Revamped college science course improves student performance -- in spite of cuts

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Students overall performed better – and educationally disadvantaged students generally made even greater strides than everyone else – in an introductory biology course at a university where recent budget woes doubled class sizes for the course, cut lab times and reduced the number of graduate teaching assistants.

The keys to success are instructors who guide learning rather than lecture, and who structure courses so students are more likely to come to class having read assignments and where they undergo intensive practice to develop critical thinking and problem solving skills. So say findings based on an introductory biology course at the University of Washington being published in the June 3 issue of *Science*.

"We show that a highly structured course design, based on daily and weekly practice with problem solving, data analysis and other higher-order cognitive skills, improved the performance of all students in a college-level introductory biology class and reduced the achievement gap between disadvantaged and nondisadvantaged students – without increased expenditures," wrote the co-authors. The increased expenditures refer to special funding some institutions use to provide disadvantaged students with supplementary instruction, mentoring and other support.

Educationally disadvantaged students, including some who are the first in their families to attend college and members of underrepresented minorities, are generally capable students who may lack experience with

problem-solving and reasoning skills needed in college-level science classes.

In the UW biology course described in Science, the gap separating disadvantaged students from their classmates was cut nearly in half. The progress came in spite of budget problems since 2009 that increased class sizes from 345 to 700 in the course, reduced labs from 3 hours to 2 hours a week and cut the number of graduate assistants from one for every 50 to one for every 88 students.

"We've known for years now that active learning works better than traditional lecturing," said Scott Freeman, co-author and UW lecturer in biology. "What our research shows is that in our class, there is a disproportionate benefit for the highest-need students. If an institution has a commitment to supporting a student body from diverse socioeconomic backgrounds, our data make the change to active learning even more urgent. But faculty will need support to make the change, and be rewarded if they start teaching better."

"It's already been shown that active learning improves performance in classes of 30 or 40, but this is the first time its effectiveness has been documented on the scale of classes with 350 students, and then 700 students," said David Haak, lead author, who conducted the research while a graduate student at the UW and is now a postdoctoral fellow at Indiana University.

"As this study indicates, our faculty take their teaching very seriously and are constantly looking for ways to innovate and find the most effective techniques to enhance learning, even when those techniques are the result of reduced resources due to budget cuts," said Phyllis Wise, UW interim president. "Necessity in this case is indeed the mother of invention, as this research shows. Our faculty are remarkably adaptable and inventive, a recipe for success every time."

Active learning in the UW introductory biology course might mean the instructor talks for two to three minutes, asks the class a question and tells students to talk with others in their lab group. Then the instructor might ask the students to individually give the answer, using clickers that let the instructor see via a computer how well students are understanding the question, or the instructor might call on a student from each group to explain to the class of 700 what that group concluded.

"Active learning that promotes peer interaction makes students articulate their logic and consider other points of view when solving problems, leading to learning gains," the co-authors wrote.

An active learning approach was coupled as an experiment with what the researchers called a highly structured course format. For example, students were encouraged to complete assigned readings by requiring them to take online quizzes based on what they read every night before class. They also took weekly practice exams with essay questions that, while graded, didn't carry a heavy weight as far as the course grade.

"With active learning and a highly structured format, students don't just regurgitate information, something they're quite good at after high school," Haak said. "Instead, if they haven't already learned it, they find out how to apply information in new ways, to develop higher-order thinking. Such higher-order thinking is the first step in mastering science."

Comparing students in two highly structured quarters led by Freeman versus 27 quarters with little or no active learning, the researchers found that, although students overall benefit from structure, educationally disadvantaged students experience a disproportionate benefit, with the achievement gap being cut 45 percent, the co-authors say. The comparison was made after controlling for variation in student ability and preparation quarter to quarter.

The researchers said it would be a misuse of their findings for institutions to simply tell instructors to start using active learning and to double the size of their classes.

"We should move to active learning as quickly as possible, but realize that most faculty lack training in these techniques and may also lack the time to develop needed materials," Freeman said. "For example, you need a bank of good clicker questions and exercises where you randomly call on students, supported by reading quizzes and weekly practice exams. These take time and money to develop and test. I was able to develop these materials because I taught the biology course repeatedly and am a lecturer – so all I get paid to do is teach.

"Faculty members who have already written lectures for a course are often reluctant to change their teaching style because of the start-up cost in both time and money. It's encouraging that at the UW, biology faculty have adopted new methods once we have developed them and once they've seen data showing that they work."

Other co-authors on the paper are Janneke Hille Ris Lambers, UW assistant professor of biology, and Emile Pitre, UW associate vice president of minority affairs. The work was funded by the UW College of Arts and Sciences, the Howard Hughes Medical Institute undergraduate science education program and the National Science Foundation.

The course in the study is UW's Biology 180, the first of three quarters of classes that must be passed by anyone wanting to major in biology and have a chance to enter pre-med, pre-biomed, genetics or other biology and health sciences programs. Biology 180 has one of the highest enrollments of any UW courses, with 2,000 students taking it last year.

"Bio 180 is a 'gateway' course to biology and life sciences but our co-

author Emile Pitre pointed out a few years ago that the number of educationally disadvantaged students failing the class was actually making it a 'gatekeeper' course," Haak said. "We wanted to see what we could do to improve that."

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