Ahead of the Game? Course-Taking Patterns under a Math Pathways Reform

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Abstract: A controversial, equity-focused mathematics reform in the San Francisco Unified School District (SFUSD) featured delaying Algebra I until ninth grade for all students. This study examines student-level longitudinal data on mathematics course-taking across successive cohorts of SFUSD students who spanned the reform's implementation. We observe large changes in ninth and tenth grades (e.g., delaying Algebra I and Geometry). Participation in Advanced Placement (AP) math initially fell 15% (6 percentage points) driven by declines in AP Calculus and among Asian/Pacific-Islander students. However, growing participation in acceleration options attenuated these reductions. Large ethnoracial gaps in advanced math course-taking remained.

Introduction

The scope and sequencing of secondary mathematics curricula have become a focal point in broader debates over how schools should simultaneously promote equitable learning opportunities and student excellence. The stakes of this disagreement are high. Completion of advanced math courses in high school (i.e., those with content beyond Algebra II) has strong links to longer-run economic success through improving access to post-secondary STEM pathways (Altonji, 1995; Goodman, 2019; Long et al., 2012). However, ethnoracial gaps in math attainment are large and persistent (Conger et al., 2009). Nationally, 48% of Asian/Pacific Islander (API) students and 22% of White students enroll in Calculus by their senior year, compared with only 14% of Hispanic students and 11% of Black students (Loveless, 2021). The San Francisco Unified School District (SFUSD) has also observed stark disparities in course-taking (Carranza, 2015). For example, among SFUSD students who started high school in 2012, only five percent of Black students and seven percent of Hispanic students enrolled in AP Calculus (rates that were three and five times higher among their White and API peers, respectively).

Centering these equity concerns, SFUSD reformed its math pathways beginning in SY 2014-15 (Carranza, 2015). Figure 1 presents typical course progression before (panel A) and after (panel B) the reform. In a turn away from their previous eighth-grade Algebra-for-All policy, the District ceased offering Algebra I prior to ninth grade (Tintocalis, 2015). This practice represented a break from a decades-long national trend towards broadening early access to Algebra I (i.e., curricular intensification) but aligned with features of the newly adopted California Common Core State Standards (CCSS).

The CCSS introduced a more rigorous three-year middle school math sequence than had existed under the prior standards (California Department of Education [CDE], 2015). While many districts in California continued to offer Algebra I in eighth grade, this required compressing content across grades 6 and 7. SFUSD did not embrace this strategy. Instead, SFUSD's superintendent positioned the District as a trailblazer "ahead of the game" in responding to what some math researchers referred to as the "failed practices of tracking and early acceleration" (Boaler et al., 2018; Carranza, 2015).

The controversy over SFUSD's reform has figured prominently in ongoing state and national debates about math policy (Boaler et al., 2018; Boaler & Schoenfeld, 2018; Fortin, 2021; Loveless, 2022; Mo, 2021; Randazzo, 2024; Sawchuk, 2018; Tucker, 2019). The originally proposed new California Math Framework (CMF) recommended delaying Algebra I until ninth grade and emphasizing the Common Core middle school math standards (Boaler et al., 2018; Boaler & Schoenfeld, 2018). Proponents of the CMF specifically pointed to SFUSD as a model district for detracking (Jones, 2022).

The positioning of the reform by the District and observers as "detracking" was premised on the notion that it would *reduce* rates of Algebra I repetition and *delay* the emergence of achievement-based differentiation in course pathways, thereby shrinking academic stratification at the high school level. However, critics argue that delaying Algebra I holds back high-achieving students and unintentionally introduces new barriers to college readiness (Evers & Wurman, 2022; Fensterwald, 2022; Ford, 2022; Hong, 2021). This debate has focused attention on understanding SFUSD's distinctive reform (Fortin, 2021). One aim of this study is to establish consensus around a set of critical but contested stylized facts on the policy's implications for student outcomes.

Specifically, we provide independent evidence on the implications of the math pathways reform for average math attainment as well group-level differences in take-up of advanced courses. Our analysis uses longitudinal, student-level data for six SFUSD cohorts who spanned the policy's introduction. We explore two research questions that address changes to *level* and *difference* in course-taking, respectively.

Research Question 1 – How did high school math enrollment – in each grade level and cumulatively across four years of high school – change in the years after the implementation of the reform?

Research Question 2 – To what extent did course-taking changes vary by ethnoracial category and influence group-level disparities in attainment?

In the appendix, we also consider changes in student *performance* (i.e., course credits earned). Our study does not provide policy recommendations but instead describes patterns in math enrollment to inform the broader conversation about understanding and designing secondary math pathways in the post intensification-consensus era.

Tracking and Acceleration in Math Education

The issues surrounding SFUSD's math reform fit squarely within two aspects of policymaking and research that have shaped math education for decades: tracking and curricular intensification (i.e., "acceleration"). A prominent concern about tracking, broadly defined as the assignment of students into classes on the basis of academic achievement, is that it reproduces and amplifies inequities in learning opportunities across race and class (Clotfelter et al., 2021; Conger et al., 2009). Math course pathways are highly fragmented (Han et al., 2023) and schools disproportionately assign minoritized students to lower-level tracks when placement is based on achievement metrics (e.g., test scores) that correlate with socioeconomic status (Conger et al., 2009; Kalogrides & Loeb, 2013; Reardon, 2019). And when the determinants of course assignment are discretionary (i.e., based on teacher recommendation), minoritized students are under-identified for high-status pathways (Card & Giuliano, 2016; Grissom & Redding, 2016).

Tracking influences educational quality along multiple dimensions (Domina et al., 2019). For instance, students in lower-achieving tracks are more likely to be assigned less experienced teachers (Kalogrides & Loeb, 2013) and are exposed to lower achieving peers (Antonovics et al., 2022).

Furthermore, a substantial ethnographic literature reveals cases in which both teachers and students in lower-track classes hold depressed expectations of students' academic potential (Gamoran, 1989; Oakes, 2005). Legette and Kurz-Costes (2021) find that student motivation and sense of belonging in school are negatively related to lower-level track placement, even after controlling for prior achievement. A body of largely qualitative and observational studies also found that tracking was academically harmful to low-achieving students (Rui, 2009).

However, more recent and quasi-experimental research identifies positive impacts on test score and academic attainment outcomes for students across the achievement distribution (Ballis & Heath, 2021; Card & Giuliano, 2016; Cohodes, 2020; Collins & Gan, 2013; Cortes & Goodman, 2014; Figlio & Page, 2002). These findings are largely attributed to the benefits of pedagogical targeting facilitated by achievement-homogeneous classrooms (Antonovics et al., 2022; Duflo, 2001).

Curricular intensification, typified by the Algebra-for-All movement of the 1990s and 2000s, centered early access to Algebra I as a focal point of math policy (Domina et al., 2014; Moses & Cobb Jr., 2001; Stein et al., 2011). Researchers observed that minoritized students were less likely to be enrolled in Algebra I in eighth or even ninth grade than their White peers (Conger et al., 2009; Oakes et al., 1990). Meanwhile, a substantial but correlational literature established a relationship between early take-up of Algebra I with higher test scores and more advanced course-taking (Gamoran & Hannigan, 2000; Stein et al., 2011).

The movement successfully expanded take-up of eighth grade Algebra I, especially in California where a series of policy initiatives[1] beginning in the late 1990s increased enrollment from 16% in 1999 to a peak of 65% in 2013 (Domina et al., 2016; Rosin et al., 2009). However, the impacts of early acceleration on student achievement are mixed and vary by baseline student proficiency-level (Domina et al., 2015; Stein et al., 2011). Quasi-experimental studies have consistently found that, rather than opening up college-preparatory pathways for students who would have otherwise been placed in lower-level tracks, low-proficiency students are negatively or negligibly influenced by early acceleration. Clotfelter et al. (2015) find that early acceleration had "unamibiguously negative" consequences for lower-achieving students but carried small benefits for high performers. This finding is replicated by regression-discontinuity studies that identify heterogeneous impacts by prior achievement wherein eighth graders who are 'ready' for Algebra I see gains for acceleration but low proficiency students do not (Dougherty et al., 2015, 2017; Lafortune, 2018; McEachin et al., 2020). Overall, in California, modest overall declines in 10th grade math achievement have been attributed to eighth grade Algebra-for-All (Domina et al., 2015).

Coincident with rhetoric around the failure of Algebra-for-All and with the roll-out of the CCSS, the past decade has brought a shift *against* intensification. Fewer students in California now enroll in high school level math before ninth grade. Freshmen in 2019 were about half as likely to be enrolled in Geometry and about 20 percentage points *more* likely to be enrolled in Algebra I than ninth graders were in 2013 in the state (authors' calculation; CDE, 2019).[2] International comparisons suggest that delaying meaningful curricular divergence improves average student outcomes by preserving a wider array of educational opportunities (Hanushek & Wößmann, 2006), but the implications of *de*intensification for both average achievement and group-level differences in achievement have yet to be quantitatively evaluated in the United States.

This study's focal reform is responsive to the concerns surfaced by these contemporary tracking and acceleration debates. Primarily, SFUSD's new policy aimed to limit proficiency-based stratification in course-taking (i.e., "tracking") by keeping students on uniform pathways until 11th grade. Previously, high Algebra I repetition rates had resulted in fragmented ninth grade math course-taking (Figure 2), with students from minoritized groups disproportionately enrolled in Algebra I rather than Geometry (Figure A3). By delaying Algebra I to ninth grade, the District typified a backlash to the notion that expanding math acceleration in middle schools is an effective solution to stratified achievement in high school.

This study therefore provides leading evidence on the implications of a notable transition in education policy with respect to both overall course-taking and ethnoracial equality in math progression. Suggestively, in their study of curricular intensification during the Algebra-for-All movement, Domina et al. (2016) find that restricting a single dimension of curricular choice (i.e., placing most students *into* eighth grade Algebra I) does *not* produce more equal outcomes if novel forms of differentiation are easily created. Here, we provide the first empirical investigation of course-taking patterns after curricular choice is constrained by uniformly *removing* eighth grade Algebra I.

