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ACCELERATING MATHEMATICS:

Findings from the AMP-UP Program at Bergen Community College

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INTRODUCTION

Developmental coursework in mathematics is a significant hurdle to student persistence and completion at community colleges in the United States (Complete College America, 2012). The negative impact of these coursework assignments falls disproportionately on poor and minority students, exacerbating performance gaps (Attewell, Lavin, Domina, & Levey, 2006). Thus, ironically, remedial policies purportedly designed to increase college success have had precisely the opposite effect. While most researchers and policymakers agree that some mathematics coursework may be necessary in college, not all students need the same mathematics preparation for their careers. Recent research reveals that mathematics sequences proceeding through algebra with the presumed goal of calculus – the models most favored in K–12 and postsecondary education in the United States – do not reflect workers' reported mathematics use at work (Douglas & Attewell, 2017). Indeed, even researchers within the mathematics discipline recognize that college algebra is the end of formal mathematics for most students, rather than a prerequisite (Gordon, 2008; National Research Council, 2013).

Recognizing the practical implications of requiring long sequences of developmental courses that students often fail to complete, policymakers and institutions across the country have started modifying developmental coursework or eliminating developmental requirements entirely (Bailey et al., 2016). Florida no longer requires developmental placement testing or remedial coursework in either math or English (Fain, 2013). The California State college system has eliminated its developmental pathways and testing, opting instead for a corequisite approach (Xia, 2017). Colorado has reformed developmental pathways in both English and mathematics, moving toward a corequisite model for the latter (McKay, Michael, & Khudododov, 2016). The City University of New York has experimented with corequisite placement into statistics (Logue, Watanabe-Rose, & Douglas, 2016; Logue, Douglas, & Watanabe-Rose, 2019).

In 2015, Bergen Community College (BCC) received a grant from the U.S. Department of Education,First in the World grant program, Alternatives to Mathematics Education: An Unprecedented Program (AMP-UP), to study a corequisite approach to developmental math education. The proposed corequisite intervention was modified by the college's mathematics department when some members of the faculty raised concerns about whether the corequisite model could have a negative impact on student success. The revised initiative focused instead on accelerating students' progress through developmental math coursework – allowing students to complete developmental and college-level mathematics within their first semester of college. The Department of Education approved a study based on this revised intervention. This study, conducted by researchers at the Education and Employment Research Center at Rutgers, the State University of New Jersey, describes the implementation of this accelerated model and examines the three-year outcomes of the first two cohorts to experience the accelerated course sequence.

STUDY ELEMENTS

Intervention Condition

At BCC, the intervention condition allows eligible students to complete both their developmental and college-level math requirements by the end of their first semester. All intervention group students are assigned to a 7.5-week accelerated developmental algebra course (MAT 040), then, if successful in that course, move on to a 7.5-week college-level mathematics course (MAT 130). These accelerated courses are intensive commitments – students attend class four days per week, two hours per day. Students receive three credits upon completion of the college-level course. Figure 1 is a pathway diagram for both the intervention and comparison condition. In this model, developmental education and college-level math are offered separately, but students who pass both courses in a single sequence will complete their college math requirement in one semester. Accelerated courses are offered in both traditional classroom and self-paced online formats. Self-paced courses use ALEKS instructional software, which allows students to work independently on topic-specific modules; they are given online access to a course instructor who can answer questions as they arise.[1] The intervention condition remained generally consistent over the course of the grant and persists to the time of this writing.

