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ACTIVE LEARNING LEADS TO HIGHER GRADES AND FEWER FAILING STUDENTS IN SCIENCE, MATH, AND ENGINEERING

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THINK BACK TO when you learned how to ride a bike. You probably didn't master this skill by listening to a series of riveting lectures on bike riding. Instead, you tried it out for yourself, made mistakes, fell down a few times, picked yourself back up, and tried again. When mastering an activity, there's no substitute for the interaction and feedback that comes from practice.

What if classroom learning was a little more active? Would university instruction be more effective if students spent some of their class time on active forms of learning like activities, discussions, or group work, instead of spending all of their class time listening?

A new study in the Proceedings of the National Academy of Sciences addressed this question by conducting the largest and most comprehensive review of the effect of active learning on STEM (Science, Technology, Engineering and Mathematics) education. Their answer is a resounding *yes*. According to Scott Freeman, one of the authors of the new study, "**The impact of these data should be like the Surgeon General's report on "Smoking and Health" in 1964–they should put to rest any debate about whether active learning is more effective than lecturing.**"

Before you study something quantitatively, you have to define it. The authors combined 338 different written responses to arrive at the following definition of active learning:

> Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.

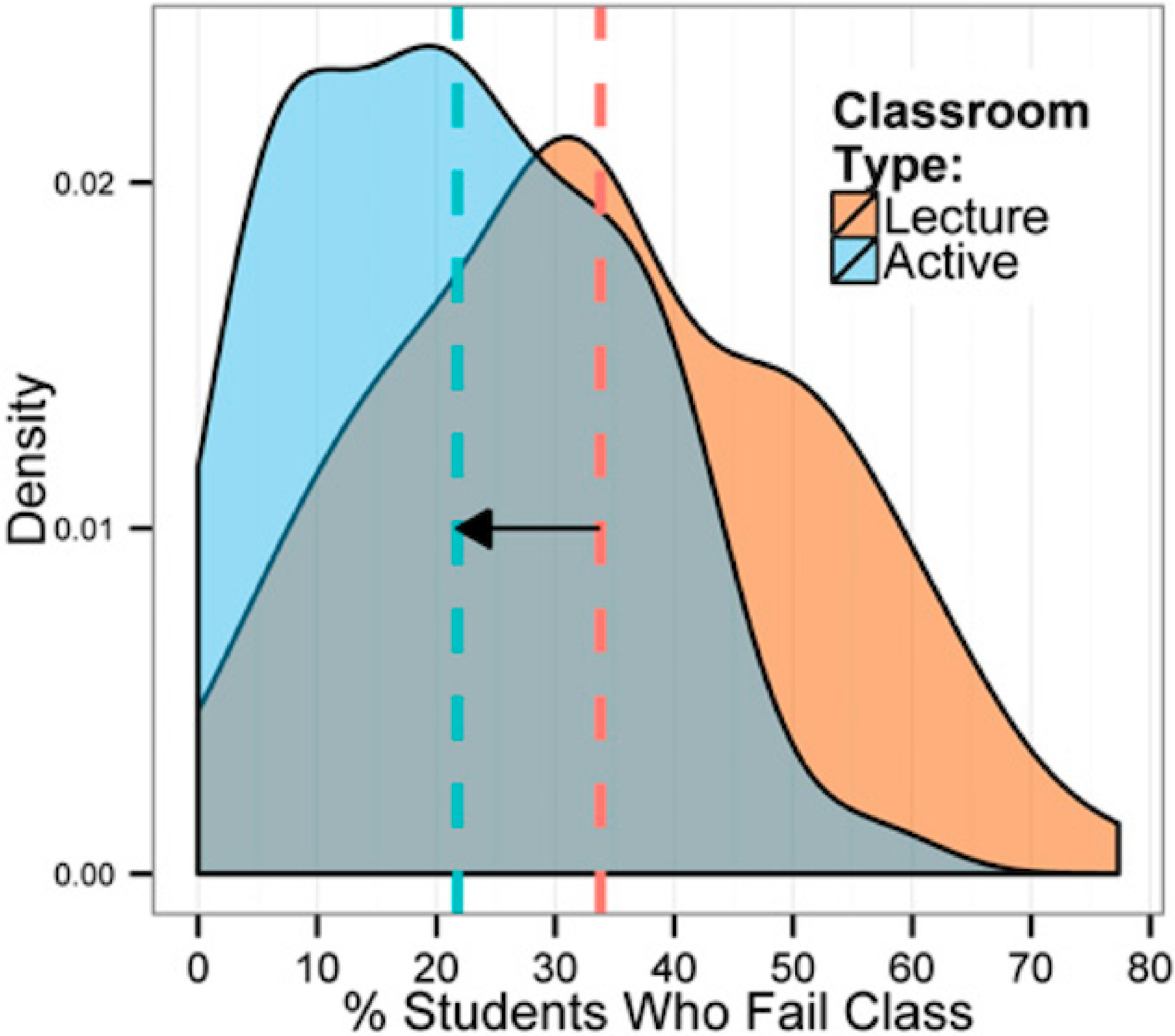
They then searched for classroom experiments where students in a STEM class were divided into two groups – one group engaged in some form of active learning, while the other group participated in a traditional lecture. At the end of the class, both groups took essentially identical exams.

