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February 2023

PACE
Policy Analysis for California Education

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Acknowledgements

This research was supported by the College Futures Foundation through grants to Education Insights Center (EdInsights) at Sacramento State University and the California Education Lab at the University of California, Davis; by UC Office of the President, Multicampus Research Programs and Initiatives, through grant M21PR3278; and by the Institute of Education Sciences, U.S. Department of Education, through Grant R305E150006 to the Regents of the University of California. Analysis of these data is made possible through a research partnership and data-sharing agreement with the California Department of Education (Michal Kurlaender, principal investigator). The authors are grateful to Maureen Carew, Andrea Venezia, and Pamela Burdman for their expertise, guidance, and review of research.

This report, like all PACE publications, has been thoroughly reviewed for factual accuracy and research integrity. The authors assume full responsibility for the accuracy of the report contents.

Suggested Citation
Reed, S., Bracco, K., Kurlaender, M., & Merritt, C. (2023, February). *Innovating high school math through K–12 and higher education partnerships* [Report]. Policy Analysis for California Education. edpolicyinca.org/publications/innovating-high-school-math-courses-through-k12higher-education-partnership

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Executive Summary

Despite clear evidence of the benefits of taking advanced math courses in high school, access to and success in these courses are not experienced equally. Only about half of California high school seniors enroll in an advanced math course, and nearly one-quarter of seniors do not take any math. To increase equitable access to advanced math, six partnerships between university faculty and high school math specialists have developed advanced innovative math (AIM) courses as viable alternatives to traditional 12th-grade math courses. This report highlights the ways in which these partnerships demonstrate and benefit from the common features of successful intersegmental partnerships.

- **Investment of state resources:** Five partnerships were awarded grants through the California Mathematics Readiness Challenge Initiative; six received financial support from private foundations.
- **Shared purpose:** Driving the work is a shared belief that many students are not well served by existing math courses. AIM courses, although varying in content, use a common student-centered pedagogy with the goal of increasing students' confidence in quantitative reasoning.
- **Commitment to equity:** The shared purpose is grounded in commitment to equity, with courses targeting students who might not otherwise enroll in math during their senior year. This commitment to equity is evidenced by course enrollment that is representative of the racial and socioeconomic diversity in participating districts.
- **Community building:** The partnerships create community across institutions through ongoing professional development and professional learning communities. Teachers value the support, collaboration, iteration, and camaraderie.
- **Capacity development:** Teachers gain skills and confidence in novel instructional strategies and report using some of these strategies in their other courses.
- **Improved educational outcomes:** Quantitative analysis indicates that enrollment in an AIM course increases the likelihood that students will complete course requirements for California State University or University of California eligibility by 3–10 percentage points, and, in some cases, improves high school math grades. Enrollment in an AIM course also increases the likelihood of attending college.

Although evidence clearly indicates success for these intersegmental partnership efforts, truly innovating and diversifying advanced math pathways for high school students requires continued investments of political will and financial resources as well as ongoing coordination among segments of the education system.

Introduction

A critical factor for success in postsecondary education and the labor market is academic preparation for college-level coursework (Howell et al., 2010; Long et al., 2012; Rose & Betts, 2004). Taking advanced math courses during high school is positively associated with enrolling in college (Dougherty et al., 2017; Kim et al., 2015; Long et al., 2012), completing college (Adelman, 1999, 2006; Smith et al., 2017), and earning higher incomes (Rose & Betts, 2004). Advanced course-taking facilitates access to and success in college and career by serving as a signal of the potential candidate's skills to college admissions officers and employers, and by supporting the development of the quantitative skills and knowledge necessary for college and career success (Kurlaender et al., 2019). Moreover, a recent study of Los Angeles Unified School District graduates found that enrollment in a math course during 12th grade has a positive impact on college eligibility, enrollment, and persistence (Wainstein et al., 2023). Despite clear evidence of the benefits of math course-taking in high school, only about half of all California high school students enroll in an advanced math course during their senior year, and nearly 25 percent do not take any math (Asim et al., 2019; Reed et al., 2023). Access to advanced math courses is not equally distributed, with Asian American and White students overrepresented in higher level math courses and Black, Latinx, and socioeconomically disadvantaged students overrepresented in lower level math courses (Asim et al., 2019; Reed et al., 2023).

Disparities in advanced math course-taking and readiness for college-level math are the result of systemic inequalities in educational opportunity. The shortage of highly qualified math and science teachers as well as an inequitable distribution of resources often limit students' access to high-quality, engaging math instruction during the early and middle grades, resulting in many being poorly prepared for more advanced courses (Ingersoll & Perda, 2010; Liu et al., 2008; Ronfeldt et al., 2013; Sutcher et al., 2019). In high school, course availability and academic supports that ensure success depend on which schools students attend, with schools that primarily serve low-income students offering fewer advanced courses and fewer resources for college preparation (Adelman, 1999; Conger et al., 2009; Monk & Haller, 1993; Schreiber, 2002). Disparities in advanced math course-taking within schools may also be the result of unequal advising, outdated placement practices, and ill-planned course scheduling (Attewell & Domina, 2008; Gamoran, 1987).

To increase equitable access to advanced math, several intersegmental partnerships between university faculty and high school math specialists are developing and implementing high school math courses as alternatives to traditional advanced math courses (Bracco et al., 2018; Friedmann, 2017). These courses aim to increase students' confidence in quantitative reasoning and mathematical problem-solving as well as to demonstrate a greater relevance of math in everyday life to help students succeed in postsecondary education and beyond. The alternative courses specifically target students with college-going aspirations who might not otherwise enroll in a math course during their senior year, whether because of lack of confidence and interest in math or as a result of poor advising and course placement.

