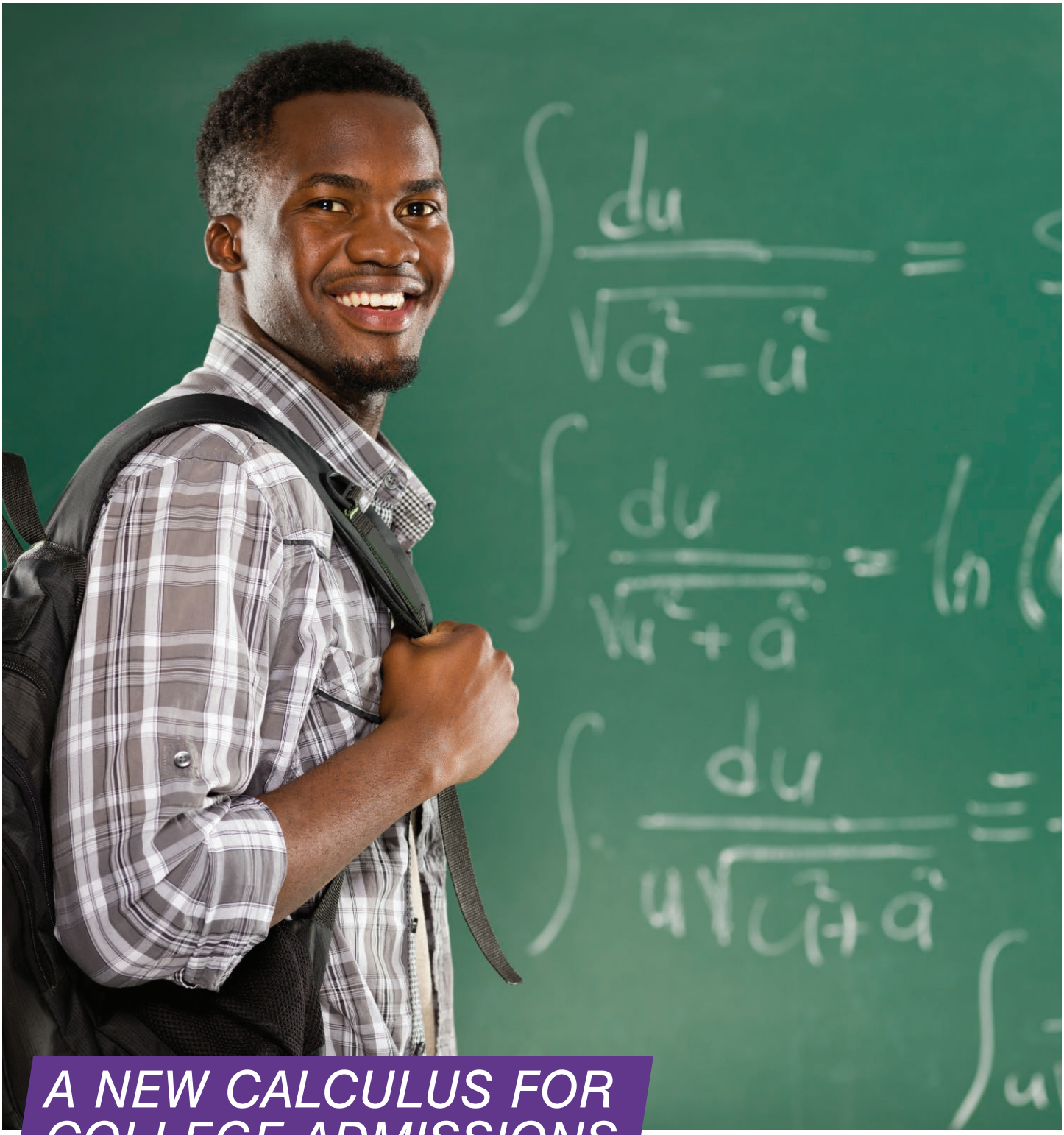


A NEW CALCULUS FOR COLLEGE ADMISSIONS

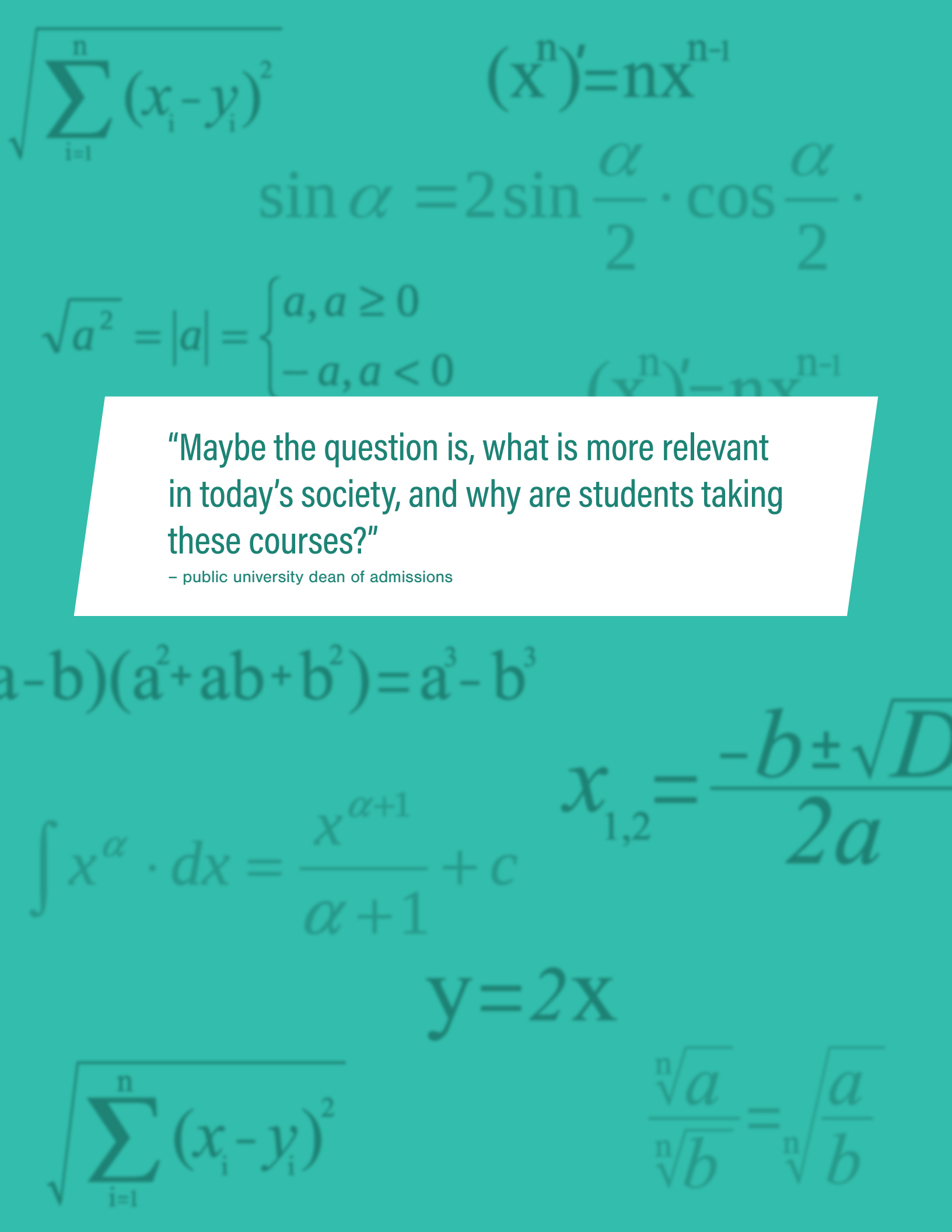
HOW POLICY, PRACTICE, AND PERCEPTIONS OF HIGH SCHOOL MATH EDUCATION LIMIT EQUITABLE ACCESS TO COLLEGE

By Veronica Anderson and Pamela Burdman

January 2022

JUST EQUATIONS

NACAC



"Maybe the question is, what is more relevant in today's society, and why are students taking these courses?"

