Twelfth Grade Math and College Access

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Introduction

Students' academic preparation during high school, including the courses they take, influences their educational and economic success in adulthood (see, e.g., Miller, 1998; Murnane et al., 2000; Rose & Betts, 2004). Research on the association between course taking and academic or economic outcomes consistently suggests that taking a more advanced math curriculum in high school improves students' likelihood of enrolling in college, and in a four-year college specifically (Aughinbaugh, 2012; Byun, Irvin, & Bell, 2015; Long, Conger, & Iatarola, 2012), and increases their earnings in adulthood (Goodman, 2019; Joensen & Nielsen, 2009).

This report examines the effects of taking math in 12th grade on several academic outcomes, including high school grade point average and course completion and college enrollment and persistence. We also investigate whether particular types of math courses (for example, Calculus or Statistics) are especially beneficial for students' academic success.

Sample

Our study uses longitudinal administrative and survey data from the Los Angeles Unified School District (L.A. Unified), the second-largest school district in the United States. L.A. Unified serves a large geographic area (over 700 square miles) and educates over 500,000 students. We focus on two cohorts of students who were first-time 11th graders in either 2015-16 or 2016-17 and who remained in the school district through the following academic year (i.e., through what would typically be their 12th grade year). This longitudinal sample allows us to measure students' academic preparation as of the end of 11th grade and to follow both cohorts of students for two years after their high school graduation. See Appendix A for additional details on the data sources and sample.[1]

[1] The L.A. Unified data include students who were enrolled in traditional or affiliated charter high schools but do not include students from independent charter schools. We exclude students from our analyses who attended alternative schools, continuation schools, community day schools, and opportunity schools because these schools tend to serve students whose course-taking patterns and options are likely to differ substantially from those in our sample. We also exclude students with a documented disability as of the end of 11th grade because those students' math requirements for high school graduation can differ from those of students without disabilities.

Table 1. Sample Characteristics

	Mean / %	SD	N
Female	53.17%	49.90%	45,339
Race/Ethnicity			
Native American or Alaskan Native	-	-	45,295
Asian American	4.76%	21.29%	45,295
African American	7.77%	26.77%	45,295
Filipinx	3.57%	18.55%	45,295
Latinx	75.54%	42.99%	45,295
Pacific Islander	-	-	45,295
White	7.62%	26.54%	45,295
Ever Eligible for Subsidized Meals from 9th-11th Grade	92.30%	26.66%	44,539
Parents'/Guardians' Educational Attainment			
Not a High School Graduate	24.41%	42.96%	45,392
High School Graduate	20.58%	40.43%	45,392
Some College	12.13%	32.65%	45,392
College Graduate	9.11%	28.77%	45,392
Graduate School	3.97%	19.51%	45,392
Decline to Answer or Missing	29.80%	45.74%	45,392
English Learner Classification in 11th Grade			
English Only	28.88%	45.32%	45,392
Initial Fluent English Proficient	17.32%	37.84%	45,392
Limited English Proficient	5.55%	22.89%	45,392
Reclassified Fluent English Proficient	48.14%	49.97%	45,392
Participated in the Gifted and Talented Program in 11th Grade	22.79%	41.95%	45,392
Cumulative Overall Weighted GPA at End of 11th Grade	2.91	0.76	45,391
Number of Semesters of AP Classes Taken from 9th-11th Grade	2.68	3.28	43,795
Met or Exceeded Standards on the 11th Grade ELA SBAC*	63.88%	48.04%	44,397
Met or Exceeded Standards on the 11th Grade Math SBAC*	29.36%	45.54%	44,365
Educational Expectations in 11th Grade			
Unsure	12.17%	32.69%	33,418
High School or Less	3.88%	19.32%	33,418
Associate Degree or Certificate	6.58%	24.79%	33,418
Bachelor's Degree or Higher	77.37%	41.85%	33,418

*Smarter Balanced Assessment

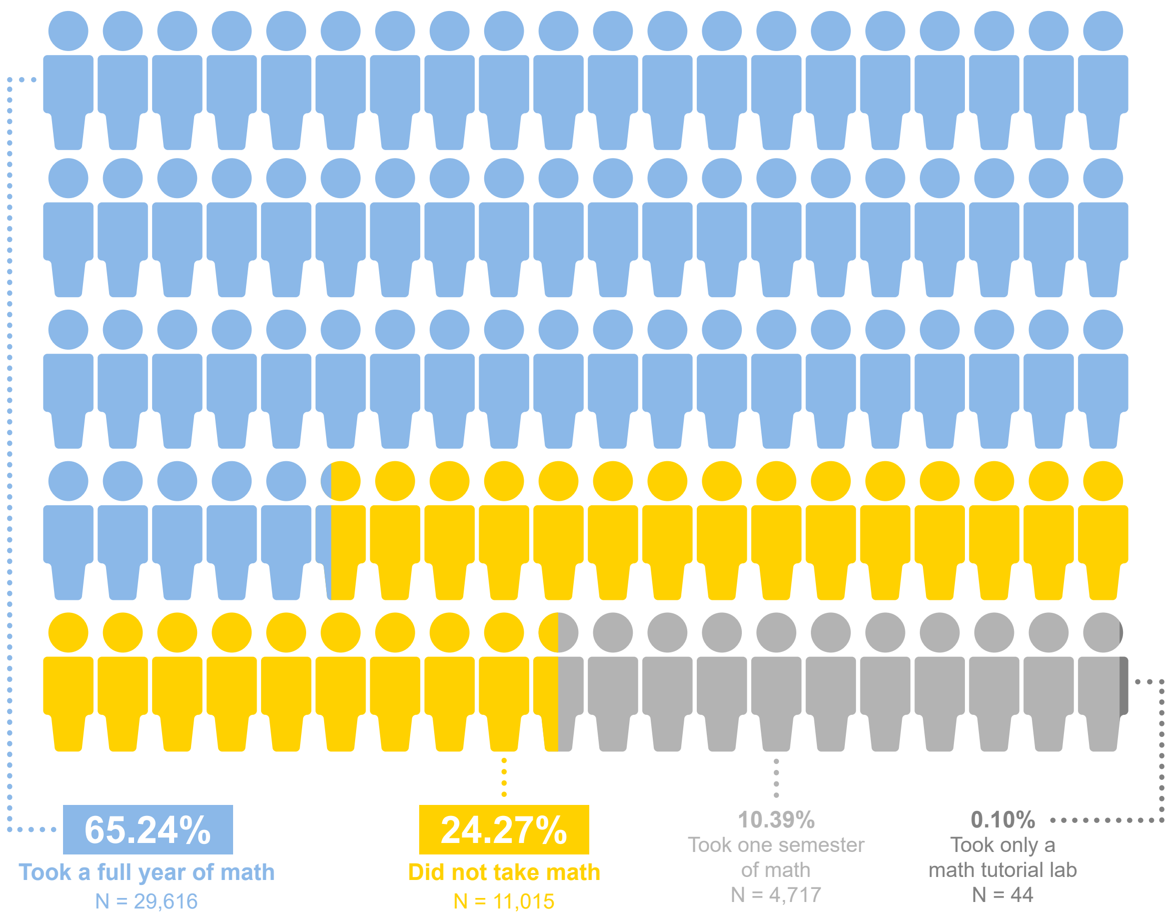
Note: This table includes 2015-16 and 2016-17 first-time 11th graders who attended a traditional or affiliated charter school, did not have a documented disability, and had complete 11th and 12th grade transcript data. See the Technical Appendix for more details. We redact cells with fewer than 11 students and cells that contain less than 1% or more than 99% of the sample.

Table 1 shows that our sample has slightly more girls than boys and is over 75% Latinx.[2] Over 90% of the sample qualified for subsidized meals at some point during high school. As of the end of 11th grade, about 6% of the students in our sample were classified as "Limited English Proficient." By the end of 11th grade, students' weighted GPAs averaged slightly below a B, the typical student had taken more than one year-long AP course, and nearly 30% met or exceeded standards on the statewide standardized math test.[3]

Twelfth Grade Math Enrollment

About two-thirds (65%) of the students in our sample took a full year of math in 12th grade, while nearly a quarter (24%) took no math at all (see Figure 1). About 10% enrolled in a single semester of math. We exclude those students from our analyses because our goal is to estimate the impact of taking a full year of math compared to taking no math at all.

Figure 1. 12th Grade Math Course Taking in L.A. Unified



Note: This figure includes 2015-16 and 2016-17 first-time 11th graders who attended a traditional or affiliated charter school, did not have a documented disability, and had complete 11th and 12th grade transcript data. See the Technical Appendix for more details.