Summer Bridge Program

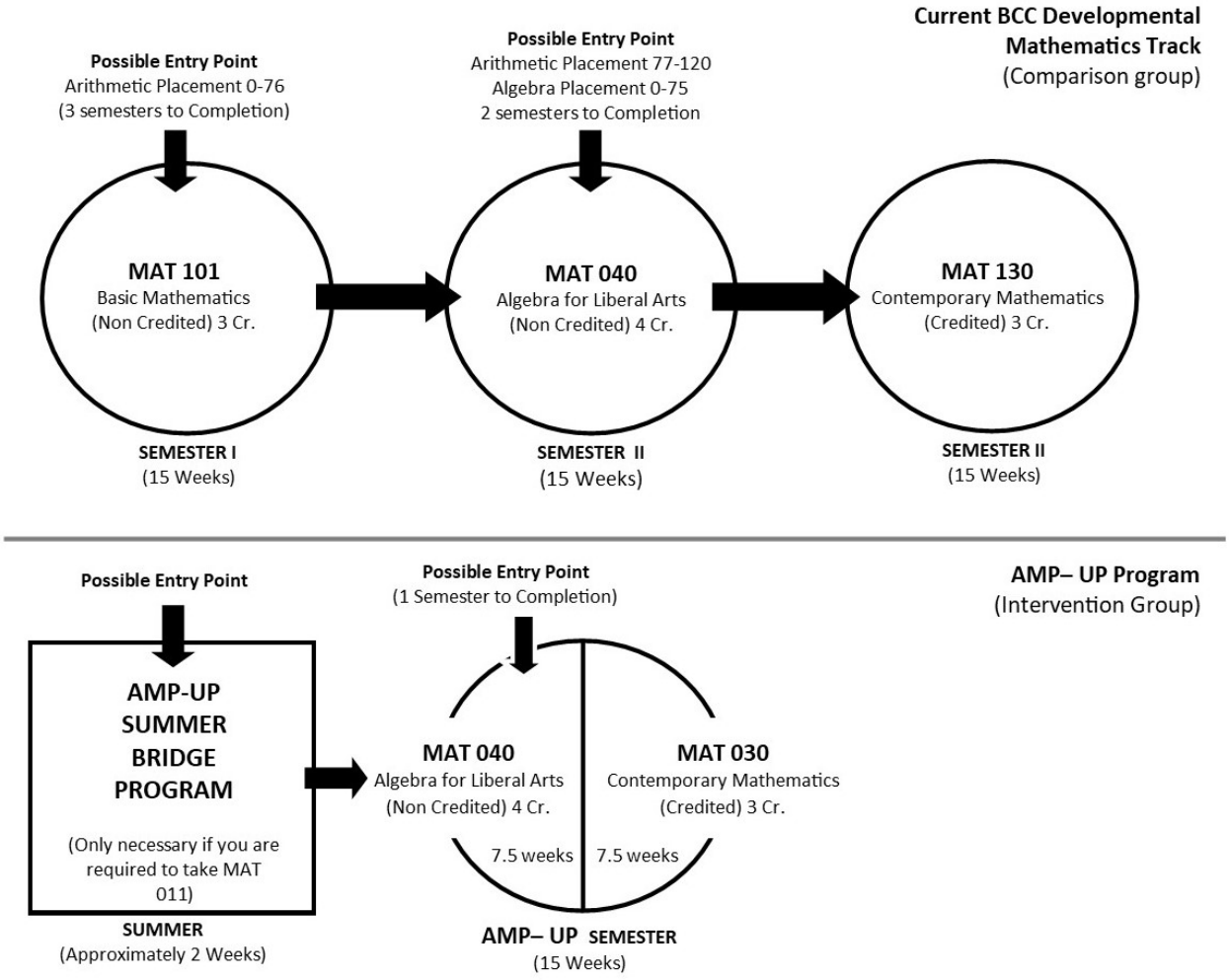
For treatment group students who place into a two-course developmental math sequence beginning with arithmetic, the intervention also includes a self-paced Summer Bridge course taken prior to their first term of enrollment in the college. This program uses ALEKS software and allows students to complete coursework at home or at the college's computing lab, where AMP-UP staff are available to provide support. At the start of the program, students take a knowledge assessment that pares down their coursework to only the components they have not yet mastered. At the end of the self-paced program, students must take and pass the departmental final for MAT 011, the college's developmental arithmetic course.

Comparison Condition

Students in the comparison condition continue along the college's standard developmental mathematics pathway, which, depending on a student's score on the Accuplacer exam, could take up to three semesters to complete. They have access to all academic support services afforded to the regular student population. Comparison group students were eligible to begin their first assigned developmental math course in the term of random assignment.

[1] Self-paced MAT-130 courses used Pearson's MyMathLab software to align with the course textbooks.