A High School Mathematics Pathways Reform

In February 2014, the SFUSD school board unanimously approved a proposal put forward by Superintendent Richard Carranza for an ambitious restructuring of math course pathways (Figure 1). This policy repositioned Algebra I from being the default math class for eighth graders to one that was not offered *until* ninth grade. There were two main academic goals: (1) to deepen content mastery for *all* students (SFUSD, 2014b) (2) to improve equity by boosting outcomes for lower proficiency students, who were more likely to belong to ethnically or racially minoritized groups. Our analysis responds to research questions that are paired directly with these goals. First, how did high school math enrollment – in each grade level and cumulatively across four years of high school – change in the years after the implementation of the reform? Second, to what extent did course-taking changes vary by ethnoracial category and influence group-level disparities in attainment?

Early acceleration was targeted on the belief that compressing prerequisite content so that students could take Algebra I in middle school had resulted in a "mile-wide and inch-deep" curriculum, with few eighth graders developmentally prepared to engage with high school-level course work (SFUSD, 2014b). Repetition rates (i.e., students taking Algebra I for a second time in ninth grade) were high, and disproportionately so for Black and Hispanic students (Figure A3). The Superintendent's proposal summarized these concerns by pointing out that very few students were making on-time progress through the current math sequence: across the 2011-12 and 2012-13 school years, only 19% of tenth graders, and only one percent of Black tenth graders, had passed the state math assessment *and* not repeated math coursework.

Disquiet about early acceleration was rhetorically prominent in the lead-up of the reform (SFUSD, 2014a). For example, in March 2015, Superintendent Carranza invited Professor of Mathematics Education Alan Schoenfeld to speak to the board when the policy was proposed. Dr. Schoenfeld noted that the Mathematical Association of America urged schools not to "rush students through the curriculum so they can take Calculus in their senior year" and advised that "it's much better for everyone to proceed at a more measured pace, going deeper rather than faster." The empirical research which specifically challenges this assertion for sufficiently prepared students was nascent at the time the policy was adopted (Card & Giuliano, 2016; Dougherty et al., 2017; Lafortune, 2018; McEachin et al., 2020).

Beginning with the graduating class of 2019, *all* students were to follow a uniform course sequence of CCSS math through eighth grade followed by Algebra I in ninth grade. The reform took effect for eighth graders in SY 2014-15, and for ninth graders in SY 2015-16. The District further aimed to delay the emergence of academic stratification by limiting opportunities for acceleration in high school before 11th grade, at which point students were considered old enough to personalize their coursework in service of their future goals (Boaler et al., 2018; Carranza, 2015). Eleventh graders could enroll in a "compression course" that combined Algebra II and Pre-Calculus topics into a single-block year-long class (Carranza, 2015). Tenth graders could also accelerate by "doubling up" in Geometry and Algebra II, but this option was not taken up as widely as the compression course.

Unlike math acceleration in middle school, where tracks are often formed based on prior achievement, high school acceleration options were open to all students who had passed prerequisite courses.

SFUSD implemented this reform to a mixed community response. Some parents opposed the removal of Algebra I from middle school. They argued the new policy disadvantaged students who were "super-smart" or "ambitious" (Christopher, 2016; Tintocalis, 2015; Tucker, 2019). However, the District's African American Parent Advisory Council (AAPAC) submitted a letter to the Board of Education expressing support for the reform, describing it as "rais[ing] expectations for all students while effectively eliminating racially biased tracking" (AAPAC, 2015).

Proponents of the reform encouraged sceptics to consider the Algebra I delay in the context of CCSS implementation (Carranza, 2015; Christopher, 2016). Specifically, the redesigned California eighth grade math class introduced students to more rigorous content, including algebra topics, than a pre-CCSS integrated eighth grade math course would have (CDE, 2015; Christopher, 2016). Some districts responded to this scope and sequence change by compressing content across middle school courses so that eighth graders could still enroll in Algebra I. SFUSD opted to instead enroll all students in the unabridged Common Core-aligned middle school sequence and define the formal pathways for acceleration (i.e., the compression course) in later grades. This approach aligned with the CDE's warning that "decisions to accelerate students into the Common Core Standards for higher mathematics before ninth grade should not be rushed" (CDE, 2015).

Even so, one parent lamented this reform as promoting a "cookie-cutter approach" to education and feared her son might "lose his engagement in school because it's not moving at a fast enough pace for him" (Tintocalis, 2015). This response is consistent with an established literature that finds a preference for targeted acceleration (i.e., tracking) among some parents (Fu & Mehta, 2018; Kariya & Rosenbaum, 1999; Wells & Serna, 2010). Parents groups have since mobilized around a petition, a lawsuit, and a potential ballot initiative to overturn the 2014 policy (Tucker, 2023). This sustained opposition suggests that, as an additional matter to policy impacts on educational quality and equity, there are substantial political barriers to pursuing academic equality by constraining curricular differentiation via *de*intensification (Lee, 1993).

A specific driver of parent resistance is that, without the option to accelerate in eighth grade, taking calculus before college requires compressing five courses (i.e., Algebra I, Geometry, Algebra II, Pre-Calculus and AP Calculus) into the four years of high school. While the University of California (UC) recommends that students intending to pursue study in a STEM field take four years of high school math, they do not specifically privilege calculus over a precalculus or statistics course (Ford, 2022). However, parents and counselors tend to view calculus as more critical to college-admissions success than admission officers say it is (Burdman & Anderson, 2022; Schwartz, 2022).

This status of the Algebra II/Pre-Calculus compression course is also contentious. It satisfies Pre-Calculus requirements in SFUSD and is deemed "advanced" within the District, but is an Algebra II equivalent per California's public university system (Regents of the University of California, 2018).[3] We choose to center the "Advanced Placement" (AP) designation in our analysis to proxy for advanced coursework because it is clear-cut and was emphasized as a success metric when the policy was initially proposed (Carranza, 2015).

Adding further complexity, course offering was not identical across campus nor was policy implementation static across cohorts. In SY 2020-21, the six SFUSD high schools with the highest percentages of API students all offered AP Statistics and AP Calculus while only two of the six high schools with the highest percentages of Black students did so.[4] Twelve percent of Hispanic students and 13% of Black students are enrolled in campuses that do not offer any AP courses compared with 5% of White students and only one percent of API students. Black students, especially, are disproportionately concentrated in SFUSD's alternative high schools (e.g., schools for students behind on credits for graduation), which are typically smaller and less likely to offer advanced course options.

Because most students at these campuses are in 11th and 12th grade, when most advanced course-taking occurs, the 12% and 13% figures understate the relevant share of Black and Hispanic students whose home campus does not offer AP math courses. And, while the reform originally intended to keep students on a predominantly uniform pathway until 11th grade, acceleration options were made more widely available to later cohorts.[5] In addition to the "compression course" taken mostly by juniors, a ninth grade Geometry summer course was added for the class of 2021. We incorporate the "on-the-ground" evolution of the policy in our analysis and discussion of results by considering multiple post-reform time horizons.

Data and Methodology

Our analysis uses longitudinal, student-level data for six cohorts of SFUSD high-school students, which evenly span the policy change. SFUSD provided these data under the aegis of a Researcher-Practice Partnership (RPP). These data include student identifiers, demographic information, and academic transcripts including course identifiers, credits attempted, credits earned, and letter grade received. We observe 23,309 unique students – approximately 4,000 students for each of the cohorts examined. Table 1 presents descriptive statistics on the composition of this sample. API students compose the largest racial/ethnic group (45%), followed by Hispanic students (26%).[6]

Table 1. Racial/Ethnic Composition of SFUSD High School Students by Class

For our main analysis, we define cohorts based on the expected graduation year of first-time ninth graders (i.e., those expected to be in the graduating classes of 2016 through 2021).[7] We use this cohort definition because entering ninth graders experienced the cohort-specific changes in SFUSD's mathematics pathways (i.e., Algebra I as the default math enrollment for this group). This construction excludes students who transfer into the District after ninth grade (typically, less than 10 percent of a senior class) and includes students who are not necessarily observed graduating in the District. We consider the empirical relevance of this cohort rule by reproducing our main findings (Appendix

Figures A5, A6, and A7) with cohorts created using graduation years of first-time seniors (i.e., including transfers in while excluding transfers out). Our results are effectively unchanged.

The accurate identification of math courses in the transcript data is critical for our analysis.[8] We collaborated directly with SFUSD staff to validate all math courses observed in the transcript data of our sample cohorts and to appropriately aggregate these courses into categories like Algebra I or Pre-Calculus. First, we retained all course observations for which the course title, id, or category indicated that it was a math course. We used these fields to then introduce common groupings (e.g., "CCSS Geometry", "Geometry A", "Geometry B", "Geometry P", "Geometry H"[9], and "Geometry" are all collapsed into the category "Geometry). SFUSD verified the accuracy of these course-category matches and provided feedback on ambiguous observations (e.g., "Accel Math A H"). Categories were finalized after a second round of collaborative coding and review. We exclude courses taken outside of SFUSD and transferred into the District, because these courses are coded inconsistently and thus cannot be categorized.

Our main analyses compare conditional means defined for different dimensions of math course-taking and performance and by traits such as graduation cohorts (e.g., pre- and post-reform), grade levels, and student race/ethnicity. Following federal guidance on conducting descriptive education research, we eschew foregrounding statistical inferences about the changes observed in these data (Loeb et al., 2017). We do, however, report regression-based tests of statistical significance in the appendix. These inferences compare pre- and post-reform outcomes aggregated over the three pre-reform and the three post-policy cohorts (Table A2) and across the single cohorts immediately preceding and following the reform (Table A3). Finally, we note that sharp changes in course-taking that coincide exactly with the first post-reform cohort (i.e., a more than doubling of the share of ninth graders enrolled in Algebra I; Figure 2) suggest an impact of the policy in a manner that has conceptual parallels to a formal causal analysis.

Results

Course Enrollment by Grade

In Figure 2, we present the course-taking pathways of students by grade and their expected graduation cohort. Prior to the reform, average year-to-year fluctuation in course-taking within a particular grade was approximately three percentage points. We therefore only consider magnitude changes in the post-reform era of greater than three percentage points to be meaningful.

Panel A illustrates how ninth grade math course-taking differed sharply across cohorts that entered high school before and after the policy change (i.e., the pre-reform graduation cohorts of 2016 through 2018 and the post-reform cohorts of 2019 through 2021). Prior to the reform, most ninth graders enrolled in Geometry (e.g., 52% in the 2018 cohort) or Algebra I (e.g., 37% of the 2018 cohort), and these enrollment patterns were quite stable. Ninth grade Algebra I enrollments in the pre-reform period are broadly attributable to course repetition by students who failed, as eighth graders, to earn course credit and/or pass the state end-of-course exam, which was phased out in spring 2013. Consistent with the policy intent, we observe a clear and dramatic discontinuity beginning with the Class of 2019. Geometry enrollment fell by 45 percentage points to 7% while enrollment in Algebra I jumped 53 percentage points to 90%. This shift attenuated slightly for the 2021 cohort primarily due to enrollment in a new Geometry summer course.