Drawing on extensive qualitative research with the higher education faculty who led the course development and the K–12 math teachers who facilitated the courses, this report highlights the efforts of six partnerships to implement advanced innovative math (AIM) courses designed for high school seniors. We examine these efforts through a lens of intersegmental partnership to understand better the critical elements of implementation. This report describes the reach of these courses, the characteristics of enrolled students, and early evidence of the courses' impact on student outcomes. The report is accompanied by six case studies that further detail the work of each partnership and the students it serves. Together, the report and case studies provide evidence for policymakers and education leaders of the potential to innovate around college-preparation coursework in math, the experiences of K–12 math educators, and areas for continuing collaboration between K–12 and higher education.

Qualitative Research

Qualitative research includes interviews with project directors and high school teachers, using semistructured protocols. Researchers interviewed project directors from each of the six partnerships at the launch of the project and in two follow-up discussions about course goals, implementation, enrollments, and student outcomes.

Teacher perceptions were drawn from interviews with 20 teachers from 20 different high schools implementing the partnership courses. Teacher interviews were recorded and transcribed, then coded and analyzed.

Descriptive Statistics

Statistics were calculated from course-level data in the California Longitudinal Pupil Achievement Data System (CALPADS), which was made available to the research team through a partnership and data-sharing agreement with the California Department of Education (Michal Kurlaender, principal investigator).

Policy Context for Improved Preparation for College-Level Mathematics

Efforts to increase math course-taking among high school students have long been a central focus in college- and career-readiness initiatives. During the past several decades, educators have debated the timing of algebra (Loveless, 2008, 2013) as well as what types and sequence of math courses in high school are necessary for college readiness and success (ACT, 2007; Bozick & Ingels, 2008). Much of that research has met with mixed results. For example, the acceleration research is not conclusive as to whether eighth-grade algebra has a positive or negative impact on longer term outcomes (Clotfelter et al., 2015; Domina et al., 2015;

Heppen et al., 2011; Loveless, 2008). In other efforts, nearly 60 percent of California public school districts have augmented their graduation requirements with a third and sometimes fourth year of math, although California standards require only 2 years of math to graduate (Gao, 2021). The state's 4-year university systems, California State University (CSU) and the University of California (UC), require 3 years of high school mathematics for admission and recommend a fourth year.[1] CSU recently considered revisions to its admission criteria that would formally require students to complete an additional yearlong course in quantitative reasoning in high school (including math, science, or computer science) to be eligible for admission (Smith, 2022). Although the proposal ultimately was not approved, it spurred conversations about the need to increase and equalize access to math course-taking for high school seniors throughout the state.

High school math course-taking traditionally follows a sequence leading to calculus as a capstone course for seniors bound for 4-year colleges (Burdman et al., 2021). However, there is much debate about the necessity of calculus—and the sequence of courses leading to it—as preparation for college-level math. Calculus often acts as a gatekeeper for 4-year college admissions, especially for highly selective colleges or programs (National Council of Teachers of Mathematics, 2022). Although some K–12 educators and college faculty argue that calculus provides a strong foundation for higher education, especially for students hoping to major in science, technology, engineering, and math (STEM) fields, critics of the calculus-focused pathway stress that for many students entering diverse non-STEM fields, topics like statistics, data analysis, and computer science may be more relevant (Academic Senate of the California State University, 2016; Burdman et al., 2021). Educators and researchers have increasingly advocated for greater diversity in high school math courses to support the development of quantitative literacy for all students and to ensure that courses other than calculus also lead to college preparation, even for the state's more selective 4-year colleges and universities (Burdman, 2015; Burdman et al., 2018; Charles A. Data Center, 2020; Daro & Asturias, 2019; National Council of Teachers of Mathematics, 2018). This expanded diversity in math courses is reflected in the proposed revisions to the *Mathematics Framework for California Public Schools: Kindergarten Through Grade 12*, which has been the subject of much active debate[2] but is expected to be adopted by the State Board of Education in 2023, following further review and revisions (California Department of Education, 2022).

[1] See the admissions requirements for the California State University at calstate.edu/apply/freshman/getting_into_the_csu/pages/admission-requirements.aspx and for the University of California at admission.universityofcalifornia.edu/admission-requirements/freshman-requirements

[2] For more about the controversy surrounding the proposed Mathematics Framework, see calmatters.org/education/k-12-education/2021/11/california-math/ and edsource.org/2022/california-revises-new-math-framework-to-keep-backlash-at-bay/669010

Intersegmental Partnership as a Lever for Improvement

Prior research indicates that collaboration among education sectors can increase student engagement, high school completion, and college enrollment (Domina & Ruzek, 2012; Friedmann, 2017; Rippner, 2017). Intersegmental partnerships that successfully attain these outcomes share some common features (Reed et al., 2018, 2019):

- investment of financial and human capital,
- shared purpose among partners,
- commitment to equity,
- community built on trust and collaboration, and
- improved outcomes for students.

Leaders of intersegmental collaboration assert that investing in the development of leadership capacity and directing funds to sustain collaboration and provide continuity are critical conditions for the success of these partnerships (Reed et al., 2019). Effective intersegmental partnerships are also grounded in a shared purpose aimed at addressing a clearly articulated problem of practice that can be solved only through the coordination of multiple organizations (Reed et al., 2018, 2019). This shared purpose serves as a foundation on which to build community and trust, create cohesion, and strengthen sustainability. Perhaps most important, education leaders with extensive experience facilitating intersegmental partnerships agree that "realization of improved outcomes through intersegmental collaboration requires an unwavering equity focus" (Reed et al., 2019). It is through this framework that we investigate efforts by high school and higher education faculty to partner on innovating advanced high school math courses.

Innovating High School Math Through Intersegmental Partnerships

In this report, we feature six intersegmental partnerships formed to develop and implement AIM courses. The partnerships were selected for this study because of their participation in a professional learning community facilitated by the researchers and their colleagues from Education Insights Center. Table 1 provides key information about each partnership, including the name of the AIM course that it developed, the university leading the partnership, the number of districts implementing the course, and the share of the 12th-grade cohort in those districts that enrolled in the course for the 2018–19 academic year. Although only 2.3 percent of 12th graders statewide enrolled in these innovative courses in 2018–19, participation rates ranged from 12–19 percent of seniors in districts where the courses were offered. Moreover, course developers and partner districts report that since 2018–19, the number of districts and/or schools adopting the courses and the number of students enrolling continues to grow. For more information on the pedagogy and content of each course, see the case studies available on the PACE website at edpolicyinca.org/publications/innovating-high-school-math-courses-through-k12higher-education-partnership.

