

Innovating education to educate innovators: Lessons from Physics Education Research



@eric_mazur

Using Existing Evidence to Improve STEM Education
2017 AAAS Annual Meeting
Boston, MA

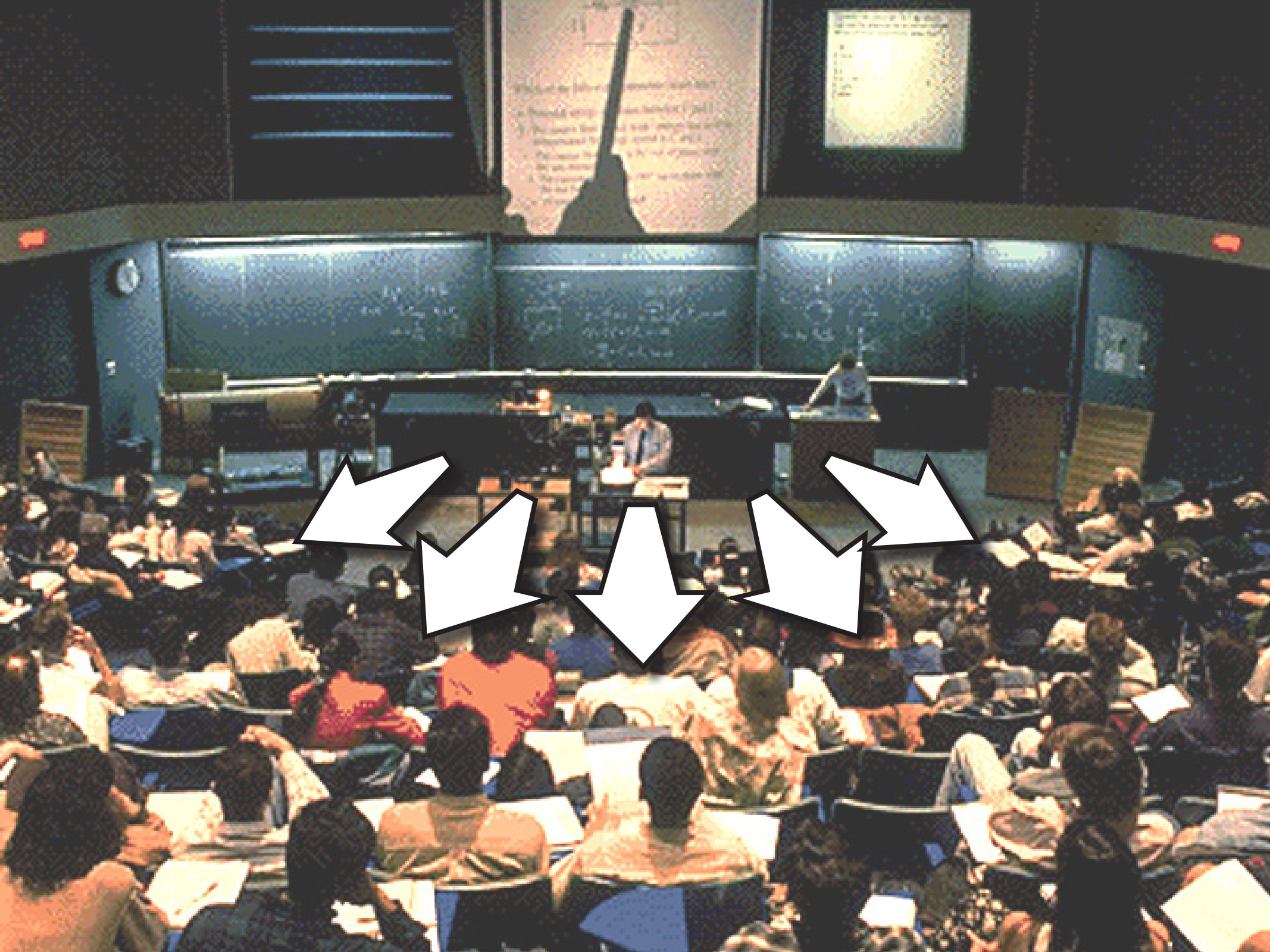














CLASS

1st exposure



ROOM

