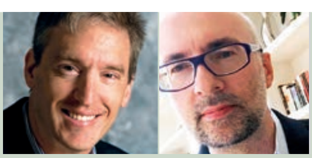
FORUM

Rethinking Math Education

Educators differ on curriculum and methods

In 2021, California set off a national debate on the future of K–12 math education when the state unveiled new guidelines for teaching the subject. The proposed curriculum framework, though non-binding, calls for schools to: offer data-science courses in addition to algebra, pre-calculus, and calculus; have students take algebra in 9th grade rather than 8th; and ask teachers to infuse social-justice concepts into math lessons.

Should U.S. K–12 math curriculum change—and if so, how? Should schools emphasize "deeper understanding" or drilling and memorization? Should they shift their emphasis toward data science and away from calculus? What are the tradeoffs and risks of these different approaches, and which path will best prepare students to thrive as citizens and as workers in our ever-changing economy? In this forum, University of Chicago economist Steven Levitt and his colleague Jeffrey Severts advance one perspective, while Boaz Barak, computer science professor at Harvard, and Adrian Mims of The Calculus Project offer another.



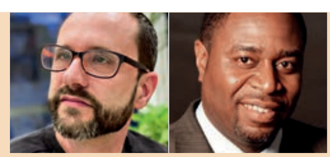
Every Student Needs 21st-Century Data-Literacy Skills

By STEVEN LEVITT and JEFFREY SEVERTS

MOST EDUCATORS understand that school curricula must evolve as the world changes. Refusing to adapt would do a terrible disservice to students, leaving them poorly prepared for their futures. Striking the right balance is difficult, but our schools usually find a way to forge ahead, teaching more Spanish and less Latin, more Angelou and less Shelley.

But math instruction seems to resist this needed evolution. Math is viewed by some as an immutable revelation, as if Pythagoras himself chiseled the curriculum into stone tablets and brought them down from the mountaintop.

CONTINUED ON PAGE 68



Data Science Is No Panacea for High-School Math Education

By BOAZ BARAK and ADRIAN MIMS

SCIENCE, TECHNOLOGY, engineering, and mathematics are the fastest-growing fields in terms of both student interest and job opportunities. For example, in California, the number of bachelor's STEM degrees increased at a rate more than triple that of other degrees between 2010–11 and 2016–17. This is for good reason: studies show that STEM majors enjoy higher salaries and lower unemployment. The growth of STEM fields makes K–12 mathematics education more relevant than ever. Students without strong mathematical foundations will be shut out of these higher-paying

CONTINUED ON PAGE 69

MICHAEL GLENWOOD

LEVITT AND SEVERTS *CONTINUED FROM PAGE 66*

Thou shalt teach synthetic division! Thou shalt master factoring higher degree polynomials!

Why this perception persists is a mystery. High school math instruction has changed before. The current gauntlet of algebra through calculus was set in the 1960s in response to Russia's Sputnik. To win the Space Race and the Cold War, the United States needed more scientists and engineers, and a steady diet of quadratic equations and differentials was considered the best way to cultivate them. Before this abrupt shift, high school math had been evolving slowly to include algebra and Euclidean geometry, in response to changing admissions standards at selective universities. In 1926, only 10 of the 310 questions on the SAT were about math, and those questions were limited to arithmetic and basic algebra.

Today, we could be more confident in our current math curriculum if little had changed in the world since the 1960s. But that would be an absurd position to take, of course. Society has been transformed over the past six decades, and in ways that have dramatically affected how we use math in our lives. Nearly every one of us walks around with a powerful computer in our pocket, capable of making billions of calculations per second. Each day, we collectively generate enough data to fill five Libraries of Congress. And the Internet has disrupted almost everything, including our most trusted sources of information. We now must sort fact from fiction for ourselves. Do cosmetics cause cancer? Is Covid-19 a threat to a healthy 5-year-old? Was the last election stolen?

