UCLA Los Angeles Education Research Institute

Twelfth Grade Math and College Success

LAERI RESEARCH REPORT | SEPTEMBER 2023

Leonard Wainstein, Reed College
Carrie E. Miller, UCLA
Meredith Phillips, UCLA
Kyo Yamashiro, LMU
Tatiana Melguizo, USC

REED COLLEGE
LMU School of Education
UCLA School of Education & Information Studies
USC Rossier School of Education
UCLA Luskin School of Public Affairs

www.laeri.luskin.ucla.edu | e-mail: laeri@luskin.ucla.edu

Acknowledgments

We thank Los Angeles Unified School District Staff from the Division of Instruction and the Office of Data and Accountability for their collaboration on this project. We are particularly grateful to the past and present members of the secondary math instruction and counseling teams, including Philip Ogbuehi, Firoza Kanji, Patricia Heideman, Amy Uyeshima, Jesus Angulo, Burgandie Montoya, Shelly Alavez, and the local district math and counseling coordinators, for their insightful contributions during meetings and presentations. We thank Kathy Hayes and Mollie Rudnick for their helpful comments on a draft of this report, and we thank Annika Park for copyediting and designing this report. We thank College Futures Foundation for their generous, multi-year support of this research project and of the Los Angeles Education Research Institute (LAERI). We also thank the Mayer and Morris Kaplan Family Foundation and the Luskin School at UCLA for their infrastructure support of LAERI. This research project is affiliated with LAERI and has benefited from its research and partnership infrastructure.

Disclaimers

This report reflects the analyses and interpretations of the authors. Readers should not attribute the report’s findings or interpretations to the Los Angeles Unified School District, the funders of the work, or others who contributed to the project.

Introduction

Social scientists have a long history of studying the association between students' high school course taking and their eventual educational and economic success (e.g., Miller, 1998; Murnane, 2000; Rose & Betts, 2004). Many studies focus specifically on the benefits to advanced math course taking, which seems to improve students' college enrollment and future earnings (Aughinbaugh, 2012; Byun, Irvin, & Bell, 2015; Goodman, 2019; Joensen & Nielsen, 2009; Long, Conger, & Iatarola, 2012). In *Twelfth Grade Math and College Access* (Wainstein et al., 2023), we investigated the link between taking 12th grade math and college enrollment and persistence in the Los Angeles Unified School District (L.A. Unified) and found results consistent with this literature – students who took 12th grade math were more likely to enroll and persist in college. However, that report stopped short of examining students' academic performance while in college.

This report builds on *Twelfth Grade Math and College Access* by investigating the effects of taking 12th grade math on students' credit accumulation and grades during the first two years of college, both overall and in science, technology, engineering, and math (STEM) courses. Research on the links between high school math course taking and college course taking is relatively sparse. Studies suggest that taking more math in high school improves students' scores on college math placement tests (Long, Iatarola, & Conger, 2009; Roth et al., 2001), thereby reducing students' placement into remedial math courses in college. Taking more math in high school also seems to increase students' likelihood of choosing a STEM major in college (Federman, 2007; Trusty, 2002). A recent report about students who attend a California State University (CSU) suggests that taking an additional quantitative reasoning course in high school may help students pass their first math course in college, graduate from college, and complete a STEM degree (Sepanik et al., 2022). We add to this literature by investigating whether taking math in 12th grade makes it more likely that students will complete more math or STEM courses during their first two years of college or earn better grades in them. We also examine whether certain types of high school math courses (e.g., Precalculus, Calculus, or Statistics) are particularly effective at preparing students for math and STEM courses in college. For reasons of data availability, we estimate these effects only for L.A. Unified students who attended a California community college or California State University, Northridge (CSUN).

Background

This study contributes relevant empirical evidence to two debates about high school math requirements in California. Currently, to be eligible for admission to California public four-year universities (e.g., CSU and University of California (UC) campuses), students must earn at least a C in a series of college prepatory courses in particular subject areas, referred to as the "A-G requirements." The math A-G requirement includes three courses – Algebra 1, Geometry, and Algebra 2, or their equivalents.[1] In 2019, the CSU Board of Trustees proposed that the CSU math requirements be revised to include an additional quantitative reasoning course, ideally taken in the 12th grade, in the hopes that students would finish high school with stronger quantitative skills and be more prepared for STEM coursework in college (CSU, 2020). This proposal generated opposition from some school districts, advocates, and policy makers because of concerns that the policy would make it harder for students at high schools with insufficient math course offerings to meet a four-year math requirement (Gordon & Burke, 2019). In response to this debate, the CSU commissioned an independent review, which indicated that while a substantial portion of students were *not* meeting the A-G requirements, among those who *were* (and thus were CSU-eligible) the vast majority took an additional quantitative reasoning course even without an explicit requirement to do so. Students who took an additional quantitative reasoning course did better in their first college-level math course and were more likely to earn a college degree (Sepanik et al., 2022). Due to concerns about math course availability and the educational challenges students faced during the pandemic, however, CSU decided against revising its admissions requirements (Smith, 2022).

In recent years, policy makers, educators, and advocates have also been debating which types of high school math courses best prepare students for college. While some argue that non-traditional courses, especially Statistics and Data Science, are especially useful in this era of big data (Burdman, 2022; Levitt et al., 2022), others argue that traditional courses, such as Algebra 2, Precalculus, and Calculus offer better preparation for college, especially in STEM fields (Levitt et al., 2022; Ford, 2022).

In addition, during the period of this study, California community colleges and the CSUs made important changes in how they place students into math courses. Understanding these policy changes is essential for interpreting the results from this study and thinking about their generalizability to today's policy climate (a point we revisit in the Discussion). The students in this study entered college in the 2017-18 and 2018-19 school years. During those years, community college students took math placement exams when they arrived on campus, and the colleges used students' scores on those exams to place students into either "developmental" math courses (e.g., Arithmetic, Pre-algebra, Algebra 1, Geometry) or "college-level" math courses (e.g., math courses that could count toward a bachelor's degree at a CSU, UC, or another four-year college) (Melguizo et al., 2014; Melguizo et al., 2015).[2] Assembly Bill 705 (AB 705), which passed in 2017 and was fully implemented in the fall of 2019, largely eliminated developmental math, so that community colleges now must place all students directly into college-level math courses, along with curricular and student supports. In addition, under the current policy, community colleges decide students' initial math placement using various non-test-based indicators, such as high school grade point average (GPA) and high school math course taking (California Community Colleges, 2018).

A similar transformation occurred in the CSUs under Executive Order 1110 (EO 1110), which was implemented in the fall of 2018. In earlier years, CSU students took math (and English) placement tests that determined whether those students would start in developmental coursework, which did not count toward a bachelor's degree. Under EO 1110, all CSU students are now placed directly into college-level coursework, and CSU uses multiple measures – including overall and math high school GPAs, standardized test scores,[3] and math course taking – to determine whether students need to enroll simultaneously in a co-requisite or support course to accompany the college-level course (CSU, 2017).[4] In addition, for students with the lowest level of math readiness, CSUN, where many in our sample enrolled, requires that students take an "early start" math course, Math 196, as their first math course, either in the fall of their freshman year or in the preceding summer (CSUN, n.d.a; Bracco et al., 2019).[5] Although Math 196 courses count toward a bachelor's degree, they do not satisfy CSUN's quantitative reasoning requirement (CSUN, n.d.b), which means that students who take Math 196 must take an additional math course to graduate.