deeper understanding



CLASS

1st exposure



ROOM

deeper understanding



ROOM

1st exposure



CLASS

deeper understanding



question



question



think



question



think



poll



question



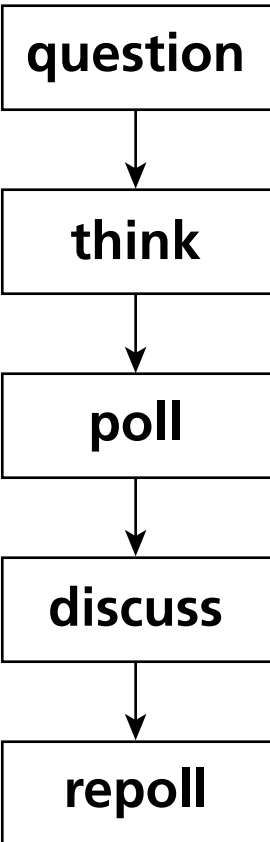
think



poll



discuss





question



think



poll



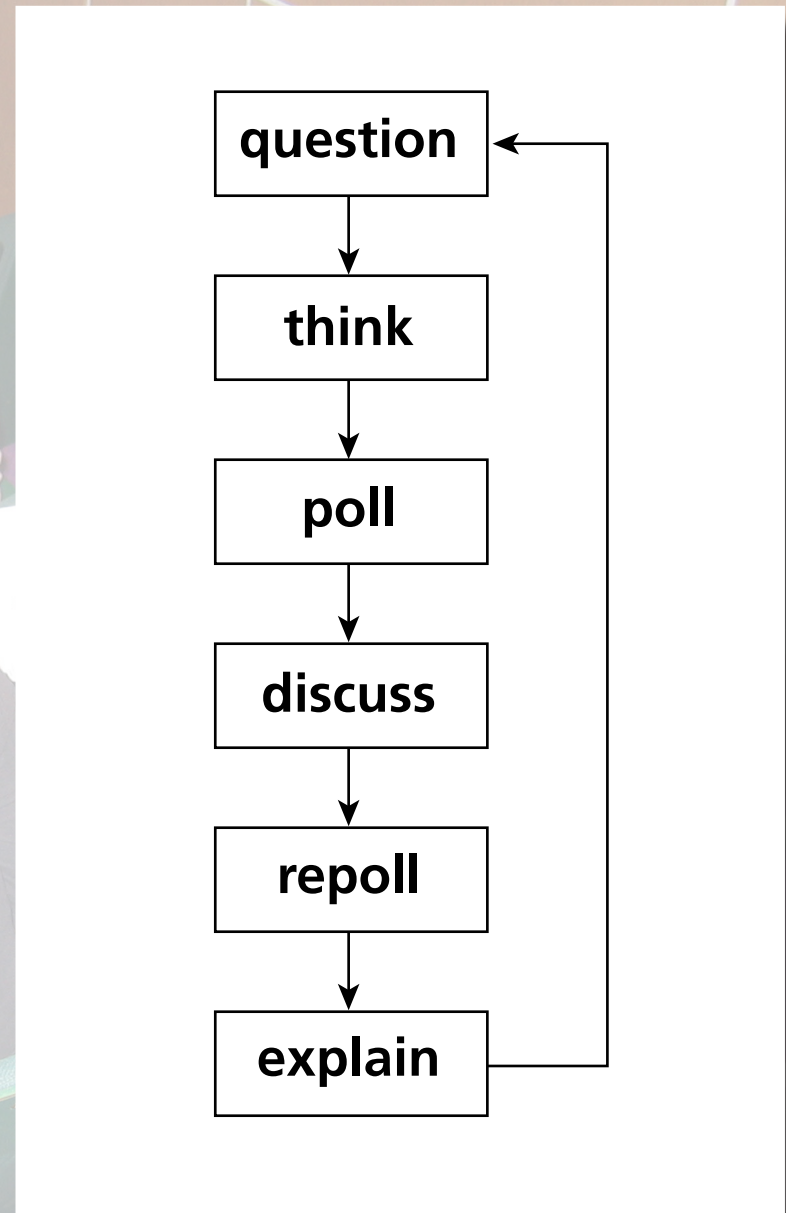
discuss



repoll

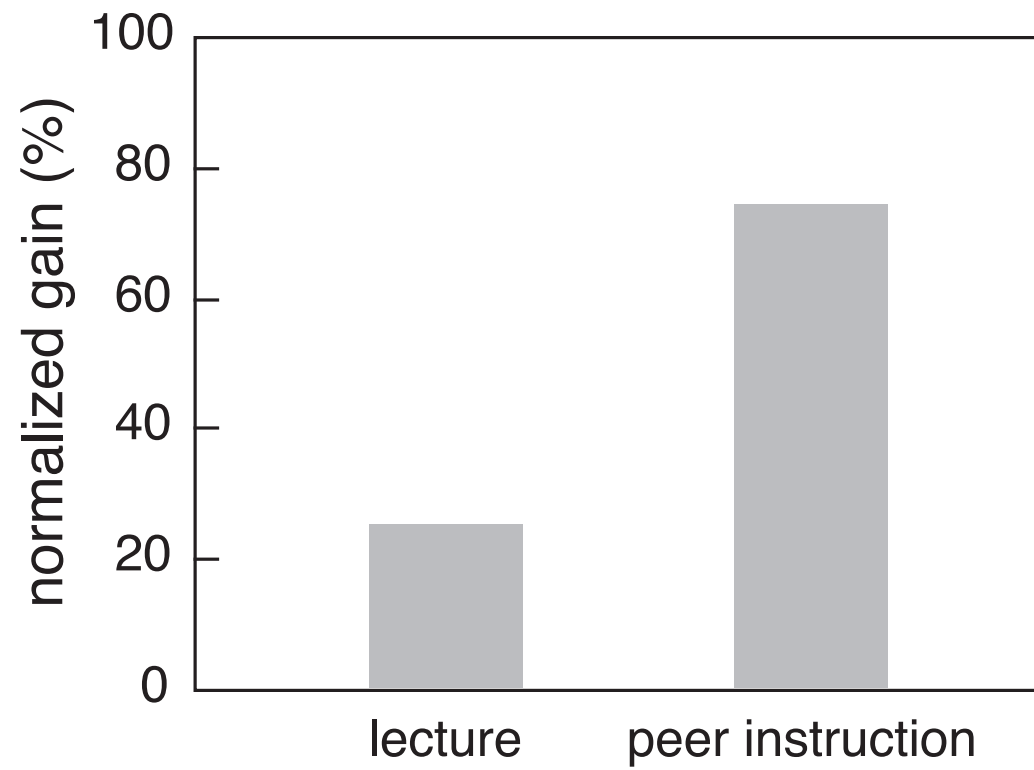


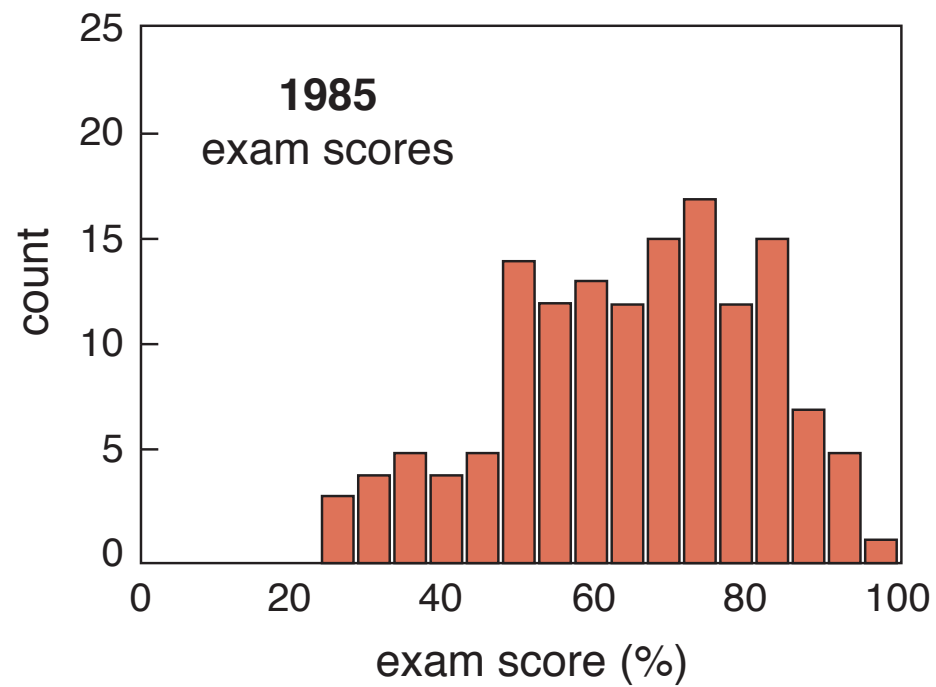
explain

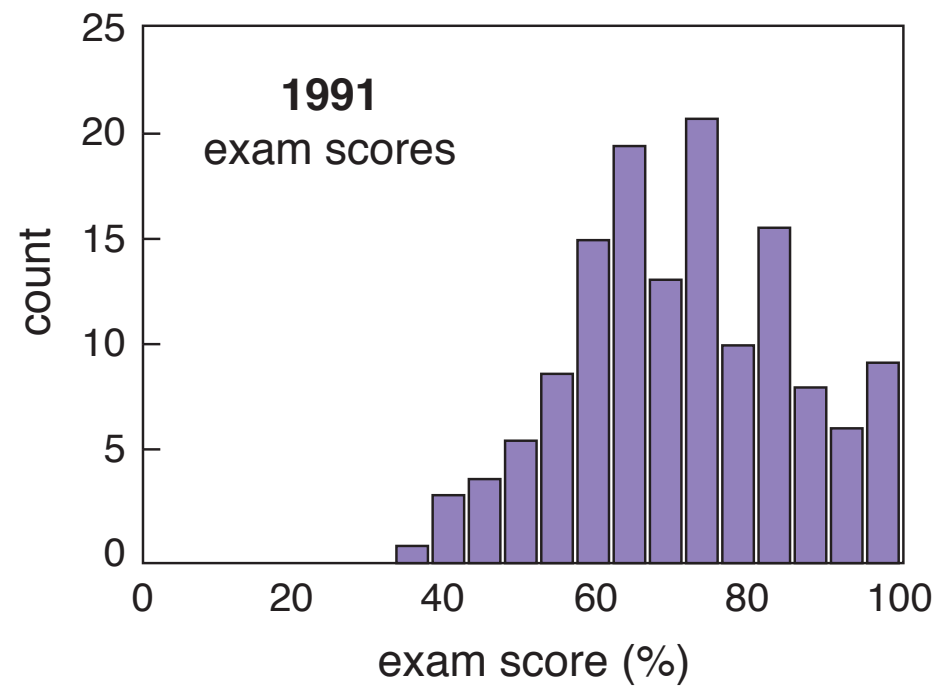


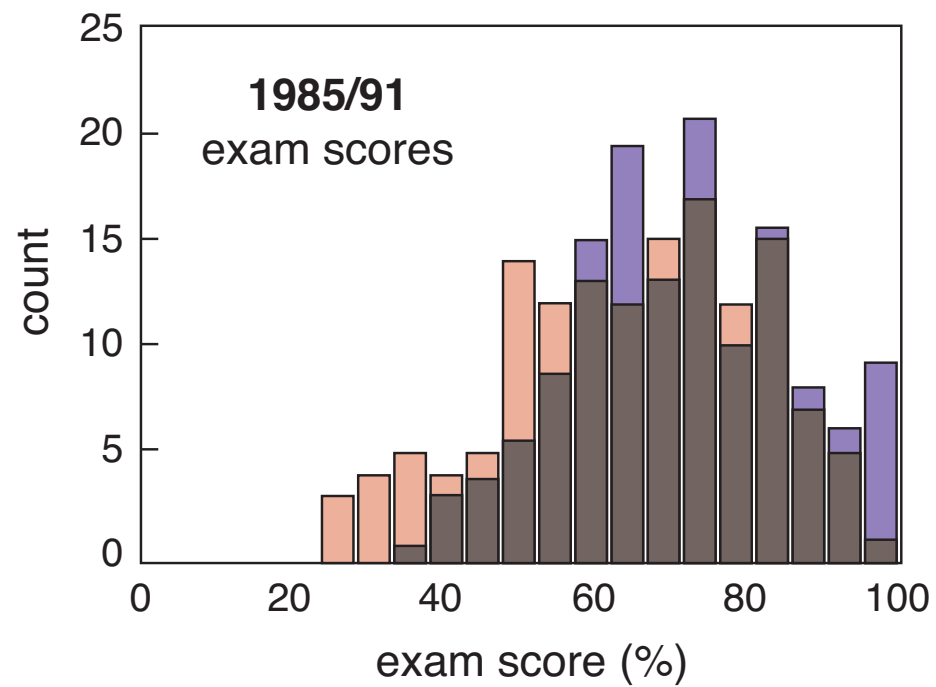
Higher learning gains