Panel B illustrates a similarly large change in math enrollment among tenth graders. Comparing the graduation cohorts of 2018 and 2019, Geometry enrollment increased by 38 percentage points (i.e., from 40% to 78%) while exclusive enrollment in Algebra II decreased by 33 percentage points (i.e., from 38% to 5%). As in Panel A, we observe some attenuation in these changes for the 2020 and 2021 cohorts.

Among 11th graders (Panel C), enrollment in Algebra II increased between 2018 and 2019 (i.e., 40% to 54%) while enrollment in precalculus fell (i.e., 41% to 16%). We also observe, beginning with the 2019 cohort, that roughly 20 percent of 11th graders enrolled in the "compression course" combining Algebra II and Pre-Calculus content. In the 2020 and 2021 cohorts, we observe 11th graders who had already accelerated (i.e., by taking the math validation exam, enrolling in summer school Geometry, or doubling up concurrently on courses) enrolling in standalone Pre-Calculus.

Finally, Panel D illustrates changing patterns in 12th-grade course-taking. Between the 2018 and 2019 cohorts, participation in AP Calculus fell by six percentage points (i.e., from 30% to 24%). Enrollment in year-long Pre-Calculus initially jumped by 10 percentage points but declined to pre-reform levels for the 2021 cohort. A modest but distinct increase in take-up of AP Statistics and a trend towards greater Probability and Statistics participation also characterizes post-reform enrollment. We also note that enrolling in a 12th grade math course is not required for graduation, and we observe only small changes in the share of SFUSD seniors taking no math courses (i.e., roughly one in four). These students are counted in the denominator of this figure's dependent variable.

Cumulative Course Enrollment

The imperative to increase the enrollment of Black and Hispanic students in advanced math courses was a central motivation for this reform (Carranza, 2015). In Figure 3, we therefore illustrate how participation in advanced math in high school varied across cohorts for all students as well as specifically among the four largest racial/ethnic groups in the District (i.e., Asian or Pacific Islander, White, Hispanic, and Black).[10]

Figure 3. Enrollment in Advanced Courses by Race/Ethnicity

In Figure 3, we present trends in the share of students – within cohort and sub-group – to ever enroll in a particular advanced math course. Prior to the reform, average year-to-year fluctuation in cohort-level advanced course enrollment by twelfth grade was approximately two percentage points. Only magnitude changes greater than two percentage points are therefore considered meaningful.

These data underscore the stark racial/ethnic disparities that motivated the reform. For example, Panel A presents data on precalculus enrollment and shows that—across all cohorts—White and API students in SFUSD take precalculus at rates roughly two to four times higher than their Black and Hispanic peers.[11] We observe a temporary reduction in the White-Hispanic and White-Black disparities following the policy change, but no change in course-taking rates relative to Asian/Pacific Islander students.

Specifically, in the Class of 2018, only 13% of Black students enrolled in precalculus at some point in their high school career, while 20% did so in the Class of 2019 (i.e., a 55% increase). Concurrently, White enrollment in precalculus declined by 6 percentage points. This shrunk the White-Black precalculus enrollment gap by 43% (i.e., from 43 to 30 percentage points) and the White-Hispanic gap by 33% (i.e., from 25 to 17 percentage points). The difference in the API-Black student precalculus enrollment remained above 50 percentage points for all observed cohorts, and was within one percentage point (i.e., 57 versus 58 percentage points) between the classes of 2018 and 2021.

In Figure 3 Panel B, we present enrollment in Probability and Statistics. Overall enrollment in Probability and Statistics remained flat (i.e., 10% versus 12%) after the policy change. Take-up increased across all racial/ethnic groups in subsequent years, with 17% of the Class of 2021 enrolling in the course. Notably, Black students enrolled in Probability and Statistics at the highest rate, while API students enrolled in the more rigorous AP Statistics (Panel D) at the highest rate. This may reflect the previously noted differences in course offerings across SFUSD high schools. Disparities in Probability and Statistics enrollment are slight (i.e., within five percentage points across all groups in most years) and do not exhibit consistent trends across cohorts.

Figure 3 Panel C presents enrollment in AP Calculus and shows a six percentage-point decline (i.e., a 21% decrease) in aggregate enrollment following pathways reform. Again, we observe large gaps in course-taking by racial/ethnic subgroup and lower take-up for Black and Hispanic students, with fewer than 10% of Black and Hispanic students enrolled in Calculus for every year in our sample. Whether the class of 2018 is compared to the class of 2019 or the class of 2021, White-Black and White-Hispanic gaps in AP Calculus enrollment are either stable or increase slightly (i.e., by two to three percentage points). API-Black and API-Hispanic disparities initially shrank (i.e., by eight and 10 percentage point, respectively) as API AP course enrollment dropped. However, underlying differences do not meaningfully change when the 2018 cohort is compared with the 2021 cohort (i.e., 41% to 38% and 39% to 37%, respectively).

Enrollment in AP Calculus declined immediately following the reform but held steady in AP Statistics. Figure 3 Panel D illustrates the broader trend: AP Statistics enrollment was increasing prior to the policy's implementation and continued to do so afterward. This enrollment increase is seen for all racial/ethnic subgroups except Black students. From 2018 to 2021 disparities in AP Statistics enrollment among graduating cohorts *grew* substantially. Across that timespan, the White-Black and API-Black differences in AP Statistics participation grew by five percentage points and eleven percentage points, respectively. Analogous White-Hispanic and API-Hispanic disparities were more stable, increasing by only three and two percentage points.

In Panel E we combine take-up of AP Calculus and AP Statistics to convey what share of each cohort took at least one AP math course before the end of 12th grade. We observe a five-percentage point (i.e., 15%) decrease in the percent of students enrolling in an AP math course immediately after the policy's implementation. As more students in later cohorts enrolled in acceleration options, AP math enrollment returned to its 2018 levels. The net result of patterns observed in Panels C and D is that from the class of 2018 to the class of 2021, the White-Black and White-Hispanic AP math enrollment gaps grew by five and seven percentage points, respectively. API-Black and API-Hispanic AP math differences were more stable (i.e., only three percentage points and one percentage point) after initial declines from the class of 2018 to 2019 (i.e., negative four percentage points and negative nine percentage points).

Panel F shows the percentage of students not enrolling in math in 12th grade. Though a fourth year of math is not required for admission to the University of California or California State University systems, it is recommended. Additionally, the value of "recency" in content exposure suggests that enrolling in a 12th grade math course may improve post-secondary math achievement (Bracco et al., 2020). We observe that in the Class of 2018, 25% of students chose to not enroll in 12th grade math whereas in the Class of 2019, 23% did. For the class of 2019, the difference in forgoing a 12th grade math course was 14 percentage points between Black and White students and 24 percentage points between Black and API students. These disparities reflect a marginal (i.e., one to two percentage point) growth in gaps observed among the class of 2018.

Credit Attainment

Another explicit goal of the policy was to increase credit attainment in math by building a stronger foundation in middle school. SFUSD leadership hoped the policy would lead to more students not just enrolling but also earning credit in college preparatory math courses (Carranza, 2015). In Figures A2 and A4, we present the share of a graduation cohort earning a full year of credit in a course at some point during high school (see Appendix for further discussion of patterns in earned credit).[12] We show that changes in credit attainment largely mirrored enrollment.

Discussion

In this study, we illustrate how math course-taking patterns shifted for students in SFUSD after the implementation of a substantial math pathways reform. In short, when enrollment in Algebra I in ninth grade became the norm, so did tenth-grade enrollment in Geometry as well as the delay of Algebra II and precalculus to later years. Notably, the introduction of the reform coincided with a sharp reduction in AP Calculus enrollment concentrated particularly among API students, though acceleration options attenuated this decline for later cohorts. However, the pre-reform trend of increasing AP Statistics enrollment continued, while take-up of a *non-AP* Probability & Statistics class also expanded. Yet, the large ethnoracial gaps in AP math course-taking did not decrease. We do observe a modest immediate post-reform increase in precalculus take-up, particularly for Black students, but approximately one third of these enrollments were in the Algebra II/Pre-Calculus compression course rather than year-long Pre-Calculus. We observe only course enrollment and credit attainment and cannot say how longer-term outcomes (e.g., college-level math participation, student self-concept as math learners) changed.

The policy met its first order goal to reduce tracking in ninth and tenth grade. More than 80% of ninth grade students enrolled in Algebra I and over two thirds of 10th graders enrolled in Geometry in each observed post-policy year. Because of increased uniformity in course-taking in grades 9 and 10 (see Figure 2, panels A and B) students were more likely, post-reform, to be enrolled in the same course as a given same-grade peer. However, the policy failed to achieve its primary goal of increasing enrollment of students from historically marginalized groups in advanced math courses. The percent of Black students enrolling in AP math courses remained statistically indistinguishable from the pre-policy period while Hispanic student enrollment in AP math increased by just one percentage point.

Furthermore, the reform aimed to meet equity objectives without reducing academic achievement among other student groups. Yet, we observe large initial declines in AP math enrollment for White and API students. When the District introduced new acceleration options (e.g., summer Geometry) and improved awareness of existing ones (e.g., the compression course), participation in AP math returned to pre-reform levels. This adjustment led to increased stratification in ninth and tenth grade for the classes of 2020 and 2021 compared with the class of 2019, undoing progress towards the detracking objective. Most recently, the District has announced it will reintroduce Algebra I to eighth grade. This decision follows substantial community pressure including a lawsuit and ballot measure, as well as the dissemination of post-reform student enrollment and achievement data – including the findings of this study. In AY 2024-25 the district will pilot opt-in, double dose (i.e., concurrent Algebra I and Math 8), and universal models for eighth grade Algebra I (Tucker, 2023). In contrast to the top-down, uniform deferral of Algebra I from eighth grade in AY 2014-15, this approach will allow the District to learn and iterate before scaling any new math pathway reform to all schools.