Table 1. Advanced Innovative Math Courses, Partners, and 12th-Grade Enrollment, 2018–19

AIM course	University—lead partner	Number of K–12 districts	Number of students	Percentage of cohort
Discrete Math for Pre-College Students (DMPC)	San Diego State University	3	1,066	12
Introduction to Data Science (IDS)	University of California, Los Angeles	12	1,558	16
Mathematical Reasoning With Connections (MRWC)	Cal Poly Pomona	17	2,756	16
Quantitative Reasoning With Advanced Mathematical Topics (QRAT)	Sacramento State University	15	1,093	13
Transition to College Math and Statistics (TCMS)	California State University, Northridge	1	2,437	19
Transition to College-Level Math (TCLM)	California State University, Monterey Bay	5	99	14

Note. Rates were calculated by aggregating the number of seniors in the schools offering each course.

We examine the experiences of course developers and teachers in these partnerships to understand better the factors that support intersegmental collaboration and innovation of math pathways as well as to inform further efforts to increase, expand, and diversify math courses. In the following sections, we highlight the ways in which these partnerships demonstrate many of the common features of successful intersegmental partnerships identified in the literature.

Investment of State Resources

In 2016–17, then-Governor Jerry Brown's budget proposed the use of $3 million in federal carryover funds for a competition to "create a grade 12 mathematics course that would prepare students for college-level schools and CSU campuses" (Brown, 2016). From this proposal, the California Department of Education created the California Mathematics Readiness Challenge Initiative (CMRCI)[3] and invited applicants to

> provide in-depth professional learning opportunities in mathematics for collaborative teams of secondary educators, their school-site administrator, and faculty from their partner IHEs [institutions of higher education] to support the implementation and evaluation of grade twelve experiences that are designed to prepare pupils for placement into college-level courses in mathematics. (California Department of Education, 2016)

[3] For more information on this program, see cde.ca.gov/pd/ps/itqsahe.asp.

Although it did not specifically call for creating new courses, the request for applications emphasized a partnership approach to

> adapt and/or develop grade twelve experiences that focus on the needs of students who have completed three years of college-preparatory mathematics courses but are not expected to be deemed ready for college-level mathematics courses upon matriculation to a postsecondary educational institution. (California Department of Education, 2016)

Five of the six partnerships in this study were awarded CMRCI grants, and although some already had courses in place, others developed new courses as a result. All six partnerships received additional financial support from private foundations.

Shared Purpose

Driving the work of the partnerships is a shared belief, clearly articulated by one partnership leader, that "a lot of students are not well served … by the existing math courses such as calc, pre-calc, and statistics." At present, far too few high school seniors enroll in advanced mathematics courses that would adequately prepare them for college-level math in different fields of study. Only about half of high school seniors take a math course beyond Algebra 2, and 25 percent do not enroll in any math course (Asim et al., 2019; Reed et al., 2023). There are multiple reasons why students do not enroll in advanced math courses in high school, including but not limited to poor experience in previous courses, lack of access to course options in a hierarchical sequence in math, school scheduling conflicts, poor advising, low high school graduation requirements, and/or misinformation about college admissions and major requirements. As such, most of the partnerships aim to implement courses that provide a viable alternative for 12th-grade students who want to pursue postsecondary education but may not be interested in or have access to traditional advanced math courses in their senior year. With one exception (Introduction to Data Science), these courses target students who have completed Algebra 2 or Integrated Math III but who may not wish to continue on the calculus track.

Developing an alternative 12th-grade math course goes beyond simply offering an additional class. Interviews with course developers indicated that AIM courses offer a different perspective on and way of engaging with math. A course developer described this: "[We are] trying to design [courses based on] what integrated/interconnected math really looks like. We want students to think about and understand how interconnected math is."

This integrated approach to math shows up in both the content and pedagogy of the courses. The six courses vary in content, covering both traditional and new topics, such as data science, computer science, statistics, and game theory among others (see the case studies on the PACE website for more details). Despite the differing content, the six courses are grounded in

a common student-centered pedagogy emphasizing collaboration and problem-solving. Rather than take the traditional "sage on the stage" approach, teachers encourage students to work together to figure out how and why to approach a problem, here described by one teacher:

> *There is a lot more collaboration with students. There's a lot more [of me as a teacher trying] to get that conceptual understanding before [the students] do the procedures. "Can you figure out what the whole point to this is before I even tell you?"*

Teachers noted that this approach of working in groups, grappling with conceptual understanding, and communicating how and why they approached a problem in a particular way helped students develop skills they need not only in math courses but also in college and in life. Prior research on student experience in two of these courses affirms teachers' observations and experiences. Students enrolled in DMPC and IDS described feeling connected to a community of learners and experiencing intellectual curiosity and creative freedom (Heinzman, 2020).