Sample

We use longitudinal administrative and survey data from L.A. Unified, combined with students' college transcript data from all California community colleges and CSUN, provided through the district's partnership with the California Partnership for Achieving Student Success (Cal-PASS). Our results would be more representative, and we would have more statistical power, if we could include data from all four-year universities in California, but CSUN is the only four-year university widely attended by L.A. Unified graduates that provided data to Cal-PASS in the years that we study, and we do not have access to student-level college transcript data from other four-year colleges. Fortunately, CSUN enrolls approximately 10% of L.A. Unified students who enroll in college each year – more than any other two- or four-year college (Phillips, Yamashiro, & Jacobson, 2017).

In this report, we focus on students who were first-time 11th graders in either 2015-16 or 2016-17, remained in L.A. Unified through the following academic year (i.e., their normative 12th grade year), and enrolled either in a California community college or at CSUN within a year of graduating from high school. These longitudinal samples allow us to measure students' academic preparation as of the end of 11th grade and follow the students for two years after they have matriculated to community college or CSUN.[6] Appendix A provides additional details on the data sources and samples.

Table 1. Sample Characteristics

	Community College Sample (N=14,729)			CSUN Sample (N=2,925)		
	Mean / %	SD	N	Mean / %	SD	N
Female	51.55%	49.98%	14,714	57.26%	49.48%	2,925
Race/Ethnicity						
Native American or Alaskan Native	-	-	14,702	-	-	2,924
Asian American	3.39%	18.11%	14,702	5.37%	22.55%	2,924
African American	7.64%	26.56%	14,702	4.24%	20.16%	2,924
Filipinx	3.52%	18.44%	14.702	3.66%	18.78%	2,924
Latinx	76.85%	42.18%	14,702	77.43%	41.81%	2,924
Pacific Islander	-	-	14,702	-	-	2,924
White	7.77%	26.77%	14,702	8.69%	28.17%	2,924
Ever Eligible for Subsidized Meals from 9th-11th Grade	93.17%	25.22%	14,441	93.59%	24.50%	2,900
Parents'/Guardians' Educational Attainment						
Not a High School Graduate	24.67%	43.11%	14,729	25.91%	43.82%	2,925
High School Graduate	21.24%	40.90%	14,729	22.05%	41.47%	2,925
Some College	13.42%	34.08%	14,729	13.23%	33.89%	2,925
College Graduate	8.90%	28.48%	14,729	10.84%	31.09%	2,925
Graduate School	3.20%	17.59%	14,729	3.45%	18.26%	2,925
Decline to Answer or Missing	28.58%	45.18%	14,729	24.51%	43.02%	2,925
English Learner Classification in 11th Grade						
English Only	29.07%	45.41%	14,729	23.35%	42.31%	2,925
Initial Fluent English Proficient	16.39%	37.02%	14,729	20.75%	40.56%	2,925
Limited English Proficient	4.99%	21.77%	14,729	2.32%	15.07%	2,925
Reclassified Fluent English Proficient	49.45%	50.00%	14,729	53.57%	49.88%	2,925
Participated in the Gifted and Talented Program in 11th Grade	17.75%	38.21%	14,729	22.63%	41.85%	2,925
Cumulative Overall Weighted GPA at the End of 11th Grade	2.71	0.66	14,729	3.26	0.48	2,925
Number of Semesters of AP Classes Taken from 9th-11th Grade	1.91	2.65	14,278	2.90	2.81	2,863
Met or Exceeded Standards on the 11th Grade ELA SBAC*	58.15%	49.33%	14,467	77.07%	42.04%	2,905
Met or Exceeded Standards on the 11th Grade Math SBAC*	20.61%	40.45%	14,437	33.86%	47.33%	2,906
Educational Expectations in 11th Grade						
Unsure	13.96%	34.65%	10,634	7.77%	26.77%	2,215
High School or Less	3.70%	18.87%	10,634	1.13%	10.57%	2,215
Associate Degree or Certificate	8.18%	27.41%	10,634	2.30%	15.00%	2,215
Bachelor's Degree or Higher	74.17%	43.77%	10,634	88.80%	31.54%	2,215

*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. Students in the Community College sample enrolled in a California community college within one year of high school graduation, had a GPA in their first two years of college, and did not enroll at a four-year university in the same semester that they first enrolled in community college. Students in the CSUN sample enrolled at CSUN within one year of high school graduation and had a GPA in their first two years of college. 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 both the community college sample and the CSUN sample are predominantly Latinx (over 75%) and low-income (over 90% of students qualified for free or reduced-price meals at some point during high school).[7] The community college sample is more evenly split between women and men while CSUN has a larger percentage of women (57%). As of the end of 11th grade, the students who attended community college were slightly more likely to be classified as Limited English Proficient or English Only, and slightly less likely to be classified as Initial Fluent English Proficient or Reclassified Fluent English Proficient, than the students who attended CSUN. Unsurprisingly, given that community colleges are open-access institutions and CSUN is academically selective, students' high school academic performance and educational expectations differ between the community college and CSUN samples. Those who attended community colleges had average high school GPAs in the "B-" range, compared to over a "B" average for those who attended CSUN. Community college students also took fewer Advanced Placement (AP) courses when they were in high school than did CSUN students, and they were less likely to meet 11th grade test score benchmarks than their CSUN-attending peers.[8] In addition, as of the end of 11th grade, more of the students who later enrolled in community colleges were unsure about their educational expectations or hoped to complete an associate degree rather than a bachelor's degree.

Twelfth Grade Math Enrollment

Table 2 shows that during their 12th grade year, 61% of the community college sample took a full year of math, 27% took no math at all, and 12% enrolled in a single semester of math. A higher percentage of the CSUN sample – nearly 71% – took a full year of math in 12th grade and fewer students took no math at all (22%) or took only one semester of math (7%).[9] In our analyses, we exclude students who enrolled in only one semester of math because we aim to estimate the effect of taking a full year of math in 12th grade compared to taking no math at all.

Table 2 also describes the types of math courses students in both samples took in 12th grade. Among students who enrolled in a full year of math, more than half of both samples took either Precalculus – 28% for community college students and 27% for CSUN students – or Statistics – 25% for community college students and 29% for CSUN students. The samples differ the most in the percentage of students who took Algebra 2 or Calculus. About 18% of the community college sample took Algebra 2 in 12th grade compared to only 4% of the CSUN sample. And nearly a quarter (24%) of the CSUN sample took Calculus in 12th grade, compared to 13% of the community college sample. Similar percentages of students in both samples (12-13%) took the district's non-traditional math courses in 12th grade (e.g., Transition to College Mathematics and Statistics (TCMS)[10] or Introduction to Data Science (IDS)[11]).