We note two caveats to the interpretation of these results. First, the absence of a clear decline in course-taking disparities across ethnoracial groups does not necessarily indicate how course-taking changed across students with differing levels of prior achievement. For example, a reform-driven narrowing of course-taking disparities across low- and high- achieving students may not be detectable in ethnoracial differences. Second, these findings are situated within larger, unsettled debates on the propriety of calculus, statistics, and "data science" courses – with contingent implications for Algebra I – for high-school graduates. Calculus has historically been perceived as a prerequisite for admissions to competitive colleges and as a stepping stone into STEM careers (Bressoud, 2021). Indeed, 87% of college counselors in public high schools report a belief that "calculus gives applicants an edge in the admissions process." However, only 53% of post-secondary admissions counselors agree with that statement (Burdman & Anderson, 2022; Schwartz, 2022). Research on the college and career impacts of high school math assignment is needed to fully contextualize the normative implications of policies like the one examined here.

We conclude with a broader observation about our findings. They indicate that a singular focus on Algebra I policy is unlikely to address key barriers to equitable math course-taking. Large ethnoracial gaps in advanced math course-taking motivated this reform but were largely unchanged in the post-reform period. Initial reductions in some group-level disparities, driven by a drop in participation of API students in AP Calculus and White students in precalculus courses, attenuated rapidly and were offset by a widening AP Statistics gap. If this policy had predominantly functioned to lower the course-taking ceiling for students who *would* have passed Algebra I in eighth grade (a disproportionately White and API group in the pre-reform era), we would expect large and sustained declines in ethnoracial advanced course-taking gaps. A surprising finding of our study is that this is not observed.

This result could be explained by differences in course-offerings across campuses and counseling practices. Because Black and Hispanic students are disproportionately enrolled in alternative schools in 11th and 12th grade, they have access to fewer AP math opportunities. Notably, only Black and Hispanic students are more likely to enroll in Probability and Statistics than AP Statistics, despite these courses having formally identical prerequisites. Discretionary advising likely plays an outsized role in shaping advanced course-taking patterns because participation in acceleration pathways and advanced courses is elective. That is, completion of a math course beyond the Algebra I-Geometry-Algebra II sequence is not required for either SFUSD graduation or matriculation to one of California's public universities, nor is take-up of summer school or Algebra II/Pre-calculus compression. Approximately one quarter of all 12th graders opt not to enroll in any math course, but this population encompasses about 40% of Black 12th graders and a third of Hispanic seniors. Furthermore, despite the sustained exclusion of eighth graders from Algebra I in SFUSD, the observed growth in both AP Statistics and AP Calculus enrollment among API students across post-reform cohorts indicates increased take-up of alternative acceleration pathways (i.e., the compression course and summer school). AP course-taking for Black and Hispanic students is flat across the same period.

It is plausible that Black and Hispanic students are insufficiently encouraged to enroll in acceleration options or in math courses, especially at the AP level, as twelfth graders. This phenomenon would be broadly consistent with Irizarry's (2021) finding that interactions with counselors *decrease* the likelihood that Hispanic students remain on an advanced math track in high school. A concerted effort to increase take-up of twelfth-grade math courses among Black and Hispanic students could reduce gaps in advanced course-taking more effectively than policies that limit eighth grade course enrollment. In other words, *deintensification* policies will have limited impact on cumulative course-taking inequality when opportunities for curricular differentiation persist downstream (i.e., alternative acceleration pathways, advanced elective courses).

Additionally, moving Algebra I to ninth grade may impose structural *new* constraints on future course opportunities for low- as well as high achievers relative to the pre-reform era. Specifically, students who must repeat core coursework (i.e., Algebra I, Geometry, Algebra II) have fewer academic years to do this if their first opportunity to take Algebra I is in ninth versus eighth grade. In other words, deferring Algebra I entry reduces the number of chances available to low proficiency students to recover from setbacks in their progression through the typical course sequence. Because, historically, detracking efforts emphasized curricular intensification (i.e., acceleration) rather than delays within pathways, this study provides unique policy insights for a novel (but not isolated) reform strategy.

Notes

1. The state revised its standards to recommend all eighth graders be enrolled in Algebra I and later added penalties for schools who continued to enroll eighth graders in pre-algebra classes.
2. Or equivalent integrated math courses (i.e., Mathematics I *or* Algebra I, Mathematics II *or* Geometry).
3. Compared to the California CCSS for Mathematics Precalculus Overview, the scope and sequence of the SFUSD compression course excludes units on conic sections, vector and matrix quantities, and the study of polar coordinate systems is optional.
4. For example, Ida B. Wells High School is a small alternative high school that was about 20% Black and 10% Asian in 2020-21, the last year of data in our study. That year, the school offered Algebra I, Geometry, Algebra II, Pre-Calculus, and Probability & Statistics; the school offered no Advanced Placement options in math. The other alternative campuses (Downtown High School and Independence High School) also offered no Advanced Placement math courses that year. In addition, the June Jordan School for Equity – a small, traditional high school that also serves a disproportionate share of the District's Black students – also did not offer Advanced Placement math courses that year.
5. An exception was also made for students who attended eighth grade outside of SFUSD. These students could enroll in Geometry as ninth graders if they passed an assessment called the Math Validation Test.
6. When the measured racial/ethnic identity of a student changes over time (i.e., less than two percent of students), we rely on the most recent, non-missing value.

7. We note that the COVID-19 pandemic began in March 2020 after the Class of 2020 had already enrolled in a slate of courses and thus their enrollments are not affected by the pandemic. For the Class of 2021, though, it is possible that the pandemic affected their decisions to enroll in particular coursework and led them to enroll in lower-level courses, thus tamping down the effect of the pathways change. Our findings do not bear out this concern: the Class of 2021 generally enrolled in more rigorous mathematics coursework than the Class of 2020.
8. Course articulation across schools and, especially, districts challenges researchers because naming conventions and rigor for ostensibly identical courses are rarely standardized. These issues are attenuated for our analysis because we consider course-taking within a single district.
9. The district ended the practice of designating courses covering ostensibly the same content as honors versus standard level classes simultaneously to the Algebra I policy change.
10. In the appendix, we present corresponding regression-based estimates of statistical significance based on comparing the entire pre- and post-reform cohorts (Table A2) as well as the cohorts just before and after the reform (Table A3).
11. We define precalculus participation here to include the Algebra II/Pre-Calculus compression course though it is not recognized by the state system of higher education as meeting Precalculus requirements. In Appendix Figure A1, we show how participation in yearlong vs. compressed versions of precalculus varied starkly across cohorts.
12. A full year of credit is defined as 10 credits; SFUSD students earn 10 credits if they earn a D or above in both semesters of a course and must have at least 30 credits of math to graduate.

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Table 1: Racial/Ethnic Composition of SFUSD High School Students by Class

	2016	2017	2018	2019	2020	2021
Asian or PI N	1954	1802	1828	1755	1599	1622
percent	49.71%	46.81%	47.26%	45.79%	40.74%	41.57%
Black N	362	330	308	302	299	286
percent	9.21%	8.57%	7.96%	7.88%	7.62%	7.33%
Hispanic N	953	996	1013	982	1149	1045
percent	24.24%	25.87%	26.19%	25.62%	29.27%	26.78%
Multiracial N	68	74	90	101	183	194
percent	1.73%	1.92%	2.33%	2.64%	4.66%	4.97%
Native American N	22	28	12	24	14	9
percent	0.56%	0.73%	0.31%	0.63%	0.36%	0.23%
White N	339	348	363	390	427	480
percent	8.62%	9.04%	9.38%	10.17%	10.88%	12.30%
Decline to State N	233	272	254	279	254	266
percent	5.93%	7.06%	6.57%	7.28%	6.47%	6.82%
Total N	3931	3850	3868	3833	3925	3902

Figure 1A. Simplified pre-reform potential course progression. Applies to graduating cohorts of 2016-2018, applied to grade 8 through AY 2013-14.

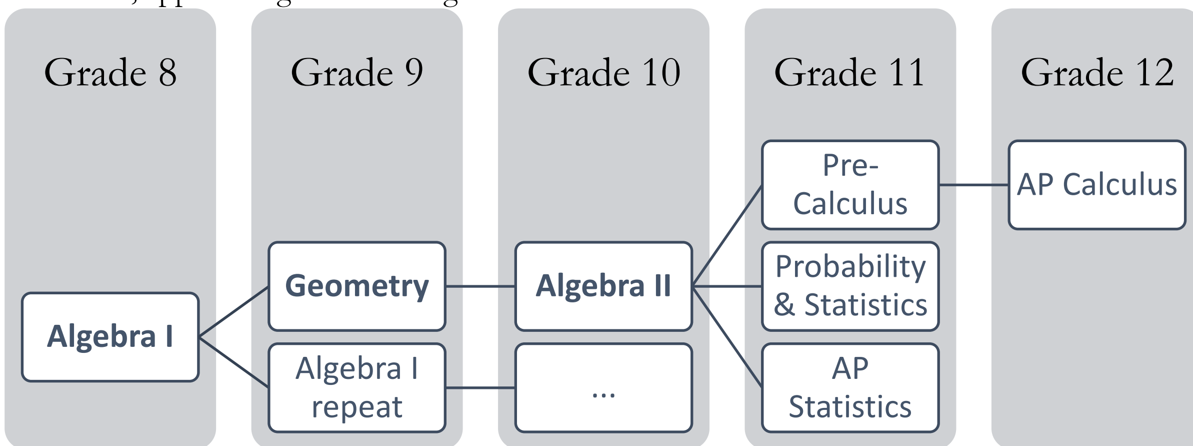
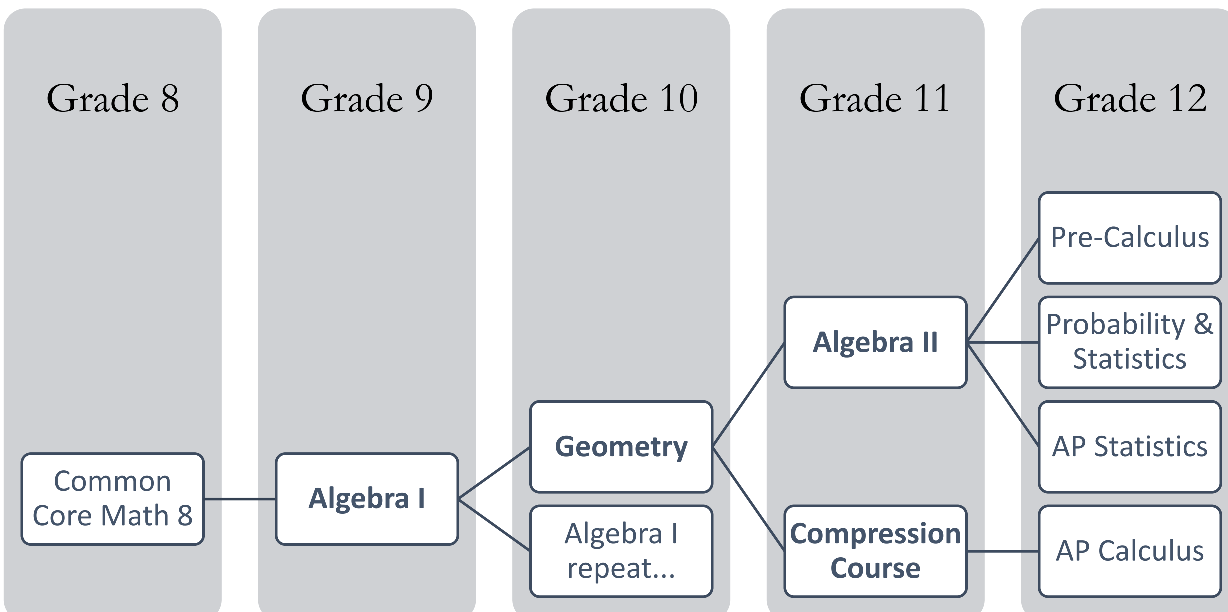