– public university dean of admissions

ACKNOWLEDGMENTS

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ABOUT JUST EQUATIONS

Just Equations reconceptualizes the role of mathematics in ensuring education equity for students. An independent resource on the equity dimensions of math education in the transition from high school to college, Just Equations advances evidence-based strategies to ensure that math policies give all students the quantitative foundation they need to succeed in college and beyond. Just Equations' work is supported by the College Futures Foundation, Bill & Melinda Gates Foundation, Valhalla Foundation, and The James Irvine Foundation.

ABOUT NACAC

The National Association for College Admission Counseling (NACAC), founded in 1937, is an organization of more than 25,000 professionals from around the world dedicated to serving students as they make choices about pursuing postsecondary education.

ABOUT THE AUTHORS

Veronica Anderson is a communications and planning strategist with expertise in education, media, and public policy. As the principal and founder of the consulting firm PenUltimate Group, she works with leadership teams at school districts and education nonprofits that aim for equitable access, robust engagement, and overall student success. During her career, she has been an education reporter and editor, and has served as a member of the steering committee for the University of Chicago Consortium on School Research.

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> "In moving away from test scores, calculus will be the next frontier for battles of access and equity in higher education."
>
> – public university admissions director

The race to calculus—a path steeped in education inequity—starts in middle school. That's when math placement decisions determine whether students have access to calculus in high school. A student who takes the standard route of algebra in ninth grade, geometry as a sophomore, and Algebra II as a junior won't make it to calculus by 12th grade.[1] Only students who pursue accelerated pathways and study algebra in seventh or eighth grade can reach calculus by their senior year—unless they take summer classes, or their school offers compressed math during the regular school year to provide a leg up on prerequisites that map to calculus.

For years, leading math organizations have cautioned against this pattern. Not all students have the opportunity to accelerate through mathematics. Many who do miss out on foundational math learning and encounter problems later. Even many students who successfully complete high school calculus end up taking calculus again—or even a lower-level math course—when they get to college (Bressoud, 2020). Plus, the emphasis on calculus, a course that has changed little in 50 years, can crowd out the teaching of statistics and data science, subjects that are likely more meaningful for many students' lives and career goals. (See *Math and Science Organizations Urge Change*, p. 5.)

Nevertheless, taking calculus is considered a priority by many families who want to put their teens in the sweet spot for competitive college admissions. For decades, the course has been the highest math course offered at many high schools, reinforcing perceptions that calculus is a must-have for those seeking admission to competitive colleges and universities (Bressoud, 2020). Not all high schools even offer calculus, and access to the course is stratified by race and income. Few colleges and universities stipulate calculus as a universal requirement for admission and it is not included among any state's high school math standards. Still, conventional wisdom says that applicants with calculus on their transcripts have an advantage.

Fostering quantitative skills is an essential goal for K–12 schools and colleges. Increasingly, though, math professional associations and state education systems are promoting a broader, more up-to-date definition of quantitative reasoning. At least half of states' higher education systems support diversified or "modernized" math pathways, in which the choice of required math courses aligns with students' fields of study (Burdman et al., 2018; Charles A. Dana Center, 2020). A decade ago, many colleges and universities required students to complete a general education course such as college algebra or precalculus to graduate, even though the course had no relevance to the majority of students' majors. Today, public institutions in many states also accept alternatives—such as statistics, quantitative reasoning, and mathematical modeling—that better align with students' interests.

Importantly, proponents of these new options note that they are more reflective of how math is used in many careers. Data science itself, a discipline that employs statistical methods and programming to answer questions using real-world data, is not just a new course but a flourishing new college discipline and profession. Its relevance to modern work and life has students voting with their feet. When the University of

[1] Also comparable are integrated math sequences that blend concepts and skills from Algebra I, Algebra II, and geometry that track to precalculus by 12th grade.

MATH AND SCIENCE ORGANIZATIONS URGE CHANGE

Over the past decade, math- and science-focused professional associations and national councils have been making the case for broadening the math pathways students pursue from high school to college:

2011: A panel hosted by the Committee on Mutual Concerns, a joint committee of the Mathematics Association of America and the National Council of Teachers of Mathematics, proposes reorganizing the math courses from high school to college into four sequences: (1) data analysis, combinatorics, and probability, (2) statistical thinking, (3) linear algebra, and (4) multivariate applications of calculus and statistics.

2012: MAA and NCTM issue a joint position statement noting that getting through calculus should not be the "ultimate goal of the K–12 mathematics curriculum."

2013: A National Research Council report, *The Mathematical Sciences* in 2025, says that college math offerings "have not kept pace with the large and rapid changes in how the mathematical sciences are used in science, engineering, medicine, finance, social science, and society at large," suggesting different pathways for "bioinformatics, ecology, medicine, computing, and so on" (p. 10).

2015: Authors of a five-year MAA study on calculus note, "The worst preparation a student heading toward a career in science or engineering could receive is one that rushes toward accumulation of problem-solving abilities in calculus while short-changing the broader preparation needed for success beyond calculus" (Bressoud et al., 2015, p. vi).

2018: In *Catalyzing Change in High School Mathematics*, the NCTM recommends "eliminating some obsolete legacy content—for example, some traditional symbolic manipulation from algebra 2 ... for all students to learn other, more relevant content and mathematical processes, including more relevant topics from data analysis and mathematical modeling."

2019: Teams from 23 states participate in the Conference Board of the Mathematical Sciences' forum to consider how "changes in demographics, economic demands, and the mathematical sciences themselves are forcing reconsideration of the pathways into and through college-level mathematics."

2020: Charles A. Dana Center's Launch Years: A New Vision for the Transition From High School to Postsecondary Mathematics report notes that the "narrow pathway toward calculus ... fails to serve most students" but nevertheless "sends a clear signal to high schools, parents, and students" that such courses are "the best or only mathematics options to pursue in preparation for college."

California, Berkeley piloted its Foundations of Data Science course in 2015, for example, the campus reported that it was the fastest-growing course in its history (Belkin, 2018). And the frequency of headlines about algorithms and data analytics underscores the prominence and influence of data science.