The authors looked at studies where both groups were taught by the same instructor and the students were assigned at random to each group, as well as less ideal experimental conditions, where the instructors differed, or the students weren't assigned to groups at random. They evaluated the performance of these studies using two metrics – their scores on identical exams, and the percentage of students that failed (receiving a D, F or withdrawing from the class). In all, they identified 228 studies matching their criteria, to analyze further.

Here's what they found.

1. Students in a traditional lecture course are 1.5 times more likely to fail, compared to students in courses with active learning

The authors found that 34% of students failed their course under traditional lecturing, compared to 22% of students under active learning. This suggests that, just in the studies that they analyzed, 3,500 more students would have passed their courses if taught with active learning. By conservative estimates, this would have saved the students about 3.5 million dollars in tuition. The authors point out that, were this a medical study, an effect size this large and statistically significant would warrant stopping the study and administering the treatment to everyone in the study.

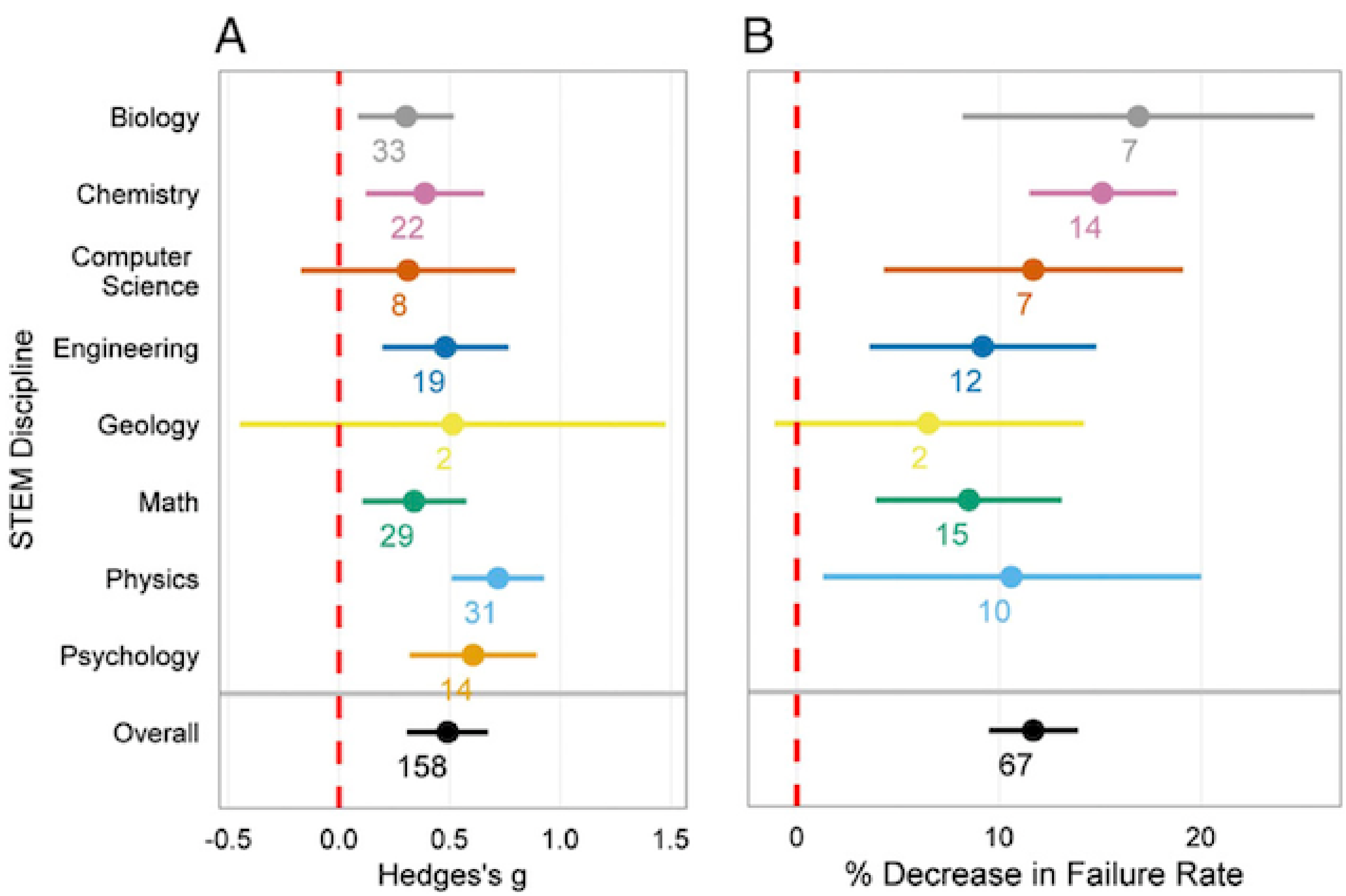


A comparison of how students performed in active learning and lecture courses. The horizontal axis is the failure rate, and the vertical axis is the relative number of courses with that failure rate. Under active learning, the average failure rate drops from 33.8% to 21.8%. Image Credit: Freeman et al, PNAS.

A large drop in the number of failing students meets a demonstrated need to increase the retention of STEM students, and should be taken very seriously. Nearly a third of all students entering US colleges and universities intend to major in STEM fields, and more than half of these students eventually either switch their majors to a non-STEM field or drop out of college without a degree. This attrition problem is particularly acute for minorities, as only 20% of under-represented minority students who are interested in the STEM fields finish university with a STEM degree.

2. Students in active learning classes outperform those in traditional lectures on identical exams

On average, students taught with active learning outperformed those taught by lectures by 6 percentage points on their exam. That's the difference between bumping a B- to a B or a B to a B+. Here's another way that the authors describe this result. Picture a student in a traditional lecture class who scored higher than 50% of the students on the exam. If the same student were taught with active learning instead, they would score higher than 68% of the students in this lecture class.