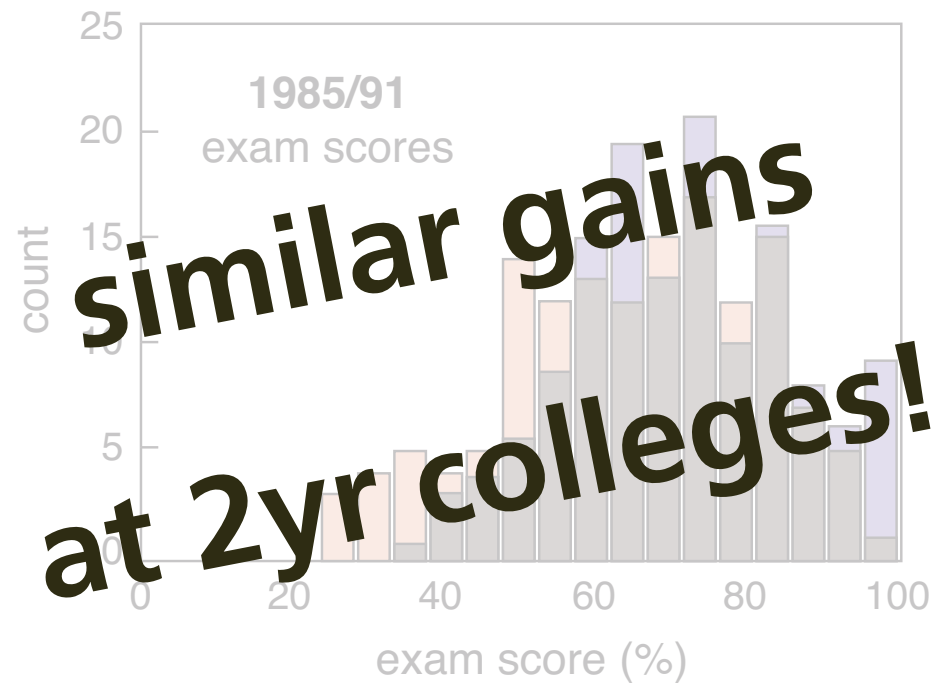
INSTRUCTION







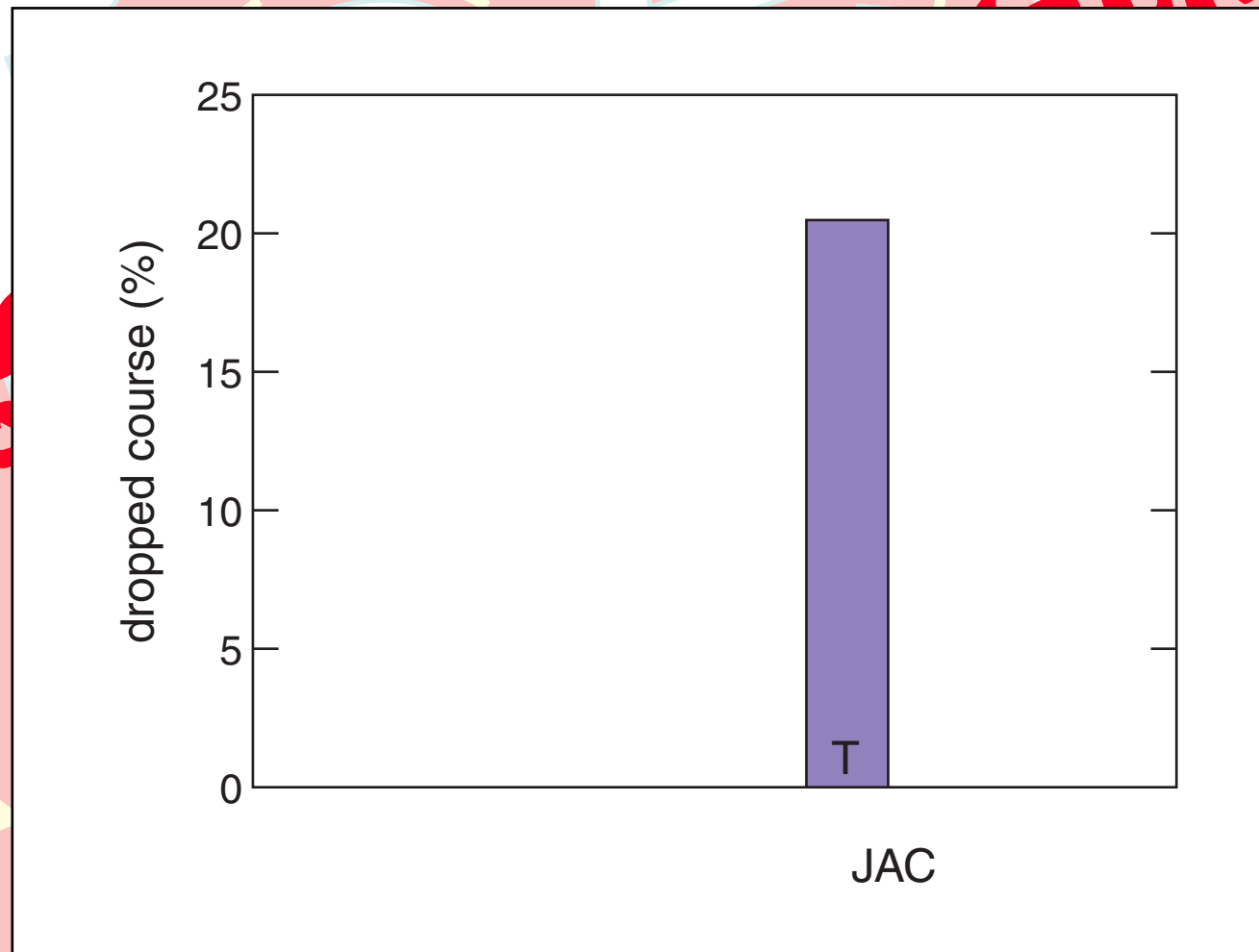




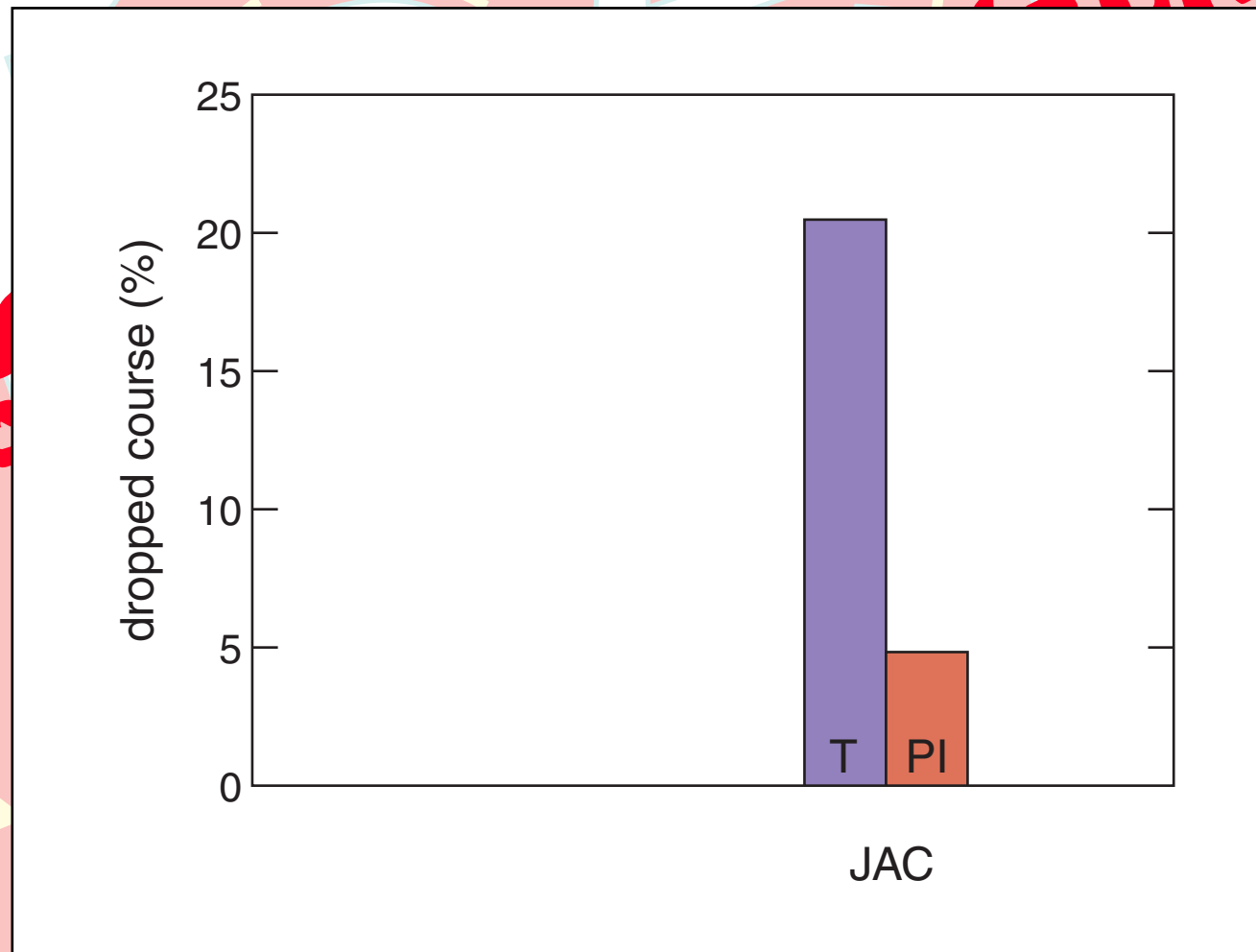
Higher learning gains

Better retention

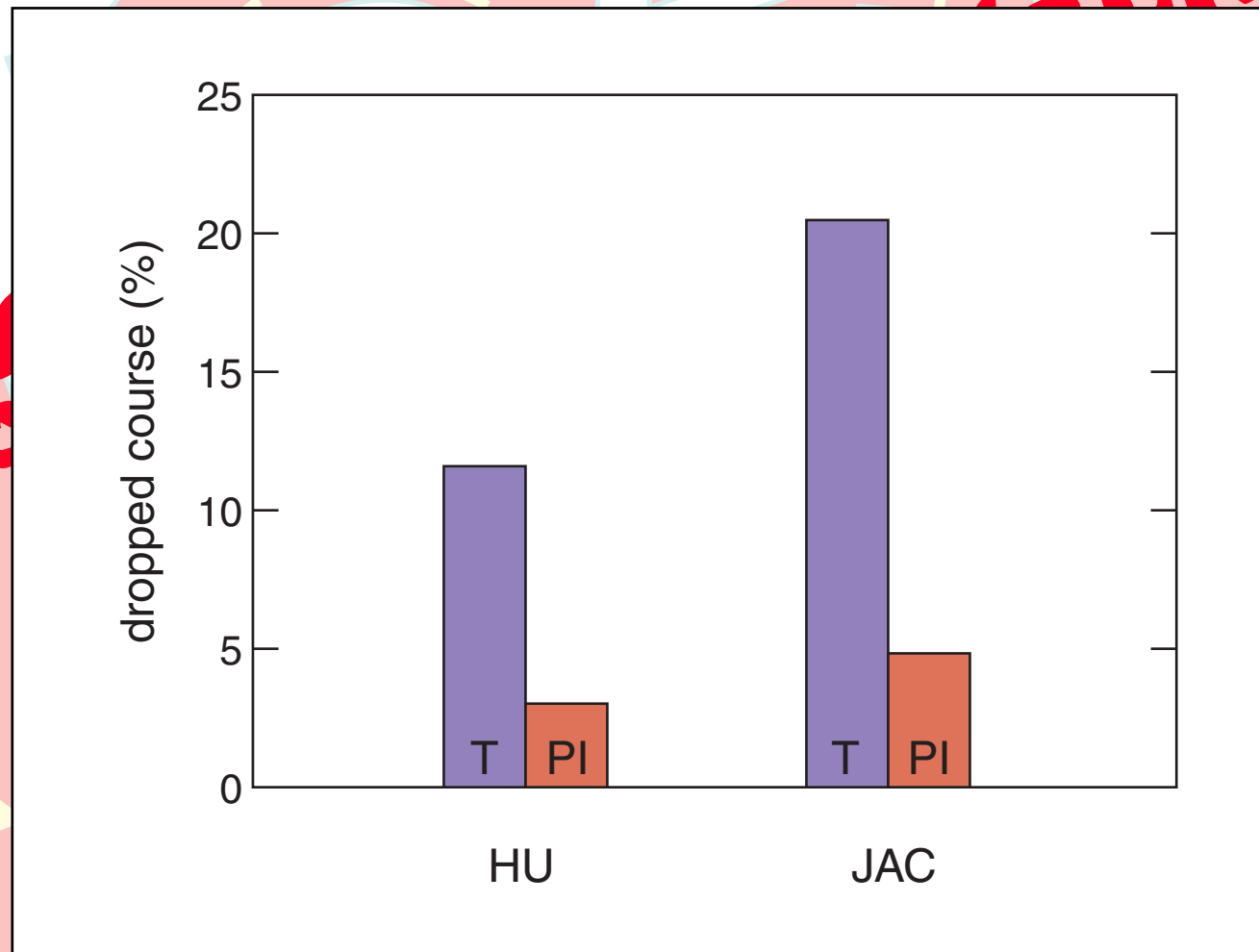
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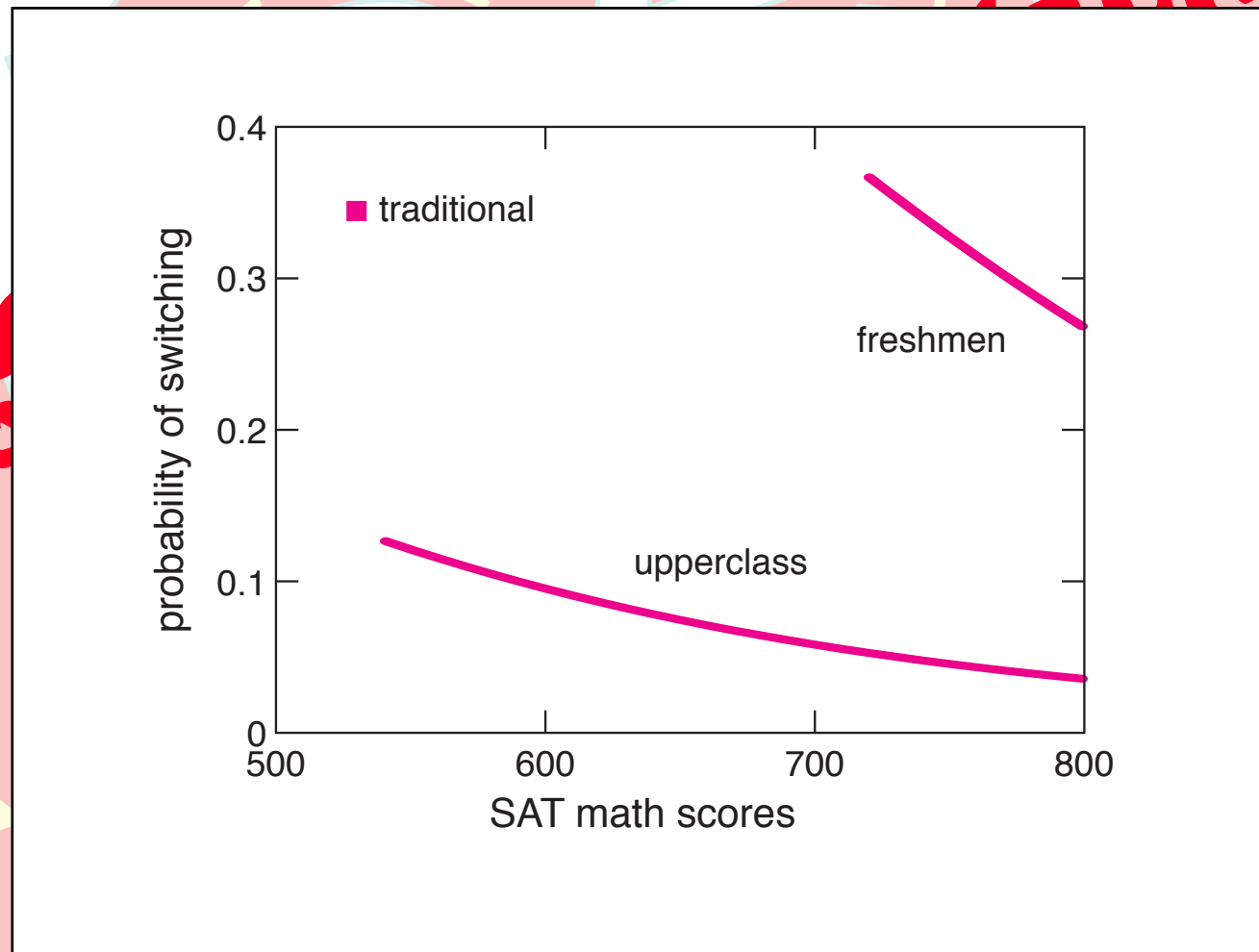