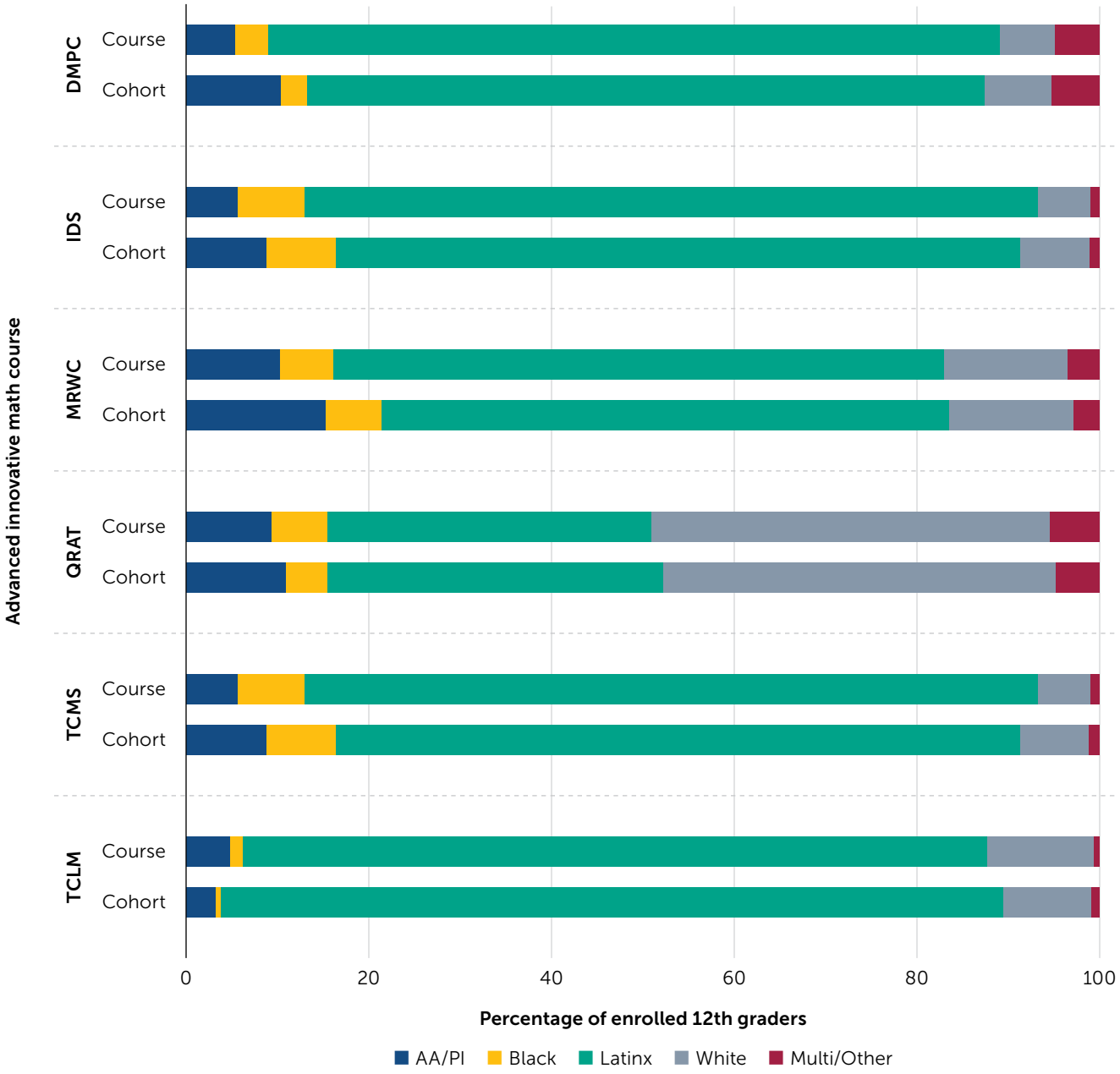
Commitment to Equity

The collaboration between developers and teachers is grounded in a commitment to equity, specifically equitable access to advanced math courses that serve the college-going aspirations of all students. Most of the partnerships target students who might not otherwise enroll in a math course during their senior year because of prior struggles, lack of engaging curriculum, poor preparation, or limited information about the importance of high school math even when pursuing non-STEM college degrees. A course developer described the focus on equity in the context of the pervasive tracking in high school math:

> *A lot of what has happened [with implementation of] this course highlights the inequities … like how students [select] honors classes versus lower level classes. So, for some students it is having an advocate at the school to steer them to this option. Traditional rhetoric … is about math tracking, ranking … calculus is king. We are trying to change the messaging around this.*

