1c). Here, we found a significant, negative Pearson correlation between the number of terms since the student's first MSU mathematics instruction and their final course grade ($r = -0.34$, $p < 0.01$). A significant, negative correlation persists even when the one obviously extreme case (a student who first had MSU mathematics instruction nine years prior) is removed. We note that when students completed the required developmental mathematics instruction through a summer bridge program instead of through the formal course, we assumed the term to be the summer prior to matriculation.

Figure 1. QL1 grades. For QL1 Groups A, B, and C, a) distribution of final course grades with passing and non-repeatable (C or better) grades noted in blue shades and DFW grades noted in yellow shades and b) mean final course grades $\pm$ SD. For QL1 Group C only, c) final course grades versus terms since the student's first MSU mathematics instruction, with bubble area representing the number of students.

CA Grades, DFW Rate, and Grades vs. Term of First Math Instruction.

Completing these same analyses for CA in Fall 2017 yields a Group A of 68 students (out of 2,396 total) for whom the developmental mathematics course was waived based on their participation in the CIE cohort program. Comparison of DFW rates (Table 1) and final grades (Figs. 2a and 2b) across the three groups reveals similar trends as for QL1. The ANOVA again shows a statistically significant relationship between the comparison group and final course grades (Welch's $F(2, 70) = 11.9, p < 0.001, \omega^2 = 0.13$), representing a medium-large effect size (Kirk 1996). The *post hoc* Games-Howell procedure shows that the final grades for Group B students are significantly different from the other groups ($p < 0.05$). Though Groups A and C are not statistically distinguishable in this case, the average final course grade for Group C is lower than that for Group A. The Pearson correlation between final course grade and the number of terms since the student's first mathematics instruction (Fig. 2c) is negative though nonsignificant ($r = -0.06, p = 0.77$).

Limitations. These analyses cannot be fully replicated for QL2 because enhanced sections of this course were offered only in Spring 2018. Veritably all enrolled students had either earned a score of 10 or greater on the mathematics placement exam or previously passed required developmental mathematics instruction (or both). In other words, no students enrolled in Spring 2018 QL2 having had both their developmental mathematics requirement waived and no developmental mathematics instruction; our group of primary interest (Group A) with respect to this research question does not exist in this case.

RQ2: Comparing Enhanced and Non-Enhanced Course Sections

Defining the Student Groups. The enhanced course sections were designed primarily for Group A students, and we have already discussed the lack of a completely appropriate comparison group that includes students enrolled in non-enhanced course sections. To facilitate the best possible comparison between enhanced and non-enhanced course sections, here we introduce a new group of students: Group D (Table 1) students are comparable to Group C with respect to some important mathematical characteristics, namely having earned a low mathematics placement score (< 10) and having previously passed some developmental mathematics instruction. The key difference between the two groups is that Group C students were enrolled in enhanced course sections and Group D students were enrolled in non-enhanced course sections.

Figure 2. CA grades. For CA Groups A, B, and C, a) distribution of final course grades with passing and non-repeatable (C or better) grades noted in blue shades and DFW grades noted in yellow shades and b) mean final course grades $\pm$ SD. For CA Group C only, c) final course grades versus terms since the student's first MSU mathematics instruction, with bubble area representing the number of students.

QL1, QL2, and CA Grades and DFW Rate. The differences in final QL1 course grades of students in the non-enhanced (mean $\pm$ standard error = 2.9 ± 0.12) and enhanced (2.6 ± 0.12) sections are statistically different when compared by an independent two-sample t-test, where there is no assumption of equal variance ($t(138) = -2.0$, $p < 0.05$). It is surprising that students in the enhanced course sections earned statistically *lower* grades than students in the non-enhanced sections. We also found a similar, statistically significant result for QL2 students in the non-enhanced (3.0 ± 0.19) and enhanced (2.5 ± 0.12) sections ($t(58) = -2.5$, $p < 0.05$). In CA, the average grades for students in the enhanced sections (1.9 ± 0.25) were again lower than the average grades for the non-enhanced students (2.0 ± 0.06), though this difference was not statistically significant ($t(470) = -0.23$, $p = 0.82$). The distributions of and mean final course grades across all these groups are shown in Figures 3a and 3b. The DFW rate is significantly different for Group C and D students in QL1 ($X^2(1) = 9.13$, $p < 0.01$) but not in QL2 ($X^2(1) = 3.30$, $p = 0.08$) or CA ($X^2(1) = 0.70$, $p = 0.43$) (Table 1).