Figure 1: Pathway Diagram for Intervention and Comparison Conditions



ANALYTIC METHODS

Participants

BCC students required to take developmental mathematics were eligible for the study. The study excluded students who intend to pursue four-year programs in science, technology, engineering, and mathematics (STEM); business; or health science fields. This decision was made because the college-level math course in the intervention condition is unlikely to transfer to local colleges offering those programs. The intensity of math course-taking for intervention group students (four days per week) is explained prior to consent, which results in some students who would otherwise be eligible to opt out. In this way, the generalizability of findings may be limited.

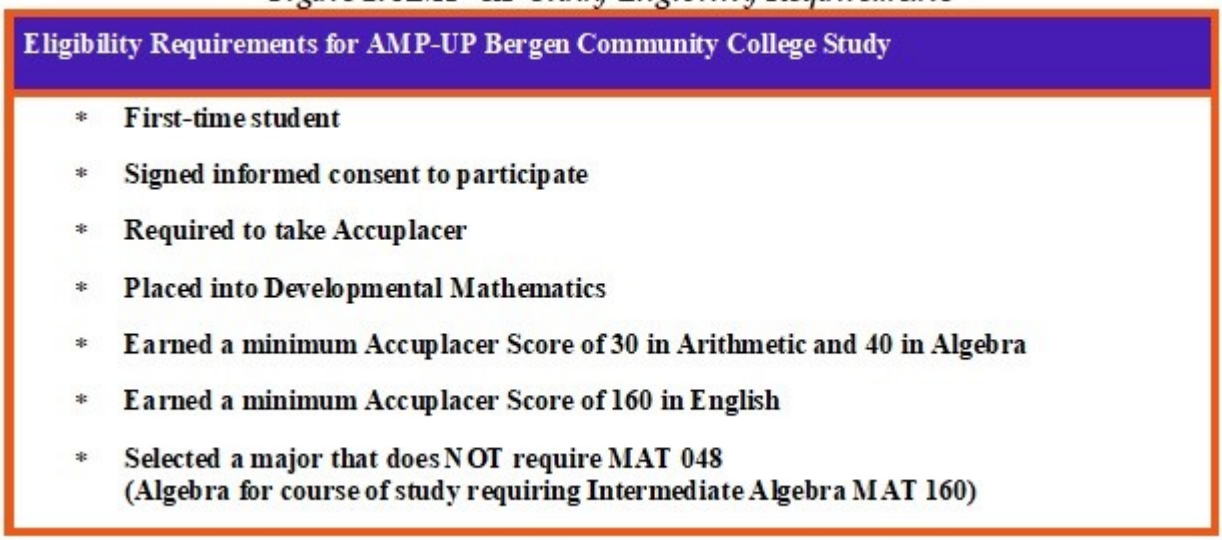
Sample Formation

Identification of eligible students took place at the school's placement testing center. Eligible students were informed of the program and directed to speak with AMP-UP staff. Prior to each recruitment period, the evaluation team created a random assignment spreadsheet using a random sequence generator, then used this list to fill numbered envelopes.[2] Consenting students were each given an envelope that contained their group assignment by testing center staff, who would then record each student's identifying information along with envelope number and group assignment. This allowed the evaluation team to audit the random assignment process. After random assignment, AMP-UP staff helped all participating students (in both conditions) to schedule their first-semester courses. They also directed students placed in basic mathematics toward the AMP-UP Summer Bridge program.

Sample

In all study years, recruitment was lower than expected, both because the program excluded very popular programs of study in STEM, business, and health, and because of the intensive nature of the intervention courses. Figure 2 shows the eligibility requirements for the AMP-UP program. In the analysis that follows, the first two cohorts of students potentially exposed to the intervention condition are combined for a total of 233 participants. The study used a 2-to-1 randomization, resulting in an intervention group size of 156 and a comparison group size of 77.

Figure 1: AMP-UP Study Eligibility Requirements



Outcome Measures

The AMP-UP intervention at BCC is designed to benefit students by accelerating progress through their developmental mathematics requirements. Developmental math is a major

[2] The random sequence generator is available at https://www.random.org/sequences/.

obstacle for community college students. Thus, we hypothesized that students in the intervention condition would show higher rates of retention, faster completion of college-level mathematics requirements, higher overall credit accumulation, and higher graduation rates than their counterparts in the comparison condition. Retention is measured as cumulative semesters enrolled over two academic years. Completion of college-level mathematics is measured at the end of the second year to afford students in the comparison condition adequate time to complete these requirements; total credit accumulation is also measured at the end of the second year. Graduation rates are measured at the end of three years, which represents 150 percent of standard completion time.