Math is viewed by some as an immutable revelation, as if Pythagoras himself chiseled the curriculum into stone tablets and brought them down from the mountaintop.

Our lives have been changed by this revolution in so many ways, including the way we work. Seven of the 10 fastest-growing jobs in America are related to data. And while most of those roles are highly technical, computing and data have seeped into everyone's workplace. Auto mechanics used to turn wrenches. Now they plug cars into computers and interpret the results. Teachers used to give lectures and write on chalkboards. Now they record their lessons on YouTube and analyze their students'

CONTINUED ON PAGE 70

The current gauntlet of algebra through calculus was set in the 1960s in response to Russia's Sputnik. To win the Space Race, the U.S. needed scientists.

SHUTTERSTOCK

BARAK AND MIMS
CONTINUED FROM PAGE 66

and faster-growing fields. Hence, improving K–12 education, in particular for lower-income students and students of color, is of the utmost importance.

Given that context from the job market, the billion-dollar question is: why does the United States rank 36th out of the 79 countries included in the Programme for International Student Assessment math rankings? Those results followed two massive education-reform initiatives, No Child Left Behind and the Common Core state standards. Neither one lifted the United States into the top tier of performers globally.

There is no simple explanation for U.S. performance in these rankings, but to improve that performance, it is crucial to understand a key fact of U.S. math-education-reform initiatives: there is a hyper-focus on math curriculum and not enough attention paid to teacher recruitment, training, and retention. We know that a student's success in math rests heavily on having a highly qualified teacher. A robust math curriculum is useless if teachers are not equipped with the material and training to deliver it well. Top-performing countries on the PISA exams, such as Japan, South Korea, Estonia, the Netherlands, and Poland, have varying curricula (with Estonia's and Poland's still influenced by the Soviet system), demonstrating that success in math education is less about changing curricula and more about *who* is teaching it and the *training and support* they get.

Increasing the number of highly trained math teachers addresses another education crisis that the math curriculum cannot address alone: capacity and access. According to the U.S. Department of Education's Office for Civil Rights, advanced mathematics is offered at only 65 percent of high schools, and calculus is offered at only 50 percent of high schools. Moreover, the 5,000 high schools with more than 75 percent Black and Latino student enrollment offer advanced math and calculus at a significantly lower rate than that of high schools overall.

The increased importance of STEM fields for future career options, economic growth, and national security places particular emphasis on topics such as algebra and calculus. In particular, calculus is part of the curriculum in all STEM majors; students who complete a calculus course in high school have a significant advantage for pursuing STEM coursework and job opportunities during college. Calculus and advanced algebra are also at the heart of the "machine learning revolution" that led to recent breakthroughs in artificial intelligence, and an understanding of these topics is a key skill for work in data science. Far from being relics from the "Sputnik era," calculus and algebra are more important than ever in K–12 education.

Unfortunately, recent efforts at "education reform," including the (in progress) proposals for the California Mathematics Framework, devalue such fundamental mathematical courses. In particular, some have advocated replacing them with "data science," asserting that this subject is more relevant than the "antiquated curricula" of algebra and calculus courses in our modern world. These advocates also claim that data science is somehow "a more equitable alternative to calculus" and can be a tool for addressing educational gaps. Both claims are false.

The growth of STEM fields makes K–12 math education more relevant than ever. Students without strong mathematical foundations will be shut out of these higher-paying and faster-growing fields.

LIZ MOUGHON / *L.A.TIMES*

Emily Osorio-Hernandez, 6, writes numbers for a math assignment at a California elementary school in 2019. The Golden State unveiled new proposed math guidelines in 2021.

Claims about the relevance of data science confuse the importance of the field itself with what can be taught in a K–12 course. Much as a high-school first-aid course does not prepare one for a career in medicine, a high-school data-science course can only give students a superficial taste of the area. Indeed, such a course is more properly called a "data-literacy" course

CONTINUED ON PAGE 71

LEVITT AND SEVERTS *CONTINUED FROM PAGE 68*

test scores with sophisticated software. Can you imagine how often today's children will be working with data when they come of age?