QL1 and QL2 Regression Analyses. Because students are not distributed randomly among the groups, it is clearly possible that differences between Groups C and D exist for reasons other than their course section type (enhanced or non-enhanced). Therefore, we report the results of linear stepwise regressions that model the impact of various predictors on students' final course grades in QL1 and QL2 (Table 2). We used a listwise forward entry method in which the initial model contains only a constant term, and then additional predictors that explain the most remaining variance are added in each subsequent step. Using the set of variables detailed in the Methods section, we found that course section type (enhanced or non-enhanced) was not a significant predictor of final course grades. Rather, the most important covariates in the models were prior mathematics course GPA, race, and (for QL2) ACT mathematics component score. The Variance Inflation Factor (a collinearity diagnostic that measures the degree to which there are strong linear relationships between predictor variables) for all covariates was also less than 3.0, implying that multicollinearity due to correlation between the predictors does not substantially impact our regression results (Field 2009).

Figure 3. Groups C and D grades. For QL1, QL2, and CA Groups C and D, a) distribution of final course grades with passing and non-repeatable (C or better) grades noted in blue shades and DFW grades noted in yellow shades and b) mean final course grades $\pm$ SD.

Table 2
Regressions Relating Predictor Variables to Final Course Grades

	Predictor	<i>B</i>	<i>SE B</i>	<i>Std. B</i>	<i>t</i>	<i>p</i>
QL1* <i>n</i> = 85	Intercept	2.48	0.28	--	8.76	< .001
	Prior math course GPA	0.36	0.10	0.33	3.44	< .01
	Race	-0.77	0.23	-0.33	-3.37	< .01
QL2** <i>n</i> = 85	Intercept	0.21	0.63	--	0.33	0.74
	Prior math course GPA	0.45	0.09	0.40	4.86	< .001
	Race	-0.50	0.21	-0.21	-2.40	0.02
	ACT/SAT math score	0.09	0.03	0.26	3.09	< .01

*Adjusted proportion of variance (R^2) = 0.26.

** R^2 = 0.42.

Using the same list of predictor variables, we applied binary logistic regression to model the impact of these predictors on the DFW rates for students in Groups C and D (Table 3). Binary logistic regression is appropriate for explaining variation in a dichotomous outcome variable such as earning a non-repeatable passing grade (i.e., 2.0 or above), or earning a D-grade or F-grade or withdrawing from the course. Again using a forward stepwise model, we found no evidence that course section type significantly predicts the likelihood of students earning a D-grade, F-grade, or withdrawing from the course altogether. Rather, prior mathematics course GPA, race, ACT mathematics component score, and having high financial need emerged as the most important covariates. The regression results for both final grades and DFW rate with all variables included are presented in the Appendix.

Table 3
Logistic Regressions Relating Predictor Variables to DFW Rate

	Predictor	<i>B</i>	<i>SE B</i>	<i>Exp(B)</i>	<i>p</i>
QL1* <i>n</i> = 86	Intercept	0.96	1.22	2.62	0.43
	Prior math course GPA	0.91	0.37	2.49	0.01
	Race	-3.29	1.34	0.04	0.01
	High financial need	2.34	1.06	10.41	0.03
QL2** <i>n</i> = 101	Intercept	15.51	6731	5.5E6	1.00
	Prior math course GPA	0.82	0.31	2.28	< .01
	ACT/SAT math score	0.18	0.09	1.20	0.05
	High financial need	-19.91	6731	0.00	1.00

*Proportion of variance (R^2) = 0.20 (Cox & Snell), 0.32 (Nagelkerke).

