EDUCATION WEEK

Move Over, Calculus. Statistics Is on the Rise

By Sarah D. Sparks
May 22, 2018

For more than 30 years, calculus has been seen as the pinnacle of high school math—essential for careers in the hard sciences, and an explicit or unspoken prerequisite for top-tier colleges.

But now, math and science professionals are beginning to question how helpful current high school calculus courses really are for advanced science fields. The ubiquitous use of data in everything from physics and finance to politics and education is helping to build momentum for a new path in high school math—one emphasizing statistics and data literacy over calculus.

"We increasingly understand the world around us through data: gene expression, identifying new planets in distant solar systems, and everything in between," said Randy Kochevar, a senior research scientist at the Education Development Center, an international nonprofit that works with education officials. Statistics and data analysis, he said, "is fundamental to many of the things we do routinely, not just as scientists but as professionals."

He and other experts are still debating the best way to integrate a new approach in an already crowded high school curriculum. One of the most difficult philosophical challenges: how to prevent a statistics path from replicating the severe tracking and equity problems that have long existed in classical mathematics.

"There's a sense that calculus is up here and statistics is a step below," said Dan Chase, a secondary mathematics teacher at Carolina Day School in North Carolina, adding that he often struggles to suggest to students that, "if you are interested in engineering, that might be a good reason to go to calculus, but if you are interested in business or the humanities or social sciences, there are different paths you might go, even if you are a top-achieving math student."

On face value, new expectations for students already seem to be moving toward statistics. Both the Common Core State Standards, on which many states' math requirements are based, and the Next Generation Science Standards call for teaching data analysis and statistics, both on their own and in the process of learning other concepts.

But Kochevar warned: "There's a huge disconnect; if you look closely at the science standards, they are expecting students to have tremendous faculty with using data by middle school, but if you look at the courses, it's really not clear where those skills are supposed to be filled."

Both sets of standards need more integration of data and statistics, he and others argue, because they were developed in the early years of the big data boom. Studies tracking data worldwide through the years **have found people produced 1.5 exabytes of new data in 1999**—or roughly 250 megabytes of data for every person alive—but by 2011, when states were adopting and implementing the math standards, **people produced more than 14 exabytes a year**. Today, people worldwide produce 2.5 exabytes of data every *day*, and the **total data have doubled every two years**.

Ironically, the rapid expansion of big data and statistics use in the broader society and economy comes at the same time American students seem to be struggling with those concepts. From 2007 to 2017, 4th and 8th students' scores on the National Assessment of Educational Progress in mathematics fell significantly on problems related to data analysis, statistics, and probability—a decline that helped drive overall dips on the math test in 2017.

In part, experts say, that's because statistics and data analysis have traditionally taken a back seat to calculus in high school math, and most students already have difficulty completing the classical path.

"The idea that statistics is hard is grounded in that fact that if you took statistics 10 years ago, you had to take calculus first, and the statistics used formal probability ... with theorems that built on calculus," said Uri Treisman, a mathematics professor and the executive director of the Charles A. Dana Center at the University of Texas at Austin. He's been working with K-12 and university systems to develop a statistics pathway as an alternative to classical calculus.

It's an idea that others have pushed back on, by situating a high school statistics pathway as either advanced material only suitable for students who have already passed calculus—or a less-rigorous path for students who can't hack it in classical math.

"Any time you have multiple pathways, the advantaged will capitalize on one and that will become the 'real' one," Treisman said. "If we are going to create data science pathways, they had better be anchored in things that lead to upward social mobility and have a rigor to them. We have to make sure new pathways have at least equal status as the traditional one—and ensure everyone has access to them. If we allow [statistics and data] to be the easy or weaker path, we relinquish the commitment to equity we started with."

Mixed Signals in Calculus

For a picture of how severe that inequity can get, one only has to look at calculus.

Until about 1980, calculus was seen as a higher education course, primarily for those interested in mathematics, physics, or other hard sciences, and only about 30,000 high school students took the course. That began to change when school reformers glommed onto calculus as an early example of a rigorous, college-preparatory course, said David Bressoud, a mathematics professor at Macalester College and a former president of the Mathematical Association of America, who has examined the evolution of calculus studies.