The increase in student grades (left, measured in standard deviations), and the percentage decrease in the failure rate (right), broken down by subject. Image Credit: Freeman et al, PNAS.

Both these results were incredibly robust. They held up for all of the STEM subjects for which there was sufficient data. They held in large and small classes (although the impact of active learning was larger in small classes), and they held in introductory as well as upper-level courses. The exam performance results also held up irrespective of how the students were split into the two groups – whether the groups had the same or different instructors, or whether the student were randomly assigned to courses or not. The authors were also careful to account for whether their study was affected by publication biases (the bias to publish positive results over negative ones) and they found that this did not significantly impact their findings.

I asked Scott Freeman whether star lectures with strong teaching evaluations should be interested in these findings as well. He responded,

"Most of the studies we analyzed were based on data from identical instructors teaching active learning v lecturing sections; some studies (e.g. Van Heuvelen in Am. J. Physics; Deslauriers et al. in Science) have purposely matched award-winning lecturers with inexperienced teachers who do active learning and found that the students did worse when given "brilliant lectures." We've yet to see any evidence that celebrated lecturers can help students more than even 1st-generation active learning does."

I'll leave the last word with Scott, who makes a strong case for active learning.

"[Under active learning,] students learn more, which means we're doing our job better. They get higher grades and fail less, meaning that they are more likely to stay in STEM majors, which should help solve a major national problem. Finally, there is a strong ethical component. There is a growing body of evidence showing that active learning differentially benefits students of color and/or students from disadvantaged backgrounds and/or women in male-dominated fields. It's not a stretch to claim that lecturing actively discriminates against underrepresented students."

References

Freeman et al. Active learning increases student performance in science, engineering, and mathematics. PNAS.

Data on STEM attrition rates from the Department of Education's STEM attrition report and the President's Council of Advisors on Science and Technology report.

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