Analytic Approach

Comparisons on these outcomes were analyzed using an Intent-to-Treat (ITT) model specification. Groups were compared as they were randomly assigned, irrespective of subsequent behavior vis-à-vis the intervention condition.

Statistical Adjustments

Initial data indicate that random assignment produced balanced intervention and comparison groups. Baseline data were collected data following the What Works Clearinghouse (WWC) Procedures and Standards for Postsecondary Education Research (What Works Clearinghouse, 2016). Specifically, we collected data on students' receipt of Pell grants and parents' highest level of education as measures of socioeconomic status, and students' mathematics placement test (Accuplacer) scores as a continuous measure of students' academic achievement. We begin by presenting unadjusted effect size estimates of student outcomes, then present adjusted estimates using OLS regression.

STUDY FINDINGS

Descriptive Statistics and Unadjusted Outcomes

Table 1: AMP-UP at Bergen Community College – Fall 2016 and Fall 2017 Cohorts, Baseline Equivalence and Three-Year Outcomes

	AMP-UP 2016 and 2017 Study Cohorts	
	Business-As-Usual Condition (N=77)	Intervention Condition (N=156)
Gender		
Male	50.7%	52.3%
Female	49.4%	47.7%
Race/Ethnicity[1]		
White/Asian	42.9%	39.1%
Black/Hispanic	45.5%	50.0%
Other/No Race Specified	11.6%	10.9%
Mean (std. dev) Age	19.3 (2.6)	19.2 (2.8)
Student SES - Parental Education Level		
High School or Less	35.1%	32.1%
Some College – Associate's	24.7%	34.6%
Bachelor's Degree or More	27.3%	19.9%
Unknown/No Data	13.0%	13.5%
Student Received Pell in Study Year		
No	55.8%	59.6%
Yes	44.2%	40.4%
Mean (std. dev.) Algebra Placement Score	53.9 (10.4)	53.1 (10.4)
Outcomes in three academic years		
# of terms enrolled (Std. Error)	3.3 (0.23)	3.6 (0.16)
% Completed Any DE Math*	64.9%	78.2%
% Completed Any CL Math***	35.1%	65.4%
# of College-Level Credits Completed (Std. Error)	24.9 (2.7)	29.0 (2.0)
Completed a Degree	11.6%	19.9%

* p<.05 ***p<.001 (t-tests for continuous variables, Chi-Square tests for Categorical Variables)

[1] Statistical significance unchanged with the detailed version of the race/ethnicity variable

Table 1 presents descriptive statistics and preliminary outcomes analysis for the first two AMP-UP cohorts at BCC. The demographic characteristics of the intervention and comparison groups are approximately equal with regard to gender, race/ethnicity, and age at entry; no significant differences are observed. In terms of the key measures for establishing baseline equivalence – parental educational attainment and developmental placement test scores – students were also approximately equivalent. Overall, these data suggest that random assignment produced equivalent treatment and comparison groups.

Three-year outcomes suggest important treatment effects for the AMP-UP program. Compared with students in the comparison group, a larger proportion of students in the treatment group completed one or more developmental math courses. Furthermore, a far greater proportion of the treatment group had completed college-level math by the end of the Spring 2018 semester (65% compared with 35%). The intervention group completed more college-level credits on average (29.0) than the comparison group (24.9), but this difference was not statistically significant. We do note that this credit-earning difference (5.1 credits) is substantially larger than the credit value of the college-level math course taken by students in the intervention group (3 credits). Finally, we note that students in the intervention group were 8.3 percentage points more likely to complete a degree, though this difference is not statistically significant. But given that these latter two results align with other findings in the literature on developmental mathematics, we proceed to examine these results further by adjusting for student characteristics.