Figure 1B. Simplified post-reform potential course progression. Applies to graduating cohorts of 2019-2021, implemented in grade 8 for AY 2014-15.



Note: These figures show the *primary,* but not comprehensive, course pathways available to students prior to and following the change in policy outlined by this paper. The three-course sequence required for graduation from SFUSD is bolded. Students often retake these courses if completion requirements are not met (i.e., by receiving failing grades that do not confer credit or failing to pass subjects tests under the California Standards Tests that were required through AY 2012-2013). After failing a course, students will sometimes progress to the next course but double up in a later year to remediate that credit (e.g., by taking Algebra I and Geometry in 10th grade). For all cohorts, students could compress this sequence by "doubling up" and enrolling in two courses within the same academic year. However, this option was not available for all courses or at all campuses. For the class of 2021, the offer of a summer school Geometry course between ninth and tenth grade expanded acceleration in high school. Furthermore, not all high school campuses offered all advanced courses such as AP Calculus. Following the policy change, students could replace year-long Algebra II and Pre-Calculus courses with a "Compression Course" including content from both. This course is classified as an Algebra II course by the UC/CSU system.

Figure 2. Course Enrollment by Grade

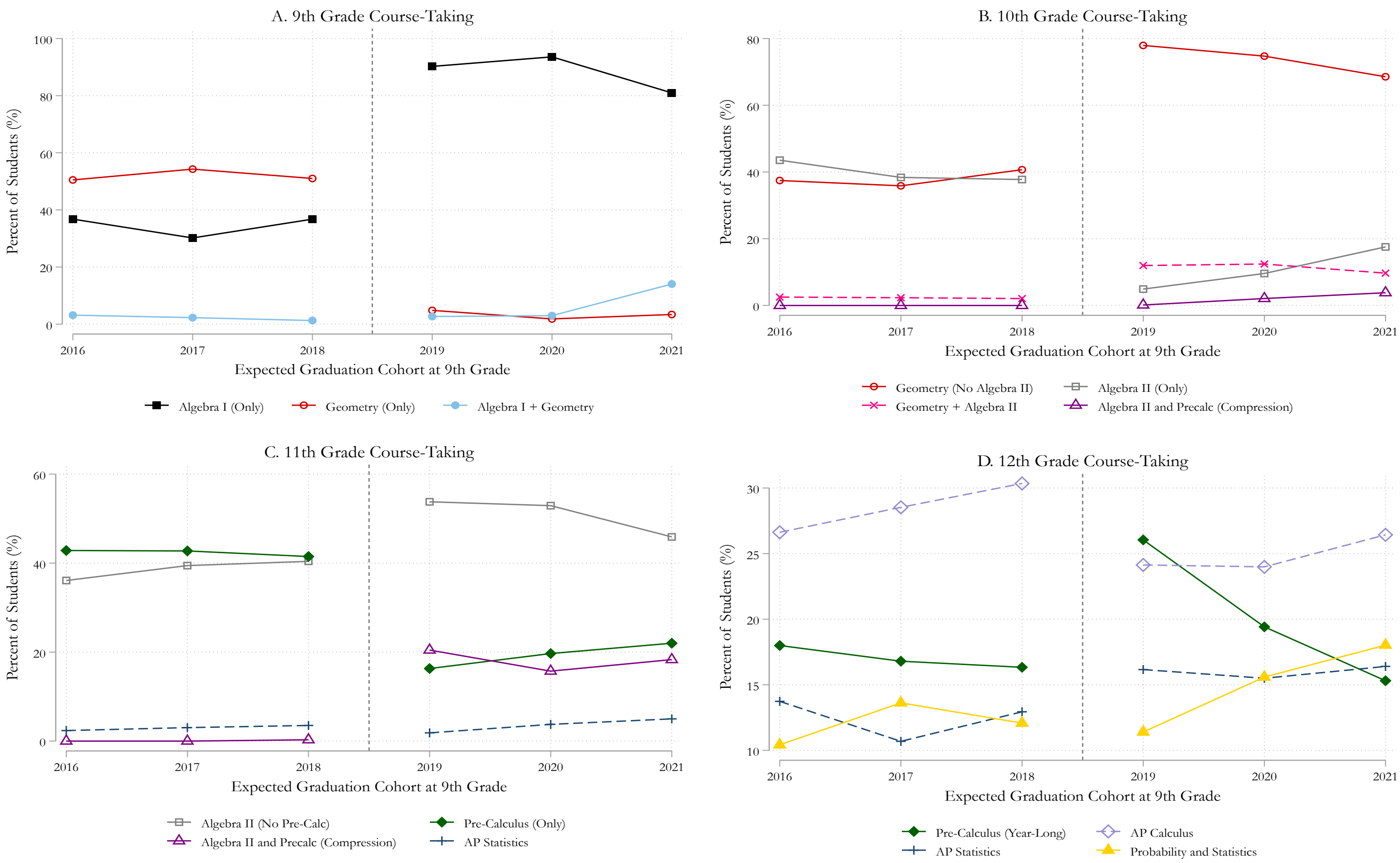


Figure 3. Enrollment in Advanced Courses by Race/Ethnicity

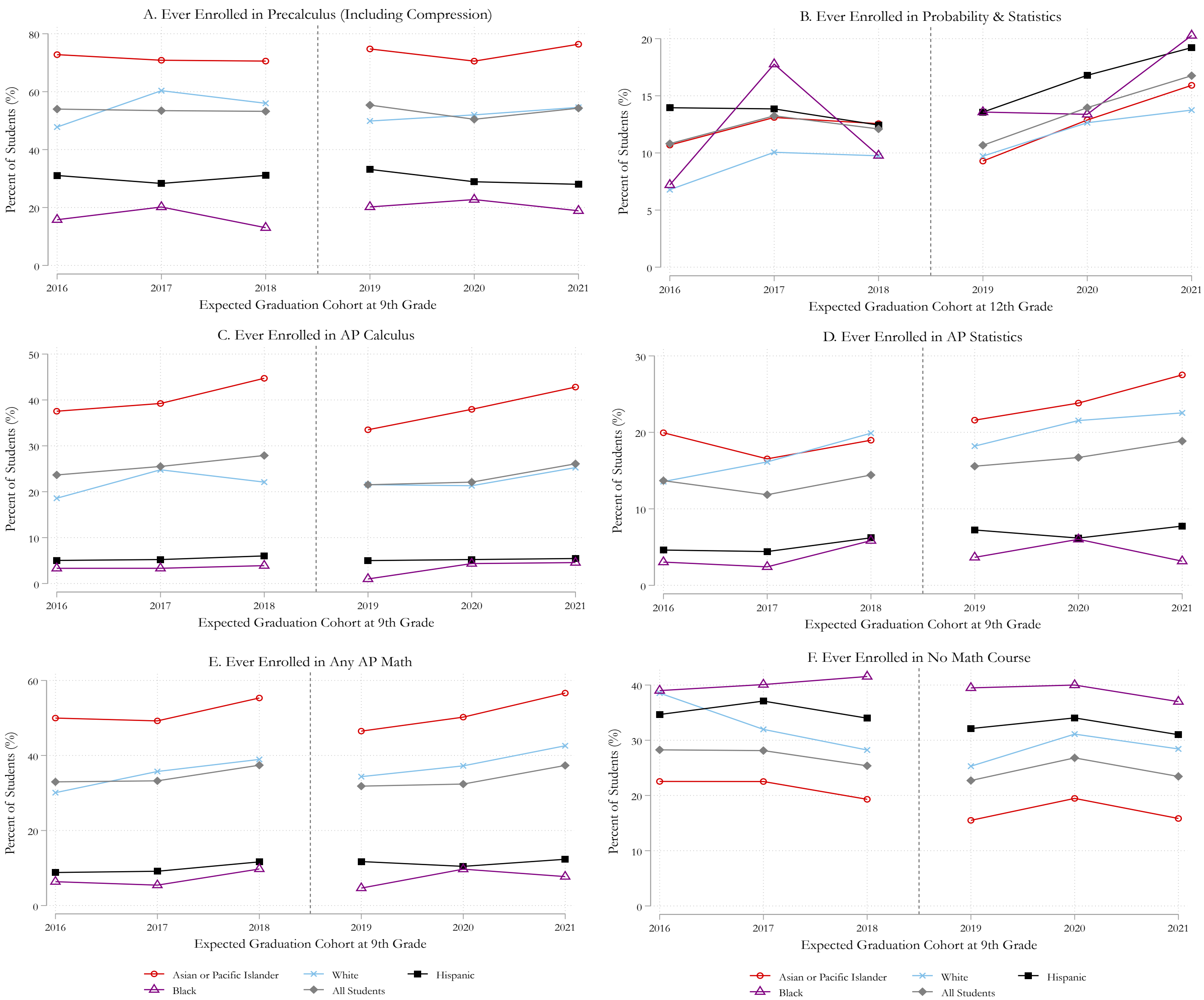


Table A1: Math Course-Taking Patterns of SFUSD High School Students by Class

	2016	2017	2018	2019	2020	2021
Took Algebra 1 in 9th Grade: N	1568	1250	1471	3562	3790	3706
percent	39.89%	32.47%	38.03%	92.93%	96.56%	94.98%
Ever Took Precalculus (Inc. Compression): N	2122	2058	2058	2122	1981	2119
percent	53.98%	53.45%	53.21%	55.36%	50.47%	54.31%
Ever Took Probability & Statistics: N	425	510	468	409	548	654
percent	10.81%	13.25%	12.10%	10.67%	13.96%	16.76%
Ever Took AP Calculus: N	916	982	1079	825	867	1018
percent	23.30%	25.51%	27.90%	21.52%	22.09%	26.09%
Ever Took AP Statistics: N	538	456	558	597	656	736
percent	13.69%	11.84%	14.43%	15.58%	16.71%	18.86%
Ever Took AP Math: N	1296	1280	1447	1220	1271	1457
percent	32.97%	33.25%	37.41%	31.83%	32.38%	37.34%
Total N	3931	3850	3868	3833	3925	3902