** R^2 = 0.36 (Cox & Snell), 0.51 (Nagelkerke).

Limitations. Just as the analyses for RQ1 could not be completed for QL2, some contextual factors hinder us from being able to complete these RQ2 analyses for CA. In particular, the listwise regression method requires that each student (or case) in the model have complete data for every variable. Only 70 (15%) of the 474 CA Group C and D students have complete data for all relevant predictor variables. The variable missing most often for these students is prior mathematics course GPA, and it is usually missing for two reasons. First, the majority of summer bridge programs that include mathematics instruction are targeted at students who need CA as part of their degree program; successfully completing a bridge program prepares a student for CA but does not contribute to their prior mathematics course GPA. In contrast, it would be more likely for QL1 and QL2 students to take the developmental mathematics course. The second (and related) reason is that CA plays a foundational role in degree programs, whereas QL1 and QL2 are terminal mathematics courses. This manifests as QL1 and QL2 students having more semesters on average between matriculation and their QL1 or QL2 enrollment, during which they may have enrolled in more formal mathematics coursework. Together, these contextual factors prevent the analysis of meaningful regression models for CA.

Discussion

Our first research question centered on comparing outcomes among three groups of students: Group A, those who had low mathematics placement scores and yet had their prerequisite developmental mathematics requirement waived; Group B, those whose placement score led to the waiving of the developmental requirement; and Group C, those with low placement scores who had engaged in prior mathematics experiences at MSU to fulfill the requirement. These analyses were completed for the three groups of students in two courses, QL1 and CA, with students in all three groups being taught by the same instructor in their respective courses. As noted in the results, one might expect Group A students to show the lowest final grades as well as the lowest rate of passing the course with a non-repeatable grade given that Group B and C students have demonstrated some prior success in mathematics. However, for both QL1 and CA, Group C students earned lower final course grades and had higher DFW rates in comparison to students in Groups A and B. The final grade differences were statistically significant in QL1, though not for CA.

We find cause for concern in examining differences between Group A and Group C students, especially in the context of QL1 where final grade differences are both statistically significant and practically meaningful. Conversations about alternatives to developmental mathematics are important, yet these results suggest that a student's timing in taking university-required mathematics coursework may

be just as important, if not more so. Perhaps it is important for instructors to pay attention to students who are taking introductory mathematics courses after their first year (i.e., sophomores, juniors, and seniors), in addition to those who take the course as freshmen. Importantly, we conjecture that this distinction is not about age, but rather about students who have passed prerequisite coursework and—for whatever reason—elected to take introductory mathematics courses later in their undergraduate studies. Indeed, as noted, a significant correlation exists between number of terms since the student’s first MSU mathematics instruction and their final course grade in QL1.

Even if there are confounding differences between Group A and Group C students, there is reason to expect that increased time since prior mathematics coursework may not be advantageous for students. For example, Group C students could be those wary of taking further mathematics coursework and decide to wait to complete it. If several semesters pass after developmental coursework, students may forget basic skills used in those courses (e.g., fluency with percentages). Indeed, in a different context, Fike and Fike (2012) reported that first-time-in-college students who deferred completion of developmental mathematics coursework in their college career had significantly worse first-semester GPAs and first-year retention rates, and there may be other reasons for why students taking mathematics coursework several semesters after passing developmental mathematics instruction would perform better or worse in a given course. Alternatively, these results may reflect an overall benefit of the CIE program for students, as they were largely in Group A, and first-year learning communities have been shown to improve both academic and non-cognitive outcomes for students (Xu et al. 2018).