High schools, some of which have offered AP Statistics for years, are also experimenting with new rigorous and relevant course options. Offerings in data science, discrete math, and statistics have the potential to promote students' quantitative reasoning skills and readiness for college learning. But they challenge the traditional hegemony of calculus. Until these newer sequences are considered on par with the calculus path—which remains uncommon at selective universities—they will remain in the shadow of calculus, their growth held in check regardless of how much students learn. For new math pathways to take hold, they must be regarded by high schools as rigorous, college-prep options, and students pursuing those pathways must be rewarded in the college admissions process (Charles A. Dana Center, 2020).

As math education evolves to reflect the realities of new technologies and careers, a disconnect exists between many of the academic departments that are propelling these innovations and the college admissions offices that determine who their future students will be. The awareness by many departments in the sciences, social sciences, and humanities of the value of new types of quantitative analysis skills has not yet permeated many admissions offices, particularly at many elite private institutions whose practices have outsize influence over the field (NACAC & NASFAA). As long as colleges and high schools still view calculus as a singular sign of academic status, students and families seeking entry to the most competitive campuses will continue to view the course as a down payment on their ticket to get in.

The purpose of this report is to explore evolving views of the role that calculus plays in education and college admissions. Through a national survey and a series of interviews, it examines four-year college and university admission **policies** with respect to high school math course-taking, the often unwritten **practices** that determine how those policies actually operate, and the **perceptions** that influence evaluations of students' high school records. It highlights **recent policy changes**, such as those adopted by California universities, that place a priority on new math pathways. And it suggests **steps that faculty, admissions offices, and education leaders can take** to realign those policies, practices, and perceptions with the changing role of math in education. The goal is to stimulate new thinking on the part of college administrators, faculty, admissions officers, and K–12 leaders about the contours and content of college math preparation in the 21st century.

METHODOLOGY

For this report, Just Equations partnered with the National Association for College Admission Counseling to research the role of high school advanced math courses in college admissions. The goal was to learn about how higher educational institutions weigh these subjects among entrance requirements. The survey was sent to admissions officers at 1,250 four-year colleges and universities. Among the 137 institutions that responded, 58 percent were private nonprofits and 42 percent were public entities.

We also conducted in-depth interviews with admissions professionals (e.g., deans of admission, directors of admission, or admission officers) at 15 public and private four-year institutions. These discussions provided more nuance on admissions policies, processes, and practices, especially in the realm of decisions that relate to math requirements and advanced math course-taking in high school.

Unless otherwise noted, all quotations in the report come from the interviews or from survey responses. Because not all interviewees wished to have their names or institutions disclosed, we have treated all responses as anonymous, identifying only the type of institution that is represented. Unless otherwise noted, mentions of specific institutions by name refer to publicly available information.

MATH AND COLLEGE ADMISSION POLICY

Decisions about who gets admitted to college, especially selective institutions, are the result of a complex mix of policy and practice, and math expectations are part of that mix. Most colleges have minimum entrance requirements or a set of core courses they expect students to have completed in high school to be eligible for admission. More than half of the colleges and universities that responded to our survey require three years of math for all applicants, and another 38 percent stipulate four years. Only 12 percent require applicants to have taken a minimum of just two years of math. This tracks with findings of a national survey about high school graduation requirements, which found that 28 states require three years of math to graduate, another 22 require four years, and the remaining six either require two years or don't specify a requirement. A majority (29) of states' default high school math requirements did not put students on track to be eligible for admission to a public university in the state (Achieve, 2020). In addition, according to a 2021 study, 29 percent of high schools in the country don't offer the courses required for admission to STEM disciplines at their state's public flagship universities.

Many, but not all, colleges specify what some of those courses should be. Though calculus as an absolute requirement is rare, the required courses often include the traditional sequence of Algebra I, geometry, and Algebra II. Among the handful of schools that look for applicants to have calculus on their transcripts, many noted that applicants who did not have access to calculus at their high schools would not be penalized. This sentiment, however prevalent, was not universal. One admissions officer at a private university noted that such a student's application would be considered "cautiously."

Completing the required high school courses does not guarantee entry. Except for the least selective, institutions generally have additional criteria. At many public universities, these are fairly transparent. Under state law, the University of Texas at Austin, for example, guarantees admission for all high school graduates in the state who are in the top 6 percent of their class and have completed the required courses—including four years of math. At University of Arizona, every eligible applicant—in state and out of state—with an unweighted 3.0 grade-point average is assured admission.

Other institutions use a more extensive or holistic review process, in which applicants are evaluated based on a series of academic, experiential, and personal factors. The University of California's comprehensive review is a notable example. To sort through the tens of thousands of applications they receive every year for first-year slots, its nine undergraduate campuses may consider up to 14 criteria. (See *UC Comprehensive Review*, p. 7)

Private colleges and universities also evaluate applicants based on academics, personal characteristics, and experiences, but their criteria tend to be more opaque. Extracurricular activities

UC COMPREHENSIVE REVIEW

Partial list of criteria that UC campuses may consider in selecting their freshman classes:

- Grade-point average in UC system–approved high school courses, with extra points for UC-certified honors courses.
- Number of UC system–approved courses beyond minimum requirements, including UC-certified honors, Advanced Placement, and International Baccalaureate courses.
- Outstanding performance in academic subjects or special projects in any field of study.
- Applicant's place of residence and location of high school.
- Accomplishments in the context of applicant's circumstances.
- Academic performance in the context of educational opportunities available to applicant.
- Special talents, achievements and awards; special skills; or demonstrated special interests.

and letters of recommendation may factor heavily as well. In the ongoing lawsuit over its admissions practices, Harvard published a detailed description of its whole person review process. "Harvard College holds an expansive view of excellence and takes into account many factors when building a class," it notes. Those factors include grades and college admissions test scores, personal essays, leadership and life experiences, teacher recommendations and alumni interviews, extracurricular activities, sports, awards, and race/ethnicity.

Given the number of variables that are evaluated during admissions reviews, math would seem a relatively small component in the overall mix. But math is a core academic subject, and calculus on a transcript carries the prestige and presumption of intelligence. And admissions officers do need factors to distinguish among tens of thousands of applicants.

> *"Calculus is an easy answer to a complicated question. Institutions are looking for a simple gatekeeper. We are looking for ways to determine excellent and extraordinary students."*

Math requirements are often determined by faculty or admissions committees, or, for many public institutions, by state departments of education or university governing boards. When colleges review applicants' math course–taking—as is the case for most colleges in our survey—it is done at the outset of the admissions process, when transcripts are evaluated for general eligibility. A handful of less-competitive schools noted that math is not evaluated. One respondent explained that math coursework is assessed only if an applicant is "on the bubble" or when an applicant is appealing a denial of admission. Another shared that high school coursework is assessed only after students enroll, when advisors are counseling students about which math courses to take.

Some high schools don't have the resources to offer calculus courses. While 50 percent of all high schools offer calculus, only 38 percent of high schools with predominantly Black or Latinx enrollment offer calculus (U.S. Department of Education, 2018). Students in rural areas are also less likely to have access to the course (Saw & Agger, 2021). What happens to applications from otherwise high-achieving applicants who do not have access to calculus? Most survey respondents say that if the candidate has made the most of the academic opportunities offered by their school but did not take calculus because their school doesn't offer it, then they are not penalized. Overwhelmingly, admissions officers (89 percent) say calculus is not necessary for all applicants.

