Students understand calculus better when the lessons are active

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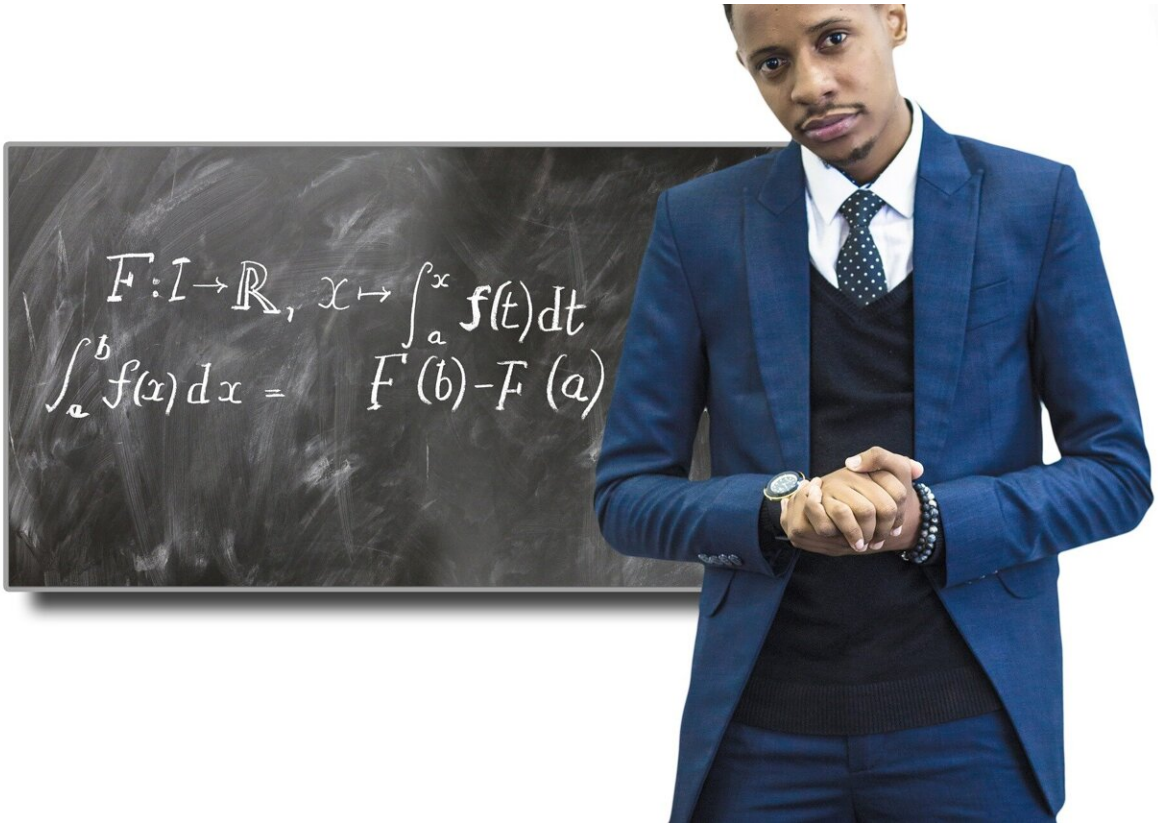

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College students learn more calculus in an active learning course in which students solve problems during class than in a traditional lecture-based course. That's according to a peer-reviewed study my colleagues

and I published in Science. We also found that college students better understood complex calculus concepts and earned better grades in the active learning course.

The findings held across racial and ethnic groups, genders and college majors, and for both first-time college and transfer students—thus, promoting success for all students. Students in the active learning course had an associated 11% higher pass rate.

If you apply that rate to the current 300,000 students taking calculus each year in the U.S., it could mean an additional 33,000 pass their class.

Our experimental trial ran over three semesters—fall 2018 through fall 2019—and involved 811 undergraduate students at a public university that has been designated as a Hispanic-serving institution. The study evaluated the impact of an engagement-focused active learning calculus teaching method by randomly placing students into either a traditional lecture-based class or the active learning calculus class.

The active learning intervention promoted development of calculus understanding during class, with students working through exercises designed to build calculus knowledge and with faculty monitoring and guiding the process.

This differs from the lecture setting where students passively listen to the instructor and develop their understanding outside of class, often on their own.

An active learning approach allows students to work together to solve problems and explain ideas to each other. Active learning is about understanding the "why" behind a subject versus merely trying to memorize it.

Along the way, students experiment with their ideas, learn from their mistakes and ultimately make sense of calculus. In this way, they replicate the practices of mathematicians, including making and testing educated guesses, sense-making and explaining their reasoning to colleagues. Faculty are a critical part of the process. They guide the process through probing questions, demonstrating mathematical strategies, monitoring group progress and adapting pace and activities to foster student learning.

Why it matters

Calculus is a foundational discipline for science, technology, engineering and mathematics, as it provides the skills for designing systems as well as for studying and predicting change.

But historically it's been a barrier that has ended the opportunity for many students to achieve their goal of a STEM career. Only 40% of undergraduate students intending to earn a STEM degree complete their degree, and calculus plays a role in that loss. The reasons vary depending on the student. Failing calculus can be a final straw for some.

And it is particularly concerning for historically underrepresented groups. The odds of female students leaving a STEM major after calculus is 1.5 times higher than it is for men. And Hispanic and Black students have a 50% higher failure rate than white students in calculus. These losses deprive the individual students of STEM aspirations, career dreams and financial security. And it deprives society of their potentially innovative contributions to solving challenging problems, such as climate resilience, energy independence, infrastructure and more.

What still isn't known

A vexing challenge in calculus instruction—and across the STEM

disciplines—is broad adoption of active learning strategies that work. We started this research to provide compelling evidence to show that this model works and to drive further change. The next step is addressing the barriers, including lack of time, questions about effectiveness and institutional policies that don't provide an incentive for faculty to bring active learning to their classrooms.

A crucial next step is improving the evidence-based instructional change strategies that will promote adoption of active learning instruction in the classroom.

What's next

Our latest results are motivating our team to further delve into the underlying instructional strategies that drive student understanding in calculus. We're also looking for opportunities to replicate the experiment at a variety of institutions, including high schools, which will provide more insight into how to expand adoption across the nation.

We hope that this paper increases the rate of change of all faculty adopting active learning in their classrooms.

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