"The more schools did this, the greater the expectation that they would do it" from parents, and district leaders—and in particular from colleges and universities, Bressoud said. "It's not just math majors or engineering majors; this has become an accepted requirement for admission to top universities. You are not going to get into Duke if you haven't taken calculus, even if you plan to major in French literature."

Today, some 800,000 students nationwide take calculus in high school, about 15 percent of all high schoolers, and nearly 150,000 take the course before 11th grade. Calculus classes have been and remain disproportionately white and Asian, with other student groups less likely to attend schools that offer calculus or the early prerequisites (like middle school algebra) needed to gain access to the course.

For example, in 2015-16, black students were 9 percentage points less likely than their white peers to attend a high school that offered calculus and half as likely to take the class if they attended a school that offered it. And if black students did get into a class, their teachers were also less likely to be certified to teach calculus than those of white students, according to an Education Week Research Center analysis of federal civil rights data.

And despite the rapid growth of calculus as a gold standard, university calculus experts argue it is a much weaker sign that a student is actually prepared for postsecondary math in the science fields than it appears.

In fact, **a new report by the Mathematics Association of America and the National Council of Teachers of Mathematics** found many students who took Advanced Placement Calculus AB still ended up retaking calculus in college—and 250,000 students end up needing to take even lower-level courses, like precalculus or algebra.

In the end, the report found taking calculus in high school was associated with only a 5 percentage point increase on average in calculus scores in college—from 75 percent to 80 percent. Rather, the best predictor of earning a B or better in college calculus was a student earning no less than As in high school Algebra 1 and 2 and geometry.

So if high school calculus isn't the best indicator of a student prepared for college-level math, what does it signify in college admissions? In a word: Money.

More than half of students who take calculus in high school come from families with a household income above $100,000 a year, according to **a study this month in the Journal for Research in Mathematics Education**. By contrast, only 15 percent of middle-income students and 7 percent of those in the poorest 25 percent of families take the course.

"Math is even more important to upward mobility now than it was 20 or 30 years ago, because ... it's seen as related to your general ability to solve problems quickly," Treisman said, adding that as a result, "there's general anxiety and panic about equity issues for anything new, even though the current [calculus] pathway is a burial ground for students of color."

Forging a New Path

Statistics and data literacy advocates hope diversifying the field of interesting and rigorous math courses could broaden students' path to STEM and other careers. As of 2017, the **U.S. Bureau of Labor Statistics estimations** showed that jobs that require data literacy and statistics are among the 10 fastest-growing occupations in the country.

"We have two paths forward," said William Finzer, a senior scientist at the Concord Consortium, which works with school districts to improve their math curricula. "The easier one—like **the path computer science took**—is to develop a course or a subject area and get schools to give it time. ... The problem of that is, it doesn't spread the opportunity very widely. It becomes concentrated in the small group of kids who elect to take the course—and it's just one more subject to take."

Finzer instead envisions a more holistic approach in which at least one class a year—be it math, biology, or even civics or history—asks students to grapple with making sense of large data sets. Such an approach, he said, "would make a huge difference, because it would mean when you came out of high school, data would not be foreign to you."

EDC's Oceans of Data Institute is building learning progressions for statistics and data literacy at different grades. The progression

Progression for Statistics and Data

EDC's Oceans of Data Institute is building learning progressions for statistics and data literacy at different grades. Randy Kochevar, who directs the institute, said they are based on the acronym **CLIP**, meaning students learn how to use:

Complex, multi-variable data ("We're not just looking at hours of sunlight and heights of bean plants," he said);

Larger data sets than students need to answer any one question, so they are forced to sort and understand relevance;

Interactively accessed data, rather than sample graphs just written out on paper; and

Professionally collected data that forces students to think about how and why it was collected—and what biases may exist in the samples.

Source: Oceans of Data Institute

would include concepts in statistics and data literacy, but also computer science—to be able to use common programming and tools used by data professionals—and more philosophical concepts, such as the ethical use of statistics and privacy protections.

Education Week Researcher Alex Harwin contributed to this report.

Vol. 37, Issue 32, Pages 12-13

Published in Print: May 23, 2018, as **Move Over, Calculus. Statistics Is on the Rise**