> *"We look at the courses they took and how they performed. If they're maxing out courses with strong recommendation letters, then we'd advocate for admission."*

> *"We have admitted students without precalculus."*

Admissions officers are paying more attention to student background, with the understanding that lack of access to advanced math does not mean lack of ability. "Expectations for first-generation students or students from under-resourced schools will be somewhat different," said one public university admissions leader. More students are being admitted from high schools where calculus is not offered, noted another public university admissions officer. To support these students once they enroll, the official explained, classes, tutoring, and additional supports are available, especially for those pursuing engineering.

> *"We consider what is available to a student. No penalty if calculus is not offered."*

> *"We only consider what was available to the student at their home high school. We never expect a student to look outside that high school curriculum."*

> *"Perfectly admissible if they have exhausted all other math courses available to them at their school."*

"It's a problem with perception if a student thinks they shouldn't apply if they didn't take calculus."

On the other hand, campuses with a STEM (science, technology, engineering and mathematics) focus that require calculus for all or nearly all admitted students tend to hold the line:

"We occasionally will admit students who are missing one of our required courses on a conditional basis assuming they will take the required course during the summer before they enroll."

"We cannot admit students who have not taken calculus in high school, so the student would be denied."

"We see if they had calculus elsewhere, such as at a local college."

Another barrier to equity is tracking within schools. Researchers have documented the role of racial and gender bias in how students are placed in middle school math. Such placement decisions have implications for a student's transcript, with high-performing Black and Latinx students less likely to be placed on accelerated tracks (Gao & Adan, 2016; National Council of Teachers of Mathematics, 2018), which can also reduce their access to advanced courses in other subjects (Baker, 2021).

PERCEIVED GOLD STANDARD?

A perceived advantage of taking calculus, especially AP Calculus, is an improved chance of getting admitted to highly competitive colleges. At many highly selective colleges and universities, a preponderance of first-year students arrive on campus with calculus under their belts, a phenomenon that exists even at a small, private, liberal arts institution. Consider Wesleyan University, where 79 percent of the incoming fall 2021 class had completed math through calculus—a rate that far exceeds the most recently documented national trends. According to the National Science Board, only 19.3 percent of high school students in 2013 had completed calculus or higher by the time they graduated, and attainment rates for calculus vary substantially by race and ethnicity. (See *Calculus Attainment of High School Graduates,* p. 9.)

Gaining admission figures prominently among the reasons given by college freshmen for taking calculus

Calculus Attainment of High School Graduates

By gender, race, and income

Source: National Science Board, 2018
*By SES within racial/ethnic group

during high school. This is especially true for students who take AP Calculus but don't ultimately earn college credit based on an AP exam score, according to surveys of students. Rather than enroll in calculus because they loved math or had an inherent interest in STEM, the most common answer (81 percent of respondents) students gave for taking the course was, "AP Calculus looks good on college applications" (Rosenstein & Ahluwalia, 2017, p. 33). As one high school math teacher lamented, "The goals of most high school students taking calculus are focused on college admissions rather than mastery of the content" (Teague, 2017, p. 45).

Even doing well in AP Calculus doesn't guarantee or predict advanced math standing in college. Estimates are that fewer than 20 percent of students who took it go straight to Calculus II in college. Another 30 percent take Calculus I, a repeat of the AP course. The other half of students take precalculus or remedial algebra courses, non-calculus pathway courses such as statistics, or no math at all (Bressoud, 2017, p. 5).

Indeed, research shows that high school calculus completion is less an indicator of preparation for college and more a signal of family income. Students from high-income families complete calculus in high school at a rate that is more than four times that of students from low-income families (National Science Board, 2018).

Regardless of whether calculus is necessary preparation for college, entrenched beliefs about academic rigor and the premium placed on calculus as a sign of rigor play a significant role in admissions, as illustrated by responses to our national survey of admissions professionals:

- When asked to name which advanced high school math courses carry the most weight for admissions, respondents' top three choices were AP Calculus (75 percent), regular calculus (73 percent), and precalculus (50 percent)—all ahead of AP Statistics (38 percent).

- An overwhelming number of respondents (79 percent) agreed with the statement, "Students who have taken calculus are more likely to succeed in college."

- Close to 80 percent said faculty at their institutions place a high priority on calculus as a sign of rigor.

CALCULUS FOR STEM MAJORS?

Calculus is considered relevant for a number of undergraduate fields of study. Those who wish to earn degrees in fields with a calculus prerequisite may be well-served by taking the course in high school. Besides math, engineering, chemistry, and physics, programs cited by admissions officers for which calculus is recommended or highly recommended include neuroscience, biology, computer science, agriculture, business, and health science. STEM focused institutions that require calculus for all applicants include California Institute of Technology, MIT, Harvey Mudd College, and Franklin W. Olin College of Engineering.

Fewer than a quarter of institutions had outright requirements for such programs, but some had shadow requirements. One private university, for example, had no formal requirement but noted that the schools of engineering and business are not interested in students who have not taken calculus. Another that strongly recommends calculus for engineering says it will accept students without calculus, but only if rigor and strong performance are demonstrated elsewhere in the students' transcripts.

Despite these responses, the preference for calculus is not actually a requirement at most institutions. Fewer than 5 percent of respondents—all at private institutions—considered calculus a blanket requirement for all or most majors. More common (21 percent) was a requirement for calculus for those who seek admission to study engineering, physical science, math, technology, or business (see *Calculus for STEM Majors?*, p. 10). Yet some colleges still advise high school students to take the course. In conversations with admissions officers, private colleges and universities were more likely to recommend calculus for all applicants than their public counterparts. "Calculus is the gold standard that people in this business use as a shortcut," said one dean of admissions at a selective, private university.

As postsecondary institutions adopt new math pathways, admissions policies and practices remain a barrier to diversifying and modernizing high school math pathways. Entrenched beliefs about pathways that culminate in calculus can stifle innovation and opportunity in secondary academics, especially among schools that are focused on college prep.

The beliefs also feed the pressure students feel to enroll in calculus, a pressure felt far beyond the gates of the elite colleges whose preferences help drive it. "I worked [here] before it was as competitive as it is now," said a director of admissions at a public university. "I see more students with precalculus and calculus now than before. Most of our applicants exceed math requirements."

BRANCHING OUT: STATISTICS AND NEW MATH PATHWAYS

To move beyond the perceived gold standard of calculus, greater awareness and acceptance of new evidence-based math pathways is necessary. Yet, for courses outside the traditional calculus pathway, variation in admission policies and attitudes is wide. Some public institutions, notably UC, have made clear that AP Statistics is not only accepted for admission but also receives equal weight in the admission process to other advanced math courses. In 2020, the UC system went further, revising its admission policy to include data science among courses that would be accepted toward the required three or recommended four years of math—a step that was considerably ahead of its peers.