Table 2. 12th Grade Math Course Taking in the Community College and CSUN Samples

	Community College Sample (N=14,729)		CSUN Sample (N=2,925)	
	N	%	N	%
Took a full year of math	8,954	60.79%	2,070	70.77%
Precalculus	2,498	27.90%	559	27.00%
Statistics	2,194	24.50%	594	28.70%
Algebra 2	1,644	18.36%	92	4.44%
Calculus	1,208	13.49%	505	24.40%
Transition to College Mathematics and Statistics	643	7.18%	182	8.79%
Introduction to Data Science	387	4.32%	86	4.15%
Other	199	2.22%	47	2.27%
Below Algebra 2	181	2.02%	<11	<1%
Did not take math	4,001	27.16%	657	22.46%
Took one semester of math	1,761	11.96%	195	6.67%
Took only a math tutorial lab	13	<1%	<11	<1%

Note: The percentages in the rows for the individual math courses (e.g., Precalculus) are among students in the corresponding sample who took a full year of math in 12th grade (e.g., among community college students who took a full year of math in 12th grade, 27.90% took precalculus). 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. Students in the Community College sample enrolled in a California community college within one year of high school graduation, had a GPA in their first two years of college, and did not enroll at a four-year university in the same semester that they first enrolled in community college. The CSUN sample enrolled in CSUN within one year of high school graduation and had a GPA in their first two years of college. 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.

Methodological Approach

As discussed in *Twelfth Grade Math and College Access*, the main challenge of using non-experimental data to estimate the effect of taking 12th grade math on students' college-related outcomes is accounting for the fact that many factors, such as students' prior math achievement, the availability of math courses at students' schools, and students' post-secondary aspirations, influence whether or not students take math in 12th grade, and those same factors also influence students' college enrollment and performance. We approach this challenge in several ways, largely following the methods in Wainstein et al. (2023).

Because whether students take math in 12th grade, and which course they take, depends heavily on which math courses they have already taken and whether they need to take math in 12th grade to graduate from high school or to become eligible for admission to a four-year university, we begin by classifying students into six groups based on their math course-taking patterns and math course performance by the end of 11th grade.

Table 3A defines these groups for students in our community college sample and shows how the groups differ on several academic characteristics.

Table 3A. Student Groups with Similar Math Course-Taking Histories, Community College Sample

	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 the 11th Grade Math SBAC (SD)
Group 1: 2 or More Courses Short of Math A-G Complete with a D	268 (2.2%)	267 (99.6%)	Algebra 2 (76.4%)	Geometry (28.1%)	1.78 (0.40)	0.4% (6.1%)
Group 2: 1 Course Short of Math A-G Complete with a D	1,596 (13.1%)	1,578 (98.9%)	Algebra 2 (67.2%)	Geometry (7.3%)	2.14 (0.48)	2.9% (16.9%)
Group 3: Math A-G Complete with a D	1,411 (11.6%)	729 (51.7%)	Precalculus (41.7%)	Statistics (22.8%)	2.30 (0.44)	5.9% (23.5%)
Group 4: Math A-G Complete with a C	4,243 (34.9%)	2,673 (63.0%)	Precalculus (60.3%)	Statistics (18.2%)	2.75 (0.54)	11.5% (32.0%)
Group 5: Math A-G Complete with a C + 1 Advanced Math	3,756 (30.9%)	2,544 (67.7%)	AP Calculus AB (32.5%)	Statistics (25.9%)	3.06 (0.56)	36.6% (48.2%)
Group 6: Math A-G Complete with a C + 2 or More Advanced Math	893 (7.3%)	664 (74.4%)	AP Statistics (29.8%)	AP Calculus BC (25.3%)	3.44 (0.52)	75.7% (42.9%)

Note: This table includes all students in the community college analytic sample – see the Technical Appendix for more details on this sample. The percentages (%) in the "N" column are out of the community college analytic sample (e.g., 34.9% of students in the community college analytic sample were in Group 4). The percentages (%) in the "Took Math" column are out of the student group (e.g., 63.0% 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, 60.3% 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%.

Table 3B. Student Groups with Similar Math Course-Taking Histories, CSUN Sample

	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 the 11th Grade Math SBAC (SD)
Group 1: 2 or More Courses Short of Math A-G Complete with a D	<11	<11	-	-	-	-
Group 2: 1 Course Short of Math A-G Complete with a D	73 (2.9%)	73 (100.0%)	Algebra 2 (67.1%)	Transition to College Math and Statistics (12.3%)	2.64 (0.51)	2.7% (16.4%)
Group 3: Math A-G Complete with a D	41 (1.6%)	38 (92.7%)	Precalculus (36.8%)	Algebra 2 (18.4%)	2.77 (0.48)	12.2% (33.1%)
Group 4: Math A-G Complete with a C	908 (35.8%)	678 (74.7%)	Precalculus (61.7%)	Statistics (18.0%)	3.13 (0.45)	15.3% (36.0%)
Group 5: Math A-G Complete with a C + 1 Advanced Math	1,174 (46.3%)	892 (76.0%)	AP Calculus AB (39.8%)	Statistics (24.6%)	3.37 (0.43)	42.2% (49.4%)
Group 6: Math A-G Complete with a C + 2 or More Advanced Math	334 (13.2%)	246 (73.7%)	AP Calculus BC (32.9%)	AP Statistics (28.0%)	3.56 (0.40)	75.1% (43.3%)

Note: This table includes all students in the CSUN analytic sample – see Appendix A for more details on this sample. The percentages (%) in the "N" column are out of the CSUN analytic sample (e.g., 35.8% of students in the CSUN analytic sample were in Group 4). The percentages (%) in the "Took Math" column are out of the student group (e.g., 74.7% 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, 61.7% of them took Precalculus). Note that students may take more than one math course in a year. We redact cells with fewer than 11 students.

Table 3B includes the same information for the CSUN sample. Groups 1 and 2 consist of students who had not yet completed their high school math graduation requirements and thus needed to take math in 12th grade in order to graduate from high school (Group 1 students were two or more courses short of the high school math graduation requirement, while Group 2 students were one math course short). Nearly everyone in these groups took a full year of math in 12th grade, and typically took Algebra 2 or Geometry. Students in the other four groups had already fulfilled the math requirements for high school graduation by the end of 11th grade. However, Group 3 students had yet to meet the minimum math requirements for eligibility for admission to a public four-year university in California (i.e., earning a C or better in Algebra 1, Geometry, and Algebra 2 or their equivalents). Of the students in Group 3, just over 50% of the community college sample took math in 12th grade (typically Precalculus or Statistics). A much higher percentage of the Group 3 students who eventually enrolled at CSUN took 12th grade math (93%), which makes sense given that they needed math in 12th grade to be able to meet the math A-G requirements for admission to CSUN. Students in Groups 4, 5, and 6 completed their math A-G requirements prior to 12th grade, so they did not need to take math in 12th grade to meet minimum four-year college eligibility requirements. Nonetheless, 63%, 68%, and 74% of Groups 4, 5, and 6, respectively, in the community college sample took math in 12th grade. In the CSUN sample, the percentage of Group 4 and Group 5 students who took math was higher (75% and 76%, respectively), and the percentage in Group 6 was similar (74%). Group 4 students tended to take Precalculus or Statistics, while Group 5 and 6 students usually took AP Calculus (AB or BC, respectively) or Statistics/AP Statistics.