Although we do not have data on why some students take math in 12th grade while others do not, many students undoubtedly take math to fulfill high school graduation or college admissions requirements. L.A. Unified requires that students earn at least a D in math through Algebra 2—or its equivalent—to graduate from high school (L.A. Unified, 2016). California requires that students take a

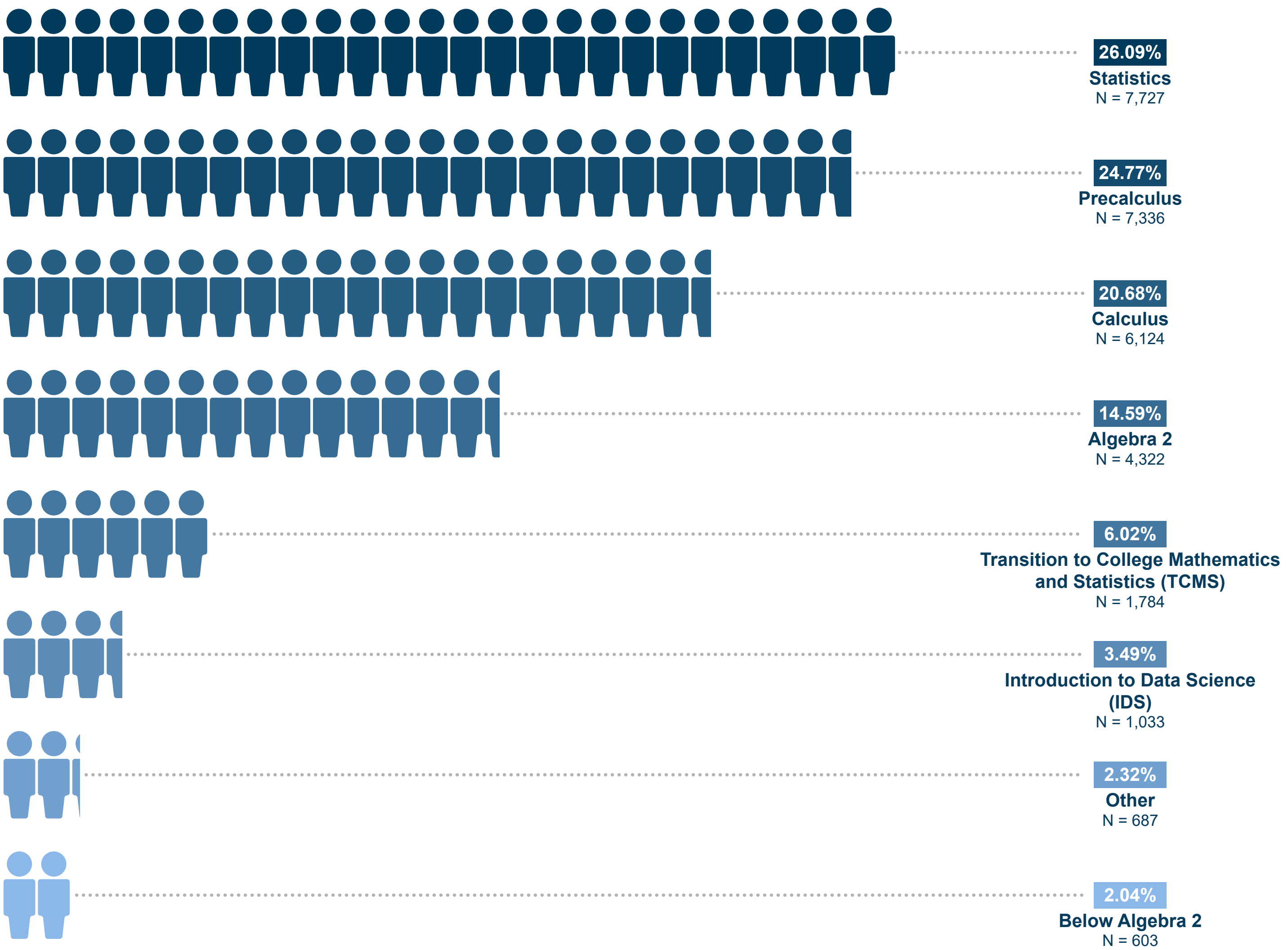
[2] For a comparison of first-time 11th graders in the district as a whole and those in our sample, see Appendix Table A3.

[3] In California, students take math and English language arts tests developed by the Smarter Balanced Assessment Consortium (SBAC), which are part of the state's Assessment of Student Performance and Progress (CAASPP).

series of college preparatory courses in a set of subject areas, referred to as the “A-G requirements,” and earn at least a C in them, to be eligible for admission to a public four-year university (e.g., California State University (CSU) and University of California (UC) campuses). For the math A-G requirement, students must complete Algebra 1, Geometry, and Algebra 2, or their equivalents, with at least a C.[4] Students who have already met these high school graduation or four-year college eligibility requirements by the end of 11th grade may take additional math in 12th grade for a variety of reasons, such as following advice from high school counselors or other adults to do so, wanting to improve their competitiveness for admission to more selective majors or more selective universities, enjoying math or thinking of themselves as being good at math, or believing that math is important preparation for success in college, life, or their intended careers.

Figure 2 shows the different types of math courses students took in 12th grade. Of the students in our sample who enrolled in a full year of math in 12th grade, more than half took either Statistics (26%) or Precalculus (25%). About one fifth took Calculus (21%) and a smaller percentage took Algebra 2 (15%).

Figure 2. 12th Grade Math Courses Taken by First-Time 11th Graders



Note: This figure includes 2015-16 and 2016-17 first-time 11th graders who attended a traditional or affiliated charter school, did not have a documented disability, had complete 11th and 12th grade transcript data, and took a full year of 12th grade math. See the Technical Appendix for more details.

[4] Students may also “validate” these courses by taking higher level courses and earning at least a C in those, or by earning particular scores on relevant college readiness tests (for details, see University of California, 2021).

Approximately 10% of students took alternative courses that have been offered more recently in the district, such as Transition to College Mathematics and Statistics[5] (TCMS) or Introduction to Data Science[6] (IDS), both of which can be taken instead of or after Algebra 2,[7] and count as Algebra 2 equivalents for the purposes of high school graduation and eligibility for state public university admissions.

Methodological Approach

To identify the effects of taking math in 12th grade (or a particular type of math or statistics course), we compare the outcomes of students who were similar in their academic preparation at the end of 11th grade but made different math choices in their senior year. We first classify students into six groups that shared similar math course-taking patterns within their group and similar math course performance as of the end of 11th grade. We do this both because students' prior math course taking and performance are strongly related to whether students take 12th grade math, and to which math course they take, and because we hypothesize that the effects of taking math on students' high school and postsecondary outcomes may differ among these six student groups.

Table 2 describes these groups and how they differ from one another on key academic characteristics. Groups 1 and 2 include students who needed to take math in 12th grade to graduate from high school (Group 1 was two or more courses short of the math courses they needed for graduation, while Group 2 was one math course short). Nearly all of the students in those groups (100% and 99%, respectively) took a full year of math in 12th grade (typically either Algebra 2 or Geometry). Students in the remaining four groups had fulfilled the math requirements for high school graduation. But students in Group 3 needed to complete at least one math course in 12th grade with a C or better to meet the minimum math requirements for eligibility for admission to a public four-year university in California. Over 50% of students in Group 3 took a 12th grade math course (typically either Precalculus or Statistics). Students in Groups 4, 5, and 6 had already completed their math A-G requirements by the end of 11th grade, so they did not need to take a math course to meet minimum four-year college eligibility requirements. Nonetheless, 67%, 73%, and 79% of the students in those groups, respectively, took a 12th grade math course. Group 4 students typically took Precalculus or Statistics, while Group 5 and 6 students most commonly took AP Calculus (AB or BC, respectively) or Statistics/AP Statistics.

[5] Per L.A. Unified (2017), TCMS covers a blend of topics in math and statistics through application to real-life problems, including: interpreting categorical data (e.g., comparisons of proportions such as risk reduction and relative risk); functions that model change (e.g., exponential and logarithmic transformations); counting methods (e.g., combinations and permutations); and the mathematics of financial decision-making (e.g., simple and compound interest).
[6] Per L.A. Unified (2020), IDS is designed to introduce students to data analysis and computer coding, and is meant to prepare students for careers in statistics, biology, the social sciences, and law.
[7] L.A. Unified's math placement policy states that TCMS is only open to students who have completed Algebra 2. However, during the period of our study, some schools enrolled students in TCMS instead of Algebra 2. Students can fulfill the Algebra 2 graduation and college eligibility requirements by earning a C or better in a course such as TCMS.