N. Lasry *et al.*, *Am. J. Phys.*, 76 (2008)



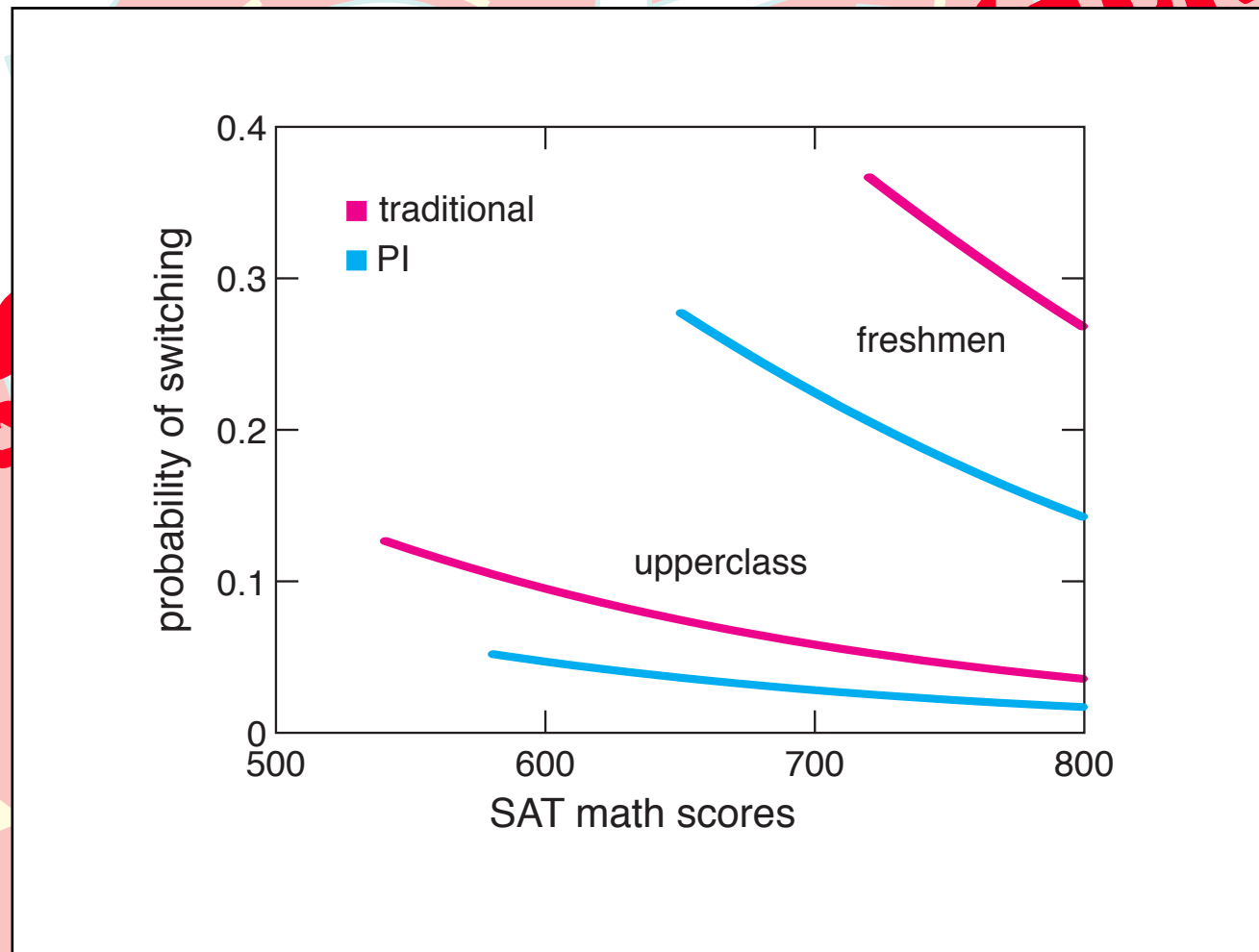
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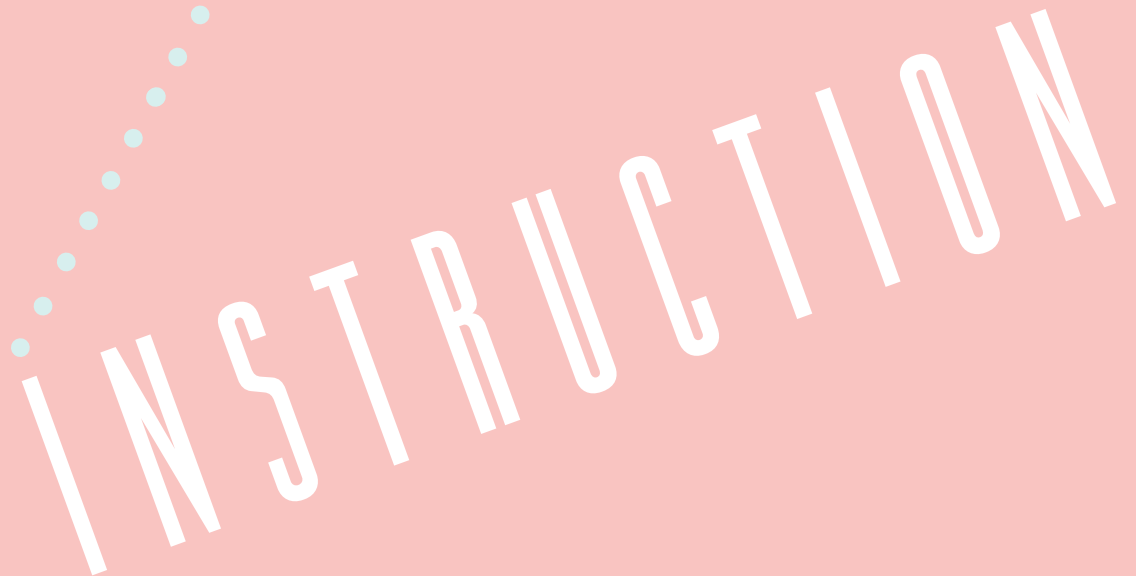
J. Watkins et al., *J. Coll. Sci. Teach.*, 42 (2013)