In this report, we show the estimated effects of taking math, or taking a particular type of math course, for the community college sample in Groups 3, 4, and 5, and for the CSUN sample in Groups 4 and 5. We do not estimate effects for Group 3 CSUN students because nearly all CSUN students in that group took math in 12th grade, so we cannot reliably investigate the effects of *not* taking math for that group. We exclude students in Groups 1 and 2 from both the community college and CSUN analyses for the same reason. We also exclude analyses for Group 6 (i.e., students who, by the end of 11th grade, had taken two or more math courses beyond the college eligibility requirements) because this highly advanced course sequence has become increasingly uncommon in recent years.

We measure many student characteristics as of the end of 11th grade that could influence both students' 12th grade math course taking and their college-related outcomes, with the goal of comparing the college-related outcomes of students who were similar on these predictors but differed in whether or not they took 12th grade math, or in the type of math course they took. Table 4 lists these predictors.[12]

We then use various quasi-experimental methods, each of which makes different assumptions about how to equate students on these predictors. Finally, we perform sensitivity analyses that quantify how biased our results could potentially be. See Appendix B for a detailed description of the various estimation approaches we use, Appendix C for estimates from all the methods, and Appendix D for results of the sensitivity analyses.

We report results from a method that estimates each student's probability of taking 12th grade math using the predictors listed in Table 4, and then matches students who took 12th grade math to students who did not take 12th grade math but who had similar estimated probabilities of taking math in 12th grade.[13] We match students from the same school when possible, but when there are too few good matches within the same school, we match students who had similar estimated probabilities of taking 12th grade math but who were enrolled in different schools.[14] Then, we estimate the effects[15] of 12th grade math using Ordinary Least Squares (OLS) regression with the matched sample and using the same predictors (in Table 4) as regressors.[16]

Table 4. 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
	Science Credits Accumulated
	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
	Enrolled in a STEM-Focused School
	Advanced Math Courses Taken 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.

We show the effects of taking 12th grade math, compared to not taking 12th grade math, on various outcomes measured during the first two years of college, including: overall credit accumulation and GPA; credit accumulation and GPA in college-level math; credit accumulation and GPA in non-math STEM courses (i.e., only science, technology, and engineering courses); and getting a "head start" in college-level math (for community college students we define this as initial placement into college-level math and for CSUN students we define this as avoiding developmental math and/or Math 196 courses).[17] In addition, we compare the effects of different kinds of math courses on each of these outcomes when enough students took different types of math. For the analyses of the community college sample, we show effects within each student group separately. For the analysis of the CSUN sample, we analyze Groups 4 and 5 together because of the CSUN sample's relatively small size.

Results

1. Effects of Taking a 12th Grade Math Course

Table 5 reports the estimated effects of taking 12th grade math on students' progress and performance in the first two years of college.[18] We find that taking math in 12th grade appears to have helped Group 4 and 5 students accumulate more college-level math credits[19] – approximately 0.6 more credits on average in the first two years – in both the community college and CSUN samples, though the statistical significance of the positive estimate in the CSUN sample is sensitive to modeling and estimation choices (see Appendix C).[20] It is possible that taking math in 12th grade increased students' interest in, or feelings of self-confidence about, math coursework, which led them to take more math coursework in college. It is also possible, however, that the students who took 12th grade math did so because they planned to take math and STEM courses in college, which is something we are unable to measure in our data.[21]

At least part of the positive effect we find for math credit accumulation seems to be attributable to 12th grade math having given students a head start in accumulating college-level math credit. Table 5 shows that Groups 4 and 5 in the community college sample who took 12th grade math were approximately 6 to 7 percentage points more likely to start in college-level math than were similar peers who did not take math in 12th grade. Groups 4 and 5 in the CSUN sample who took 12th grade math were 12 percentage points more likely to avoid developmental math and Math 196 courses than were similar peers who did not take math in 12th grade. Because the community college students in our sample entered college before the implementation of AB 705, it seems likely that taking math in 12th grade helped prepare students for the math placement test at the start of community college, increasing the chances that they would be placed into college-level math. The effect we see in the first cohort of our CSUN sample probably arose for similar reasons (this cohort entered college before EO 1110). For our second cohort of CSUN students, taking 12th grade math (paired with high enough math test scores or a high enough high school math GPA) was one way to avoid Math 196 under CSU policy (Bracco et al., 2021). The positive results we find for math credit accumulation for community college students and CSUN students resemble Sepanik et al.'s (2022) findings that CSU students who took an additional quantitative reasoning course in high school were more likely to pass their first college math course.[22]

Despite accumulating more math credits, however, we do not find that students who took math in 12th grade earned higher overall GPAs or higher math GPAs in college than similar peers who did not take 12th grade math. And students who took 12th grade math may have earned slightly lower grades in their non-math STEM courses, though the statistical significance of these estimates is slightly sensitive to other modeling and estimation methods (see Appendix C). A possible explanation for this seemingly negative impact on non-math STEM grades is that students who took 12th grade math probably also took more challenging STEM courses in college than did their peers who did not take 12th grade math – we see descriptive evidence (in Appendix C) of that pattern for college *math* courses, so it is plausible that it also holds for other STEM courses.

Table 5. Estimated Effects of Taking Math in 12th Grade (Compared to Not Taking Math) on Community College and CSUN Outcomes

	Community College			CSUN
	Group 3	Group 4	Group 5	Groups 4-5
Overall				
Credits Accumulated	3.987**	1.361	0.653	-0.407
GPA	0.016	-0.015	-0.031	-0.087
College-Level Math				
Credits Accumulated	0.308*	0.575***	0.633***	0.634**
GPA	-	-0.059	0.035	-0.049
Non-Math STEM				
Credits Accumulated	0.603*	0.504*	0.260	0.674
GPA	-	-0.181*	-0.033	-0.155*
"Head Start" in College-Level Math				
Started in College-Level Math	0.003	0.057**	0.065*	NA
Avoided Developmental Math	NA	NA	NA	0.128***

Note: These results show point estimates and statistical significance from the "Cluster Matching with OLS" models, where standard errors have been clustered by school. We redact estimates for which the matching yielded poor covariate balance. For analysis of community college outcomes, we include school fixed effects as regressors, and for analysis of CSUN outcomes, we include school-level predictors. See Appendix B for more information. The Ns for each estimate are as follows: for credits accumulated (overall, college-level math, and non-math STEM), N=852 for community college Group 3, N=3,108 for community college Group 4, N=2,730 for community college Group 5, and N=1,920 for CSUN Groups 4-5; for overall GPA, N=879 for community college Group 3, N=3,119 for community college Group 4, N=2,785 for community college Group 5, and N=1,954 for CSUN Groups 4-5; for college-level math GPA, N=932 for community college Group 4, N=1,306 for community college Group 5, and N=1,552 for CSUN Groups 4-5; for non-math STEM GPA, N=1,257 for community college Group 4, N=1,429 for community college Group 5, and N=1,718 for CSUN Groups 4-5; and for starting in college-level math or avoiding developmental math, N=685 for community college Group 3, N=2,612 for community college Group 4, N=2,359 for community college Group 5, and N=1,865 for CSUN Groups 4-5. See Appendix C for Ns, standard errors, and results from all models. See Appendix Table A2 for more details on how we define all these outcomes. *p<0.05, **p<0.01, and ***p<0.001.