The admission team at Stanford University has taken similar steps. Before 2018, Stanford's recommendations for prospective students read "four years (including calculus)." Then they were revised to call for four years of math focused on fundamental skills in algebra, geometry and trigonometry. A more recent revision, published in 2021, prescribes "any" rigorous preparation in fundamental math skills and lists calculus, statistics and data science together as courses it "welcomes" (see *Stanford Recognizes New Math Pathways,* p. 11).

However, our survey revealed that statistics is not universally recognized as rigorous, particularly when it comes to more selective private institutions. Though AP Statistics squeaked into the top four on the list of courses with the most weight in admissions, it was cited by half as many admissions professionals as AP Calculus and ranked considerably lower than precalculus. A majority (61 percent) of respondents said statistics is not as rigorous as calculus, with private colleges and universities more likely to answer this way (65 percent) than public ones (57 percent).

> *"Statistics does not meet college prep (as determined by math faculty)."*
>
> *"It would distress me to think of disregarding the importance of rigorous math preparation. Calculus needn't be required of all, but I disagree with undervaluing the accomplishment of pursuing calculus versus statistics."*
>
> *"We do see [calculus and statistics] differently. We think about what correlates to a first-year experience. ... If a student is already taking calculus in high school, they're better prepared for that transition. ... Not to say that another student wouldn't be able to do it with some help. But stats? I don't know. Stats is good and can be challenging for some students, but stats can be taught so differently, even in an AP curriculum. Calculus is probably a better ... transition class to what you learn in college."*

STANFORD RECOGNIZES NEW MATH PATHWAYS

Pre-2018 statement on math requirements for admission: four years (including calculus)

2018 statement: Four years, with significant emphasis on fundamental mathematical skills (algebra; trigonometry; plane, solid, and analytic geometry)

2021 statement: Four years **of any rigorous** mathematics incorporating a solid gorunding in fundamental skills (algebra, geometry, trigonometry). **We also welcome preparation in skills related to statistics, data science, and calculus.**

Some institutions, such as UC, calculate a weighted GPA, in which each AP course confers five points instead of four for an A, for example. Nonetheless, admissions professionals don't view all AP courses equally. According to one public university dean of admission, a student with five AP courses in hard science, calculus, and English has "more rigorous courses in our minds" than a student who has five APs in social and interdisciplinary sciences.

Given the ambivalence that extends even to AP Statistics, it is no wonder that relatively few colleges have acknowledged the growth of rigorous data science courses at the high school level. Plus, the courses are very new in most places. A number of states, including Ohio, Washington, and Georgia, are including data science within their K–12 math standards. And schools in New Jersey, Oregon, and New York have begun piloting data science courses. But to date, only California—where a data science course piloted by UCLA six years ago is now offered at more than 60 schools across 17 districts—offers such courses at any scale. So it is not surprising that California is the first state university system to list data science as an acceptable option to fulfill requirements for admission.

UC's 2020 policy places the system on the leading edge of including 21st-century math in admission practices (See *Anatomy of Change*, pp. 14-15). In fact, among the 15 admissions officers interviewed for this report, only one, from a UC, included data science when asked to list the advanced math courses they look for from applicants. While most survey respondents had seen data science on student applications (85 percent), only 38 percent said the course will fulfill their institution's math requirements for admission.

> *"We love data science. We have a major in it. It's unclear what it means on transcripts. It's not seen as a class with full potency."*

> *"Nontraditional math if it's in students' fourth year, it's OK. If it's before, then we're looking for traditional courses."*

The gap between awareness and acceptance is even wider for some nontraditional math courses, such as Social Justice Mathematics, Math in Finance, and Personal Finance. One admissions officer at a private college admitted that their school is looking for a traditional math pathway; courses such as Personal Finance or Social Justice Mathematics are not as compelling.

> *"Nontraditional math courses are viewed favorably as long as it's advanced math. Programs like economics and information science would view [those courses] favorably. Engineering, medicine, and hard sciences prefer calculus."*

By contrast, discrete math—another nontraditional high school math course used in computer science for algorithms and software development—is both widely recognized (83 percent) and accepted (76 percent). The explanation may be that college math departments have long offered a course by the same name.

CONFUSING MIX OF MESSAGES

Many institutions fall somewhere between explicitly assigning equal weight to courses such as statistics and actively discounting them. Some don't spell out which courses are required, but since many states require Algebra II in high school, requiring a high school diploma may be an indirect way of specifying. Others strive to deliver a more nuanced message. Students seeking clear answers may end up confused, or—particularly if applying to a mix of public and private colleges—decide to err on the safe side and take calculus.

When making the rounds on the college recruitment and outreach circuit, admissions officers connect with interested students, high school college counselors, and parents to promote their programs and walk through application logistics. Invariably, questions come up about calculus. Do seniors have to take calculus? Does it matter if students take statistics instead? What happens if students decide to take calculus to challenge themselves but then they don't do well in the class? According to survey responses from admissions officers, students who hear these presentations may receive a confusing mix of messages. Three to four years of math is recommended. Step up the level of rigor with each course. Perform well in those classes. Calculus is recommended but not always required. Take advanced math but not a math elective.

For instance, some respondents were quite prescriptive about calculus and related courses:

"We want students to take precalculus or calculus. We want to stretch people but not push them beyond their level of preparation. We expect them to take rigorous courses and do well in them."

"Calculus is recommended for all and expected for some."

"We recommend that all applicants take calculus, if it is available to them."

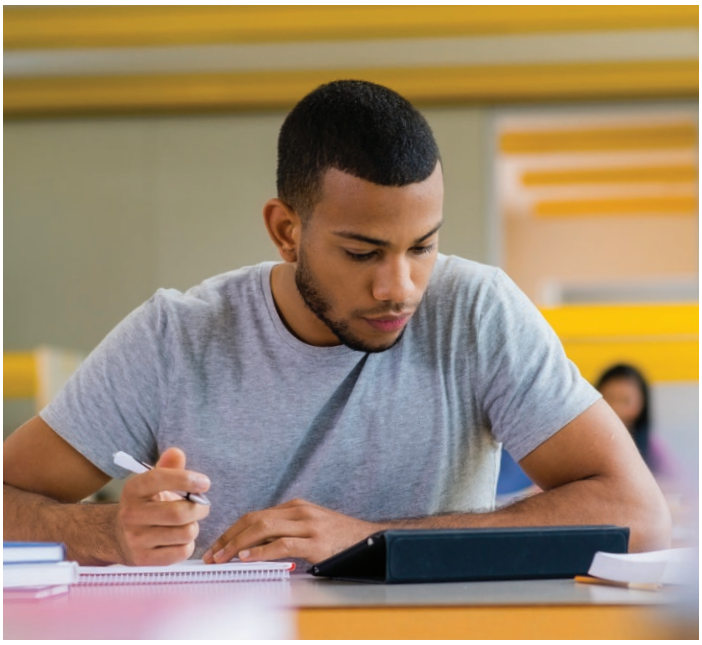
"We expect to see math through calculus. Students without calculus are much less likely to succeed in our curriculum."