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INSTRUCTION

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman^{a,1}, Sarah L. Eddy^a, Miles McDonough^a, Michelle K. Smith^b, Nnadozie Okoroafor^a, Hannah Jordt^a, and Mary Pat Wenderoth^a

^aDepartment of Biology, University of Washington, Seattle, WA 98195; and ^bSchool of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories improved by 0.47 SDs under active learning ($n = 158$ studies), and the odds ratio for failing was 1.95 under traditional lecturing (17 studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across STEM disciplines, that active learning increases scores on concept inventories more than on course examinations, and that active learning appears effective across all class sizes—although the largest effects are in small ($n \leq 50$) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the largest and most comprehensive metaanalysis of undergraduate science, engineering, and mathematics published to date. The results raise questions about the effectiveness of lecturing as a control in research on learning, empirically

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, and studio or workshop course designs. We followed guidelines for use of personal response systems with or without peer instruction, and evaluated student performance using two outcome variables: (i) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (ii) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate). The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Results

The overall mean effect size for performance on identical or formally equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 (9.781 , $P < 0.001$)—meaning that on average, student performance increased by just under half a SD with active learning compared with lecturing. The overall mean effect size for failure rates was an odds ratio of 1.95 ($Z = 10.4$, $P < 0.001$). This rate is equivalent to a risk ratio of 1.5, meaning that on average, students in traditional lecture courses are 1.5 times more likely to fail than students in courses with active learning. Average failure rates were 21.8% under active learning but 33.8% under lecturing—a difference that represents a 55% reduction in failure rates.



Active learning increases student performance in science, engineering, and mathematics

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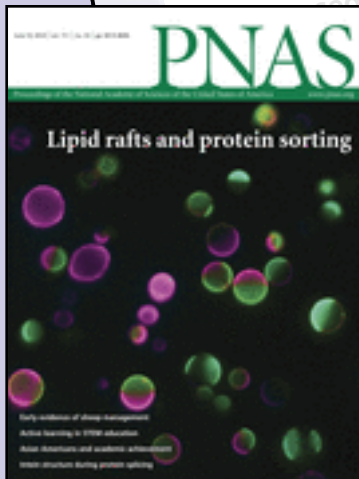
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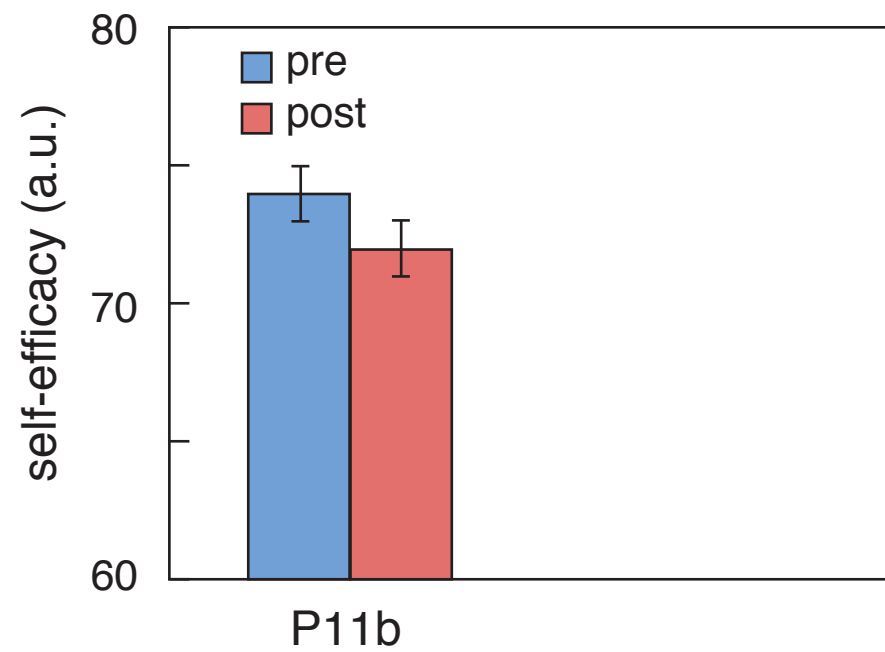
S. Freeman et al., *PNAS* 111, 23 (2014)