Table 2. Student Groups with Similar Math Course-Taking Histories

	N (%)	Took Math (%)	Most Common 12th Grade Math Course (%)	Second Most Common 12th Grade Math Course (%)	Average Cumulative Overall Weighted GPA at the End of 11th Grade (SD)	% Met or Exceeded Standards on 11th Grade Math SBAC (SD)
Group 1: 2 or More Courses Short of Math A-G Complete with a D	692 (1.9%)	690 (99.7%)	Algebra 2 (75.7%)	Geometry (30.6%)	1.75 (0.47)	0.6% (7.6%)
Group 2: 1 Course Short of Math A-G Complete with a D	3,519 (9.8%)	3,476 (98.8%)	Algebra 2 (67.4%)	Geometry (7.7%)	2.13 (0.50)	3.0% (17.2%)
Group 3: Math A-G Complete with a D	2,855 (7.9%)	1,494 (52.3%)	Precalculus (42.8%)	Statistics (21.4%)	2.29 (0.46)	6.0% (23.8%)
Group 4: Math A-G Complete with a C	11,255 (31.3%)	7,488 (66.5%)	Precalculus (62.6%)	Statistics (17.4%)	2.87 (0.56)	13.1% (33.8%)
Group 5: Math A-G Complete with a C + 1 Advanced Math	12,825 (35.7%)	9,406 (73.3%)	AP Calculus AB (39.1%)	Statistics (22.5%)	3.29 (0.57)	44.5% (49.7%)
Group 6: Math A-G Complete with a C + 2 or More Advanced Math	4,766 (13.3%)	3,757 (78.8%)	AP Calculus BC (34.1%)	AP Statistics (32.8%)	3.70 (0.48)	82.4% (38.1%)

Note: This table includes all students in our analytic sample—see the Technical Appendix for more detail on this sample. The percentages (%) in the "N" column are out of the analytic sample (e.g., 31.3% of students in our analytic sample were in Group 4). The percentages (%) in the "Took Math" column are out of the student group (e.g., 66.5% of Group 4 students took 12th grade math). The percentages (%) in the "Most Common 12th Grade Math Course" and "Second Most Common 12th Grade Math Course" columns are out of the students in the group who took math in 12th grade (e.g., among Group 4 students who took math, 62.6% of them took Precalculus). Note that students may take more than one math course in a year, which is why the percentages for the most and second most common math courses in Group 1 add up to over 100%.

For the estimates of the effects of taking math, or of taking a particular type of math, we show results for students in Groups 3, 4, and 5. Taken together, students in these groups constitute 75% of the first-time 11th graders in our sample. We exclude students in Groups 1 and 2 because nearly all students in those groups took math in 12th grade, so we cannot examine the effects of not taking math for those groups. We also exclude analyses for Group 6 (i.e., students who had taken two or more math courses beyond the college eligibility requirements by the end of 11th grade) because the district currently only recommends this highly advanced course sequence for a very small percentage of students. As a result, it has become increasingly uncommon in recent years.

The key methodological concern in using non-experimental data to estimate the effect of taking 12th grade math on students' future educational outcomes is that 12th grade math course taking is strongly determined by a wide range of factors, such as students' prior math achievement, the availability of math courses at students' schools, and students' postsecondary aspirations, and those same factors also influence students' postsecondary outcomes. In other words, part, and possibly all, of the association between 12th grade math course taking and outcomes like college enrollment may be attributable to correlation rather than causation. However, education policymakers and school staff members need information about whether to encourage more students to enroll in math in 12th grade, which math courses might be most beneficial, and which students might benefit most. Non-experimental estimates that use rigorous methods to compare the outcomes of students who differed in their 12th grade math course taking but were very similar in other ways can be useful for informing these decisions.

We approach this methodological challenge in three ways. First, we measure a large number of predictor variables at the end of 11th grade that potentially influence both students' math course taking in 12th grade and their later outcomes, and we compare the outcomes of students who were similar on those predictors but differed in their 12th grade math course taking. Table 3 lists these predictors.[8]

Table 3. Predictors

Demographics	Age (in Months)
	Gender
	Race/Ethnicity
	Subsidized Meal Eligibility
	Parents'/Guardians' Educational Attainment
	Nonresident School Enrollment
	Number of School Moves
	English Learner Status
	Gifted and Talented Program Participation
Academics	Math Weighted GPA
	Cumulative Overall Weighted GPA
	ELA SBAC Score
	Math SBAC Score
	Semesters of AP Classes Taken
	Semesters Off-Track in A-G and Graduation Requirements
	Evidence-Based Reading and Writing PSAT Score
	Math PSAT Score
	Took the SAT or ACT before 12th Grade
	AVID Program Participation
	Took a College or Career Seminar Course
	Advanced Math Course Taking by the End of 11th Grade
Behavioral	Work Effort GPA
	Cooperation GPA
	Attendance Rate
	Ever Suspended
Self-Perception	Educational Expectations
	Growth Mindset
	Academic Self-Efficacy

Note: See Appendix Table A1 for how we define these variables. AVID = Advancement via Individual Determination.

Second, we estimate various types of quasi-experimental models that use different assumptions about the best ways to equate students on these predictors, and we emphasize results that are consistent across different models. Third, we use sensitivity tests that communicate the extent to which our results may be biased. Appendix B describes our estimation approaches in detail, Appendix C shows results from all the models, and Appendix D discusses the results of the sensitivity tests.

In this report, we emphasize findings from a method that uses the predictors listed in Table 3 to estimate each student's probability of taking 12th grade math, and then matches students who took 12th grade math to students who did not take 12th grade math but who had similar predicted probabilities of taking 12th grade math.[9] We prioritize matching students from the same school, and

[8] See Appendix Table A1 for descriptions of how we measure each of these predictors.

[9] More precisely, we find non-math-takers whose propensities to take math resemble those of the math-takers *and* we

when there are not enough reasonably close matches within the same school, we match students who had similar math course-taking probabilities but who attended different schools.[10] We then estimate the effects of 12th grade math using this matched sample and Ordinary Least Squares (OLS) regression, with controls for all the same predictors.[11]

For each group of students, we show the effects of taking 12th grade math compared to not taking 12th grade math for four key outcomes: 1) cumulative, weighted grade point average by the end of 12th grade; 2) completing the A-G course sequence by the end of 12th grade with a C or better (thereby becoming eligible for admission to four-year public universities in California); 3) college enrollment; and 4) persistence into the second year of college.[12] In addition, when enough students in a group took different types of math courses, we compare the effects of those math courses on each of these outcomes.[13]

After describing the effects of math course taking, we explore whether students with similar levels of academic preparation but from different demographic groups were equally likely to take math in 12th grade. These results provide information about which types of students may need more access to 12th grade math courses at their school or more encouragement to take those courses.

Results

1. Effects of Taking a Twelfth Grade Math Course

We begin by examining whether students who took a 12th grade math course had different high school or college outcomes than their peers who were academically and demographically similar at the end of 11th grade but did not take a 12th grade math course. We find that taking math in 12th grade has small negative effects on students' GPAs; large positive effects on four-year college eligibility for students who had not completed the math A-G requirements before they started 12th grade; and moderately-sized, positive effects on college enrollment and persistence, particularly for four-year colleges.

find math-takers whose propensities to not take math resemble those of the non-math-takers. We combine these two sets of matches to approximate the average treatment effect (ATE) of taking 12th grade math.

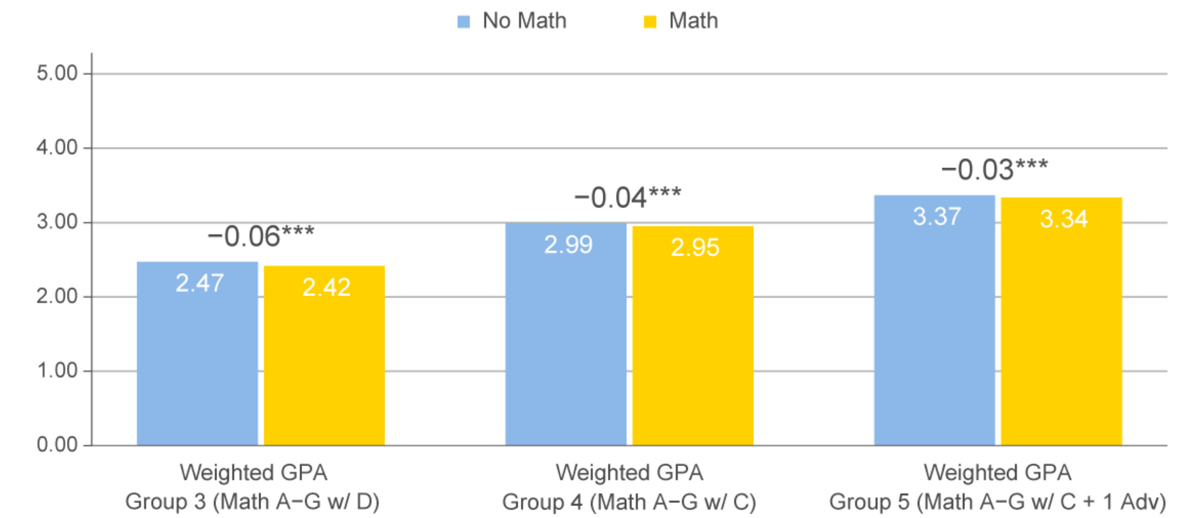
[10] Formally, we estimate propensity scores, with fixed effects for schools included in the propensity score models, and then match each math-taker with to up to three non-math-takers, and vice versa, using "preferential within-cluster matching" (Arpino & Cannas, 2016). For most course comparisons, we match students who are within .05 or .10 standard deviations (i.e., calipers) of one another on the propensity score (Lunt, 2014); we increase the number of matches from three to five if that improves balance; and we also drop students from the treatment group whose propensity scores are very different from those in the control group and vice versa (Lechner & Strittmatter, 2019).