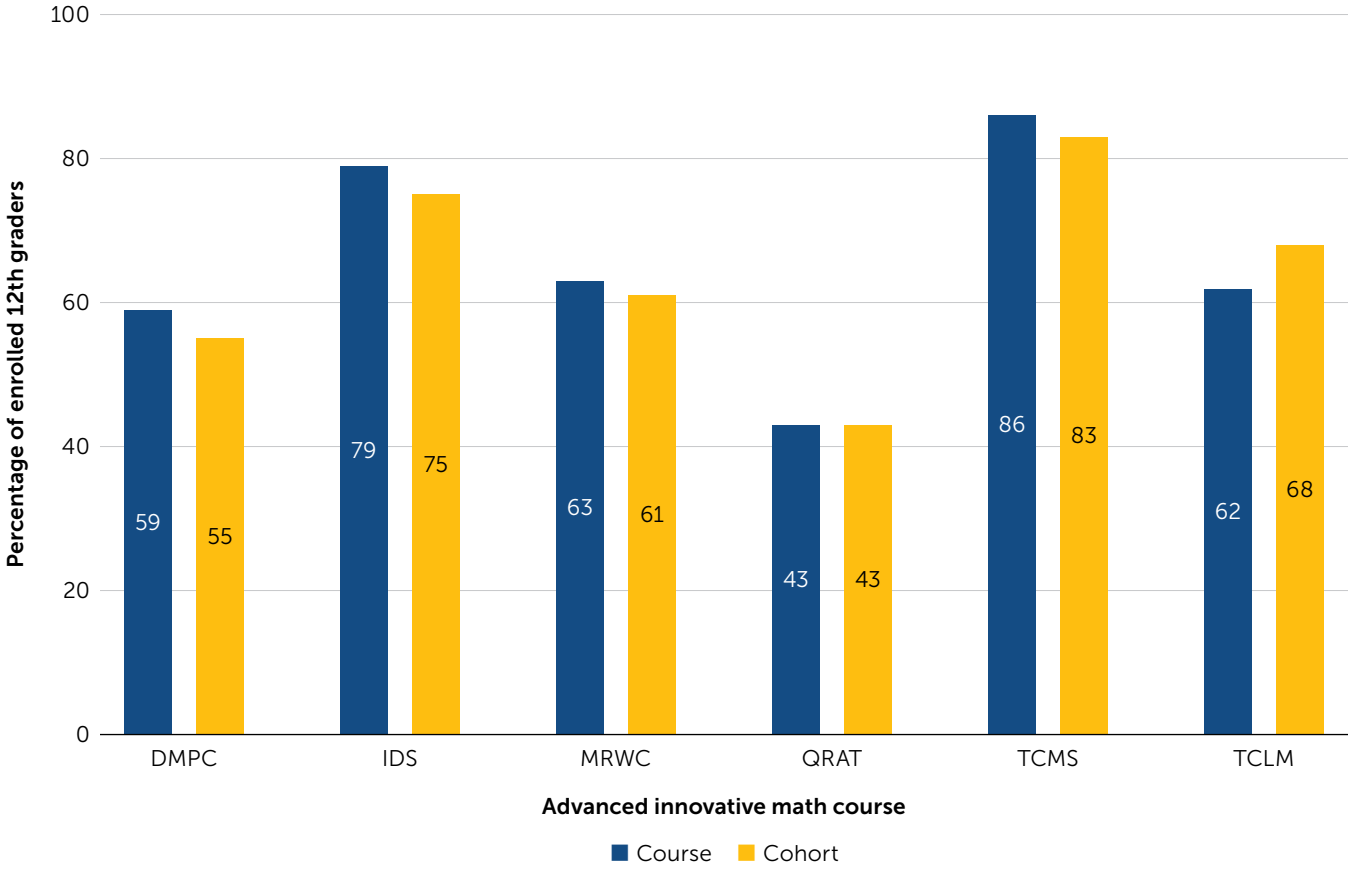
This commitment to equity is observed in AIM course enrollment, which is representative of the racial/ethnic and socioeconomic diversity in the districts participating in each partnership. In most of the partnerships, a slightly larger percentage of Latinx students enroll in the course than the percentage of Latinx students in the cohort as a whole (Figure 1). Moreover, the percentage of students enrolled in AIM courses who are socioeconomically disadvantaged (SED) aligns closely with the percentage of SED students in the cohorts overall (Figure 2).

Figure 1. Enrollment in 12th-Grade Advanced Innovative Math Courses by Student Race/Ethnicity, 2018–19



Note. Rates are calculated by aggregating the number of seniors in the schools offering each course. The course percentages include only 12th graders who took the AIM course alone rather than in combination with another math course. AA/PI includes Asian American and Pacific Islander students; Multi/Other includes Native American students, Filipino students, and students who identify with more than one race/ethnicity. For our analysis, we use the student-level race/ethnicity indicators in the 11th-grade Smarter Balanced Assessment data. For definitions of the course names, see Table 1.

Figure 2. Enrollment in 12th-Grade Advanced Innovative Math Courses by SED Status, 2018–19



Note. Rates are calculated by aggregating the number of seniors in the schools offering each course. The course percentages include only 12th graders who took the AIM course alone rather than in combination with another math course. *Socioeconomically disadvantaged status (SED)* is defined by the California Department of Education as students who either qualify for the national free or reduced-price school lunch program or who do not have a parent who graduated from high school. For our analysis, we use the student-level SED identifier in the 11th-grade Smarter Balanced Assessment data. For definitions of the course names, see Table 1.

Teachers echoed sentiments about an equity focus when discussing the design of these courses for students who have previously struggled in math. They noted that AIM courses give students the opportunity to experience success in mathematics, often for the first time:

> *And then I think the aspect of equity that I always come back to is the agency and ownership. … [Students] come into the class very hesitant and very unsure and not wanting to try something. And [then] finding that agency over time and knowing that their attempts are going to be valued and respected. And then owning the mathematics … finding the way that it makes sense to them. I think those aspects of the course definitely speak to equity.*

Community Building

A unique feature of AIM courses is the intersegmental collaboration between high schools and universities. In most cases, university faculty spearheaded the curriculum development. Reflecting the viewpoints of many of the partnerships, developers of MRWC described their initial development team as "all math educators … involved in training preservice teachers." Yet each development team worked closely with high school teachers and district specialists to test lessons and make revisions. For example, high school teachers who are members of the DMPC leadership team took the lead in determining how best to adapt the DMPC course to a remote environment when schools had to pivot to virtual learning during the COVID-19 pandemic.

Intersegmental collaboration was built through ongoing professional development (PD) and professional learning communities (PLCs). To launch the courses, developers provided PD in the summer for math teachers in partnering districts as well as at regularly scheduled convenings throughout the school year, a component appreciated by teachers. The ongoing PD led to the emergence of intersegmental PLCs, creating community across institutions and solidifying partnerships. Teachers valued the ongoing professional support, the opportunities for collaboration and iteration, and the camaraderie. As one teacher explained:

> *What keeps me there is I really like the trainings, the collaboration, because I feel like, even though I'm the only teacher at my school teaching it, I still get new ideas because of all the trainings that we have. So it really helps us build a community.*

Capacity Development

Through these PLCs, teachers gained skills and confidence in using new instructional strategies and came to see a real benefit to the pedagogical approaches they were learning, not only for AIM courses. Several teachers noted that they were beginning to use some of the same approaches in their other courses because they thought the approaches were beneficial to student learning:

> *I was already wanting to move in that direction, but actually being trained in teaching this course has kind of given me the tools to be more confident in allowing that to happen in my other classes. … I've grown in the ability to choose student work, and to ask students to present and to lead whole class discussions about that work, and so all of those things.*

Improved Educational Outcomes

At the core of intersegmental partnership between K–12 and higher education is the goal of improving educational outcomes for all students. Although causal evidence about the efficacy of these courses—relative to the alternative of taking no math or other math courses—is not easy to tease out (i.e., students are not randomly assigned to math courses), emerging research reveals a consistent positive story for students enrolled in AIM courses. Teachers are overwhelmingly positive about the benefits for students who plan to attend college but who have previously struggled with math (Bracco, 2022). In addition to citing how the pedagogical approach and content make a difference for students, teachers emphasized the benefits for student learning:

> *We do get a lot of student comments about how successful they feel for the first time. For the first time they can come to believe that they can do mathematics and that mathematics is not … about being a human computer.*

New quantitative analysis indicates that AIM courses have a positive impact on students' high school and postsecondary outcomes as well. Leveraging high school course-taking data linked to postsecondary enrollment data and using matching estimation methods, we found that enrollment in an AIM course increases the likelihood of completing the course requirements for CSU or UC eligibility by 3–10 percentage points. Additionally, in the case of some AIM courses, taking the course improves students' high school math grade point averages and their likelihood of attending college (Merritt, 2023).