Table A2. Difference in Average Course Enrollment Between Pre- and Post- Policy Cohorts

Course	All Students	Asian or Pacific Islander	Black	Hispanic	White
Precalculus (Including Compression)	-0.0019	0.0247**	0.0433*	-0.0020	-0.0251
p-value	0.7973	0.0045	0.0149	0.9311	0.2116
AP Calculus	-0.0243***	-0.0249*	-0.0013	-0.0021	0.0092
p-value	0.0000	0.0107	0.8872	0.7242	0.6367
AP Statistics	0.0374***	0.0569***	0.0058	0.0193**	0.0432**
p-value	0.0000	0.0000	0.5824	0.0012	0.0081
Probability and Statistics	0.0177***	0.0053	0.0427**	0.0320***	0.0323*
p-value	0.0001	0.3674	0.0074	0.0006	0.0131
No 12th Grade Math	-0.0291***	-0.0458***	-0.0124	-0.0277*	-0.0441*
p-value	0.0000	0.0000	0.6580	0.0402	0.0243
Any AP Math	-0.0068	-0.0052	0.0033	0.0157*	0.0327
p-value	0.2654	0.6633	0.8277	0.0380	0.1220
District-Defined Advanced Math	0.0174**	0.0230***	0.0679**	0.0306*	0.0525**
p-value	0.0050	0.0009	0.0022	0.0156	0.0083
N	23,309	10,558	1,887	6,137	2,347

Notes: This table summarizes comparisons of course enrollment for cohorts preceding (i.e., classes of 2016, 2017, 2018) and following (i.e., classes of 2019, 2020 and 2021) changes to SFUSD's Algebra assignment policy. Each cell displays the mean difference in post- versus pre- policy change enrollment by graduaton cohort defined at 9th grade entry. P-values for a post-hoc joint hypotheses test comparing the equivalence of post- and pre- policy coefficients are generated by a regression of the outcome on a set of cohort indicator variables for each subgroup-outcome comparison. In the underlying regressions, standard errors are robust and the baseline cohort (i.e., the class of 2016) is the omitted group. + $p<.1$, * $p<0.05$, ** $p<0.01$, ***

Table A3. Difference in Average Course Enrollment Between the 2018 and 2019 Graduating Cohorts

Course	All Students	Pacific	Black	Hispanic	White
Precalculus (Including Compression)	0.0216+	0.0424**	0.0721*	0.0214	-0.0620+
	(0.0114)	(0.0149)	(0.0301)	(0.0209)	(0.0364)
AP Calculus	-0.0637***	-0.1119***	-0.0290*	-0.0103	-0.0078
	(0.0098)	(0.0162)	(0.0124)	(0.0102)	(0.0302)
AP Statistics	0.0115	0.0261+	-0.0220	0.0102	-0.0163
	(0.0081)	(0.0134)	(0.0172)	(0.0112)	(0.0287)
Probability and Statistics	-0.0143*	-0.0329**	0.0384	0.0112	-0.0017
	(0.0072)	(0.0104)	(0.0260)	(0.0151)	(0.0217)
No 12th Grade Math	-0.0267*	-0.0382**	-0.0175	-0.0180	-0.0284
	(0.0105)	(0.0130)	(0.0491)	(0.0238)	(0.0354)
Any AP Math	-0.0558***	-0.0881***	-0.0510*	0.0007	-0.0476
	(0.0108)	(0.0166)	(0.0208)	(0.0144)	(0.0352)
District-Defined Advanced Math	0.0009	-0.0084	0.0553	0.0287	-0.0055
	(0.0107)	(0.0119)	(0.0376)	(0.0223)	(0.0344)
N	7,701	3,583	610	1,993	753

Notes: This table summarizes comparisons of course enrollment for cohorts preceding (i.e., classes of 2016, 2017, 2018) and following (i.e., classes of 2019, 2020 and 2021) changes to SFUSD's Algebra assignment policy. Each cell displays the mean difference in post- versus pre- policy change enrollment by graduaton cohort defined at 9th grade entry. P-values for a post-hoc joint hypotheses test comparing the equivalence of post- and pre- policy coefficients are generated by a regression of the outcome on a set of cohort indicator variables for each subgroup-outcome comparison. In the underlying regressions, standard errors are robust and the baseline cohort (i.e., the class of 2016) is the omitted group. + $p<.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A4. Difference in Average Course Attainment Between Pre- and Post- Policy Cohorts

Course	All Students	Asian or Pacific Islander	Black	Hispanic	White
Precalculus (Including Compression)	0.0065	0.0315***	0.0269+	0.0195+	-0.0154
p-value	0.3121	0.0006	0.0942	0.0679	0.4934
Probability and Statistics	0.0100*	0.0007	0.0349**	0.0164+	0.0324**
p-value	0.0150	0.8364	0.0095	0.0705	0.0061
AP Calculus	-0.0247***	-0.0214*	-0.0061	-0.0001	-0.0006
p-value	0.0000	0.0319	0.4746	0.9983	0.9514
AP Statistics	0.0379***	0.0580***	0.0062	0.0233***	0.0348*
p-value	0.0000	0.0000	0.5220	0.0001	0.0300
Any AP Math	-0.0062	-0.0006	-0.0010	0.0200**	0.0184
p-value	0.3132	0.9381	0.9021	0.0070	0.3840
N	23,117	10,511	1,848	6,075	2,318

Notes: This table summarizes comparisons of course attainment for cohorts preceding (i.e., classes of 2016, 2017, 2018) and following (i.e., classes of 2019, 2020 and 2021) changes to SFUSD's Algebra assignment policy. Attainment is defined by an indicator variable that is 1 if a student earns full credit (i.e., 10 units) for a course by the end of 12th grade. Each cell displays the mean difference in post- versus pre- policy change enrollment by graduaton cohort defined as 9th grade entry. P-values for a post-hoc joint hypotheses test comparing the equivalence of post- and pre- policy coefficients are generated by a regression of the outcome on a set of cohort indicator variables for each subgroup-outcome comparison. In the underlying regressions, standard errors are robust and the baseline cohort (i.e., the class of 2016) is the omitted group. + $p<.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A5. Difference in Average Course Attainment Between the 2018 and 2019 Graduating Cohorts

Outcome	All Students	Asian or Pacific Islander	Black	Hispanic	White
Precalculus (Including Compression)	0.0183	0.0361*	0.0352	0.0204	-0.0546
	(0.0114)	(0.0154)	(0.0268)	(0.0197)	(0.0365)
Probability and Statistics	-0.0127+	-0.0296**	0.0343	0.0081	0.0073
	(0.0066)	(0.0098)	(0.0218)	(0.0133)	(0.0202)
AP Calculus	-0.0589***	-0.1033***	-0.0290*	-0.0094	-0.0096
	(0.0096)	(0.0160)	(0.0124)	(0.0099)	(0.0296)
AP Statistics	0.0140+	0.0280*	-0.0188	0.0159	-0.0210
	(0.0080)	(0.0132)	(0.0169)	(0.0106)	(0.0282)
Any AP Math	-0.0492***	-0.0797***	-0.0478*	0.0064	-0.0490
	(0.0107)	(0.0167)	(0.0206)	(0.0138)	(0.0348)
N	7,701	3,583	610	1,993	753

Notes: This table summarizes comparisons of credit attainment for the cohort directly preceding (i.e. class of 2018) and following (i.e., class of 2019) changes to SFUSD's Algebra assignment policy. Sample sizes reflect the combined subgroup counts for those two graduation cohorts, defined at 9th grade entry. Each cell displays the coefficient and robust standard error for a bivariate regresson of an indicator for a student earning full credit for a course (i.e., 10 credits) on an indicator for the 2019 graduating cohort. Robust standard errors are listed in parentheses. + p<.1, * p<0.05, ** p<0.01, *** p<0.001.