Others expressed more flexibility around math options:

"We don't get fixated on calculus. We want to see four years of progressive math. We would rather see them take math and struggle than stop taking it, though we don't want to see a failing grade."

"We recommend that students applying to all majors challenge themselves with rigorous, foundational math courses. We'd prefer that students take the traditional courses—precalculus, calculus, statistics—than more elective math courses. This helps us ensure that they are prepared for more complex courses once they arrive."

"We tell students to challenge themselves and take advantage of the rigor available, but take something that is interesting to you."



Still others were more equivocal:

"As long as a student has prepared themselves with a rigorous and progressing math curriculum, they are eligible to be reviewed for admission. That said, if one student takes precalculus and another moves to more elective-based math courses, the first student would be considered more competitive."

"It depends on their interests and goals. They can demonstrate their preparation for college without calculus, although taking it certainly adds weight to their argument."

Even in the survey responses, answers depended on the exact phrasing of the question. Precisely 25 percent of admissions officers surveyed asserted that students who take calculus "have an edge in the admissions process," 34 percent believe applicants' "options are narrowed without calculus on their transcripts," and 48 percent said calculus "outweighs other advanced high school math courses." On the other hand, 47 percent said calculus does not give applicants an edge in admissions.

Admissions officers may be explicitly or implicitly reinforcing these mixed messages on the road, which some acknowledge may not be useful in the end.

ANATOMY OF CHANGE:

Evolving Math Requirements at California Universities

Since universities in California are a step ahead of most higher education institutions in updating their admissions requirements, they offer a useful example of the ways college faculty, state and system leaders, and college admissions officers along with high schools math instructors and counselors can contribute to such changes. The technology sector's roots in California contributed. It also helped that statistics courses had met general education requirements at both the UC and California State University for decades, whereas some state systems until recently required all graduates to take a course such as college algebra. Research organizations and institutions in the state have been national leaders in pioneering new math courses in partnership with community colleges and K–12 schools. In addition, the fine print in the systems' math requirements allowed statistics-oriented courses to meet the Algebra II requirement. Fourth, faculty leadership as well as external advocacy and awareness-building activities provided necessary momentum for change.

August 2011: The Carnegie Foundation launches its Statway (and later Quantway) sequence in several California community colleges and CSU campuses, challenging the traditional algebra-based remedial course sequence and building on college-based efforts such as Path2Stats.

December 2013: UC faculty committee the Board of Admissions and Relations With Schools (BOARS) issues a statement acknowledging as "problematic" the use of intermediate algebra as a prerequisite for transferable math. This move supports efforts at community colleges to develop statistics pathways with pre-statistics preparation instead of algebra.

August 2014: UCLA and Los Angeles Unified School District begin piloting Introduction to Data Science (IDS), with National Science Foundation support. A process within existing admissions requirements allowed the course to meet the Algebra II requirement.

August 2015: UC Berkeley pilots Foundations of Data Science undergraduate course, which becomes the fastest-growing course in campus history.

April 2016: UC's BOARS issues a statement cautioning against the race to calculus, affirming that calculus has no special weight in UC admissions.

June 2016: State legislature passes California Mathematics Readiness Challenge Initiative within state budget to incentivize high school–college partnerships' development of new nontraditional senior-year college preparatory math courses. Courses include IDS at UCLA and discrete math at San Diego State.

September 2016: CSU academic senate's Quantitative Reasoning Task Force recommends that the system "improve access to quantitative reasoning classes relevant to a student's major, interests, and career."

August 2017: CSU chancellor's executive order states that math prerequisites must be "reflective only of skills and knowledge required in the course," effectively ending the use of intermediate algebra as a blanket prerequisite. A companion order eliminates all traditional remedial courses.

March 2018: Psychology faculty launch CourseKata Statistics and Data Science course at UCLA, followed by Cal State LA in the fall, and San Mateo and San Diego district high schools in 2020.

January 2019: CSU trustees vote to study a policy proposal to require a quantitative reasoning course (in addition to the three required math courses) for admission to the system.

June 2020: YouCubed at Stanford University releases the first in a series of data science resources.

October 2020: Based on recommendations from a group of mathematics and statistics faculty, UC updates its admissions policies to explicitly accept a broader set of courses, including data science.

August 2021: Stanford changes its admissions statement to explicitly "welcome preparation in skills related to statistics, data science, and calculus."

August 2021: UC's BOARS issues a Statement on Mathematics Preparation, clarifying its expanded definition of math courses that meet mathematics admissions requirements.

September 2021: UC High School Counselor Conference session on changing math policies and practices is attended by more than 4,000 high school counselors.

"This is supposed to be about helping students, but so much in this makes it confusing," said a public university admissions director.

> *"We say to students who are interested in engineering, business, or computer science: You need calculus to be competitive for those schools. Without it, opportunity for admission may be limited."*

> *"If a student expresses interest in certain majors—business, finance, computer science, engineering—then it is recommended they take calculus or the most advanced level math offered at their high school. For any other majors, we tell students and influencers that a student should take a college preparatory curriculum, and if they're on track to take advanced math courses, they should do so."*

Yet even within STEM fields, this view is being challenged. Life sciences faculty, for example, increasingly value statistics preparation, while those in computer science emphasize the importance of linear algebra (Burdman et al., 2021). One commenter, a mathematician from Princeton, weighed in on a recent New York Times article about the backlash to shifting math pathways away from calculus: "Calculus is less useful and less ubiquitous than linear algebra and statistics in every STEM discipline." A California-based mathematician and computer scientist shared similar sentiments about calculus via Twitter: "Its position in the math hierarchy is a vestige of the aerospace boom of the 20th century combined with its prerequisite status for other STEM disciplines. It no longer makes curricular sense to make it such a centerpiece."

OPPORTUNITIES FOR CHANGE

Prestigious universities (public or private) have outsize influence over perceptions of rigor and quality, so changes they make can help shift admissions perceptions and practices far beyond their own applicant pool. New admissions practices will depend on admissions professionals becoming more familiar with emerging courses and pathways, as has begun to happen in a few states. Exactly how that occurs and who leads the process will depend on specific contexts.

Faculty from disciplines that teach or utilize these new areas of quantitative reasoning have a role to play in promoting innovation. Social scientists have long seen the importance of statistics and data science for their disciplines. Economist Steven Levitt, of the University of Chicago and "Freakonomics" fame, has launched an initiative to promote data science in high schools. Psychologists at UCLA and Cal State LA have also developed a high school statistics course. In fact, math leaders have noted the importance of math faculty learning from colleagues in other departments, because math faculty are generally not experts in how math is used in other disciplines, including STEM fields.

Particularly with the benefit of interdisciplinary dialogues, university math departments and math education scholars can have considerable sway. Increasingly, many see new approaches as key to ensuring students have meaningful math experiences that foster the quantitative literacy they will need in their careers and lives (Charles A. Dana Center, 2020; Daro & Asturias, 2019; National Council of Teachers of Mathematics, 2018).