Adjusted Outcomes

The unadjusted effect sizes presented in Table 1 demonstrate that BCC's AMP-UP program had a clear impact on students' progress through their required mathematics course sequences. There was suggestive evidence that the program positively impacted overall credit accumulation and degree completion. But the balanced groups produced by the experimental design allow us to also look at the program's impact on student persistence and completion adjusted for important student traits. Prior research demonstrates that gender, race/ethnicity, age at entry, socioeconomic status, and prior academic achievement are all important factors in college success (Attewell, Heil, & Reisel, 2011; Ewert, 2010; National Student Clearinghouse, 2017; Conger & Long, 2010; Roska, 2012). Therefore, we examine the effect of the AMP-UP intervention adjusting for these key student traits.

Table 2: Bergen Community College – Fall 2016 and Fall 2017 AMP-UP Cohorts, Adjusted Effect Size Analysis, OLS Regression

	Completed College Math	College-Level Credits	3-Year Degree Completion
Treatment Status	.33***	6.19^{t}	.09^{t}
	(.07)	(3.41)	(.05)
Gender (ref: female)			
Male	-.02	-5.27	-.06
	(.06)	(3.2)	(.05)
Race/Ethnicity (ref: White)			
Black/African American	-.13	-8.09	-.003
	(.12)	(6.17)	(.10)
Asian	.04	0.12	-.009
	(.15)	(7.68)	(.12)
Indigenous (American/Hawai‘ian)	-.81	-39.09	-.26
	(.47)	(24.30)	(.39)
Hispanic	-.08	-5.62	-.06
	(.07)	(3.79)	(.06)
Multiple Race	-.17	-10.98	-.002
	(.17)	(8.49)	(.14)
No Race Specified	-.05	0.55	.03
	(.13)	(6.92)	(.11)
Age in Study Year (Years)	-.002	0.17	.004
	(.01)	(.59)	(.01)
Parental Education Level (ref: High School or Less)			
Some College – Associate’s	.07	1.86	.06
	(.08)	(4.08)	(.07)
Bachelor’s Degree or More	.11	11.16*	.08
	(.09)	(4.62)	(.07)
Unknown/No Data	-.20*	-5.53	-.04
	(.10)	(5.23)	(.08)
Student Received Pell in Study Year	.09	6.71*	.04
	(.07)	(3.37)	(.05)
Algebra Placement Score	.01	0.31*	.002
	(.002)	(.15)	(.002)
Adjusted Comparison Group Mean	.33	23.59	.11
N		231	

*p<.05 **p<.01 ***p<.001 ^{t}p < .10

Table 2 presents adjusted effect size estimates using Ordinary Least Squares (OLS) regression. The adjusted estimates indicate that holding constant these student traits, students in the intervention condition were 33 percentage points more likely than those in the comparison condition to complete college-level math. Against the comparison group mean of 33 percent, this indicates that AMP-UP doubled the college-level mathematics completion rate for students.

With the exception of the missing indicator for parents' educational attainment, no other coefficients in this model were statistically significant.

The second column in Table 2 uses the same set of traits to predict cumulative credits earned over three years. The adjusted effect size estimate indicates that students in the treatment group earned roughly 6.2 additional credits. Even if we subtract the three college-level math credits students would earn during the intervention, there is still an additional credit earning advantage that amounts to an additional completed course. We note that this 6-credit difference is statistically significant at $p<.10$, which is considerable given the relatively small sample size for this experiment. Both measures of socioeconomic status (parent's educational attainment and Pell grant status), as well as mathematics placement scores, were statistically significant predictors of this outcome.

The last column in Table 2 examines three-year degree completion. After adjusting for student traits, we observe that students in the intervention condition are 9 percentage points more likely than those in the comparison condition to complete a degree within three years. Against the adjusted comparison group rate of 11 percent, this indicates that AMP-UP increased degree completion for intervention group students by 82 percent. As with the credit accumulation estimate, this effect is statistically significant at $p<.10$.

Summer Bridge Program

In the 2016 cohort, the Summer Bridge component of the program yielded promising outcomes that warranted further analysis (Douglas, McKay, & Edwards, 2017). As a result and to explore this further, college staff and the evaluation team collaborated to design a second experiment focused on students placed into developmental arithmetic. Students in this experiment were not eligible for the primary AMP-UP experiment, usually because they expressed interest in majors for which AMP-UP's college-level math course (Contemporary Mathematics/MAT 130) was not accepted. The intervention condition in this study was less rigorous than that presented in the primary experiment. Students in the intervention condition completed their developmental arithmetic course requirement in the Summer Bridge program but did not subsequently enroll in the accelerated one-term developmental algebra–college-level math pathway. We present the outcomes analyses for the Summer Bridge experiment, which covered the first two cohorts to experience the treatment condition at BCC.