In this new world, how useful is the math we are currently teaching in our schools? To get some insight into this question, we conducted a small survey with several hundred *Freakonomics* podcast listeners. While this sample is far from representative, it's fair to say the respondents are likely to be biased toward overestimating the value of today's math, as *Freakonomics* fans tend to be a pretty geeky crowd. The unscientific results of our poll suggest that educators have much work to do on the current math curriculum. Only 2 percent of respondents report that they use trigonometry in their daily work, while 66 percent say they are constantly building spreadsheets—a tool that is rarely covered in today's curricula. Furthermore, when asked what math topics they wish they had learned more about in high school, 64 percent named data analysis and interpretation while only 5 percent said geometry.

What should be done? Our proposal, which we call "Merge and Purge," is simple. We believe the three years that schools currently dedicate to algebra and geometry could be easily distilled down to two, simply by doing away with 1) anachronistic, computation-heavy topics that are no longer relevant in the computer age and 2) elements that do not serve as critical building blocks to higher-level math. This would open up a year of new capacity that could be dedicated to data literacy, statistics, and other forms of applied math. Kids could learn how to analyze, interpret, and visualize data. We could teach them the difference between correlation and causation. And perhaps most importantly, we could help them understand the limits of data, so they would know when to be skeptical of data-based claims.

The true power of data emerges in applications. We recommend that the data-based math course be offered early in the math sequence, so students will have opportunities to integrate data analysis into their social science, humanities, and science courses.

Merge and Purge purposely avoids creating a separate data-math track that would lead to some students choosing the new path and others sticking to the traditional one. Neither students nor parents are well equipped to weigh the tradeoffs between, for example, data proficiency and calculus. If elite colleges maintain a calculus requirement, would a student who chose a data track be disqualifying herself from admission to such institutions? Moreover, every proposal for separate tracks that we have seen positions data science as the last step in a math sequence. As noted above, we believe that data skills should be taught earlier so they can be applied throughout the broader high-school curriculum.

Critics have accused reformers like us of wanting to make math instruction less rigorous, but nothing could be further from the truth. Data science, in many ways, demands more of students. Analyzing and interpreting data requires critical thinking, creativity, and a nuanced understanding of the context within which the data were generated. Furthermore, data science is probabilistic instead of deterministic, presenting challenges not unlike those encountered in the transition from classical to quantum physics.

Data science, in many ways, demands more of students. Analyzing and interpreting data requires critical thinking, creativity, and a nuanced understanding of the context within which the data were generated.

While we believe that students have much to gain by becoming data literate, we recognize the challenges inherent in curriculum change. Teachers will need extensive professional development to acquire the requisite skills. Reaching consensus on which topics to purge from the curriculum will not be easy. And unlike some who support this change, we are skeptical of the claim that a focus on data literacy will dramatically improve the equity problems we have in education.

Still, data literacy will be a critical skill for living in the 21st century, so we must do all we can to ensure that *every* kid has the opportunity to acquire it. Some educators recognize this and are already making changes. Sal Khan, the innovator behind Khan Academy, has already adjusted the algebra-through-calculus lineup at his Lab School in Mountain View, California. Students there now spend an entire year learning data science. Forty school districts across the country are following Kahn's lead, taking the first steps toward introducing data science into their curricula. Data Science for Everyone, a coalition of individuals and organizations launched by our team at the University of Chicago, advocates for policy reform and the expansion of K–12 data-science education. And a dozen states have begun the difficult work of modifying their guidelines and standards, making room for this modernized approach. Virginia is leading the way, with plans to approve a new data-science curriculum framework for implementation in 2023. It is our hope that developments such as these represent the start of a movement to advance data-science education so that every K–12 student in America is equipped with the data-literacy skills needed to succeed in our modern world. E

BARAK AND MIMS CONTINUED FROM PAGE 69

than data science—it can be very beneficial to students but should not be considered an alternative to basic mathematical courses. The field of data science builds on mathematics, statistics, and computer science, and a thorough data-science education requires foundations in all three fields. For this reason, taking advanced math courses (algebra II, precalculus, and calculus) is a much better preparation than high-school data science, *even for students who are interested in data-science careers.* Nearly 1,700 STEM researchers, educators, and practitioners signed an open letter decrying the proposals to devalue foundational mathematics. Signatories include winners of their field's highest honors (including the Nobel Prize, the Fields Medal, and the Turing Award), as well as leaders in the field of data science itself.