State policy is another lever for change. Postsecondary systems in at least two dozen state systems have adopted a version of multiple math pathways at the college level, with some poised to address admissions requirements that support expanded high school math options. New or emerging math frameworks in states such as California, Georgia, Oregon, and Washington are beginning to reflect those priorities, though not without a concern among some parents and educators that students will lose access to calculus (which none of the frameworks require).

As the California example illustrates, state contexts do matter: It is likely no coincidence that a state known for its technology industry has been a leader in rethinking mathematics to align with a data-rich, tech-driven world (see *Anatomy of change*, pp. 14–15). California's universities were decades ahead of many of their peers in accepting statistics as meeting the math requirement for college graduation (Burdman et al., 2018). Former California Governor Jerry Brown helped seed the shift in secondary education by funding five partnerships between public universities and local school districts to develop or refine new math courses for high school juniors and seniors. One of them is Introduction to Data Science, a course developed at UCLA that teaches computational thinking and problem solving with data and a mobile app. Already, 66 high schools in California—as well as a growing number across nine other states—offer it. "It seems like a no-brainer to offer students a more relevant taste of advanced math," said a public university official who oversees policies on high school course requirements for admission.

Yet part of the challenge in gaining acceptance for new courses is that many individuals involved in promoting the new pathways have few direct ties to admissions. At least some of the existing emphasis on calculus is independent of colleges' official policies. And it's an emphasis that many high school counselors, leaders, and math teachers—those with the most direct ties to students—have internalized.

More high schools offer calculus than statistics, so some students don't have other advanced courses from which to choose. About 82 percent of high school students have access to AP Calculus, while just 63 percent have access to AP Statistics (Hayes, 2019, pp. 17–18). Plus, admissions officers say that when AP Calculus is available, students seeking access to competitive universities often feel compelled to sign up for it even if they are looking to study humanities or social sciences.

> *"You will find that students who take calculus are also more likely to take other rigorous classes and have good grades in other subjects than students who do not. At many high schools, the top students by overall GPA or rank are the ones taking calculus."*

Shifting admissions takes time, say admissions

officers at UC and other selective institutions that are explicit about not requiring calculus. Applicants are slow to give up calculus and the competitive edge they believe it imparts.

> *"Families are looking for what's the thing that mattered or what makes a difference for one student getting into a school and another not getting in. They home in on calculus as the reason. The applicant pool year-to-year is what really matters."*

> *"Parents and students reverse engineer admissions outcomes. If a student without AP Calculus was denied, they attribute the reason to calculus."*

Students are mastering what it means to turn high school into a college resume, and messages passed along from student to student will resonate more than messages from adults. One student asks another for advice on how to build the best college resume. "They will tell them to take calculus," said a public university admissions officer.

The same is true of many high school counselors, said another.

> *"If we'd ask the high school counselors what are their toughest courses, they would normally say AP Chemistry, AP Physics C, and AP Calculus BC."*

Still, statements from the mathematics community have clout. It has been nearly a decade since two leading math societies, the Mathematics Association of America and the National Council of Teachers of Mathematics, issued their 2012 guidance against the race to calculus, noting:

> *"While there is an important role for calculus in secondary school, the ultimate goal of the K–12 mathematics curriculum should not be to get into and through a course of calculus by 12th grade, but to have established the mathematical foundation that will enable students to pursue whatever course of study interests them when they get to college."*

The mathematicians' statement on the race to calculus was followed four years later by a similar one from UC's faculty-led admissions board, the Board of Admissions and Relations With Schools: "BOARS ... strongly urges students not to race to calculus at the cost of full mastery of the earlier math curriculum," it noted.

In Ohio, another state in which higher ed institutions were early to modify math requirements for college graduation, admissions leaders are now involved in an effort to overhaul the state's K–12 math framework to meet current needs and address equity. Strengthening Ohio's High School Math Pathways Initiative maps a common course of Algebra I and geometry through sophomore year, then branches into five math pathways, one leading to calculus and four others that expand student options beyond the traditional path. The initiative also seeks to align perceptions of the new math pathways with college admissions decisions. "Students and families need to have the confidence that the math pathways they choose will open the doors to be competitive for college admissions," read a statement from the initiative's advisory council. "Having clear signals from the higher education community on the acceptance of the high school math pathways will go a long way in achieving that."

SHIFTS IN POLICY AND PRACTICE

As universities around the country eliminate the use of standardized admissions tests, either temporarily due to COVID-19 or permanently, there is an opportunity for faculty to contribute to redefining math requirements to better reflect 21st-century skills, academic disciplines, and careers. Aligning college admissions with burgeoning new fields such as informatics and data science will provide the kind of clear-cut guidance to support schools in offering such courses and students in taking them.

Calculus may well be the next frontier in discussions about equity in college admissions. The idea is out there but far from widespread. "Not a lot of admissions

EXCERPTS FROM UNIVERSITY OF CALIFORNIA 2016 STATEMENT ON AP CALCULUS

All of our campuses recommend a 4th year of math, but no specific mathematics course is "preferred" over another.

Calculus is generally considered the equivalent of a 5th year of math, and while a number of students do attain that level or beyond while in high school, it is certainly not required and will not be the deciding factor in any admission decision.

Students' strengths and interests may lie in very different areas, and expecting every student to have completed calculus would be unrealistic and unfair.

Students who are interested in the math/science areas will often complete additional coursework in those two subject areas, but that does not make them more competitive for admission than a student who has, for instance, mastered one or more languages other than English. We encourage students to push themselves in areas that interest them, as those are the subjects in which they will generally earn better grades.

Some of our schools of engineering may prefer to see students who have completed or are completing calculus by the end of high school, as calculus is foundational to all engineering coursework.

folks are having the conversation about this," noted one public university admission official who was interviewed for this report. As the paradigm begins to shift in places like California and Ohio, others in admissions are starting to take note.

> *"Maybe it's time in higher ed or in admissions to reinterpret how we think about calculus. While it helps you prepare for some majors and careers, for many it doesn't. So why do we still hold it as the most rigorous?"*

> *"When I started [working for this private university], I was told [our school] prefers calculus. Now that's shifting."*

> *"We are operating on what's always been. We need to be recommending curriculums that are relevant to college success and future careers. ... Math is a hurdle that's been put up, and it's still up. We understand why it was put up there. It was a different world. ... It's time for an overhaul, but we have yet to determine what that might look like."*

For new math pathways to take hold, outdated notions about rigor must be reconsidered, so that high schools and colleges can ensure that students can acquire the quantitative skills they most need. Advancing this important issue will also involve measuring the effectiveness of new pathways to ensure they are supporting students. And that prospect raises key questions about who should take the lead in making such decisions. On their own, neither math faculty nor admissions leaders are well positioned to determine the math courses required for admission.

Admissions professionals noted that they need more information from those with subject-matter expertise. That includes faculty from the mathematical sciences as well as from the client disciplines—biology, economics, and health sciences, for instance—whose students they serve.