Table 3: Bergen Community College – Fall 2017 and Fall 2018 Sub-study Cohorts, Baseline Equivalence and One-Year Outcomes

	AMP-UP Sub-Study Cohorts 1 and 2	
	Business-As-Usual Condition (N=139)	Intervention Condition (N=142)
Gender		
Male	30.9%	38.7%
Female	57.6%	51.4%
No Gender Specified	11.5%	9.9%
Race/Ethnicity		
White/Asian	31.7%	30.3%
Black/Hispanic	63.3%	64.8%
Other/No Race Specified	5.0%	4.9%
Mean (std. dev) Age	20.3 (4.7)	20.1 (4.7)
No Age Reported	11.5%	7.8%
Student SES - Parental Education Level		
High School or Less	37.4%	35.2%
Some College – Associate's	22.3%	33.1%
Bachelor's Degree or More	28.8%	23.2%
Unknown/No Data	11.5%	8.5%
Mean (std. dev.) Algebra Placement Score	46.2 (18.8)	46.6 (20.7)
Missing Placement Test Score	2.2%	4.2%
Outcomes in first two academic years		
# of terms enrolled	2.4 (1.5)	2.5 (1.6)
% Completed Any DE Math	56.1%	52.1%
% Completed Any CL Math	20.1%	24.6%

* p-value<.05 (t-tests for continuous variables, Chi-Square tests for Categorical Variables)

[1] Statistical significance unchanged with the fully detailed version of the variable

Table 3 provides data baseline equivalence and unadjusted effect size estimates for the Summer Bridge experiment's 2017 and 2018 cohorts – measured two years following the intervention. As with the primary AMP-UP experiment, random assignment in the Summer Bridge experiment produced balanced groups. There were no statistically significant differences on any observed student characteristics, including the SES and prior academic achievement indicators. But the unadjusted outcomes show that this intervention – which only affected students taking the first course in a three-term developmental math sequence – did not produce meaningful effects. Students in the intervention group enrolled in a nearly identical number of terms, were somewhat less likely to complete any further developmental math coursework, and were only slightly more likely to have completed a college-level math course. While not inspiring on their own, these findings have implications for how we understand the impact of the primary AMP-UP intervention, which we turn to in the discussion below.

DISCUSSION

Based on a randomized controlled trial involving students assessed as needing developmental mathematics at Bergen Community College, this study investigated whether an accelerated

delivery of developmental and college-level mathematics coursework would improve student retention, gateway course completion, credit accumulation, and degree completion over three years. The intervention group enrolled in accelerated developmental and college-level coursework; those in the group who placed into developmental arithmetic also participated in a self-paced Summer Bridge program. The comparison group followed the college's usual developmental mathematics sequence, generally enrolling in their first math course in the Fall term of their first year.

The study found that both groups enrolled in a similar number of terms over three years. But in that period, intervention group students were 13 percentage points more likely to complete a developmental mathematics course and 30 percentage points more likely to complete a college-level mathematics course. The intervention group also earned 5.1 more credits and was 8 percentage points more likely to complete a degree in the study period.

When controlling for student characteristics, we observe statistically significant differences in college-level math course completion ($p<.001$), credit earning ($p<.10$), and degree completion ($p<.10$). Given the relatively small size of the study sample, we urge readers to consider both a lower threshold of statistical significance and the substantively important point estimates of these latter results. The credit accumulation advantage is the equivalent of two college courses' worth of credits, while the graduation effect constitutes an 82 percent increase over the adjusted estimate for the comparison group.

The most robust finding from the study concerns the completion of gateway mathematics courses. This finding aligns with the research on continuous mathematics enrollment, which indicates that students who enroll continuously through their college math requirements are more likely to finish them (Charles A. Dana Center, 2017; Schudde & Keisler, 2019; Smith-Jaggars & Hodara, 2014). Given that mathematics course completion is a significant stumbling block for many students, this finding in the context of a rigorous evaluation is important on its own.