Areas for Continued Intersegmental Collaboration

Given early evidence of the positive impact of AIM courses, ensuring that these courses and other innovative math pathways are available to more of California's students requires continued investment and collaboration within high schools and across education segments.

High School Advising and Counseling Practices

If AIM courses are to be implemented as designed and achieve the targeted goals, high school counselors need to be key partners in developing course-placement guidance and student-recruitment materials collaboratively with course developers and teachers. Many counselors currently believe that college admissions officers prefer calculus courses (Burdman & Anderson, 2022) and may not know whether AIM courses are a suitable alternative to calculus-track courses for seniors who plan to study non-STEM fields in college. More evidence is needed about how these courses are treated in CSU's admissions processes or UC's holistic review. Unfortunately, high school counselors have large caseloads (American School Counselor Association, n.d.) and may be unaware of many of their students' postsecondary

aspirations and goals. Descriptive and qualitative evidence suggest that course placement does not always adhere to prerequisite requirements (see the course case studies on the PACE website for more information). In some cases, high school counselors have been enrolling students in AIM courses even though they had not successfully completed the prerequisites (i.e., Algebra 2 or Integrated Math III). As one course developer noted:

> *The idea is for students who passed Math III, but maybe didn't do well. Counselors were putting students in the course who didn't pass Math III and some students who were also doing AP Stats. … Teachers got a mismatch of students … none of the schools have a written or clear process for recruiting students.*

Teacher Preparation

An additional area for continued intersegmental collaboration is the preparation of new teachers. Teachers interviewed for this study claimed that the student-centered pedagogical approach used in these courses was valuable and that they were using some of the instructional strategies in their other math courses, but they noted that the instructional strategies were new to them and not part of their teacher-preparation programs. Many suggested that it would be helpful to train new teachers in this pedagogical approach from the outset, making it an integral part of teacher preparation regardless of which math courses they will teach. One high school math teacher shared:

> *This would be a good course … to teach incoming new math teachers because you learn a variety of teaching methods. It's not always direct instruction. I think as teachers, I wish I had learned more than direct instruction.*

As such, preservice teacher programs could be engaged as partners to ensure more widespread training of the best ways to teach mathematics.

Alignment of High School Math Courses and College Admissions Policies and Practices

Alignment of high school math courses and college admissions requirements is key to the success of AIM courses as well as the successful innovation of high school math pathways more generally. Because AIM courses target students who want to pursue higher education, it is important that the courses meet eligibility requirements and that CSU and UC admissions policies consider the courses as viable alternatives to other advanced math courses. As courses approved to meet CSU's/UC's A–G course requirements, AIM courses fulfill high school math requirements for admission. UC recently expressed a commitment to accept data science, computer science, statistics, and other quantitative reasoning courses as meeting admissions requirements for a third or fourth year of high school math (Johnson, 2020; University of California, n.d.). Yet course developers and high school math teachers, along with many education advocates, express concern that these courses may not be viewed as equivalent alternatives to trigonometry, precalculus,

or statistics for purposes of college admissions, particularly at the state's most selective campuses (Anderson & Burdman, 2022; Burdman & Anderson, 2022). It is critical to pursue additional research on the impact of math course pathways and college success across different majors. In the meantime, college admissions policymakers and reviewers need to be well informed about these courses as alternatives and how they provide quantitative reasoning skills and mathematical content knowledge that may serve students well in many different fields of study.

Continued State and Education Segment Investments

Innovating high school math courses to improve students' college readiness and aligning these courses with college admissions policies will require investment of political will and financial resources from state policymakers and leaders of the public K–12 and higher education segments. The topics of high school math sequences and the quantitative reasoning skills necessary for postsecondary success have been fiercely debated, as have the implications of how policy changes might disparately affect students. Consensus on California's new Mathematics Framework is necessary for K–12 educators to have a clear path forward in their efforts to develop and implement new high school math courses as well as their efforts to strengthen and equalize opportunity in math for historically underserved students. This consensus will take political will and collaboration between the K–12 and higher education segments. Financial investments, including funds to buy out teachers' time from other responsibilities, are also needed to support collaboration between higher education faculty and high school math specialists to develop courses and to train and support teachers in innovative pedagogical practices. On a broader scale, state policymakers must address an ongoing shortage of math teachers, and institutions of higher education should enhance their preservice teacher-credentialing programs to reenvision high school math pathways and pedagogical approaches in mathematics classrooms.

Conclusion

Access to and success in postsecondary schooling is the responsibility of both K–12 educators and institutions of higher education, and improvement in equity and outcomes demands collaboration between the segments. Partnerships between high school and college-level math educators have proven valuable for high school teachers implementing AIM courses and may hold promise for improved student outcomes, particularly for marginalized student groups. Working together, these educators have sought not only to develop new curricula that approach advanced mathematics in student-centered ways but also to find new strategies for engaging students and engendering a sense of success for those who have previously struggled in traditional math courses. Realizing the goals of the AIM course developers will require continued investments of political will and financial resources as well as ongoing coordination between education segments.