Figure A1. Ever Enrolled in Course with Precalculus Content

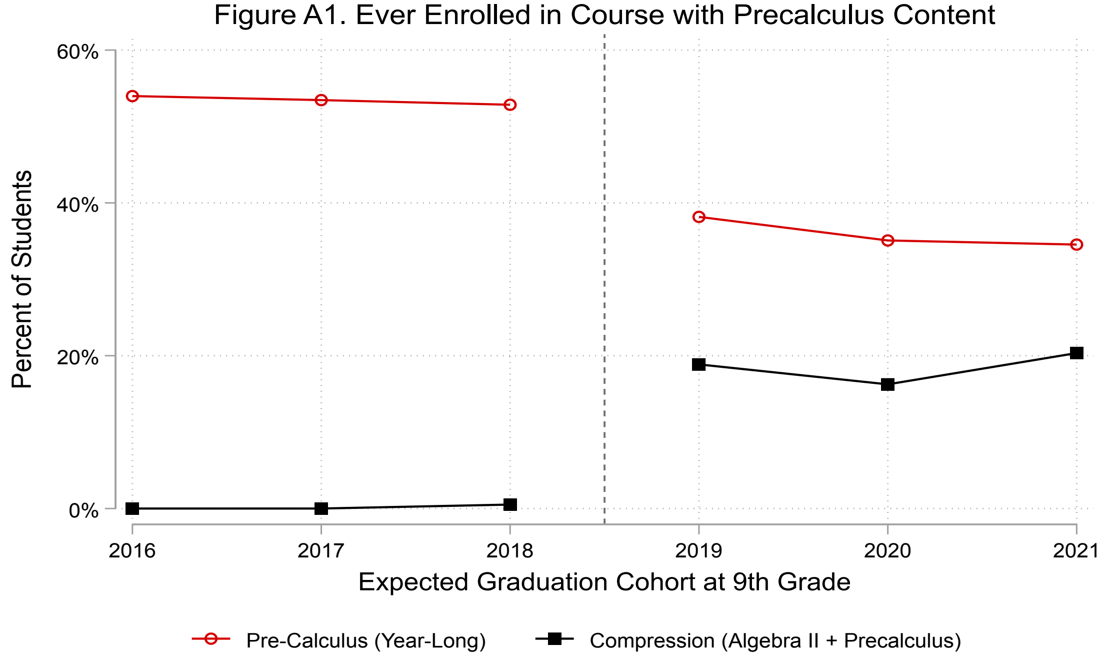


Figure A2. Success in Advanced Courses by Race/Ethnicity

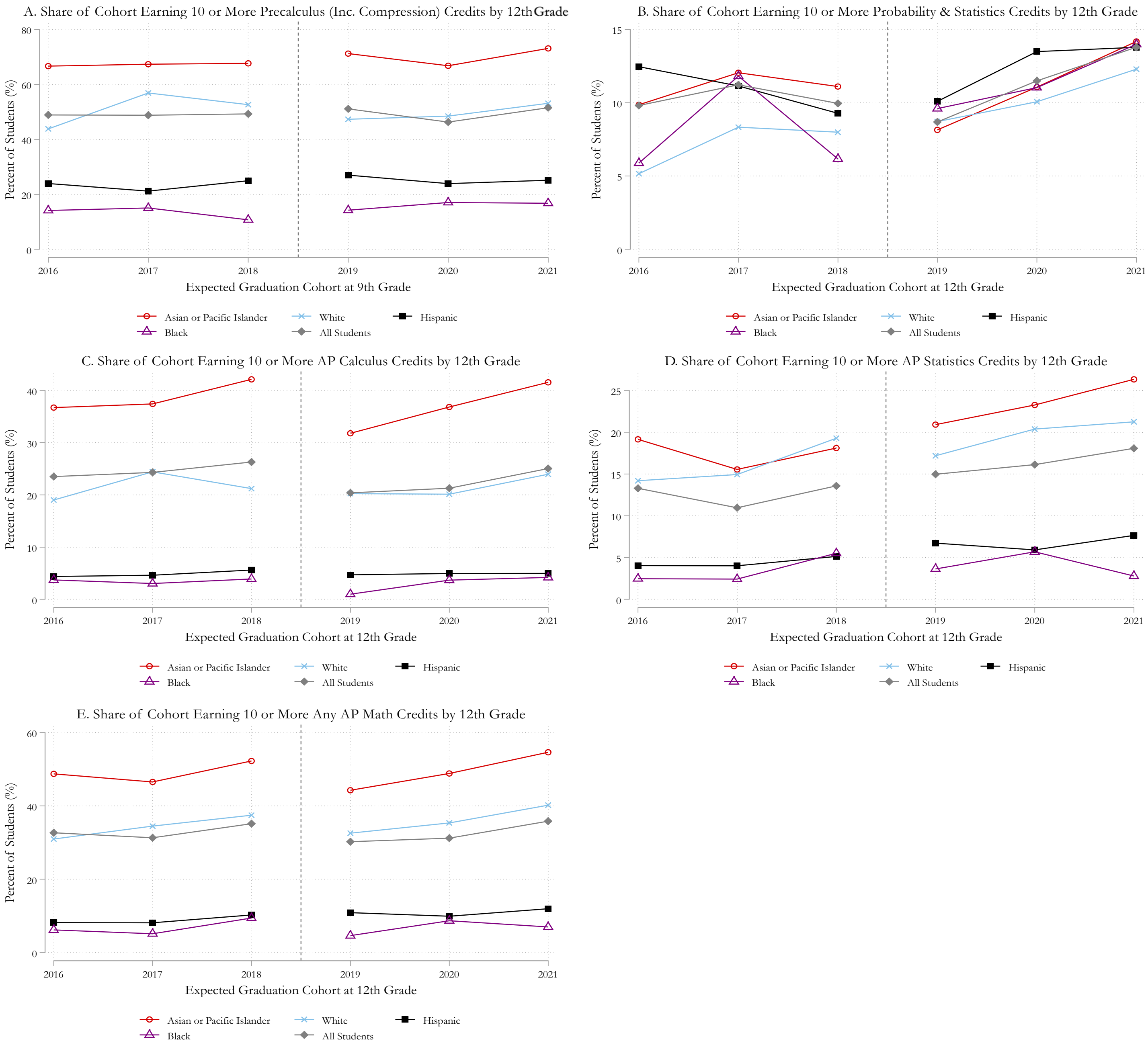


Figure A3. Enrollment in Core Courses by Race/Ethnicity

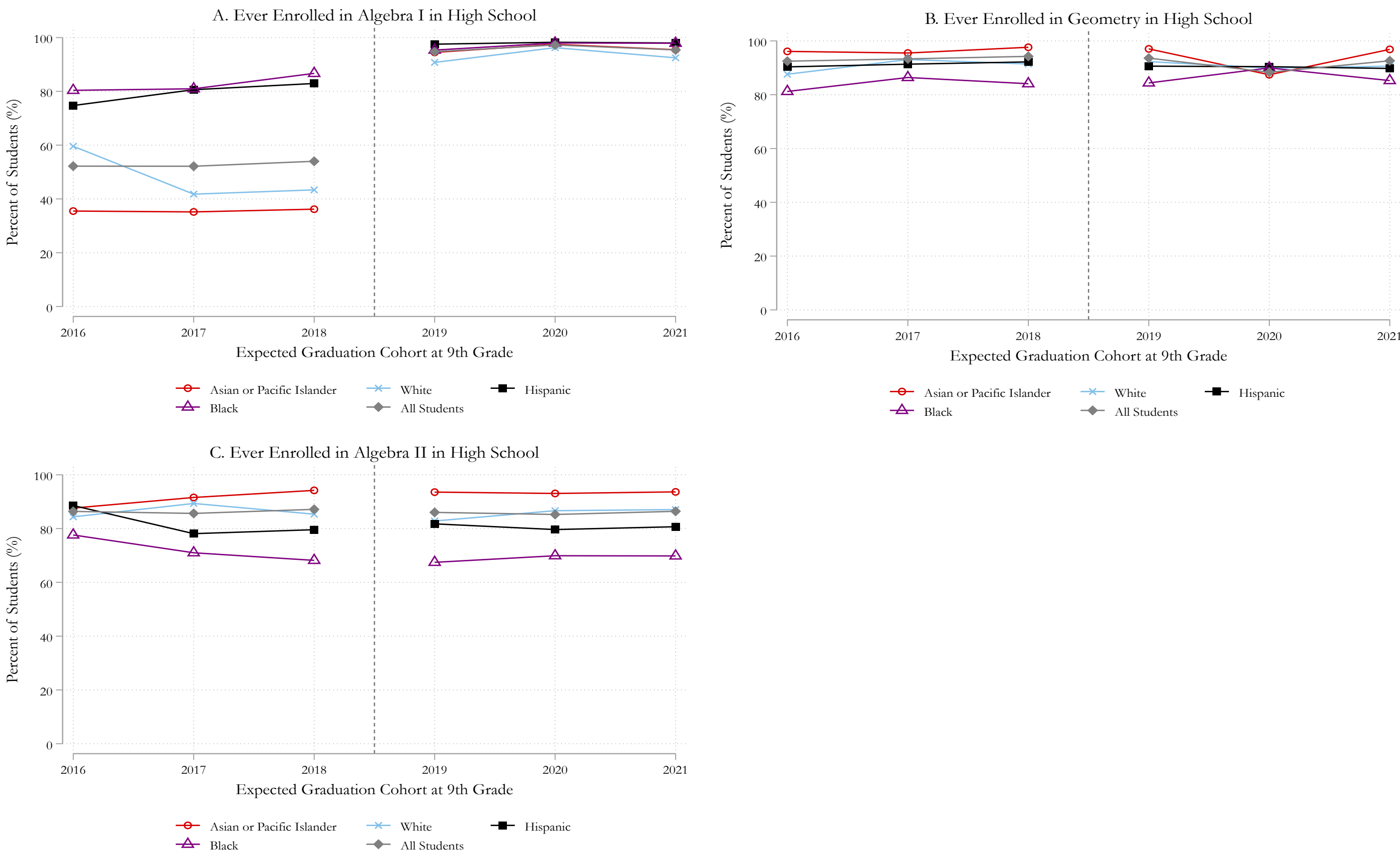


Figure A4. Success in Core Courses by Race/Ethnicity