Our second research question centered on understanding the impact that embedded remediation had on final grades and DFW rates in comparison to sections without embedded remediation. We examined differences in QL1 and QL2 course outcomes for students with low mathematics placement scores and who had previously passed some form of developmental mathematics instruction. Final course grades in both QL1 and QL2 were statistically different between the enhanced and non-enhanced sections of the course, with enhanced section students earning a 0.3 average *lower* GPA in QL1, and a 0.5 average *lower* GPA in QL2. Though this result may engender concern in the spirit of “first do no harm,” we delved deeper to understand if other characteristics of students in the courses may have been more likely to predict success. For example, students were able to enroll at will in both the enhanced and non-enhanced sections of QL1 and QL2; those students who signed up first were likely to have chosen the non-enhanced sections given that those sections had one fewer class meeting each week. Such students—those who enrolled sooner—could have other characteristics that made them more likely to succeed in the QL courses.

The forward stepwise model for course outcomes in QL1 revealed that prior mathematics course GPA and race were the best statistical predictors of final course grades. For QL2, prior mathematics course GPA, race, and ACT mathematics component score were the best statistical predictors of final course grades. It is not particularly surprising that prior mathematics GPA would be an important predictor of future mathematics course performance; so long as the courses are somewhat similar, this should be the case (Huberth et al. 2015). In both cases, the course section type was not a statistically significant predictor. Instead, controlling for other variables, the models predict that underrepresented minority students in QL1 and QL2 would earn about a 0.77 and 0.50 lower final course grade, respectively, than non-underrepresented minority students. When using logistic regression to predict D-grade, F-grade, or withdrawing from the course, the three aforementioned predictors as well as high financial need emerged as the most important covariates. Underrepresented minority students, for example, were 25 times as likely as non-underrepresented minority students to earn a D-grade or F-grade or withdraw from QL1. Given that all 28 students in QL2 who earned a D-grade or F-grade or withdrew from the course also had high financial need (among the 68 in the model who had high need), students with high financial need were significantly more likely than students without high financial need to earn a D-grade or F-grade or withdraw from the course.

In the context of our second research question, these findings suggest that the deployment of enhanced sections (in the specific semesters for which we have data) were not as influential in students' encounters with the "low bridge" as other factors; that is, opportunity gaps were not closed as the result of this intervention. What appears to have mattered most for students in these data were forms of academic capital that serve students in a variety of university contexts, not just in mathematics courses. If one assumes that corequisite remediation *should* have a significant influence in facilitating student achievement, as has been reported in various other studies (e.g., Denley 2016; Kashyap and Matthew 2017; Barbitta and Munn 2018; Royer and Baker 2018), then these negative results highlight the importance of attending to how a course's corequisite model is designed and implemented. In addition to factors like student and teacher buy-in noted by Campbell and Cintron (2018), the Dana Center Mathematics Pathways (2018) project discuss that factors such as:

- the time spent in corequisite classrooms (e.g., one hour versus three hours a week),
- the nature of corequisite work itself (e.g., review of existing course material versus review of prerequisite material),
- the in-class assessments (e.g., relevant formative assessment aligned with any summative assessments), and
- broader campus supports (e.g., study group encouragement and academic counseling)

are all important considerations one should attend to in designing and implementing a corequisite model.

At MSU, the corequisite model was implemented without explicit buy-in from or broader supports for those affected; moreover, students spent only one additional hour each week in supplemental sessions. Furthermore, each of the latter three factors bulleted above also point (in some way) to a broader aspect of equity in mathematics education that we have not attended to in this study: attention to achievement without also considering other elements of the curriculum, such as how it explicitly connects to a diverse student population, or how it promotes students' agency to effect change in the world, results in an incomplete picture of equity (Gutiérrez 2008). For example, it is well known that predominantly white institutions, regardless of intention, impose myriad barriers for students from underrepresented backgrounds (Harwood et al. 2012). In a quantitative literacy course where competence is measured primarily through computation-focused, "objective" exams—as was the case in this semester of analysis for QL1 and QL2—it is not surprising that students in certain groups might be disadvantaged (Au 2016). The use of extra meeting times each week to mitigate differences in students' background knowledge is likely to have little effect if high-impact practices for supporting student success, such as active learning and a focus on community, purpose, and sense-making, are not also in use (Kuh 2008).