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

We also investigate the effects of taking particular types of 12th grade math courses on student outcomes. We only report these results for Groups 4 and 5 in the community college sample because we could not find sufficiently similar comparison groups of students taking different types of math courses in Group 3. For community college students in Group 4, we compare the outcomes of similar students who took *Precalculus* instead of Statistics, because those were the two most common courses taken by Group 4 students. For community college students in Group 5, we compare the outcomes of similar students who took *Calculus* instead of Statistics. For CSUN students in the combined Group 4 and 5 sample, we compare the outcomes of similar students who took *Precalculus or Calculus* instead of Statistics. We also investigate whether taking one of the non-traditional math courses in L.A. Unified (e.g., TCMS or IDS) was associated with improved high school or college outcomes compared to taking a more traditional math course (e.g., Precalculus or Statistics). We do not report results for these course comparisons here, however, because few students in our samples took the non-traditional courses, resulting in our preferred estimation approaches rarely finding well-

Table 6. Estimated Effects of Taking Statistics in 12th Grade (Compared to Precalculus/Calculus) on Community College and CSUN Outcomes

	Community College		CSUN
	Group 4	Group 5	Groups 4-5
Overall			
Credits Accumulated	0.014	1.186	0.253
GPA	-0.007	0.051	0.045
College-Level Math			
Credits Accumulated	-0.413	-1.652***	-1.092***
GPA	-	0.135	0.136
Non-Math STEM			
Credits Accumulated	-0.605	-0.370	-0.971*
GPA	-	0.174	0.034
"Head Start" in College-Level Math			
Started in College-Level Math	-0.091**	-0.167***	NA
Avoided Developmental Math	NA	NA	-0.034

Note: These results show point estimates and statistical significance from the "Cluster Matching with OLS" models, where standard errors have been clustered by school. We redact estimates for which the matching yielded poor covariate balance. For analysis of community college outcomes, we include school fixed effects as regressors, and for analysis of CSUN outcomes, we include school-level predictors. Note that for community college students we compare Precalculus to Statistics in Group 4 and Calculus to Statistics in Group 5. For CSUN students, we compare Precalculus or Calculus to Statistics. See Appendix B for more information. The Ns for each estimate are as follows: for credits accumulated (overall, college-level math, and non-math STEM), N=977 for community college Group 4, N=1,085 for community college Group 5, and N=1,209 for CSUN Groups 4-5; for overall GPA, N=985 for community college Group 4, N=1,129 for community college Group 5, and N=1,242 for CSUN Groups 4-5; for college-level math GPA, N=576 for community college Group 5 and N=966 for CSUN Groups 4-5; for non-math STEM GPA, N=596 for community college Group 5 and N=1,074 for CSUN Groups 4-5; and for starting in college-level math or avoiding developmental math, N=853 for community college Group 4, N=847 for community college Group 5, and N=1,130 for CSUN Groups 4-5. See Appendix C for Ns, standard errors, and results from all models. See Appendix Table A2 for more details on how we define all these outcomes.
*p<0.05, **p<0.01, and ***p<0.001.

balanced comparison groups. See Appendix C for results from alternative approaches for these comparisons.

Table 6 reports the estimated effects of taking Statistics in 12th grade instead of Precalculus or Calculus. We find that students who took Statistics in 12th grade earned fewer college-level math credits than similar students who took Calculus—about 1.6 fewer college-level math credits on average among Group 5 community college students and 1.1 fewer credits on average among Groups 4 and 5 at CSUN.[23] In community colleges, the result for Group 5 may be due in part to Statistics-takers having been less likely than otherwise similar Calculus-takers to get a head start in college-level math. We find that Group 5 students who took Statistics were over 16 percentage points less likely to start in college-level math than were similar students who took Calculus. We find a similar result for Group 4 students, despite the statistically insignificant effect of taking Statistics instead of Precalculus on credit accumulation—Group 4 students who took Statistics were about 9 percentage points less likely to start in college-level math than were similar students who took Precalculus. These results are likely driven by the math placement policies in effect when our sample started community college because the math placement exams used at the time included content more likely to be covered in Precalculus or Calculus courses than in Statistics (e.g., trigonometry).[24] It is also possible, however, that taking Statistics instead of Precalculus or Calculus did not prepare students as well for college-level math and STEM coursework, with the negative estimate on non-math STEM credits in CSUN being further evidence of this. Or, it is possible that 12th graders who took Precalculus or Calculus instead of Statistics did so because they intended to major in a STEM field,[25] and thus took more STEM courses in college—an explanation that our models cannot completely account for because we do not have data on high school students' intended major(s).[26]

We do not find a statistically significant effect of taking Statistics instead of Precalculus or Calculus on college-level math GPA, or any GPA outcome. As in the comparison of math versus no math, we suspect this is because students who took Statistics in 12th grade tended to take different courses in college than those who took Precalculus or Calculus in 12th grade. We see descriptive evidence for this in college-level math courses, with students who took Statistics in 12th grade being less likely than students who took Precalculus or Calculus to take Calculus-focused and higher-level math coursework in college (see Appendix C; see Mishra et al., n.d. for a discussion of community college math course-taking patterns).

Discussion and Conclusion

Using longitudinal data from the Los Angeles Unified School District, California community colleges, and California State University, Northridge, we find that students who took math in 12th grade accumulated more math credits during their first two years of college than otherwise similar peers who did not take math in 12th grade. Community college students who took math in 12th grade may have also accumulated more credits overall and more credits in non-math STEM courses. In addition, students who took Calculus in 12th grade accumulated more college math credits than similar peers who took Statistics in 12th grade. These effects are probably attributable, at least in part, to students being more likely to place out of the lowest-level math courses at their colleges after having taken 12th grade math, particularly after having taken Precalculus or Calculus. Despite these effects on students' college credit accumulation, we do not find positive effects on students' college grades.

This study has several limitations that future research should aim to overcome. First, we only had access to data from one four-year university (albeit one commonly attended by L.A. Unified students), so we must rely on other recent studies, such as Sepanik et al. (2022), for a sense of whether the results are likely to hold for students who attend other four-year universities. Second, our sample of students who took non-traditional math courses, such as Introduction to Data Science, was relatively small, so we were unable to compare the effects of traditional and non-traditional courses using our preferred method. Third, although we examined students' progress and grades during the first two years of college, the students in our cohorts have not yet aged enough to measure effects on four-year college graduation.[27] In addition, we lacked measures of some important predictors of math course taking in both high school and college, though our robustness tests suggest that the effects we find for at least some groups of students would likely hold even if we could measure those predictors.

Perhaps most important, all the community college students in our sample, and the first cohort of the CSUN students, experienced college math placement policies that differ from those in place today. Despite these changes, however, current math placement policies probably still benefit students who take 12th grade math because both the community colleges and the CSUs currently use high school math course taking, in combination with high school grades, to place students into their college math courses. Moreover, taking 12th grade math may be particularly beneficial in the CSUs under the current policy because some students can place out of math support courses by taking math in 12th grade (Bracco et al., 2021). Finally, because the recommended math placement policies for community college students with lower high school GPAs who plan to major in STEM strongly recommend additional support and concurrent courses for students who have not taken Precalculus or Calculus in high school (California Community Colleges, 2018), we suspect that the advantages we find of taking Calculus over Statistics probably continue to hold in the current policy environment.