> *"I don't think admissions officers know a lot about what's even taught. ... I'm not trained in math. I don't know what is easier or not. Maybe the question is, what is more relevant in today's society, and why are students taking these courses? If they're taking calculus because they think we want to see it and we're saying it's the most rigorous course and reacting that way, then it'll just continue. The question is, is calculus still a fundamental course that students need for college?"*

> *"We are beginning to appreciate the different ways for students to get quantitative skills."*

> *"Statistics and environmental science have always been interpreted as not as rigorous. We need something to tell us if that's true."*

At some colleges, that may require bringing more faculty into decisions about admissions policy. Faculty are not always involved in setting the standards. Committees composed of faculty and admissions staff make these determinations at 40 percent of the schools that participated in our study. Another 23 percent reported that admissions staff alone decide math requirements. Another 24 percent said math requirements are determined by "other" bodies, primarily state departments of education or higher education boards. (Four "other" responses mentioned faculty or academic senates, or faculty in collaboration with admissions teams and campus leaders.)

Lastly, even if policies make room for nontraditional courses, there's a need for more knowledge among admissions staff to overcome traditional assumptions about rigor. Of the 15 admissions officers interviewed

for this report, only two reported that training for permanent and seasonal staff who review applications addresses preferences for calculus. More often, training presentations focus on rigor and process, they said. One private school professional explained their training includes examination of systemic bias and zeroes in on calculus, saying, "Calculus is great but it doesn't mean statistics is less." Readers at one public university are trained to look for advanced math, including statistics and data science. Conversations about bias for calculus have been a recent occurrence there in the past two years.

> *"People see calculus as the cream of the crop. They see statistics as advanced but not the cream of the crop. We have meetings to discuss this bias. The readers' job is to project absolutely nothing onto the application."*

THE NEXT FRONTIER

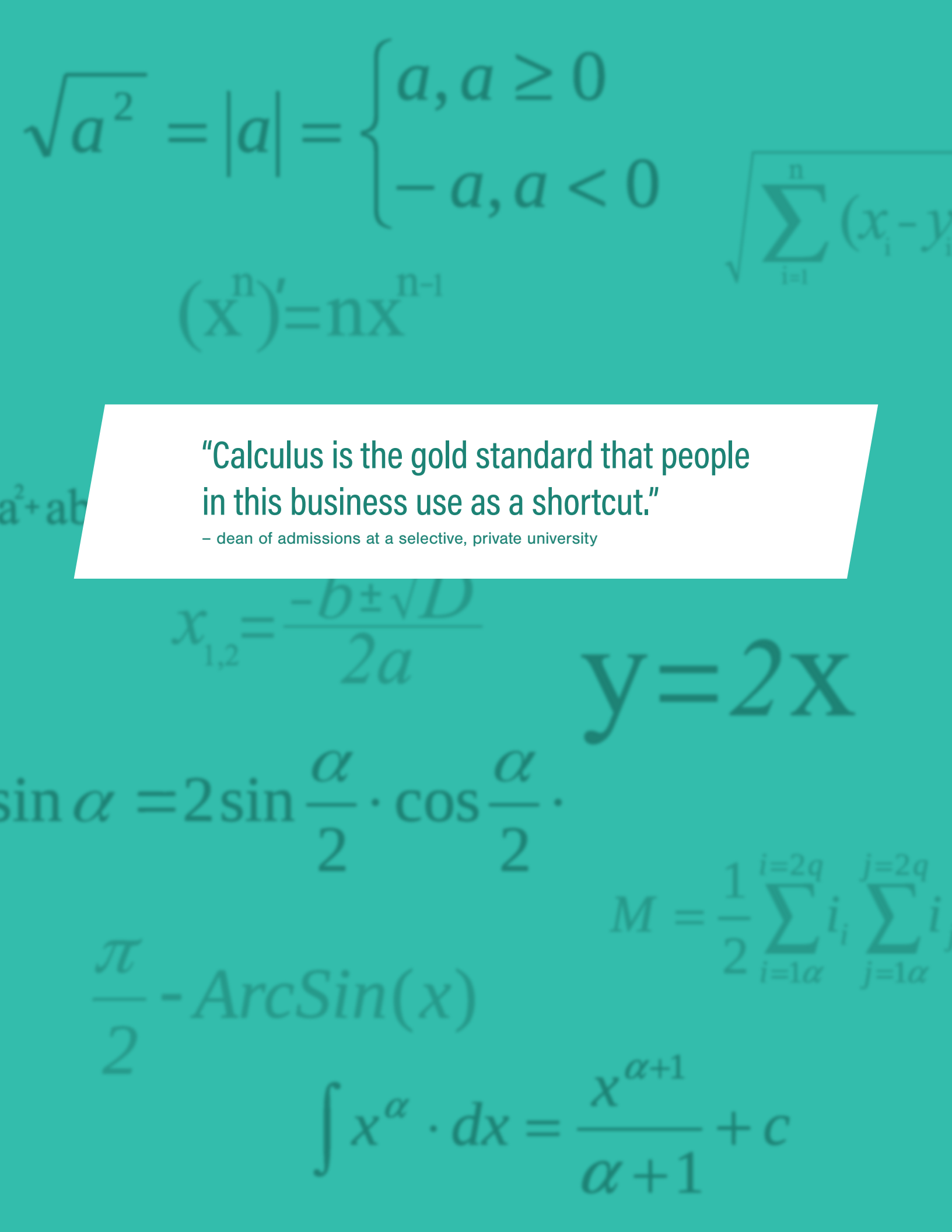
It's time to think differently about math readiness. It's time for those with authority over college admissions to reconsider policies, practices, and training that allow preferences for calculus in the admissions process to persist, preferences that can skew the composition of the student body and, as some math faculty argue, interfere with successful math learning. In particular, higher education leaders, national associations, state agencies, and other funders can pursue the following strategies. The objective is to help build awareness of new pathways and deepen conversations on campuses and at the regional or state level—with an ultimate goal of revising admissions requirements to align with 21st-century math.

Increase knowledge and understanding of new high school and college math pathways. This requires conducting relevant research on implementation and student outcomes in new math pathways and disseminating the research beyond the math community, to include admissions officers, high school administrators, and high school counselors.

Foster intersegmental, interdisciplinary, and cross-functional dialogues to inform new policies. In addition to admissions officers, participants need to include math faculty, faculty from disciplines that use mathematics, high school teachers and administrators, high school counselors, and other college-access specialists. Conversations among faculty can lead to changes in general education math requirements for various majors, which in turn have bearing on the range of math preparation that is preferred or accepted. Admissions officers, as well as high school counselors and math instructors, also need to be included in discussions, so that their policies and their guidance to students are informed by the most current practices in math education.

Address bias and misperceptions about math pathways through developing and providing training for college admissions officers and high school counselors. Both groups have demonstrated an interest in the subject. At the UC system's High School Counselor Conference in 2021, a session on new math-related admission policies and practices was attended by more than 4,000 participants. And a session at NACAC's annual conference attracted an audience of more than 200.

This study was conceived to stimulate institutional reflection and discourse and spark new ways to think about the math pathways to college. Armed with new awareness about 21st-century math in a technology-enhanced and data-rich world, high schools and colleges can further open the door for expanding math pathways—expanding opportunity for students as a result.



"Calculus is the gold standard that people in this business use as a shortcut."

– dean of admissions at a selective, private university

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