Conclusion

Across the nation, developmental education is now required for 30% to 40% of incoming college students in mathematics, writing, and reading (Bautsch 2013). Because access to coursework in mathematics ultimately yields access to resources that benefit one in society—and achievement in such courses remains unevenly distributed within and across various demographic groups—conversations about developmental mathematics education are conversations about social justice. Numerous pathways to and through college mathematics exist, and it is imperative that, collectively, we continuously redesign courses, collect data, and analyze student outcomes so as to inform the best strategies in our contexts, support student learning, and optimally mitigate costs for students as well as the institution. We have attempted to do this herein, reporting outcomes for various groups of students in developmental and college-level mathematics courses and showing that embedded remediation did not appear to affect student final course grades or DFW rates. Instead, other characteristics of students in the courses, such as previous mathematics preparation and race, appear (on the aggregate) to be better statistical predictors of the outcomes in our data. If we return to the metaphor of "low bridges", MSU's attempt to mitigate this low bridge was largely unsuccessful. This is not to suggest that corequisite models do not work in promoting student achievement but rather that we have work to do at MSU if we are to effectively implement corequisite coursework with success, as has been done in many other

contexts. We acknowledge that without replicates from additional courses, institutions, and years, we have essentially presented a quantitative case study, limiting our comparisons to one context, one academic year, and one curricular intervention. Though this work may be informative for others supporting developmental education efforts, these results do not necessarily generalize to other populations and contexts.

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References

- Au, Wayne. 2016. "Meritocracy 2.0: High-Stakes, Standardized Testing as a Racial Project of Neoliberal Multiculturalism." *Educational Policy* 30 (1): 39–62. <https://doi.org/10.1177/0895904815614916>.
- Barbitta, Susan, and William Munn. 2018. "Multiple Measures Placement in North Carolina." *New Directions for Community Colleges* 2018 (182): 59-73. <https://doi.org/10.1002/cc.20302>.
- Bautsch, Brenda. 2013. "Reforming Remedial Education." 4. Hot Topics in Higher Education. Washington, DC: National Conference of State Legislatures. http://www.ncsl.org/documents/educ/remedialeducation_2013.pdf.
- Bonham, Barbara S, and Hunter R Boylan. 2011. "Developmental Mathematics: Challenges, Promising Practices, and Recent Initiatives." *Journal of Developmental Education* 34 (3): 2.
- Burn, Helen E., Eric M. D. Baer, and Jennifer M. Wenner. 2013. "Embedded Mathematics Remediation Using The Math You Need, When You Need It: A 21st-Century Solution to an Age-Old Problem." *About Campus* 18 (5): 22–25. <https://doi.org/10.1002/abc.21134>.
- Campbell, Emily, and Rene Cintron. 2018. "Accelerating Remedial Education in Louisiana." *New Directions for Community Colleges* 182: 49-57. <https://doi.org/10.1002/cc.20301>.