Overall, the results in this report, taken together with the results in *Twelfth Grade Math and College Access* (Wainstein et al., 2023), strongly suggest that students have better college outcomes when they take math in 12th grade. They are more likely to enroll in a four-year college, to persist into a second year, to accumulate more math credits and, in some cases, to accumulate more overall credits and more non-math STEM credits, during their first two years of college. Additionally, we find that students also accumulate more math credits when they take Calculus instead of Statistics in 12th grade. However, the benefits we find for college credit accumulation of taking math in 12th grade versus not taking math, or taking Calculus instead of Statistics, may be due, at least in part, to better performance on now obsolete math placement tests. In the short term, these results imply that school staff and parents or guardians should encourage students to take math in their senior year and that policymakers and school leaders should make sure that their senior-year math course offerings are sufficient to enroll all students and varied enough to meet students' needs and interests. In the longer term, future research should build on these analyses to understand, in a broader set of universities, and under the new course placement policies, how taking 12th grade math, or taking certain types of math courses, affects students' college course taking, major choice, and degree completion.

Endnotes

1 It is also possible to "validate" these courses by earning a C or better in higher level courses, or by scoring high enough on certain college readiness tests (see University of California, 2021, for details).

2 These community college courses are more commonly referred to as "transfer-level," because some non-transfer-level math courses count toward an associate degree (Melguizo et al., 2014). However, we use the term "college-level" to maintain consistency with how we refer to CSUN courses that count toward a bachelor's degree.

3 To be placed into a math course without a co-requisite or support course, CSUN students in our second cohort who planned to enroll in Precalculus (Math 102), Mathematical Methods for Business (Math 103), Trigonometry and Analytic Geometry (Math 104), Precalculus II (Math 105), Calculus (Math 150A), or Calculus for the Life Sciences (Math 255A) were required to receive a minimum score on the Math Placement Test (MPT) in addition to meeting at least one of the multiple measures requirements (CSUN, 2018).

4 See Bracco et al. (2021) for a detailed overview of how CSUs use these measures to place students.

5 During the period of our study, CSUN offered Math 196S for students in STEM majors and Math 196QR for students in non-STEM majors (Bracco et al., 2019). CSUN offered two Math 196P courses, one meant for STEM majors and another meant for non-STEM majors, in the summer before students' freshman year through the Early Start program (CSUN, n.d.a). Kurlaender et al. (2020) found no benefit for students participating in this program relative to students who started directly in college-level math without participating in the program.

6 The L.A. Unified data do not include students from independent charter schools, so our samples only include students from traditional schools (i.e., district operated non-charter schools) and affiliated charter schools (i.e., charter schools operated by the school district). We drop from our samples students 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 differ substantially from those of students in traditional schools. 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. In the community college sample, we also exclude students who did not receive a letter grade in a credit-bearing course in their first two years of college or who enrolled in a four-year university for the first time in the same semester in which they first enrolled in community college (if those students enrolled in CSUN, we include them in our CSUN sample). In the CSUN sample, we exclude students who did not receive a letter grade in a credit-bearing course in their first two years of college. See Appendix A for details.

7 Appendix A compares these samples with all L.A. Unified first-time 11th graders.

8 California students take math and English language arts tests developed by the Smarter Balanced Assessment Consortium (SBAC). These tests are part of the state's Assessment of Student Performance and Progress (CAASPP).

9 In *Twelfth Grade Math and College Access*, we found math course-taking patterns for all first-time 11th graders in 2015-16 and 2016-17 that fell in between these numbers. Among that larger sample, 65% took a full year of math in 12th grade, 24% took no math whatsoever, and around 10% enrolled in a single semester of math (for details, see Wainstein et al., 2023).

10 TCMS covers a mix of math and statistics topics through application to real-world problems (L.A. Unified, 2017). These include 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).

11 IDS introduces students to data analysis and computer coding, and is focused on preparing students for statistics, biology, social science, and law careers (L.A. Unified, 2020). See Wainstein et al. (2023) for analogous percentages for a broader sample of L.A. Unified 12th graders.

12 For details on each of these predictors, see Appendix Table A1.

13 Specifically, we find non-math-takers whose estimated probabilities of taking math were close to those of the math-takers and we find math-takers whose estimated probabilities of not taking math resembled those of the non-math-takers. By combining these two sets of matches, we estimate the average treatment effect (ATE) of taking math in 12th grade.

14 More formally, we first estimate propensity scores and then use "preferential within-cluster matching" (Arpino & Cannas, 2016) to match each math-taker with at most five non-math-takers, and vice versa. For our community college analysis, we include fixed effects for high schools in the propensity score models. For our CSUN analysis, we exchange school fixed effects with school-level predictors that are described in Appendix Table A1, because those models achieve better balance between math-takers and non-math-takers. When matching, we use a caliper of 0.05 or 0.10 (Lunt, 2014), and we exclude students from the treatment group whose propensity scores were much higher or lower than those in the control group, and vice versa (Lechner & Strittmatter, 2019). See Appendix B for details.

15 We describe statistically significant estimates as "effects" in the interest of narrative simplicity and discuss their sizes. However, readers should keep in mind that these estimates are quasi-experimental, and thus cannot account for all the factors that might influence 12th grade math course taking and college progression and performance. Thus, all the estimates we report are probably still somewhat biased estimates of the true effects of taking math in 12th grade. We only emphasize findings that are consistent across the various methods we try, and we also calculate how robust our estimated effects are to omitted predictors.

16 This estimation strategy is "doubly robust" (Ho et al., 2007). This means that our estimates are consistent if we have correctly modeled the probability of taking 12th grade math or the outcome of interest.

17 We use Cal-PASS Plus community college and CSUN transcripts data to calculate credits accumulated, GPAs, and initial math placements. In Appendix C, we report results for supplemental outcomes at community colleges: degree-applicable math credit accumulation, degree-applicable math GPA, and starting in degree-applicable math. See Appendix Table A2 for details on how we measure all these outcomes. We had also hoped to examine persistence in a STEM major, i.e., whether taking math in 12th grade was associated with STEM-intending students continuing to major in STEM by the end of their second year of college. However, too few students in our data started college as a STEM major to find well-balanced comparison groups.

18 Note that this table excludes estimates of the effects of 12th grade math on college-level math and non-math STEM GPAs for Group 3 students in the community college sample because too few of these students had data on these outcomes, and thus we could not construct sufficiently similar comparison groups of students.

19 We also estimate a positive effect for college-level math credits among Group 3 community college students. However, the statistical significance of this estimate is sensitive to other modeling and estimation choices (see Appendix C). This is also true of the positive estimated effects for overall and non-math STEM credits among Group 3 community college students.

20 Because our estimated effects on credits are averages and community college and CSUN courses are typically worth three credits, one way of thinking about a 0.6 average increase in credits accumulated is that one out of every five students from Group 4 or 5 would have taken, and passed, one additional college-level math course in their first two years of college had all students taken 12th grade math.