The strong direction of effects on credit accumulation and degree completions align with other studies of alternatives to traditional remediation. A quasi-experimental study of the Dana Center's math pathways acceleration program (Schudde & Keisler, 2019) showed that students in the accelerated group earned an additional six credits over three years compared to students in the traditional two- to three-semester-long developmental pathway. In an experiment with corequisite mathematics at the City University of New York, Logue and her colleagues (2016, 2019) found that students randomly assigned to corequisite math courses earned six additional credits and graduated at rates about 8 percentage points higher than students assigned to a traditional developmental sequence. Though the CUNY and AMP-UP models differed in terms of sample size and design,[3] both rigorous studies arrived at the same results: intervention group students were able to complete their college-level math requirements in their first semester of

[3] The CUNY study statistics (Logue, Watanabe-Rose, & Douglas, 2016; Logue, Douglas, & Watanabe-Rose, 2019) were run on a sample of 596 students, while our AMP-UP experiment at BCC had only 233 students. Also, while AMP-UP at BCC did not employ a corequisite model *per se*, it incorporated developmental and college-level math in a single semester with a single instructor, so students likely experienced it as a corequisite course.

college. We thus interpret our findings as remarkably consistent with other estimates of the effect of accelerated and/or corequisite developmental mathematics.

The significant findings from the main AMP-UP study can also be interpreted in the context of the null findings from the Summer Bridge sub-study. We initially adopted a 'dosage' hypothesis – that the Summer Bridge program would have a smaller but still significant impact on student outcomes, since intervention group students were still completing some portion of their requirements. Given our null findings for Summer Bridge, and what existing research has found about college math sequences (from developmental through college-level), we now contend that the decisive factor in student success is the completion of *all* college math requirements, including the college-level course. Whether completion is achieved through a corequisite approach or through acceleration may be less important than the simple fact that the sequence is completed.

This leads to the question of college policy. Acceleration modifies developmental mathematics courses rather than eliminating them entirely. As such, what we have learned from this approach and its development by BCC as a resistance-born alternative to a corequisite model is that a model like this might be more palatable to colleges looking for ways to reform existing developmental math sequences. This might be especially true for colleges that need to build capacity and/or political will before adopting more progressive strategies like corequisites. This experiment indicates that while acceleration may not be the answer for all students or all colleges, it can be an important part of the developmental reform toolkit.

This model may also have some value in colleges as they change delivery models due to the COVID-19 pandemic. The self-paced option for the treatment condition could provide important lessons on successful models for delivering developmental and college math instruction remotely. For the purposes of this evaluation, we aggregated the self-paced and traditional versions of the intervention, but supplemental analyses published in earlier reports suggest that students succeeded at similar rates in both formats (Douglas, McKay & Edwards, 2017).

Sustainability

While the impacts of the AMP-UP program at BCC appear both substantial and robust to a rigorous evaluation, interventions built on grant funding always invite the problem of sustainability. AMP-UP facilitated a standalone Summer Bridge program as well as the creation of two new accelerated courses in mathematics. To get a sense of the post-grant future of these innovations, we interviewed the site manager of Bergen's AMP-UP program in the last year of the grant.

Since the traditional-format 7.5-week accelerated courses – developmental-level MAT 040 and college-level MAT 130 – are modifications to existing courses, there are no additional costs associated with continuing to run those classes. Accelerated courses were also part of the culture at Bergen prior to the grant, so the site manager felt confident that the college-level MAT 130 course would continue beyond the grant. But the self-paced developmental courses and the

Summer Bridge program both require software licenses, which were covered by grant funding. This added cost may not be a priority expense for the college despite the potential value of these options for students. The integrated nature of the treatment (e.g., enrolling students in adjacent developmental and college-level math) also presents a sustainability issue, since the college's advising practices would need to change to align with what was learned from the grant.

Sustainability of the AMP-UP components may also depend on faculty buy-in. In our experience, it is not uncommon to see resistance among faculty to changes to math pathways and redesign in developmental education. Within BCC, this resistance was apparent among some, though not all, faculty in the math department from the start of the grant. In order for this intervention to be sustained or for BCC to make further reforms to developmental math, getting faculty on board will have to be a priority.

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