[11] This estimation strategy is "doubly robust" (Ho et al., 2007) in that our estimates will still be consistent if we have correctly modeled either (i) the probability of taking 12th grade math or (ii) the outcome of interest.

[12] We measure students' grade point averages and A-G completion with district administrative data. We measure students' college enrollment and persistence with the district's National Student Clearinghouse (NSC) data. For students attending community colleges, we augment the NSC data with L.A. Unified's data from the California Partnership for Achieving Student Success (Cal-PASS Plus). In addition, in Appendix C, we report results for supplemental outcomes, including math and verbal SAT scores and students' likelihood of applying to a four-year college. See Appendix Table A2 for details on how we measure all these outcomes.

[13] For the sake of narrative simplicity, we describe statistically significant estimates as "effects," and discuss their magnitudes. But readers should keep in mind that these estimates come from quasi-experimental models that cannot adjust for all the factors that influence students' 12th grade math course taking and their high school and college outcomes, and thus the estimates are probably still somewhat biased estimates of the true effects of taking 12th grade math. When discussing the results, we emphasize only those findings that hold across the various types of models. We also note how robust the estimated effects are to the exclusion of missing predictors.

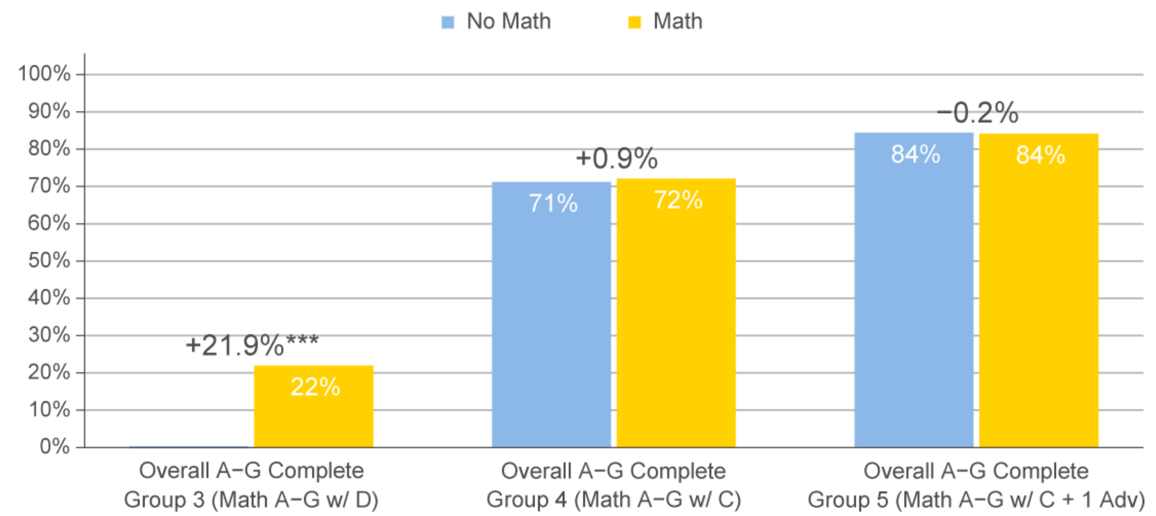
Figure 3. Estimated Effects of Taking Math in 12th Grade (Compared to Not Taking Math) on Cumulative Overall Weighted High School GPA



Note: The numbers above each pair of bars are the estimated effects of taking math. The bars show the average estimated GPAs for students who were academically and demographically similar but either did not take math (left bar) or did take math (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

Figure 3 shows that students who took math in 12th grade earned slightly lower weighted GPAs than did similar peers who did not take math. The numbers above each pair of bars are the estimated effects, for each group, of taking math in 12th grade. Each pair of bars puts these estimated effects into context, showing the average estimated GPAs of students who were academically and demographically similar at the end of the 11th grade but either did not take math in 12th grade (left bar) or did take math in 12th grade (right bar).[14] All the estimated effects are negative and statistically significant, but also quite small. The largest difference, of only .06 GPA points, is for students from Group 3 (recall that Group 3 students had not yet completed college eligibility requirements in math prior to 12th grade).[15]

Figure 4. Estimated Effects of Taking Math in 12th Grade (Compared to Not Taking Math) on Completion of Overall A-G Requirements with a C or Better



Note: The numbers above each pair of bars are the estimated effects of taking math (in percentage points). The bars show the average estimated probabilities of completing the overall A-G requirements with a C or better for students who were academically and demographically similar but either did not take math (left bar) or did take math (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

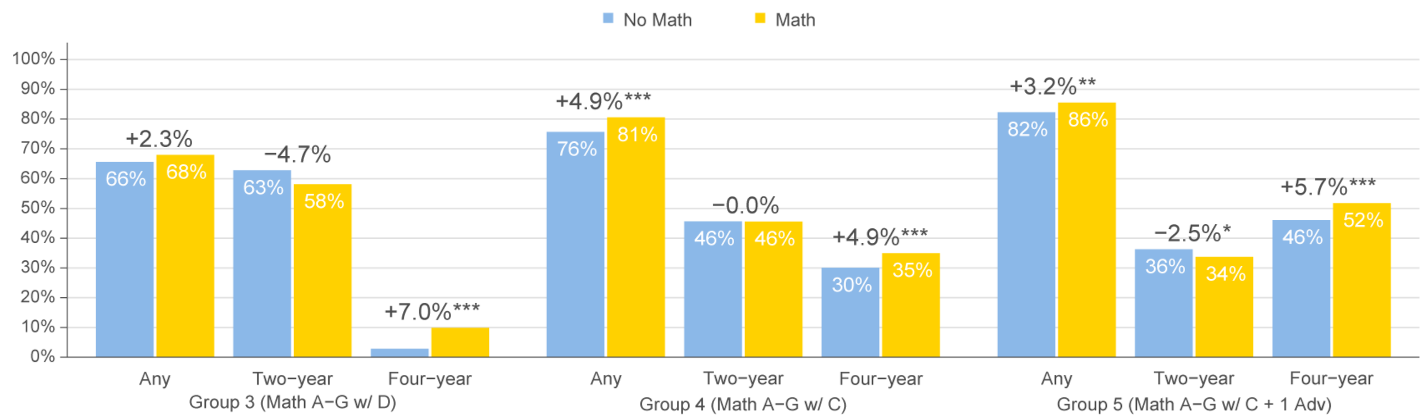
[14] More exactly, the bars report average predictions from our preferred model. See the Technical Appendix for more detail.

[15] See Appendix C to compare these results with those from our alternate models.

While taking math in 12th grade reduced students' overall GPA slightly, it provided a large boost to students' completion of college preparatory coursework (i.e., completion of all A-G public four-year college admissions eligibility requirements) for those students who had not yet completed the corresponding math requirements by the end of 11th grade (Group 3). Figure 4 shows that Group 3 students who took math in 12th grade were 22 percentage points more likely than their counterparts who did not take math to complete their A-G requirements with a C or better by the end of 12th grade. Note that the bars in Figure 4 show the average estimated probabilities of completing the A-G requirements for students who were academically and demographically similar at the end of 11th grade but either did not take math in 12th grade (left bar) or did take math in 12th grade (right bar).

Students who took math in 12th grade were also more likely than similar peers who did not take math to enroll in a four-year college. Figure 5 shows that most students from Group 3—those who needed to take math in 12th grade to meet four-year college eligibility requirements—enrolled in two-year colleges. Nonetheless, taking math in 12th grade provided some of these students the opportunity to enroll in four-year colleges instead (an estimated improvement of 7 percentage points for Group 3). Because students who enroll in a four-year college are more likely to complete a bachelor's degree than otherwise similar students who enroll in a two-year college (for a recent review, see Schudde & Brown, 2019), shifting students into four-year colleges is likely to have important, positive consequences for students' longer-term social and economic mobility. And these effects on four-year college enrollment are relatively large compared to those of many other interventions (for reviews, see French & Oreopoulos, 2017 and Page & Scott-Clayton, 2016).