21 Math standardized test scores, math GPA, high school science credits accumulated, and the indicator of enrolling in a STEM-focused school probably capture much of the variation in whether a student intended to take math and science courses in college, given that students with higher high school achievement in STEM subjects are more likely to major in STEM. But we undoubtedly still lack important predictors of math taking in high school and college, such as interest in math or in STEM-related subjects. In Appendix D, we employ the method introduced by Cinelli & Hazlett (2020) to assess the sensitivity of our estimates to unobserved predictors, such as intended major, that we cannot account for and that influence both math course taking and the outcomes we examine. Using the strength of our academic predictors to benchmark the hypothetical strength of a set of unobserved predictors, we find that the positive and statistically significant estimate of taking math on college-level math credit accumulation for community college Group 4 students is the most robust finding – to render an unmatched OLS estimated effect statistically insignificant (at the 0.05 level), unobserved predictors would need to be about one-third as predictive as all the academic predictors taken together. The college-level math credit accumulation results are less robust for Groups 3 and 5 in community college, and for Groups 4 and 5 in CSUN. Unobserved predictors would only need to be about one thirtieth (i.e., 0.03 times) as strong as the academic predictors taken together for the effect of taking math on college-level math credits earned among Group 3 community college students to be statistically insignificant, which seems likely. Among Group 5 community college students, unobserved predictors would need to be about a tenth as strong as the academic predictors taken together for the effect of taking math to be statistically insignificant, which is plausible. In CSUN, we find that the statistical significance of the estimated effect is sensitive to other modeling and estimation choices (see Appendix C) even before considering bias due to unobserved predictors. Note that this is also the case with Group 3 students in community college. Therefore, we cannot be sure that taking 12th grade math truly had a positive effect on college-level math credit accumulation. However, because our set of academic predictors is quite comprehensive, we suspect that taking math in 12th grade was indeed beneficial for college-level math credit accumulation for Group 4 community college students.

22 Note that Stepanik et al. (2022) adjust for whether students scored proficient or above in mathematics on the 11th grade SBAC, students' high school grade point average in math, and whether students were chronically absent.

23 Given that community college and CSUN courses are typically worth three credits, we might interpret a 1.6 credit difference as one in every two students taking and passing one fewer college-level math course, and the 1.1 credit difference as one in every three students taking and passing one fewer college-level math course.

24 See Rodriquez et al. (2016) for information on community colleges' math placement tests. CSUN used an internally-developed placement test consisting of algebra and trigonometry problems (CSUN, n.d.c).

25 Findings from a nationally representative sample of 9th graders suggest that STEM-intending students are more likely to take Precalculus by the end of high school than their non-STEM intending peers (Holian & Kelly, 2020).

26 Our robustness tests in Appendix D suggest that the college-level math credit accumulation results for community college Group 5 students and CSUN Group 4 and 5 students are fairly robust. To render an unmatched OLS estimated effect statistically insignificant (at the 0.05 level), unobserved predictors would need to be over two-fifths as predictive as all the academic predictors taken together, which seems unlikely given the comprehensiveness of our academic predictors.

27 Education researchers typically measure whether students graduated from a four-year college within six years of high school graduation, and that amount of time has not yet elapsed for students in our sample.

References

Aughinbaugh, A. (2012). The effects of high school math curriculum on college attendance: Evidence from the NLSY97. *Economics of Education Review*, *31*(6), 861-870. https://doi.org/10.1016/j.econedurev.2012.06.004

Arpino, B. & Cannas, M. (2016). Propensity score matching with clustered data. An application to the estimation of the impact of caesarean section on the Apgar score. *Statistics in Medicine*, *35*(12), 2074-2091. https://doi.org/10.1002/sim.6880

Bracco, K. R., Huang, C.-W., Fong, T., & Finkelstein, N. (2021) *Using multiple measures to predict success in students' first college math courses: An examination of multiple measures under Executive Order 1110 in the California State University system*. WestEd. Retrieved 6/13/22 from https://www.wested.org/wp-content/uploads/2021/07/EO_1110_Multiple-Measures_508.pdf

Bracco, K. R., Schrager, C., Calisi, G., Gutierrez, P., Salciccioli, M., & Finkelstein, N. (2019). *College-ready in the California State University system*. WestEd. Retrieved 6/13/22 from https://files.eric.ed.gov/fulltext/ED595731.pdf

Burdman, P. (2022, May 17). California students need more high-quality advanced math options. *EdSource*. https://edsource.org/2022/california-students-need-more-high-quality-advanced-math-options/672532

Byun, S. Y., Irvin, M. J., & Bell, B. A. (2015). Advanced math course taking: Effects on math achievement and college enrollment. *Journal of Experimental Education*, *83*(4), 439-468. https://doi.org/10.1080/00220973.2014.919570

California Community Colleges. (2018). *Multiple measures*. Retrieved 6/13/22 from https://assessment.cccco.edu/what-are-multiple-measures

California State University. (2017). *CSU placement of first year students based on academic preparation*. Retrieved 6/13/22 from https://calstate.policystat.com/doc_attachment/view/18089713/MTgwODk3MTM:1qRJrX:ZW5jPirz8NiSrcIV6_h580q3agRBBgH5uDUG0F6apVI/CSU%2520Placement%2520of%2520First%2520Year%2520Students%2520Based%2520on%2520Academic%2520Preparation.pdf

California State University. (2020). *Proposal to modify first-year admissions requirements*. Retrieved 08/26/21 from https://ahed.assembly.ca.gov/sites/ahed.assembly.ca.gov/files/hearings/CSU%20Proposal%20to%20Modify%20First%20Year%20Admission%20Requirements%20QR%20Fact%20Sheet.pdf

California State University Northridge. (2018). University catalog 2018 – 2019: Mathematics placement test (MPT). Retrieved 1/25/23 from https://catalog.csun.edu/archive/2018/policies/mathematics-placement-test-mpt/index.html

California State University Northridge. (n.d.a). *Pathways to excellence*. Retrieved 6/13/22 from https://www.csun.edu/prospective-students/early-start-program

California State University Northridge. (n.d.b). *B4 – Mathematics and quantitative reasoning – courses*. Retrieved 06/09/22 from https://catalog.csun.edu/general_education/b4/

California State University Northridge. (n.d.c). *Mathematics placement test (MPT)*. Retrieved 01/24/23 from https://catalog.csun.edu/policies/mathematics-placement-test-mpt/

Cinelli, C. & Hazlett, C. (2020). Making sense of sensitivity: Extending omitted variable bias. *Journal of the Royal Statistical Society: Statistical Methodology (Series B)*, *82*(1), 39-67. https://doi.org/10.1111/rssb.12348

Federman, M. (2007). State graduation requirements, high school course taking, and choosing a technical college major. *The B.E. Journal of Economic Analysis & Policy*, *7*(1). https://doi.org/10.2202/1935-1682.1521

Ford, R. (2022, June 22). Proposed mathematics pathways for California high school students raise equity concerns. *EdSource*. https://edsource.org/2022/proposed-mathematics-pathways-for-california-high-school-students-raise-equity-concerns/674400

Goodman, J. (2019). The labor of division: Returns to compulsory high school math coursework. *Journal of Labor Economics*, *37*(4), 1141-1182. https://www.doi.org/10.1086/703135