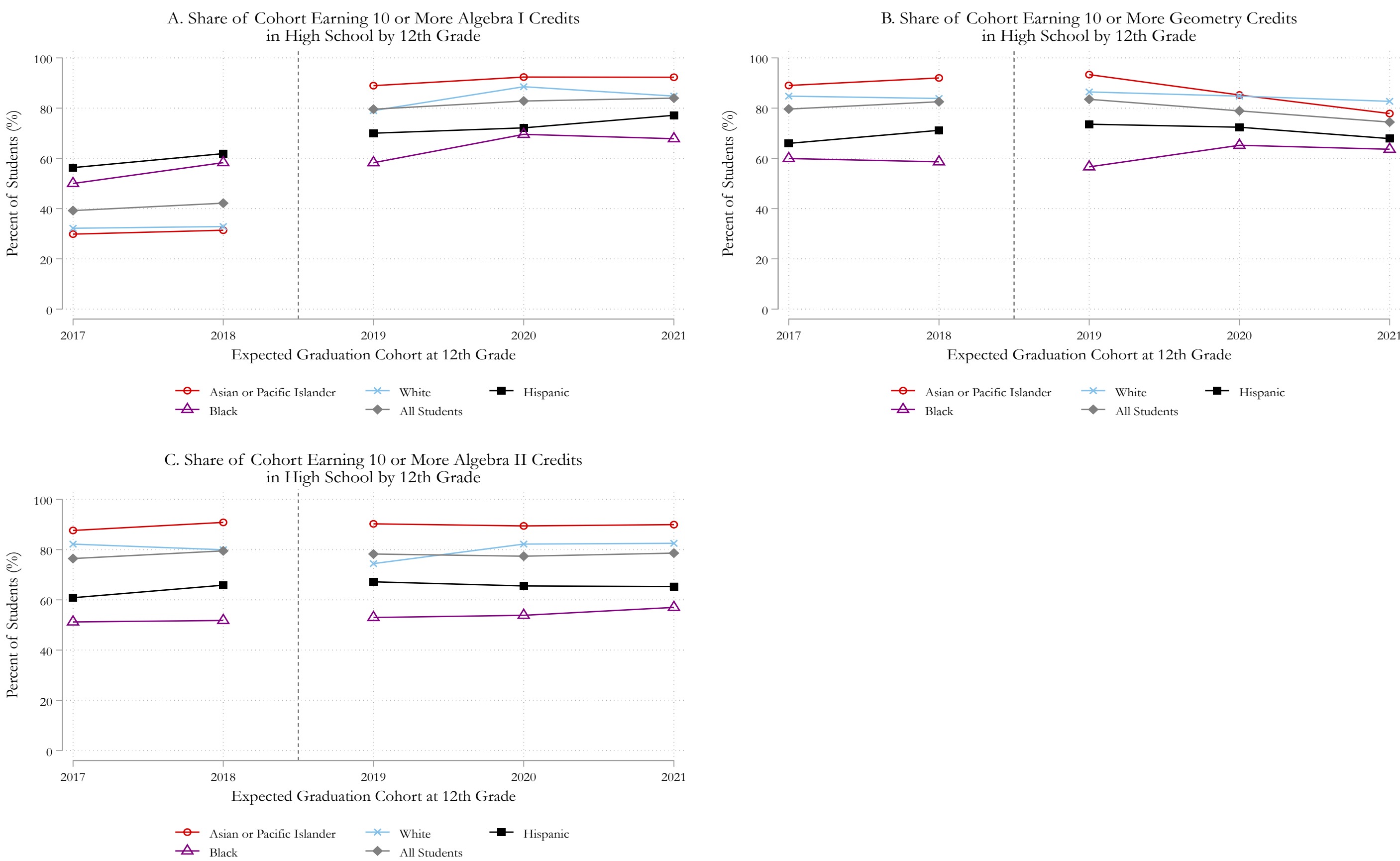


Figure A5. Course Enrollment by Grade (Alternative Cohort Definition)

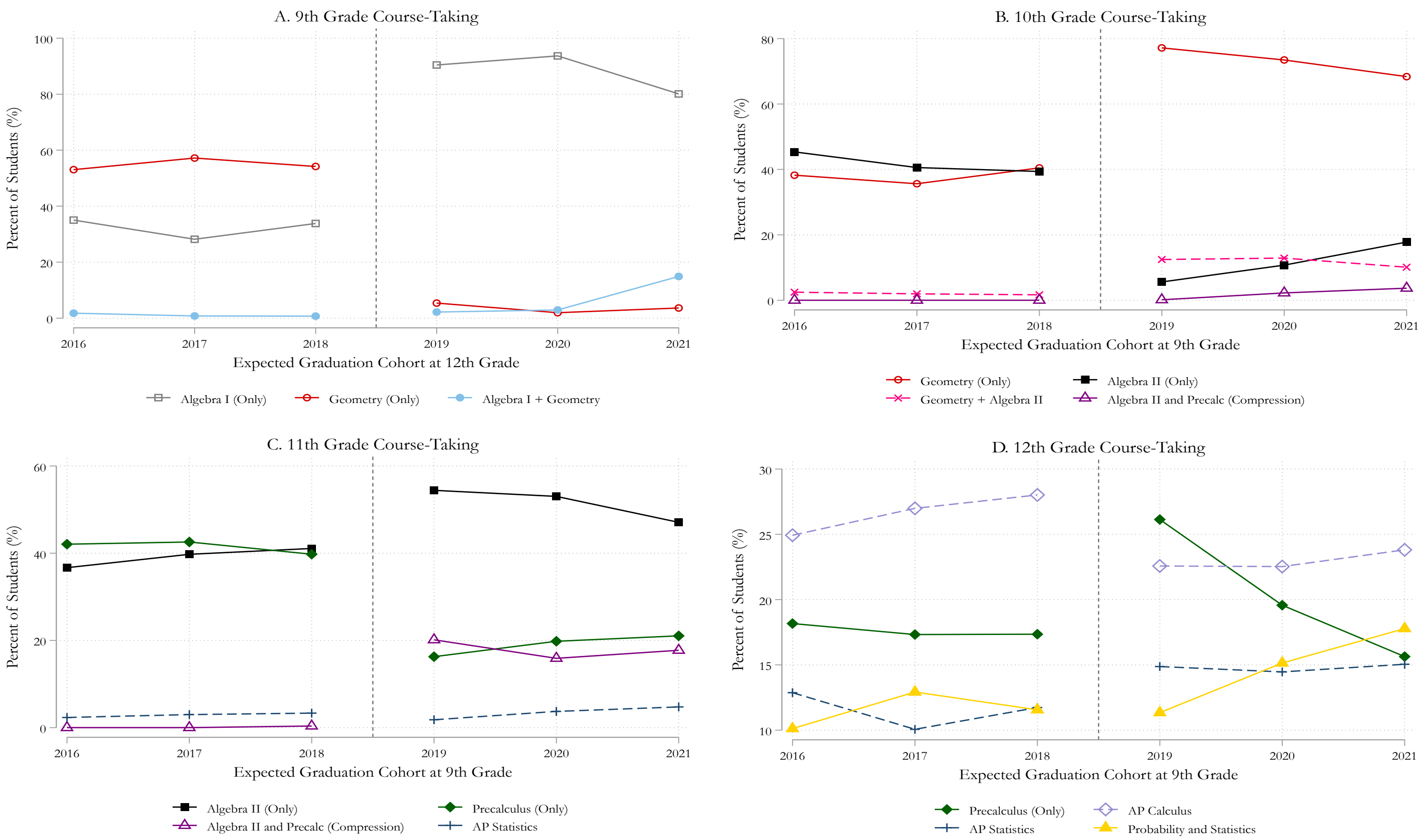


Figure A6. Enrollment in Courses by Race/Ethnicity (Alternative Cohort Definition)

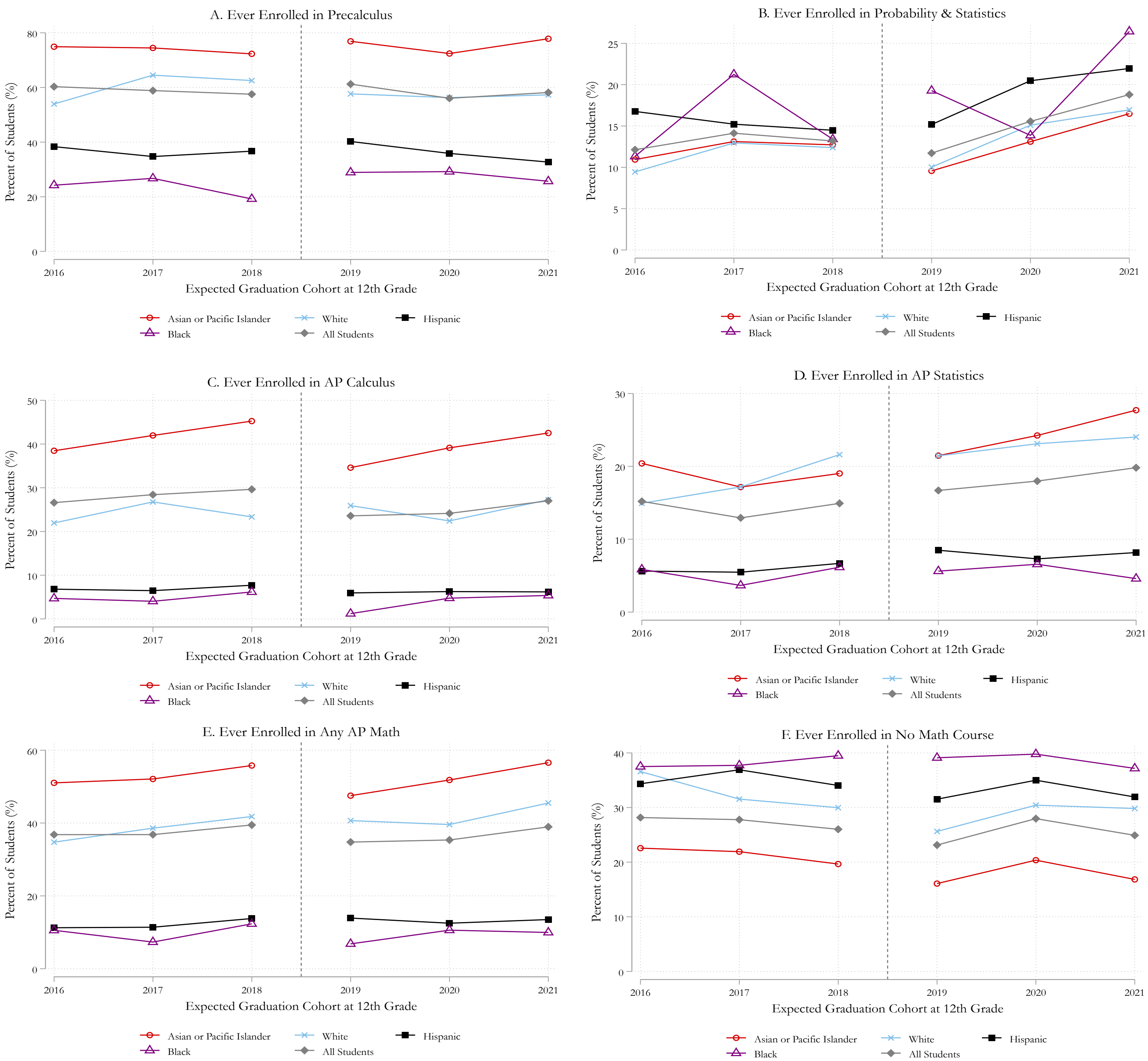


Figure A7. Success in Advanced Courses by Race/Ethnicity (Alternative Cohort Definition)