- Caro, Robert A. 1974. *The Power Broker: Robert Moses and the Fall of New York*. Knopf.
- Complete College America. 2018. "Corequisite Remediation: Spanning the Completion Divide." Accessed October 16, 2018.
<http://completecollege.org/spanningthedivide/#the-bridge-builders>.
- Dana Center Mathematics Pathways. 2018. "Co-requisite Courses: Narrowing the Gap between Instruction and Supports." Accessed October 19, 2018.
<http://dcmathpathways.org/resources/co-requisite-courses-narrowing-gap-between-instruction-and-supports>.
- Denley, Tristan. 2016. "Co-requisite Remediation Full Implementation 2015–16." Tennessee Board of Regents Technical Brief No. 3. Accessed October 19, 2018. [https://www.tbr.edu/sites/tbr.edu/files/media/2016/12/TBR CoRequisite Study - Full Implementation 2015-2016.pdf](https://www.tbr.edu/sites/tbr.edu/files/media/2016/12/TBR%20CoRequisite%20Study%20-%20Full%20Implementation%202015-2016.pdf).
- DiPrete, Thomas A., and Gregory M. Eirich. 2006. "Cumulative Advantage as a Mechanism for Inequality: A Review of Theoretical and Empirical Developments." *Annual Review of Sociology* 32 (1): 271–97.
<https://doi.org/10.1146/annurev.soc.32.061604.123127>.
- Engstrom, Cathy, and Vincent Tinto. 2008. "Access Without Support Is Not Opportunity." *Change: The Magazine of Higher Learning* 40 (1): 46–50.
<https://doi.org/10.3200/CHNG.40.1.46-50>.
- Field, Andy. 2009. *Discovering Statistics Using SPSS*. SAGE Publications.
- Fike, David S, and Renea Fike. 2012. "The Consequences of Delayed Enrollment in Developmental Mathematics." *Journal of Developmental Education* 35 (3): 2.
- Gamoran, Adam, and Robert D. Mare. 1989. "Secondary School Tracking and Educational Inequality: Compensation, Reinforcement, or Neutrality?" *American Journal of Sociology* 94 (5): 1146–83.
<https://doi.org/10.1086/229114>.
- Gaze, Eric. 2018. "Quantitative Reasoning: A Guided Pathway from Two- to Four-Year Colleges." *Numeracy* 11 (1). <https://doi.org/10.5038/1936-4660.11.1.1>.
- Gutiérrez, Rochelle. 2008. "A 'Gap-Gazing' Fetish in Mathematics Education? Problematizing Research on the Achievement Gap." *Journal for Research in Mathematics Education* 39 (4): 357–64.
- Harwood, Stacy A., Margaret Browne Hunt, Ruby Mendenhall, and Jioni A. Lewis. 2012. "Racial Microaggressions in the Residence Halls: Experiences of Students of Color at a Predominantly White University." *Journal of Diversity in Higher Education* 5 (3): 159–73.
<https://doi.org/10.1037/a0028956>.
- Hoang, H., Huang, M., Sulcer, B. and Yesilyurt, S., 2017. Carnegie Math Pathways 2015-2016 Impact Report: A Five-Year Review. Carnegie Math

- Pathways Technical Report. Carnegie Foundation for the Advancement of Teaching.
- Howington, Heather, Thomas Hartfield, and Cinnamon Hillyard. 2015. "Faculty Viewpoints on Teaching Quantway®." *Numeracy* 8 (1). <http://dx.doi.org/10.5038/1936-4660.8.1.10>.
- Huberth, Madeline, Patricia Chen, Jared Tritz, and Timothy A. McKay. 2015. "Computer-Tailored Student Support in Introductory Physics." *PLOS ONE* 10 (9): e0137001. <https://doi.org/10.1371/journal.pone.0137001>.
- Jones, Durrell A, and Beth Herbel-Eisenmann. 2015. "Undergraduate Students' Experiences in a Developmental Mathematics Classroom." In *Proceedings of the 18th Annual Conference on Research in Undergraduate Mathematics Education*, 627–31. Pittsburgh, PA.
- Kashyap, Upasana, and Santhosh Mathew. 2017. "Corequisite Model: An Effective Strategy for Remediation in Freshmen Level Quantitative Reasoning Course." *Journal of STEM Education: Innovations and Research* 18 (2): 23.
- Kirk, Roger E. 1996. "Practical Significance: A Concept Whose Time Has Come." *Educational and Psychological Measurement* 56 (5): 746–59. <https://doi.org/10.1177/0013164496056005002>.
- Kuh, George D. 2008. "High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter." Washington, DC: Association of American Colleges and Universities.
- Larnell, Gregory V. 2016. "More Than Just Skill: Examining Mathematics Identities, Racialized Narratives, and Remediation Among Black Undergraduates." *Journal for Research in Mathematics Education* 47 (3): 233–69. <https://doi.org/10.5951/jresmetheduc.47.3.0233>.
- Lucas, Samuel R. 2001. "Effectively Maintained Inequality: Education Transitions, Track Mobility, and Social Background Effects." *American Journal of Sociology* 106 (6): 1642–90. <https://doi.org/10.1086/321300>.
- Perez, Eileen, Hansun To, Mary Fowler, and Linda Larrivee. 2018. "Math Course for Liberal Arts Majors: A Pilot with Embedded Remediation." *Numeracy* 11 (1). <https://doi.org/10.5038/1936-4660.11.1.6>.
- Riegle-Crumb, Catherine, and Melissa Humphries. 2012. "Exploring Bias in Math Teachers' Perceptions of Students' Ability by Gender and Race/Ethnicity." *Gender & Society* 26 (2): 290–322. <http://dx.doi.org/10.1177/0891243211434614>.
- Royer, Dan W., and Russell D. Baker. 2018. "Student Success in Developmental Math Education: Connecting the Content at Ivy Tech Community College." *New Directions for Community Colleges* 182: 31-8. <https://doi.org/10.1002/cc.20299>.