References

Academic Senate of the California State University. (2016). *Quantitative reasoning task force final report*. asccc.org/sites/default/files/V.%20G.%20QRTF%20Final%20Report%2008-01-2016.pdf

ACT. (2007). *Rigor at risk: Reaffirming quality in the high school core curriculum*. act.org/content/dam/act/unsecured/documents/rigor_report.pdf

Adelman, C. (1999). *Answers in the toolbox: Academic intensity, attendance patterns, and bachelor's degree attainment* (ED431363). ERIC. https://eric.ed.gov/?id=ED431363

Adelman, C. (2006). *The toolbox revisited: Paths to degree completion from high school through college* (ED490195). ERIC. eric.ed.gov/?id=ED490195

American School Counselor Association. (n.d.). *Student-to-school counselor ratio 2020–2021*. schoolcounselor.org/getmedia/238f136e-ec52-4bf2-94b6-f24c39447022/Ratios-20-21-Alpha.pdf

Anderson, V., & Burdman, P. (2022, January). *A new calculus for college admissions: How policy, practice and perceptions of high school math education limit equitable access to college*. Just Equations and National Association for College Admission Counseling. uploads-ssl.webflow.com/61afa2b5ded66610900a0b97/624cc7f9378def7e51b43b5c_Just-Equations-2021-Report-New-Calculus-Final-Digital.pdf

Asim, M., Kurlaender, M., & Reed, S. (2019, August). *12th grade course-taking and the distribution of opportunity for college readiness in mathematics* [Report]. Policy Analysis for California Education. edpolicyinca.org/publications/12th-grade-course-taking-and-distribution-opportunity-college-readiness-mathematics

Attewell, P., & Domina, T. (2008). Raising the bar: Curricular intensity and academic performance. *Educational Evaluation and Policy Analysis*, *30*(1), 51–71.

Bozick, R., & Ingels, S. J. (2008). *Mathematics coursetaking and achievement at the end of high school: Evidence from the education longitudinal study of 2002*. (NCES 2008-319). U.S. Department of Education, National Center for Education Statistics. nces.ed.gov/pubs2008/2008319.pdf

Bracco, K. R. (2022, June). *A "powerful way of learning": Teacher perception about alternative math courses for high school seniors.* Education Insights Center. edinsightscenter.org/a-powerful-way-of-learning-teacher-perceptions-about-alternative-math-courses-for-high-school-seniors-courses

Bracco, K. R., Gutierrez, P., & Finkelstein, N. (2018). *Observations from the California Math Readiness Challenge Initiative (CMRC) implementation 2017–18*. WestEd.

Brown, E. G. (2016). *California state budget, governor's summary 2016–17.* State of California. ebudget.ca.gov/2016-17/pdf/Enacted/BudgetSummary/FullBudgetSummary.pdf

Burdman, P. (2015, May). *Degrees of freedom: Varying routes to math readiness and the challenge of intersegmental alignment (part two of a three-part series)*. Just Equations. justequations.org/resource/degrees-of-freedom-varying-routes-to-math-readiness-and-the-challenge-of-intersegmental-alignment-part-2-of-a-3-part-series

Burdman, P., & Anderson, V. (2022, September). *Calculating the odds: Counselor views on math coursetaking and college admissions* [Report]. Just Equations and National Association for College Admission Counseling. justequations.org/resource/calculating-the-odds-counselor-views-on-math-coursetaking-and-college-admissions

Burdman, P., Baker, M., & Henderson, F. (2021, December). *Charting a new course: Investigating barriers on the calculus pathway to STEM* [Report]. Just Equations. justequations.org/resource/charting-a-new-course-investigating-barriers-on-the-calculus-pathway-to-stem

Burdman, P., Booth, K., Thorn, C., Bahr, P. R., McNaughtan, J., & Jackson, G. (2018, May). *Multiple paths forward: Diversifying math pathways as a strategy for college success.* Just Equations and Center for the Study of Higher and Postsecondary Education. uploads-ssl.webflow.com/61afa2b5ded66610900a0b97/624dd48207b3f1c321f34f1d_Multiple-Paths-Forward-Report.pdf

California Department of Education. (2016, August 5). *2016 request for applications: California Math Readiness Challenge Initiative*. cde.ca.gov/fg/fo/r12/cmrci16letter.asp

California Department of Education. (2022, July 13). *Mathematics framework revision timeline.* cde.ca.gov/ci/ma/cf/mathfwrevtimeline2021.asp

Charles A. Data Center. (2020). *Launch years: A new vision for the transition from high school to postsecondary mathematics*. The University of Austin. utdanacenter.org/sites/default/files/2020-03/Launch-Years-A-New-Vision-report-March-2020.pdf

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2015). The aftermath of accelerating algebra evidence from district policy initiatives. *Journal of Human Resources*, *50*(1), 159–188.

Conger, D., Long, M. C., & Iatarola, P. (2009). Explaining race, poverty, and gender disparities in advanced course-taking. *Journal of Policy Analysis and Management*, *28*(4), 555–576.

Daro, P., & Asturias, H. (2019). *Branching out: Designing high school math pathways for equity* [Report]. Just Equations. justequations.org/resource/branching-out-designing-high-school-math-pathways-for-equity

Domina, T., McEachin, A., Penner, A., & Penner, E. (2015). Aiming high and falling short: California's eighth-grade algebra-for-all effort. *Educational Evaluation and Policy Analysis*, *37*(3), 275–295.

Domina, T., & Ruzek, E. (2012). Paving the way: K–16 partnerships for higher education diversity and high school reform. *Educational Policy, 26*(2), 243–267.

Dougherty, S. M., Goodman, J. S., Hill, D. V., Litke, E. G., & Page, L. C. (2017). Objective course placement and college readiness: Evidence from targeted middle school math acceleration. *Economics of Education Review*, *58*, 141–161.