Figure 5. Estimated Effects of Taking Math in 12th Grade (Compared to Not Taking Math) on College Enrollment

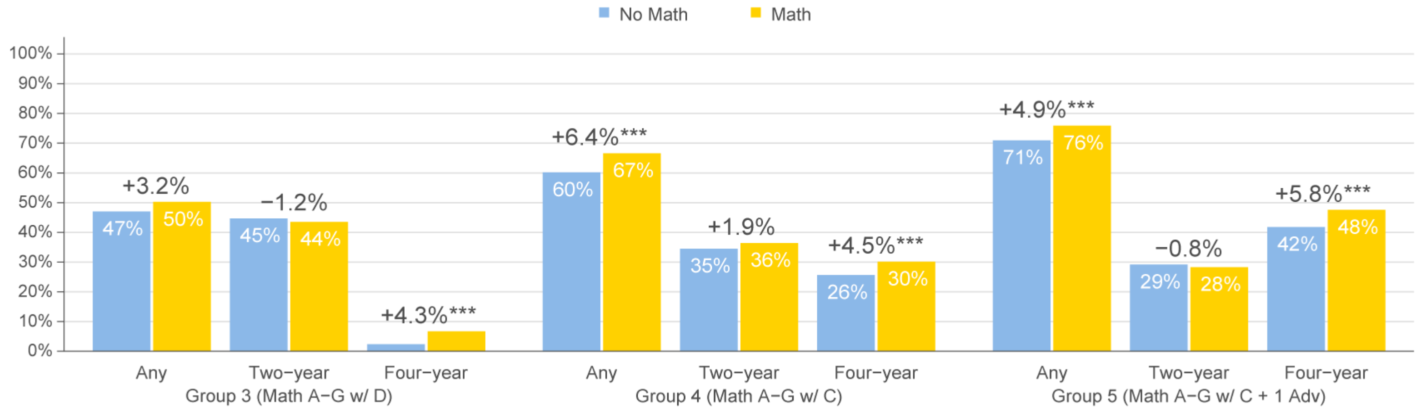


Note: The numbers above each pair of bars are the estimated effects of taking math (in percentage points). The bars show the average estimated probabilities of enrolling in each type of college for students who were academically and demographically similar but either did not take math (left bar) or did take math (right bar). See the Technical Appendix for more detail. Estimated effects may differ from differences between the bars due to rounding. *p<0.05, **p<0.01, and ***p<0.001.

For students who were already four-year college eligible in their math course sequence before they began their senior year (Groups 4 and 5), taking math in 12th grade improved their college enrollment rates overall, particularly by increasing four-year college enrollment. These effects on four-year college enrollment of approximately 5 to 6 percentage points were substantial—increasing the percentage of students who enrolled in a four-year college from 30 to 35% for Group 4 and from 46 to 52% for Group 5.

The effects of taking math in 12th grade on college persistence are similar to the results for college enrollment (see Figure 6). Taking 12th grade math improved four-year college persistence for all three groups of students, by 4 to 6 percentage points depending on the group. And for students in Groups 4 and 5, taking 12th grade math improved college persistence overall, by 5 to 6 percentage points.[16]

Figure 6. Estimated Effects of Taking Math in 12th Grade (Compared to Not Taking Math) on College Persistence



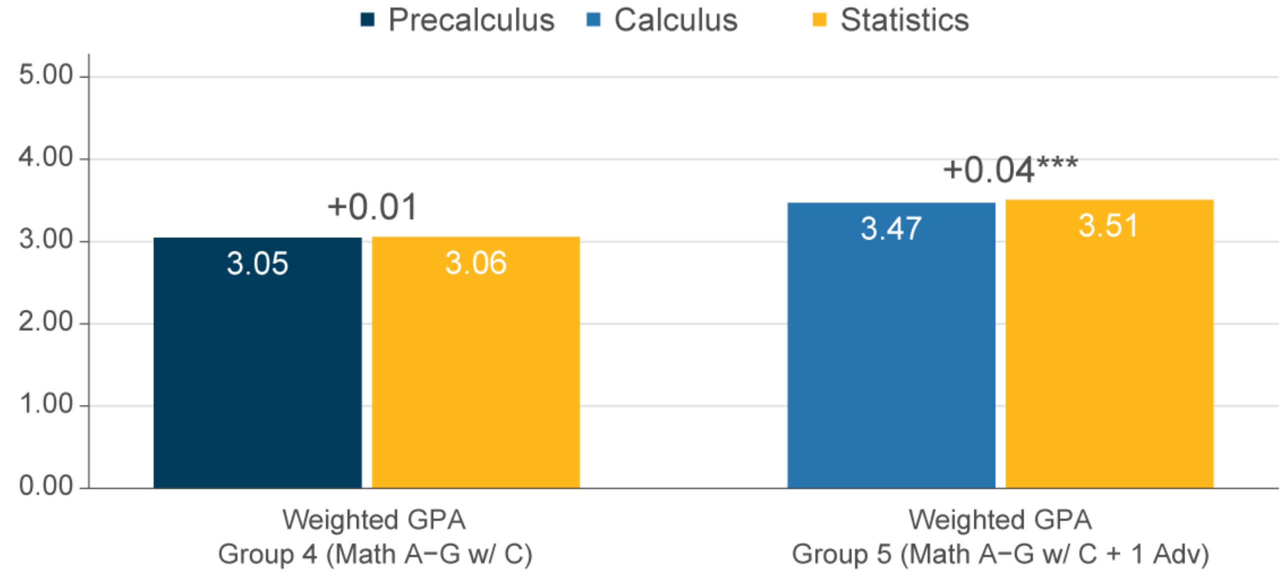
Note: The numbers above each pair of bars are the estimated effects of taking math (in percentage points). The bars show the average estimated probabilities of persisting in each type of college for students who were academically and demographically similar but either did not take math (left bar) or did take math (right bar). See the Technical Appendix for more detail. Estimated effects may differ from differences between the bars due to rounding. *p<0.05, **p<0.01, and ***p<0.001.

2A. Effects of Particular Math Courses: Statistics, Precalculus, and Calculus

We also examine whether taking *a particular type* of 12th grade math course affects students' high school or college outcomes. We only report these results for Groups 4 and 5 because we cannot construct sufficiently similar comparison groups of students taking different types of math in Group 3. For students in Group 4, we compare the outcomes of similar students who took Precalculus instead of Statistics, because those were the most common courses taken by Group 4 students. For students in Group 5, we compare the outcomes of similar students who took Calculus instead of Statistics.

[16] Using the procedure introduced by Cinelli & Hazlett (2020), we find that the robustness of these results to unobserved predictors that we cannot account for varies across the outcomes and groups (results not shown; see Appendix D). Failing to account for unobserved predictors that influence both math course taking and the outcomes of interest risks overstating the effect of 12th grade math on those outcomes. We hypothesize that the key predictors that our data do not capture include students' interest in math, confidence in their math skills, and beliefs about whether additional math preparation will be helpful for their college major or future career. Given that the academic predictors that we already include in our models are quite comprehensive and probably serve as proxies to some extent for these unmeasured variables, we hypothesize that these unobserved predictors are considerably less influential than our set of academic predictors taken together (see Appendix D for details). For example, it seems unlikely that these unobserved predictors have a stronger influence on 12th grade math course taking or college enrollment than does students' prior math performance, which we measure with math standardized test scores and GPA. From this perspective, the results for A-G completion for Group 3 seem robust. To render that effect statistically insignificant (at the 0.05 level), unobserved predictors would need to be 1.5 times as predictive as all the academic predictors taken together. On the other hand, our results are least robust for GPA. For the effect of taking math on GPA to be statistically insignificant, unobserved predictors would only need to be around one fifth as predictive as all the academic predictors taken together, which seems possible. The robustness of the results for college enrollment and persistence falls in the middle of these two extremes. For Group 3, the positive effect of taking 12th grade math on four-year college enrollment would be statistically insignificant if unobserved predictors were half as predictive as all the academic predictors taken together. For Groups 4 and 5, the positive effect of taking 12th grade math on overall college enrollment would become statistically insignificant if unobserved predictors were about a third as predictive as the academic predictors taken together. The plausibility of the existence of a set of omitted predictors that would make the estimate of taking math statistically indistinguishable from zero is debatable, and thus we cannot be certain that 12th grade math has a positive effect on college enrollment. However, given the comprehensiveness of the academic predictors, we suspect that 12th grade math is likely beneficial for A-G completion and four-year college enrollment and persistence for students like those in Group 3, and for overall college enrollment and persistence for students like those in Groups 4 and 5.