- Sowers, N, and H Yamada. 2015. "Pathways Impact Report." Palo Alto, CA: Carnegie Foundation for the Advancement of Teaching.
- Tunstall, Samuel, Vincent Melfi, Jeffrey Craig, Richard Edwards, Andrew Krause, Bronlyn Wassink, and Victor Piercey. 2016. "Quantitative Literacy at Michigan State University, 3: Designing General Education Mathematics Courses." *Numeracy* 9 (2). <http://dx.doi.org/10.5038/1936-4660.9.2.6>.
- U.S. Department of Education, Office of Planning, Evaluation and Policy Development and Office of the Under Secretary. 2016. "Advancing Diversity and Inclusion in Higher Education." Washington, DC. <http://www2.ed.gov/rschstat/research/pubs/advancing-diversity-inclusion.pdf>.
- Willis, Paul. 1978. *Learning to Labour: How Working Class Kids Get Working Class Jobs*. London: Routledge. <https://www.taylorfrancis.com/books/9781351218771>.
- Woolgar, Steve, and Geoff Cooper. 1999. "Do Artefacts Have Ambivalence: Moses' Bridges, Winner's Bridges and Other Urban Legends in S&TS." *Social Studies of Science* 29 (3): 433–49. <https://doi.org/10.1177/030631299029003005>.
- Xu, Di, Sabrina Solanki, Peter McPartlan, and Brian Sato. 2018. "EASEing Students Into College: The Impact of Multidimensional Support for Underprepared Students." *Educational Researcher* 47 (7). <http://dx.doi.org/10.3102/0013189X18778559>.
- Zachry Rutschow, Elizabeth, and John Diamond. 2015. *Laying the Foundations: Early Findings from the New Mathways Project*. MDRC. <https://eric.ed.gov/?id=ED558504>.