peer
self-efficacy

INSTRUCTION

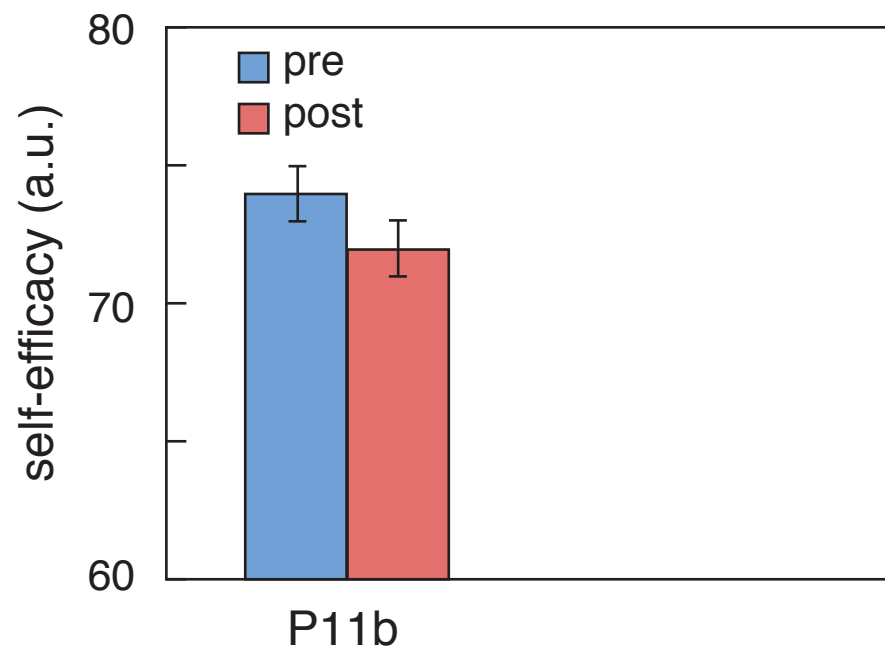


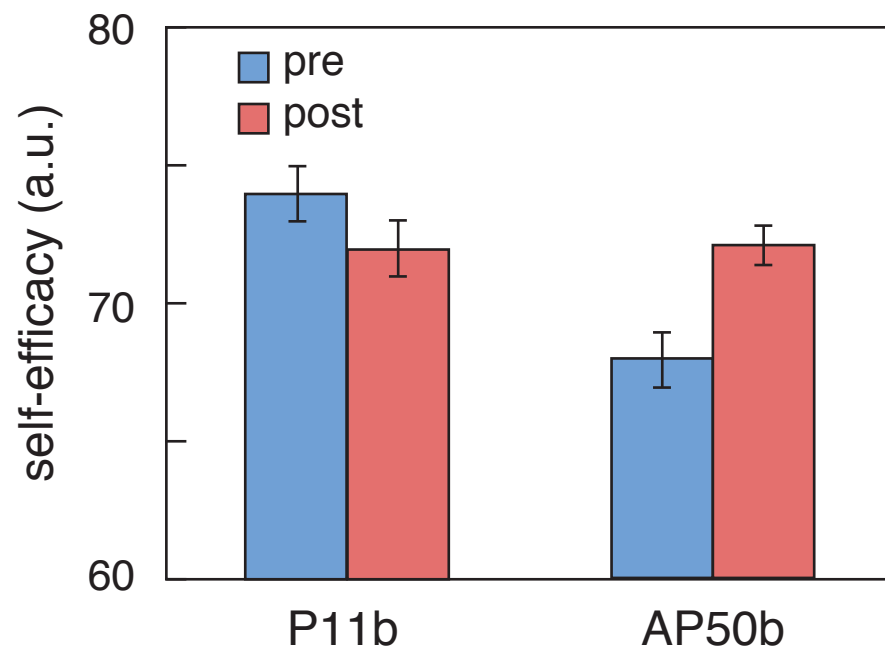
A group of four students are gathered around a wooden box containing a project. A female student with glasses is leaning over the box, pointing at something inside. Another female student is smiling and looking at the project. A male student in a plaid shirt is standing and smiling. A female student in a maroon hoodie is sitting and looking up at the project. The box contains various electronic components, including a breadboard, wires, and a small display. The background shows a classroom setting with other students and equipment.

ownership

A group of four students are gathered around a wooden box containing a project. A female student with long dark hair and glasses is leaning over the box, holding a white cup and pouring liquid into it. She is smiling. Another female student with long dark hair is standing behind her, also smiling. A male student with short blonde hair and a plaid shirt is standing to the right, smiling. A female student with short blonde hair and a maroon hoodie is sitting in front of the box, looking up at the others and smiling. The box contains various items, including a blue bowl, a white cup, and some papers. The background shows a classroom setting with a whiteboard and a door.