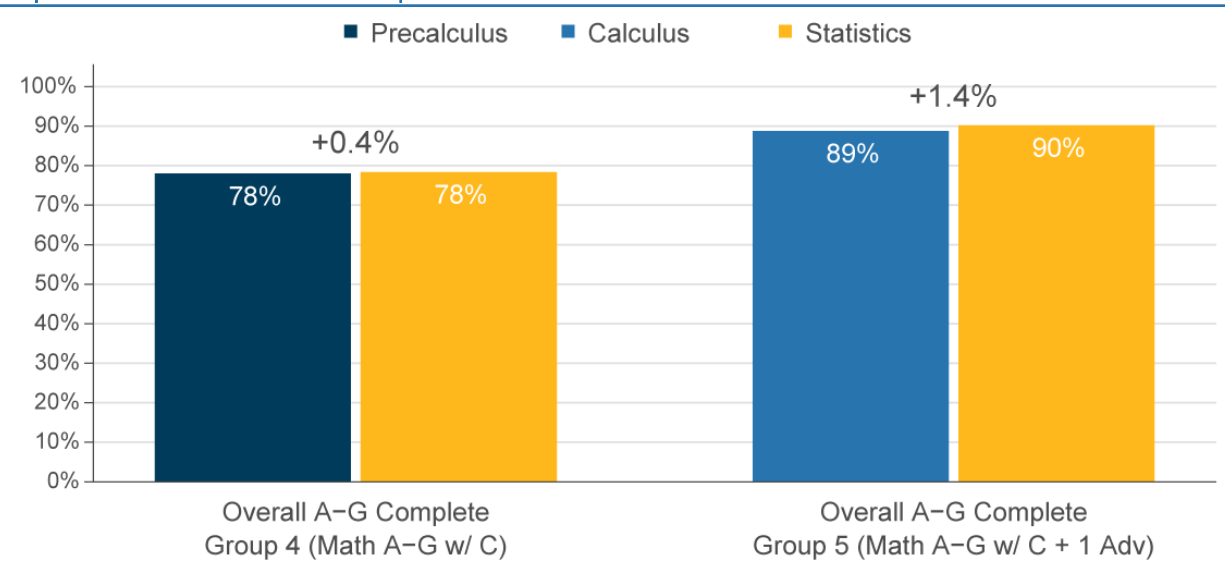
Figure 7. Estimated Effects of Taking Statistics in 12th Grade (Compared to Precalculus/Calculus) on Cumulative Overall Weighted High School GPA



Note: The numbers above each pair of bars are the estimated effects of taking Statistics instead of Precalculus/Calculus. The bars show the average estimated GPAs for students who were academically and demographically similar but either took Precalculus/Calculus (left bar) or took Statistics (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

We find that similar students in Group 4 earned comparable grades regardless of whether they took Precalculus or Statistics (see Figure 7). For students in Group 5 (i.e., those who had taken one advanced math course beyond the minimum college eligibility requirements by the end of 11th grade), however, taking Statistics instead of Calculus (typically AP Calculus) improved students' overall weighted GPAs by a small amount (.04 GPA points). Neither course choice has a statistically significant effect on overall A-G completion (see Figure 8), but the point estimates hint that taking Statistics may have slightly improved students' chances of completing all A-G requirements compared with taking Precalculus or Calculus.

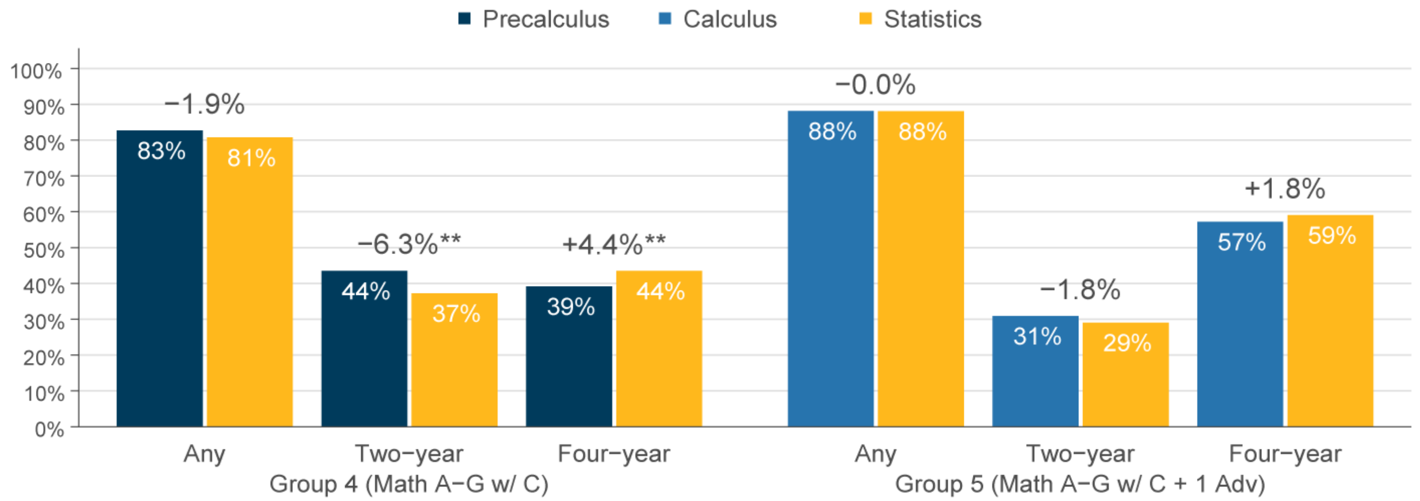
Figure 8. Estimated Effects of Taking Statistics in 12th Grade (Compared to Precalculus/Calculus) on Completion of Overall A-G Requirements with a C or Better



Note: The numbers above each pair of bars are the estimated effects of taking Statistics instead of Precalculus/Calculus (in percentage points). The bars show the average estimated probabilities of completing the overall A-G requirements with a C or better for students who were academically and demographically similar but either took Precalculus/Calculus (left bar) or took Statistics (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

Figures 9 and 10 show that, for Group 4, taking Statistics instead of Precalculus shifted enrollment to four-year institutions and increased persistence into the second year at four-year institutions.[17] Course choice is not statistically significantly related to college enrollment or persistence for Group 5, however. A likely explanation for the effect in Group 4 may be that the percentage of students who intended to major in science, technology, engineering, or math (STEM) fields was higher among those who took Precalculus than it was among those who took Statistics.[18] STEM majors are highly impacted at many CSU campuses, meaning that students who apply to those majors are held to higher admissions standards than students who apply to other majors.[19] If students who took Precalculus were more likely to apply to impacted majors, they may have had a lower likelihood of being admitted to a four-year college where that major was impacted than their non-STEM-intending peers who took Statistics. Another possible explanation for this finding is that students whose math skills were less well developed (recall from Table 2 that only 13% of students in Group 4 met or exceeded standards on the 11th grade math SBAC) may have found Statistics more engaging than Precalculus or felt more successful in it, which in turn increased their interest in continuing their education at a four-year college.[20]

Figure 9. Estimated Effects of Taking Statistics in 12th Grade (Compared to Precalculus/Calculus) on College Enrollment



Note: The numbers above each pair of bars are the estimated effects of taking Statistics instead of Precalculus/Calculus (in percentage points). The bars show the average estimated probabilities of enrolling in each type of college for students who were academically and demographically similar but either took Precalculus/Calculus (left bar) or took Statistics (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

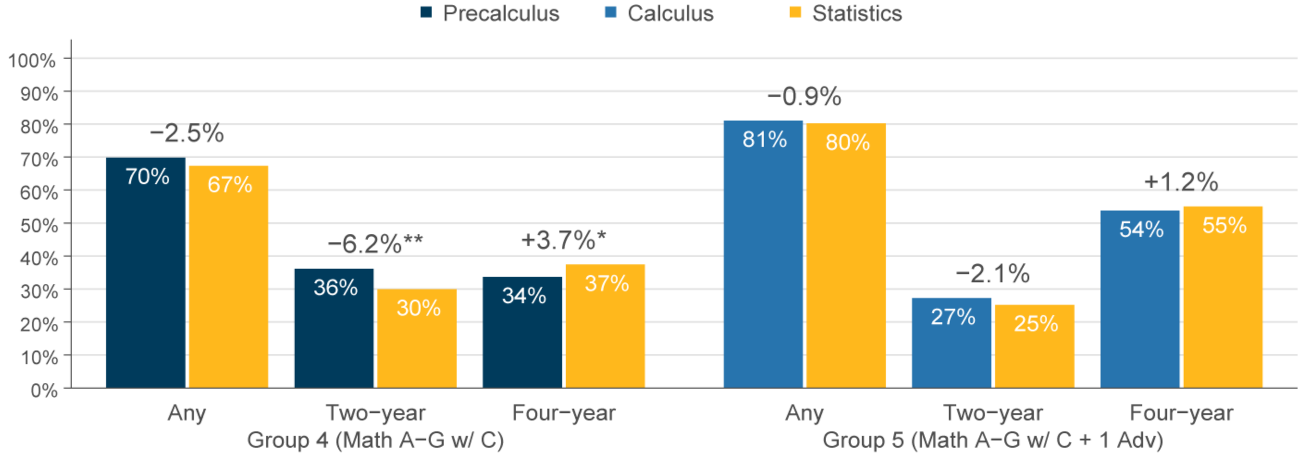
[17] The signs of these estimates (i.e., positive for four-year colleges, and negative for two-year colleges) are consistent across all our estimates. However, the statistical significance is slightly sensitive, specifically for models that exchange school fixed effects with school-level predictors, and therefore estimate the effects on a larger sample (see Appendix C for more detail).

[18] Unfortunately, we do not have any data on students' intended college major so we cannot assess this theory empirically or control for major intentions in our models. But evidence from a nationally representative study of 9th graders suggests that STEM-intending students are more likely to take Precalculus than their non-STEM-intending peers (Holian & Kelley, 2020).