Appendix

Table S1
Regressions on Final Course Grades Including All Predictor Variables

Predictor	<i>B</i>	<i>SE B</i>	<i>Std. B</i>	<i>t</i>	<i>p</i>
QL1*					
<i>n</i> = 85					
Intercept	1.62	1.59	--	1.02	0.31
ACT/SAT math score	0.01	0.04	0.02	0.14	0.89
Class level**	-0.12	0.12	-0.11	-0.99	0.33
Course section type**	-0.20	0.24	-0.09	-0.84	0.41
Gender**	-0.24	0.27	-0.10	-0.89	0.38
Financial need (low)**	-0.71	1.12	-0.19	-0.64	0.53
Financial need (mod)**	-0.77	1.09	-0.23	-0.71	0.48
Financial need (high)**	-0.32	1.08	-0.12	-0.30	0.77
High school GPA	0.62	0.34	0.22	1.85	0.07
Level entry status**	0.31	0.99	0.03	0.32	0.75
Math placement score	0.02	0.07	0.03	0.31	0.76
Prior math course GPA	0.30	0.12	0.28	2.50	0.02
Race**	-0.67	0.30	-0.29	-2.25	0.03
QL2***					
<i>n</i> = 101					
Intercept	0.15	1.01	--	0.15	0.88
ACT/SAT math score	0.08	0.04	0.23	2.33	0.02
Class level**	0.12	0.11	0.10	1.15	0.25
Course section type**	-0.25	0.24	-0.08	-1.05	0.30
Gender**	0.04	0.22	0.01	0.17	0.87
Financial need (low)**	-0.51	0.44	-0.13	-1.16	0.25
Financial need (mod)**	-0.42	0.42	-0.12	-1.00	0.32
Financial need (high)**	-0.66	0.37	-0.26	-1.77	0.08
High school GPA	0.17	0.32	0.05	0.53	0.60
Level entry status**	0.11	0.44	0.02	0.24	0.81
Math placement score	0.03	0.06	0.05	0.56	0.58
Prior math course GPA	0.41	0.11	0.36	3.60	< .01
Race**	-0.31	0.25	-0.13	-1.25	0.22

*Adjusted proportion of variance (R^2) = 0.23.

**Coding notations. Course section type: enhanced sections coded as 1, non-enhanced sections coded as 0. Gender: women coded as 1, men coded as 0. Financial need: yes coded as 1, no coded as 0. Level entry status: transfer coded as 1, freshmen coded as 0. Race: underrepresented minority group coded as 1, majority group coded as 0.

*** R^2 = 0.41.

Table S2
Logistic Regressions on DFW Rate Including All Predictor Variables

	Predictor	<i>B</i>	<i>SE B</i>	<i>Exp(B)</i>	<i>p</i>
QL1* <i>n</i> = 86	Intercept	22.34	> 100	> 100	1.00
	ACT/SAT math score	-0.16	0.14	0.86	0.26
	Class level**	-0.11	0.33	0.90	0.75
	Course section type**	-1.50	0.89	0.22	0.09
	Gender**	-0.44	0.87	0.64	0.61
	Financial need (low)**	-18.30	> 100	0.00	1.00
	Financial need (mod)**	-17.19	> 100	0.00	1.00
	Financial need (high)**	-15.08	> 100	0.00	1.00
	High school GPA	0.06	1.11	1.06	0.96
	Level entry status**	19.38	> 100	> 100	1.00
	Math placement score	0.08	0.20	1.09	0.68
	Prior math course GPA	0.95	0.43	2.60	0.03
	Race**	-3.54	1.49	0.03	0.02
	Intercept	11.74	> 100	> 100	1.00
QL2*** <i>n</i> = 101	ACT/SAT math score	0.16	0.11	1.17	0.16
	Class level**	0.18	0.30	1.20	0.55
	Course section type**	0.26	0.82	1.30	0.75
	Gender**	1.02	0.70	2.77	0.14
	Financial need (low)**	0.01	> 100	1.01	1.00
	Financial need (mod)**	-0.01	> 100	0.99	1.00
	Financial need (high)**	-20.06	> 100	0.00	1.00
	High school GPA	0.60	1.00	1.82	0.55
	Level entry status**	17.01	> 100	> 100	1.00
	Math placement score	0.20	0.18	1.22	0.26
	Prior math course GPA	0.82	0.37	2.27	0.03
	Race**	0.22	0.87	1.25	0.80

*Proportion of variance (R^2) = 0.25 (Cox & Snell), 0.40 (Nagelkerke).

**Coding notations. Course section type: enhanced sections coded as 1, non-enhanced sections coded as 0. Gender: women coded as 1, men coded as 0. Financial need: yes coded as 1, no coded as 0. Level entry status: transfer coded as 1, freshmen coded as 0. Race: underrepresented minority group coded as 1, majority group coded as 0.

*** R^2 = 0.40 (Cox & Snell), 0.57 (Nagelkerke).