Gordon, L., & Burke, M. (2019, November 8). California State University proposes to delay extra year of high school math to 2027. *EdSource*. https://edsource.org/2019/california-state-university-delays-proposal-for-extra-year-of-high-school-math-to-2027/619758

Ho, D. E., Imai, K., King, G., & Stuart, E. A. (2007). Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Political Analysis*, *15*(3), 199-236. https://doi.org/10.1093/pan/mpl013

Holian, L., & Kelly, E. (2020). *STEM occupational intentions and stability and change through high school*. (NCES 2020-167). Washington, DC: U.S. Department of Education. https://files.eric.ed.gov/fulltext/ED605916.pdf

Joensen, J. S., & Nielsen, H. S. (2009). Is there a causal effect of high school math on labor market outcomes? *The Journal of Human Resources*, *44*(1), 171-198. https://doi.org/10.3368/jhr.44.1.171

Kurlaender, M., Lusher, L., & Case, M. (2020). Is early start a better start? Evaluating California State University's early start remediation policy. *Journal of Policy Analysis and Management*, *39*(2), 348-374. https://doi.org/10.1002/pam.22198

Lechner, M. & Strittmatter, A. (2019). Practical procedures to deal with common support problems in matching estimation. *Econometric Reviews*, *38*(2), 193-207. https://doi.org/10.1080/07474938.2017.1318509

Levitt, S., Severts, J., Barak, B., & Mims, A. (2022). Rethinking math education: Educators differ on curriculum and methods. *Education Next*, *22*(4), 66-71.

Long, M. C., Conger, D., & Iatarola, P. (2012). Effects of high school course-taking on secondary and postsecondary success. *American Educational Research Journal*, *49*(2), 285-322. https://doi.org/10.3102/0002831211431952

Long, M. C., Iatarola, P., & Conger, D. (2009). Explaining gaps in readiness for college-level math: The role of high school courses. *Education Finance and Policy*, *4*(1), 1-33. https://doi.org/10.1162/edfp.2009.4.1.1

Los Angeles Unified School District. (2017). Transition to College Mathematics and Statistics. https://achieve.lausd.net/cms/lib/CA01000043/Centricity/domain/244/sec%20professional%20development/tcms/TCMS%20IOC_1_10_18.pdf

Los Angeles Unified School District. (2020). Intent to offer Introduction to Data Science (IDS), Transition to College Math and Statistics (TCMS), and/or Financial Algebra. Retrieved from https://achieve.lausd.net/cms/lib/CA01000043/Centricity/Domain/244/Intent%20to%20Offer%20Alternative%20Math%20Courses%202020-2021.pdf

Lunt, M. (2014). Selecting an appropriate caliper can be essential for achieving good balance with propensity score matching. *American Journal of Epidemiology*, *179*(2), 226-235. https://doi.org/10.1093/aje/kwt212

Melguizo, T., Koseiwicz, H., Prather, G., & Bos., J. (2014). How are community college students assessed and placed into developmental math? Grounding our understanding in reality. *The Journal of Higher Education*, *85*(5), 691-722. https://doi.org/10.1080/00221546.2014.11777345

Melguizo, T., Bos, J., Prather, G., Kosiewicz, H., Fong, K., & Ngo, F. (2015). *Assessment and placement policies and practices in developmental math: Evidence from experimentation in a large urban community college district in California*. Pullias Center for Higher Education, Rossier School of Education, University of Southern California. Retrieved 6/13/22 from https://pullias.usc.edu/wp-content/uploads/2016/01/luccd-final.pdf

Miller, S. R. (1998). Shortcut: High school grades as a signal of human capital. *Educational Evaluation and Policy Analysis*, *20*(4), 299-311. https://doi.org/10.3102/01623737020004299

Mishra, S., Swanson, E., Yucel, E. A., Ngo, F., Melguizo, T., & Ching, C. (Under Review). *STEM sorting: Unintended consequences of math pathways expansion in community colleges*. Pullias Center for Higher Education. Rossier School of Education, University of Southern California.

Murnane, R. J., Willet, J. B., Duhaldeborde, Y., & Tyler, J. H. (2000). How important are the cognitive skills of teenagers in predicting subsequent earnings? *Journal of Policy Analysis and Management*, *19*(4), 547-568.

Phillips, M., Yamashiro, K., & Jacobson, T. A. (2017). *College going in LAUSD: An analysis of college enrollment, persistence, and completion patterns*. Los Angeles Education Research Institute. Retrieved 3/13/23 from https://laeri.luskin.ucla.edu/wp-content/uploads/sites/22/2019/11/laericollegegoing082017.pdf

Rodriquez, O., Cuellar Mejia, M., & Johnson, H. (2016). *Determining college readiness in California's community colleges: A survey of assessment and placement policies*. Public Policy Institute of California. https://www.ppic.org/wp-content/uploads/content/pubs/report/R_1116ORR.pdf

Roth, J., Crans, G. G., Carter, R. L., Ariet, M., & Resnick, M. B. (2001). Effect of high school course-taking and grades on passing a college placement test. *The High School Journal*, *84*(2), 72-87.

Rose, H., & Betts, J. R. (2004). The effect of high school courses on earnings. *The Review of Economics and Statistics*, *86*(2), 497-513. https://doi.org/10.1162/003465304323031076

Sepanik, S., Ratledge, A., Shane, A., Dixon, M., & Martin-Lawrence, A. (2022). A look at California State University admissions requirements: How an additional quantitative reasoning course could affect student access and success. MDRC. https://www.calstate.edu/impact-of-the-csu/student-success/academic-preparation-quantitative-scientific-and-data-literacy/Documents/independent-study-november-2022-report.pdf

Smith, A.A. (2022, November 15). CSU will abandon proposal to create fourth year math requirement for admission. *EdSource*. https://edsource.org/2022/csu-will-abandon-proposal-to-create-fourth-year-math-requirement-for-admission/681359

Trusty, J. (2002). Effects of high school course-taking and other variables on choice of science and mathematics college majors. *Journal of Counseling & Development*, *80*(4), 464-474. https://doi.org/10.1002/j.1556-6678.2002.tb00213.x

University of California. (2021). *CSU-UC comparison of minimum freshman admission requirements*. Retrieved 08/26/21 from https://admission.universityofcalifornia.edu/counselors/_files/documents/csu-uc-a-g-comparison-matrix.pdf

Wainstein, L., Miller, C. E., Phillips, M., Yamashiro, K., & Melguizo, T. (2023). *Twelfth grade math and college access*. Los Angeles Education Research Institute. Retrieved 3/13/23 from https://laeri.luskin.ucla.edu/wp-content/uploads/sites/22/2022/12/LAERITwelfthGradeMathandCollegeAccessReport121522.pdf

The Los Angeles Education Research Institute (LAERI) conducts research to inform solutions to educational challenges facing Los Angeles.

UCLA Los Angeles Education Research Institute

laeri.luskin.ucla.edu
laeri@g.ucla.edu
@LAEdResearch
@LAEdResearchInstitute

UCLA Luskin School of Public Affairs
6241, Public Affairs Building
Los Angeles, CA 90095-1656