[19] The CSU designates campuses and programs as "impacted" when they receive more applications from qualified applicants than they can accommodate. The CSU Office of the Chancellor permits impacted campuses and programs to hold applicants to higher admissions standards than their non-impacted counterparts (CSU Office of the Chancellor, 2021). For example, California State University, Long Beach has separate admissions eligibility indices for non-STEM and STEM major applicants. The STEM major index places additional weight on students' math and science achievement and requires that students have higher grades or test scores to be eligible for admission (CSU Long Beach, 2021).

[20] Note, however, that if students' engagement with, or success in, Statistics were the main explanation for the positive effect on college enrollment of Statistics compared to Precalculus, we might also expect to see a positive effect of taking Statistics on applying to four-year colleges. But we do not see such an effect (see Appendix C).

Figure 10. Estimated Effects of Taking Statistics in 12th Grade (Compared to Precalculus/Calculus) on College Persistence



Note: The numbers above each pair of bars are the estimated effects of taking Statistics instead of Precalculus/Calculus (in percentage points). The bars show the average estimated probabilities of persisting in each type of college for students who were academically and demographically similar but either took Precalculus/Calculus (left bar) or took Statistics (right bar). See the Technical Appendix for more detail. *p<0.05, **p<0.01, and ***p<0.001.

2B. Effects of Particular Math Courses: Non-Traditional Math Courses

We also investigate whether taking one of the non-traditional math courses offered by some district schools (e.g., TCMS or IDS) is associated with improved high school or college outcomes compared to taking a more traditional math course (e.g., Precalculus).[21] We do not report these results for students in Groups 3 and 5 because smaller numbers of students in those groups took the non-traditional courses and those who did differed too much from those who took the traditional courses to yield well-balanced comparisons. We do, however, report results for students in Group 4 because those comparisons were reasonably well-balanced. Fortunately, this is a useful comparison because the developers of these courses, especially TCMS, designed them for students like those in Group 4, who had completed their A-G math requirements by the end of 11th grade (L.A. Unified, 2017, 2018).

[21] We also attempted to compare TCMS and IDS to Statistics but could not find sufficiently balanced comparison groups with our preferred estimation approach. In Appendix C, however, we present results from alternative approaches.

Our sample of Group 4 students who took the non-traditional courses is relatively small and thus our results tend to be imprecise, statistically insignificant, and vary depending on modeling assumptions.[22] Nonetheless, we report results from our preferred model in Table 4 and full results in Appendix C.

Table 4. Estimated Effects of TCMS or IDS in 12th Grade (Compared to Precalculus) on Various Outcomes for Students in Group 4

	Weighted GPA	A-G Complete with C	Any Enrollment	Two-Year Enrollment	Four-Year Enrollment	Any Persistence	Two-Year Persistence	Four-Year Persistence
TCMS	-0.001	1.5%	-2.7%	1.7%	-4.4%	-4.9%	0.9%	-5.8%*
IDS	0.054***	1.8%	-2.0%	3.7%	-5.8%	-1.1%	5.4%	-6.5%

Note: These results show point estimates (in GPA points or percentage points) and statistical significance from the "Cluster Matching with OLS" models, where standard errors have been clustered by school. See Appendix Tables C33-C40 for Ns, standard errors, and results from all models. We define "college persistence" as continuing to be enrolled in college into one's second year, after having been enrolled for one's first year. See Appendix Table A2 for more detail on how we define all these outcomes.

Compared to students who took Precalculus, students who were otherwise similar at the end of 11th grade but took TCMS earned similar cumulative weighted GPAs, but students who took IDS earned slightly higher GPAs (by about .05 weighted GPA points).

We find no statistically significant differences in college enrollment for similar students who took IDS or TCMS instead of Precalculus. We do, however, find a little evidence that similar students who took TCMS rather than Precalculus may have been slightly less likely to persist into their second year at a four-year college. Note, however, that these results vary in their magnitude and are only statistically significant in a few of our models (see Appendix C).

3. Disparities in Twelfth Grade Math Course Taking

Although we do not find consistent effects of different types of math courses, we do consistently find that students are more likely to enroll in and persist in college when they take math in 12th grade. To inform district staff about which students need more access to 12th grade math courses or encouragement to take math in 12th grade, we investigate whether particular types of students are less likely than their academically similar peers who attend the same high school to take 12th grade math. Table 5 displays these results.[23]

[22] Further, for these comparisons, we only estimate the average effect of taking TCMS/IDS *on those who took one of those courses*, rather than on all students who took either TCMS/IDS or Precalculus. More precisely, we find Precalculus-takers whose propensities to take TCMS/IDS resemble those of the TCMS/IDS-takers. We then estimate the effect of TCMS/IDS using the original TCMS/IDS-takers and the matched Precalculus-takers. This approximates the average treatment effect on the treated (ATT) of taking TCMS/IDS. We do this because we could not find enough TCMS/IDS-takers whose propensities to take Precalculus resembled those of Precalculus-takers.

[23] Appendix E provides additional results, including unadjusted differences between various groups in their 12th grade math taking, as well as differences among students who were similar academically and demographically but who did not attend the same schools.

Table 5. Disparities in Taking 12th Grade Math among Similar Students Attending the Same School

	Group 3: A-G Math Complete with a D	Group 4: A-G Math Complete with a C	Group 5: A-G Math Complete with a C + 1 Advanced Math
Gender			
Female vs. Male	-0.001	-0.052***	-0.038***
Race/Ethnicity			
Latinx vs. Asian American	-0.146	-0.025	-0.017
Latinx vs. African American	0.007	0.069**	0.036
Latinx vs. White	-0.010	0.089**	0.046*
Latinx vs. Filipinx	-0.112	0.013	-0.019
Asian American vs. African American	0.153	0.094*	0.052*
Asian American vs. White	0.135	0.114**	0.062*
Asian American vs. Filipinx	0.034	0.038	-0.002
African American vs. White	-0.017	0.020	0.010
African American vs. Filipinx	-0.119	-0.056	-0.055**
White vs. Filipinx	-0.102	-0.076	-0.065*
Ever Eligible for Subsidized Meals from 9th to 11th Grade			
Eligible vs. Not Eligible	0.037	0.000	-0.010
Parents'/Guardians' Educational Attainment			
Not HS Grad vs. HS Grad	0.006	-0.019	0.005
Not HS Grad vs. Some College	-0.033	-0.016	0.030
Not HS Grad vs. College Grad	-0.025	-0.037	0.011
Not HS Grad vs. Grad School	-0.121	-0.121***	0.014
HS Grad vs. Some College	-0.039	0.003	0.025
HS Grad vs. College Grad	-0.031	-0.017	0.006
HS Grad vs. Grad School	-0.127	-0.102***	0.009
Some College vs. College Grad	0.008	-0.020	-0.019
Some College vs. Grad School	-0.088	-0.105***	-0.016
College Grad vs. Grad School	-0.096	-0.085**	0.003
English Learner Classification in 11th Grade			
LEP vs. EO	-0.098	-0.070	-0.033
LEP vs. IFEP	-0.129	-0.083*	-0.050
LEP vs. RFEP	-0.133	-0.113***	-0.063
EO vs. IFEP	-0.031	-0.013	-0.017
EO vs. RFEP	-0.035	-0.043*	-0.030*
IFEP vs. RFEP	-0.004	-0.030*	-0.013

Note: The differences in predicted probabilities for the average student are from logistic regression models that include the variables in Table 3 as regressors and also include school fixed effects. Standard errors have all been clustered by school. See Appendix Tables E1-E3 for Ns, standard errors, and results from all models. LEP = Limited English Proficient. EO = English Only. IFEP = Initial Fluent English Proficient. RFEP = Reclassified Fluent English Proficient. *p<0.05, **p<0.01, and ***p<0.001.

Gender

Table 5 shows that girls from Groups 4 and 5 were about 4 to 5 percentage points less likely than boys in those groups to enroll in 12th grade math, even when these students attended the same school and had the same math grades and test scores as of the end of 11th grade. These gender disparities in advanced math course taking may contribute to gender disparities in physical science/engineering majors and careers (see, e.g., Riegle-Crumb & King, 2010).

Ethnicity

In terms of disparities among students from different racial and ethnic backgrounds, we find that Latinx and Asian American students in Group 4 were more likely to enroll in 12th grade math than their African American or white peers with similar socioeconomic backgrounds and academic preparation from the same school. We see similar patterns for Group 5 when comparing Asian American or Filipinx students with their African American and white peers in the same school and with similar socioeconomic backgrounds and academic preparation.

Socioeconomic Status

We have two measures of students' socioeconomic status: whether a student's family qualifies for subsidized school meals and the highest level of education attained by the student's parents or guardians. Among students who were academically similar and who attended the same school, students who qualified for subsidized school meals were no more or less likely to take 12th grade math than their peers who did not qualify for subsidized meals. However, specifically among Group 4 students (who had completed the math A-G requirements by the end of 11th grade), those with parents or guardians who had completed graduate school were substantially more likely to take 12th grade math than their otherwise academically and demographically similar peers from the same school whose parents completed less education.