Friedmann, E. (2017, June). *Building intersegmental partnerships* [Practice brief]. Policy Analysis for California Education. edpolicyinca.org/publications/building-intersegmental-partnerships

Gamoran, A. (1987). The stratification of high school learning opportunities. *Sociology of Education*, *60*(3), 135–155. doi.org/10.2307/2112271

Gao, N. (2021, February). *Does raising high school graduation requirements improve student outcomes?* Public Policy Institute of California. ppic.org/wp-content/uploads/does-raising-high-school-graduation-requirements-improve-student-outcomes-february-2021.pdf

Heinzman, E. (2020). *Math is no longer a four-letter word: A mixed methods study of two non-traditional fourth-year mathematics classes* [Doctoral dissertation, University of California, San Diego]. eScholarship. escholarship.org/uc/item/25d4s7vq

Heppen, J. B., Walters, K., Clements, M., Faria, A. M., Tobey, C., Sorensen, N., & Culp, K. (2011). *Access to Algebra I: The effects of online mathematics for grade 8 students* (NCEE 2012-4021). National Center for Education Evaluation and Regional Assistance.

Howell, J., Kurlaender, M., & Grodsky, E. (2010). Postsecondary preparation and remediation: Examining the effect of the early assessment program at California State University. *Journal of Policy Analysis and Management, 29*(4), 726–748.

Ingersoll, R. M., & Perda, D. (2010). Is the supply of mathematics and science teachers sufficient? *American Educational Research Journal*, *47*(3), 563–594.

Johnson, S. (2020, November 9). *University of California expands list of courses that meet math requirement for admission*. EdSource. edsource.org/2020/university-of-california-expands-list-of-courses-that-meet-math-requirement-for-admission/643173

Kim, J., Kim, J., DesJardins, S. L., & McCall, B. P. (2015). Completing Algebra II in high school: Does it increase college access and success? *The Journal of Higher Education*, *86*(4), 628–662.

Kurlaender, M., Reed, S., & Hurtt, A. (2019, August). *Improving college readiness: A research summary and implications for practice* [Policy brief, report]. Policy Analysis for California Education. edpolicyinca.org/publications/improving-college-readiness-research-summary-and-implications-practice

Liu, E., Rosenstein, J. G., Swan, A. E., & Khalil, D. (2008). When districts encounter teacher shortages: The challenges of recruiting and retaining mathematics teachers in urban districts. *Leadership and Policy in Schools*, *7*(3), 296–323.

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.

Loveless, T. (2008). *The misplaced math student: Lost in eighth-grade algebra.* Brown Center on Education Policy at Brookings. brookings.edu/wp-content/uploads/2016/06/0922_education_loveless.pdf

Loveless, T. (2013). *The algebra imperative: Assessing algebra in a national and international context.* Brown Center on Education Policy at Brookings. brookings.edu/wp-content/uploads/2016/06/Kern-Algebra-paper-8-30_v14.pdf

Merritt, C. (2023). *Investigating the impact of advanced math courses on high school and college outcomes in California* [Manuscript in preparation]. School of Education and Department of Economics, University of California, Davis.

Monk, D. H., & Haller, E. J. (1993). Predictors of high school academic course offerings: The role of school size. *American Educational Research Journal*, *30*(1), 3–21.

National Council of Teachers of Mathematics. (2018). *Catalyzing change in high school mathematics: Initiating critical conversations.* nctm.org/uploadedFiles/Standards_and_Positions/executive%20summary.pdf

National Council of Teachers of Mathematics. (2022, June). *Calculus: The Mathematical Association of America (MAA)/National Council of Teachers of Mathematics (NCTM) position.* nctm.org/Standards-and-Positions/Position-Statements/Calculus

Reed, S., Lee, P., Kurlaender, M., & Hernandez, A. (2018, July). *Intersegmental partnerships and data sharing: Promising practices from the field* [Practice brief]. Policy Analysis for California Education. edpolicyinca.org/publications/intersegmental-partnerships-and-data-sharing

Reed, S., Merritt, C., & Kurlaender, M. (2023, February). *12th grade math: An updated look at high school math course-taking in California*. Policy Analysis for California Education. edpolicyinca.org/publications/12th-grade-math

Reed, S., Rios-Aguilar, C., Smith Arrillaga, E., Vargas, J., & Kurlaender, M. (2019, June). *Empowering the intersegmental agenda: Opportunities for research, policy, and practice* [Practice brief]. Policy Analysis for California Education. edpolicyinca.org/publications/empowering-intersegmental-agenda-opportunities-research-policy-and-practice

Rippner, J. A. (2017). State P-20 councils and collaboration between K–12 and higher education. *Educational Policy*, *31*(1), 3–38.

Ronfeldt, M., Loeb, S., & Wyckoff, J. (2013). How teacher turnover harms student achievement. *American Educational Research Journal*, *50*(1), 4–36.

Rose, H., & Betts, J. R. (2004). The effect of high school courses on earnings. *Review of Economics and Statistics*, *86*(2), 497–513.
Schreiber, J. B. (2002). Institutional and student factors and their influence on advanced mathematics achievement. *The Journal of Educational Research*, *95*(5), 274–286.
Smith, A. (2022, November 15). *CSU will abandon proposal to create fourth year math requirement for admission*. EdSource. edsource.org/2022/csu-will-abandon-proposal-to-create-fourth-year-math-requirement-for-admission/681359
Smith, J., Hurwitz, M., & Avery, C. (2017). Giving college credit where it is due: Advanced Placement exam scores and college outcomes. *Journal of Labor Economics*, *35*(1), 67–147. doi.org/10.3386/w21147
Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2019). Understanding teacher shortages: An analysis of teacher supply and demand in the United States. *Education Policy Analysis Archives*, *27*(35).
University of California. (n.d.). *A–G policy resource guide*. hs-articulation.ucop.edu/guide/a-g-subject-requirements/c-mathematics
Wainstein, L., Miller, C., Phillips, M., Yamashiro, K., & Melguizo, T. (2023, January). *Twelfth grade math and college access*. Los Angeles Education Research Institute. laeri.luskin.ucla.edu/wp-content/uploads/sites/22/2022/12/LAERITwelfthGradeMathandCollegeAccessReport121522.pdf

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