The rush to calculus is bad for students and their futures in STEM

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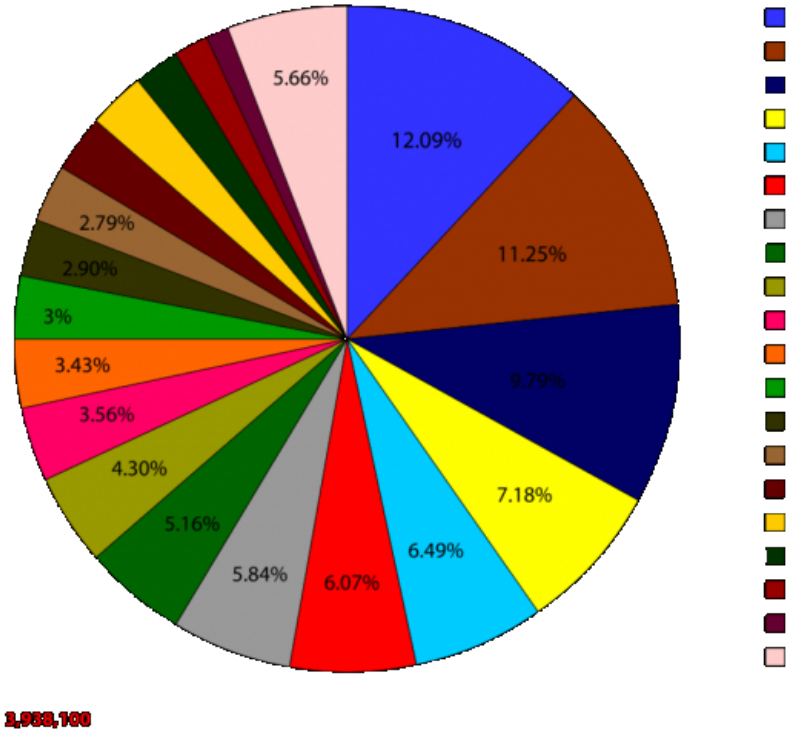

Breakdown of all Advanced Placement exams taken in 2013. Credit: Ali Zifan, CC BY-SA

Two years ago I taught a section of Calculus I to approximately 650 undergrad students in a large auditorium. Perhaps "taught" isn't the right word. "Performed," maybe? Unsurprisingly, my student evaluation scores were not as high as they usually are in my more typical classes of 35 students, but I do remember one comment in particular: "This class destroyed my confidence." According to a new report from the Mathematical Association of America (MAA), this outcome is common, even among students who successfully completed a calculus course in high school. So what is going on?

Former MAA president David Bressoud led this five-year comprehensive study funded by the National Science Foundation. He's been thinking about this problem for many years and has synthesized a huge amount of data measuring high school and college calculus enrollments. I heard Bressoud speak about some preliminary results of the study a few years ago, and one piece of data stuck in my head: in the mid-1980s, when I was in high school, approximately 5% of high school students took an AP exam in calculus.

That aligns with my personal experience in which there were about 150 students in my entire North Carolina county taking calculus in any given year (out of roughly 3,000 high school seniors). Nationally, about 60,000 students took an AP calculus exam my senior year (1987). Today? That number has risen to nearly 350,000 students taking an AP exam in calculus in 2011 (roughly 15% of high school students). As one of my colleagues remarked after Bressoud's talk, it's not as if the talent pool has gotten that much deeper in the last 30 years. This tripling of the proportion of students taking these exams feels wrong somehow.

Why the dramatic increase?

There appear to be at least two driving forces behind the rush to calculus.

One is college admissions. Students and their parents seek an advantage in the increasingly competitive admissions tournament, and the number of AP courses taken is a metric that is easy for students to boost. The increase in the number of AP exams taken is not unique to calculus; indeed, the total population of students taking exams doubled between 2003 and 2013, with the number of exams administered increasing by 150% over that period. As the name "Advanced Placement" suggests, these exams often yield college credit for students; this appeals to parents, as well, since it ostensibly lowers tuition costs later.

Another factor that must be considered is the overall decline in support for enhanced education for gifted students. In an era of shrinking education budgets, school administrators find it tempting to conflate advancement with enrichment. Pushing gifted students ahead at a faster rate via AP courses is seen as a solution for meeting the needs of advanced students.

This approach may be dangerous in any discipline, but it is especially problematic in mathematics, where a strong foundation is key to success in upper division courses. The general strategy in high school is one of uniform advancement – taking advanced coursework in all disciplines under the assumption that gifted students are exceptional in every subject. In the drive to make it to calculus by the senior year, students often rush through algebra and geometry in lockstep with their gifted peers whether they are ready for it or not.

The end result is a group of students who have "succeeded" in high school calculus without really having the proper foundations, a tower built on sand. It is quite possible for students to learn the mechanics of many categories of calculus problems and to answer questions correctly on exams without really understanding the concepts. To quote the MAA's report:

In some sense, 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.

College versus high school calculus

There are two flavors of AP calculus, AB and BC. The former is equivalent to a typical first-semester college course, while the latter covers the first two semesters. Exams are scored from 1 to 5; most universities grant credit for a score of 3 and up.

Many students take Calculus I again at their universities, even if they have a passing score on the AP exam. There are many reasons for this: some colleges insist (engineering programs in particular) and many medical schools demand that applicants take the course at a university. Or students may not feel particularly confident about their abilities. In my own experience, the number of students retaking the calculus course is very high – in a typical section of engineering calculus, up to 90% of my students have taken it in high school. While there are some positive aspects to retaking the course, there are downsides, the most notable of which is overconfidence and a student's misplaced certainty that he or she already knows the material.

A typical first-semester calculus course consists of 45 lectures delivered three times per week over a 15-week term. The pace is quick. Contrast that with a typical high school Calculus AB course, which meets five days per week for 180 class meetings. The college course covers the same material in a quarter of the time; students must therefore have solid skills in algebra and geometry along with good study and work habits to succeed.

So this is the crux of the problem: students lacking the requisite

foundational abilities may not succeed because the college faculty member expects them to be at ease with these more basic ideas, freeing them to absorb and understand the new, more conceptual material. The rush to AP Calculus has instructed students in the techniques for solving large classes of standard calculus problems rather than prepare them for success in higher mathematics.

It's precisely this disconnect that causes students to lose their confidence if they don't do well in university calculus. All through high school, the evidence suggested that they were "good at math" because they succeeded in parroting what they saw demonstrated in class. Parroting is not learning, however, and may hide a student's true abilities.

What to do?

The authors of the MAA report sum it up best:

Students are better prepared for post-secondary mathematics when they have developed an understanding of the undergirding principles which, when accompanied by fluent and flexible application of the concepts and procedures of precalculus mathematics, enable them to understand calculus as a coherent and broadly applicable body of knowledge.

Like so many issues in K-12 education, the reasons that we have gotten to the current state are manifold, and reversing trends is difficult. But if we want to advance STEM education and continue to produce a high-quality technical workforce we must confront this issue. We need to stop the rush to calculus and focus instead on a thorough grounding in algebra, geometry and functions.

Calculus is one of the great intellectual achievements of the last 400 years; shortchanging it by reducing its beauty and utility to a list of problems to be checked off a rubric does a disservice to everyone.

Source: The Conversation