Language Background

We do not find any differences in 12th grade math course taking among otherwise similar students from Group 3 who differed in their language classification. We do, however, find that when we compare Group 4 Limited English Proficient (LEP) students to their Initially Fluent English Proficient (IFEP) or Reclassified Fluent English Proficient (RFEP) peers with otherwise similar academic performance and who attended the same schools, the LEP students were less likely to take 12th grade math. These results may stem from LEP students needing to take additional English courses and thus having less space in their schedules for math. English Only (EO) and IFEP students in Group 4 were also slightly less likely than otherwise similar RFEP students to take 12th grade math. In addition, in Group 5, EO students may also have been slightly less likely than otherwise similar RFEP students to take 12th grade math.

Discussion

This report yields several key findings that can inform current education policy discussions in California. First, we find that students who took a full year of math, of any type, in 12th grade enrolled and persisted in four-year colleges at higher rates than otherwise similar peers who did not take any math courses in 12th grade. These positive effects on college enrollment and persistence occurred even though students experienced a very slight "hit" to their overall GPA when they took math in 12th grade. Second, students who began 12th grade having not yet completed the math requirements for admission to California's public four-year colleges were much more likely to be four-year college eligible by the end of 12th grade if they took math in 12th grade. Probably as a result, those students were also more likely to enroll and persist in a four-year college instead of a two-year college. Finally, students who had already completed enough math courses by the end of 11th grade to be four-year college eligible were more likely to enroll and persist in college overall, and particularly in four-year colleges, if they took math, of any type, in 12th grade. These findings mirror results from other settings about the benefits of taking a more advanced math curriculum in high school (see, e.g., Aughinbaugh, 2012; Byun, Irvin, & Bell, 2015; Long, Conger, & Iatarola, 2012).

These findings are relevant to an ongoing debate in California about whether public universities should require students to take an additional math course in high school to be eligible for college admission. In 2019, the Board of Trustees of the CSU proposed revising admissions requirements to include an additional quantitative reasoning course, recommended to be taken in 12th grade. This CSU proposal aimed to ensure that more California students graduate high school with stronger quantitative preparation so that they are prepared for college majors that require more math (CSU, 2020). Although our results do not provide evidence about the challenges of implementing this requirement, they do suggest that California students with academic trajectories similar to those in our analyses would be more likely to enroll and persist in college, particularly in four-year colleges like the CSUs, if they were to take a math course, of any type, in their senior year.

Critics of the CSU proposal have expressed concern that increasing the number of quantitative courses required for admissions might pose barriers for students who lack access to sufficient quantitative coursework at their school (see, e.g., Burdman, 2019). Although we do not assess course availability in this report, our results do indicate that policymakers and school staff should strive to ensure equity in math course taking not just between schools but also within them. When comparing the 12th grade math course-taking patterns of students who attended the same schools and who were equally well-prepared academically as of the end of 11th grade, we find that students from certain demographic backgrounds were less likely than their peers to enroll in math in 12th grade. These disparities were most apparent among students who had completed their A-G math requirements by the end of the 11th grade but had not taken any additional math courses; for these students, we find within-school disparities in 12th grade math enrollment by gender, race/ethnicity, parent or guardian education level, and English language learner status. These differences probably arise for numerous reasons—such as differences in students' perceptions of their math skills, in their understanding of the importance of math for college preparation, or in other course requirements students still need to complete during their senior year. Nonetheless, these results suggest: 1) that schools should make sure they are offering enough math courses so that all 12th graders are able to enroll in a relevant math course (while taking the other courses they need) and 2) that counselors, teachers, and parents may need to encourage students to take math in 12th grade.

A related policy debate has focused on whether taking a particular type of high school math course improves students' likelihood of enrolling and persisting in college (Rockmore, 2020). Specifically, this conversation has raised the question of whether students should enroll in traditional math courses, such as Algebra 2, Precalculus, and Calculus, or should enroll instead in alternatives such as Statistics, IDS, or other courses designed explicitly to prepare students for college-level math, such as the TCMS course. As far as we are aware, this is the first study to examine the effects of taking different types of math courses in 12th grade on students' outcomes.

Among similar students who had completed their A-G math requirements and had taken one additional math course by the end of the 11th grade (usually Precalculus), whether they took Statistics or Calculus in 12th grade was unrelated to their likelihood of enrolling or persisting in college. Among similar students who had completed their A-G math requirements by the end of 11th grade but had not taken any additional math courses, students who took Statistics as seniors were more likely to enroll and persist in a four-year college than those who took Precalculus. As mentioned earlier, a possible explanation for this finding is that students who plan to major in STEM subjects in college are more likely to take Precalculus than Statistics in 12th grade, and four-year colleges have more selective admissions standards for admitting students to STEM majors than to other majors. Unfortunately, we do not have data on high school juniors' intended majors, so we cannot investigate this possible explanation empirically.

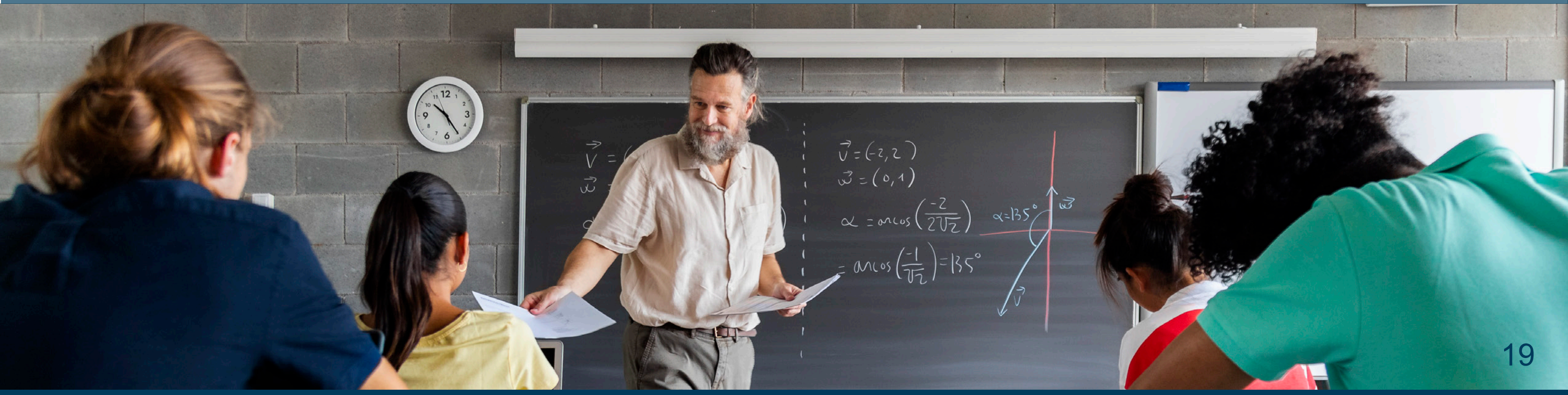
Although we had hoped to compare the effects on college enrollment and persistence of taking non-traditional courses, like IDS or TCMS, to the effects of taking traditional math courses, too few students in the school district and the time period covered by our data took a non-traditional math course in 12th grade for us to have sufficient statistical power to reliably assess the differential effects of these courses. Because more schools and districts have offered these courses in recent years, future research should investigate how taking these courses affects students' college access and success, and which students benefit from them the most.

Finally, this report does not address the important question of whether taking math in 12th grade improves students' performance in their college math courses, or whether certain types of high school math courses prepare students better for STEM majors. In a subsequent report, we will link students' 12th grade math course taking with their college transcripts to begin to understand those associations.

Conclusion

Using longitudinal data from the largest school district in California and quasi-experimental matching methods, we find that taking math in 12th grade seems to improve students' chances of enrolling and persisting in a four-year college. These results likely arise for several reasons. First, 11th graders who have not yet completed the math courses required for admission to public four-year colleges in California can improve their chances of being eligible for admission by taking math in 12th grade. Second, selective colleges and universities prefer to admit students who have taken four years of math in high school, a practice that may become even more common now that California's four-year universities and some private colleges no longer consider SAT or ACT test scores in the admissions process. Third, taking math in 12th grade may change students' peer and classroom social contexts in ways that encourage students to apply to and enroll in college.

Despite the benefits of taking math in 12th grade, many students (nearly 25% of our sample) do not enroll in a math course, of any type, in 12th grade. This is especially true among rising 12th graders who have already met the math requirements for high school graduation or for four-year college eligibility. Because taking math of any type in 12th grade would enhance these students' postsecondary opportunities, it is critical that high schools offer enough math courses to meet students' needs and that school staff and parents or guardians communicate with students about the importance of taking math in their senior year. Moreover, because we find suggestive evidence that statistics and traditional math courses have similar advantages in terms of expanding enrollment and persistence in four-year colleges, offering a variety of courses might help encourage more students to continue with math in 12th grade.



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