These experts know that the mathematical maturity gained from working through problems is crucial for STEM preparation. It is true that, these days, we all have a powerful calculator in our pocket. But this does not mean that one can be a data scientist without knowing how to multiply. Mathematics is different from literature, in that different topics rely upon each other. While it is possible to read Angelou without first reading Shelley, one cannot understand least-squares regression without first understanding the Pythagorean theorem. As an associate provost and the dean of engineering at the University of California, Berkeley, recently wrote jointly, "the pervasiveness of computers means that we should focus more on mathematical reasoning, not less."

Some advocates claim that data science is more equitable than other fields of math. To put it mildly, this claim is not justified by research. Remember, closing education gaps requires improved teacher recruitment, training, and retention. While material can always be improved, education gaps were not created by the curriculum and cannot be addressed via curricular changes. Moreover, creating "data-science pathways" as alternatives to the standard pathway can and will have a particularly harmful impact on disadvantaged students. Such pathways emphasize proficiency with computational tools such as spreadsheets over the mathematical concepts (functions, equations, symbolic manipulation, and logical reasoning) that are crucial prerequisites for more advanced math and that also build the type of thinking needed for coding. Hence, in practice, data-science pathways will become lower tracks by another name. Such "implicit tracking" can be more pernicious than explicit tracking: less-resourced students or students of color might end up choosing this track under the false impression that it leads to career opportunities, while students with more means and access to college counseling will realize that the traditional pathways keep more options open. Indeed, this seems to already have been the case, with wealthier districts in California such as Beverly Hills and Cupertino signaling their rejection of the California Mathematics Framework revisions.

Too often with math-education initiatives, education reformers do not think about the unintentional consequences for creating a de facto lower track in mathematics. For example, low-income students of color in this track will be shut out of programs such as Questbridge and Thrive Scholars. Both nonprofit organizations provide low-income students with financial support and other resources that ensure they graduate from the best colleges in the country. Such programs, as well as STEM-specific programs including Berkeley's SEED, are interested in accepting students who take the advanced mathematics courses that lead to calculus because they know the best colleges in the country look for calculus on students' transcripts, and that such courses prepare students for STEM success. These courses also help students prepare for the SAT and ACT. While one can argue that programs and colleges should not use calculus or standardized exams for admissions, it is important for K–12 education to prepare students, especially low-income students and students of color, to be successful in the world as it exists today, rather than in an ideal world that may or may not exist in the future. Not all students are interested in STEM, and not all students need to learn calculus in high school, but all students deserve honesty about the consequences of different educational pathways. Students and parents are best equipped to make this tradeoff, but they should get accurate information.

The United States has had more than its share of curricular experiments, often done on low-income students or students of color, with mixed results at best. Promoting data science at the expense of algebra and calculus is yet another experiment backed by dubious evidence. The vast majority of subject-matter experts reject it, since it won't provide students with the foundations for STEM success. While well-resourced students will find ways to bypass it, such a "reform" will mostly harm the students it purports to help. Some advocates claim that K–12 data-science courses are easier than algebra and calculus and provide better preparation for the data-intensive high-paying jobs of the 21st century. However, one maxim remains as true in this century as it was in the past: "If something sounds too good to be true, it usually is." E

Taking advanced math courses—algebra II, precalculus, and calculus—is a much better preparation than high-school data science, even for students who are interested in data-science careers.