team- and project-based learning







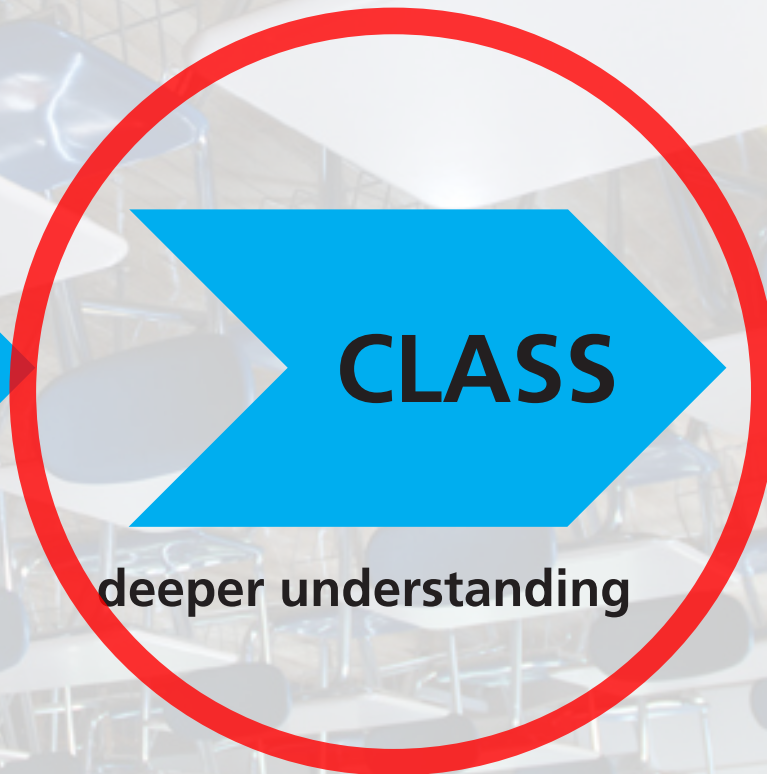
1st exposure



deeper understanding



1st exposure



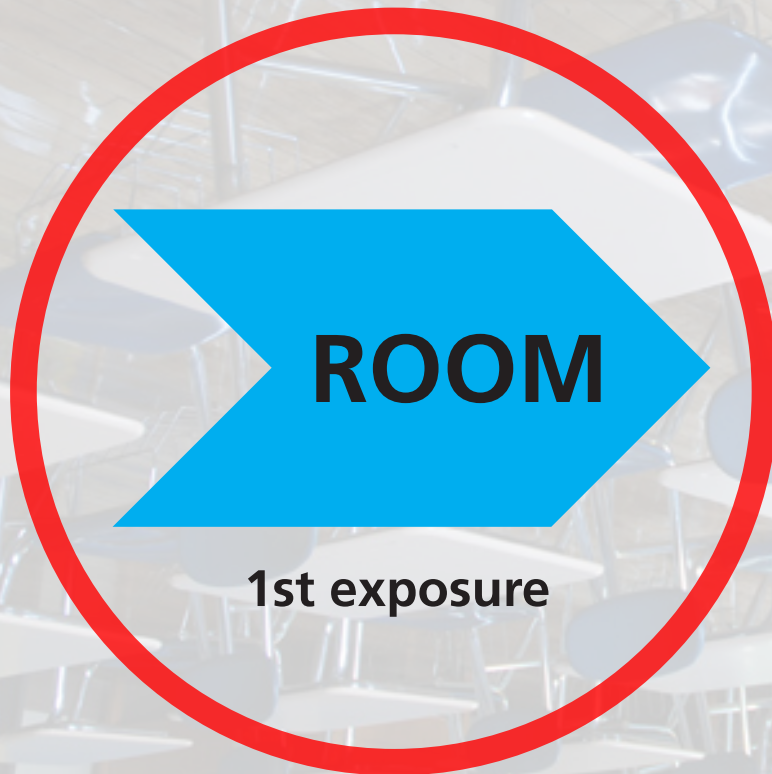
deeper understanding



1st exposure



deeper understanding

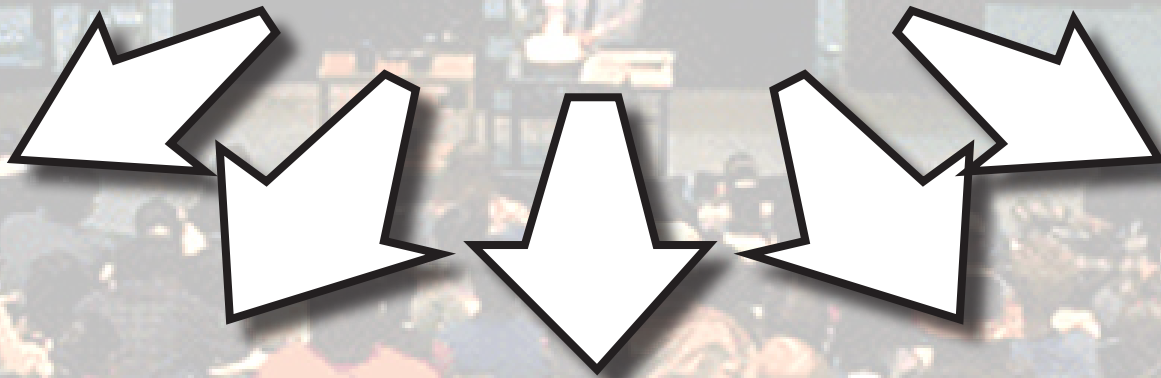


1st exposure



deeper understanding

how to effectively transfer information outside classroom?





want:
every student prepared for every class



want:
***every* student prepared for *every* class**
(without additional instructor effort)

A stylized illustration of a classroom. Several students are seated at rows of desks, facing forward. The students are depicted in various colors (yellow, green, blue, purple, pink, light green) and are holding pens or pencils, suggesting they are taking notes or participating in a lesson. The background is a solid light gray.

Solution

**turn out-of-class component
also into a social interaction!**

76 CHAPTER 4 MOMENTUM

In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

4.1 Friction

Picture a block sliding on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough or sticky. This you know from everyday experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that the velocity decreases as the block slides. The block slides easily over the smooth surface, but it comes to rest more quickly on the rougher surfaces. To bring two objects to rest with the same force, this case the wooden block and the rougher surface. The less friction there is, the more difficult it is to bring the block to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.



social learning platform



Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



4.1 (a) Are the accelerations of the motions shown in Figure 4.1 constant? (b) For which surface is the acceleration largest in magnitude?

thoughtful reading and interpretation

(b) Multiply magnitude of \vec{F} by r_{\perp} .

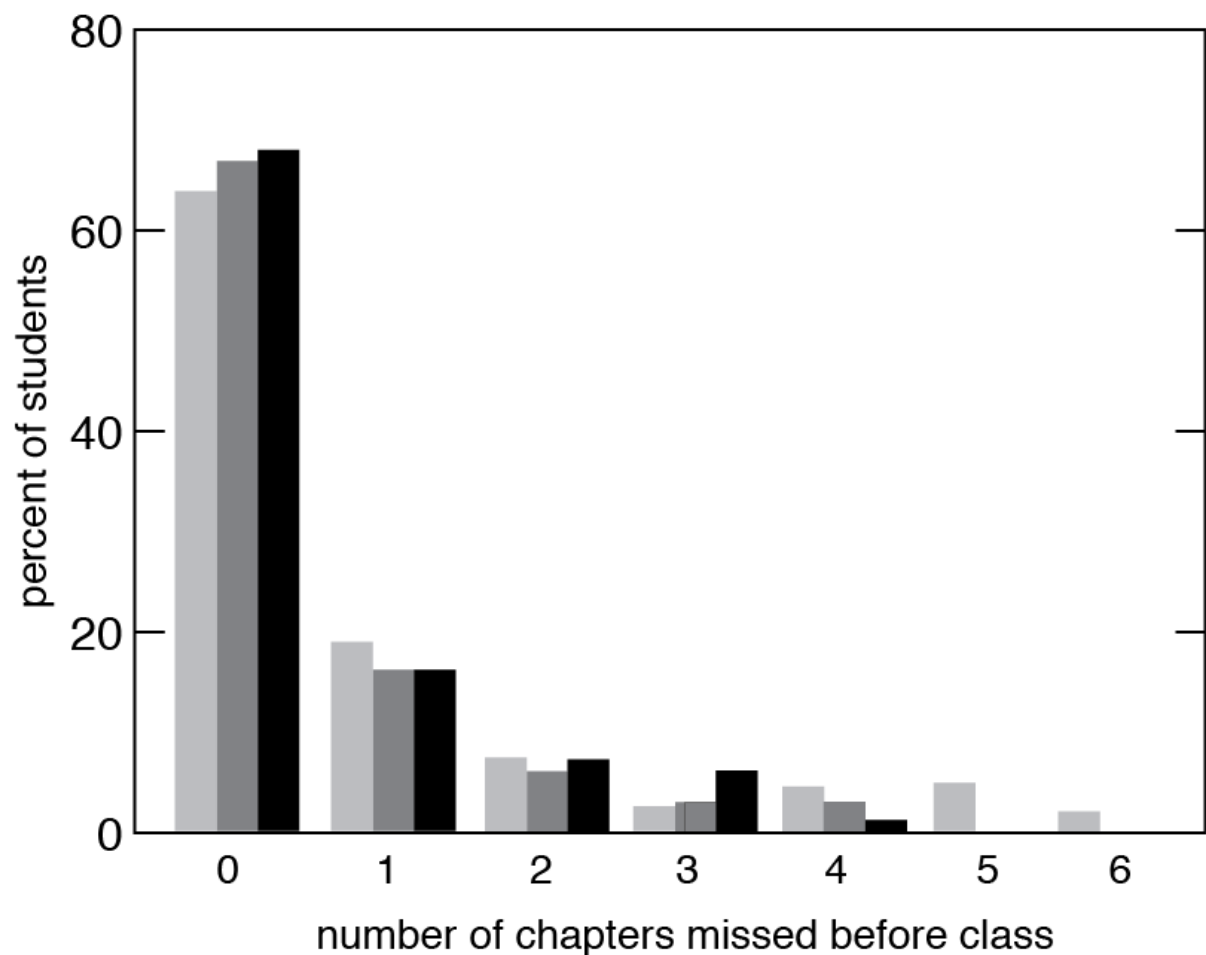


reference point

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force \vec{F}_1 to this

On the very left, we see th...

It's interesting that the white ...



I don't understand how factors tells you any lever arm distance both s know some sort of direct

I think you may be a direction separately. distance, you can attach parameters of the system explain how to choose th

This is a great question. I can think of this in terms torque is $\tau = r \times F$, with r the force. We know that force in regards to "r" it can also means is that this distance to the point where the force general convention (the r direction which happens to be perpendicular to both the radius from the axis and to the force.

Enter your comment or question and press Enter

Example 12.2 Torques on lever

Three forces are exerted on the lever of Figure 12.7. Forces \vec{F}_1 and \vec{F}_3 are equal in magnitude, and the magnitude of \vec{F}_2 is half as great. Force \vec{F}_1 is horizontal, \vec{F}_2 and \vec{F}_3 are vertical, and the lever makes an angle of 45° with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?

(a) The change in rotationa...

As we saw earlier in the chap...

Objects executing motion ar...

Generally, for rotating bod...

Does torque have the s...

thoughtful reading and interpretation

(b) Multiply magnitude of \vec{F} by r_{\perp} .

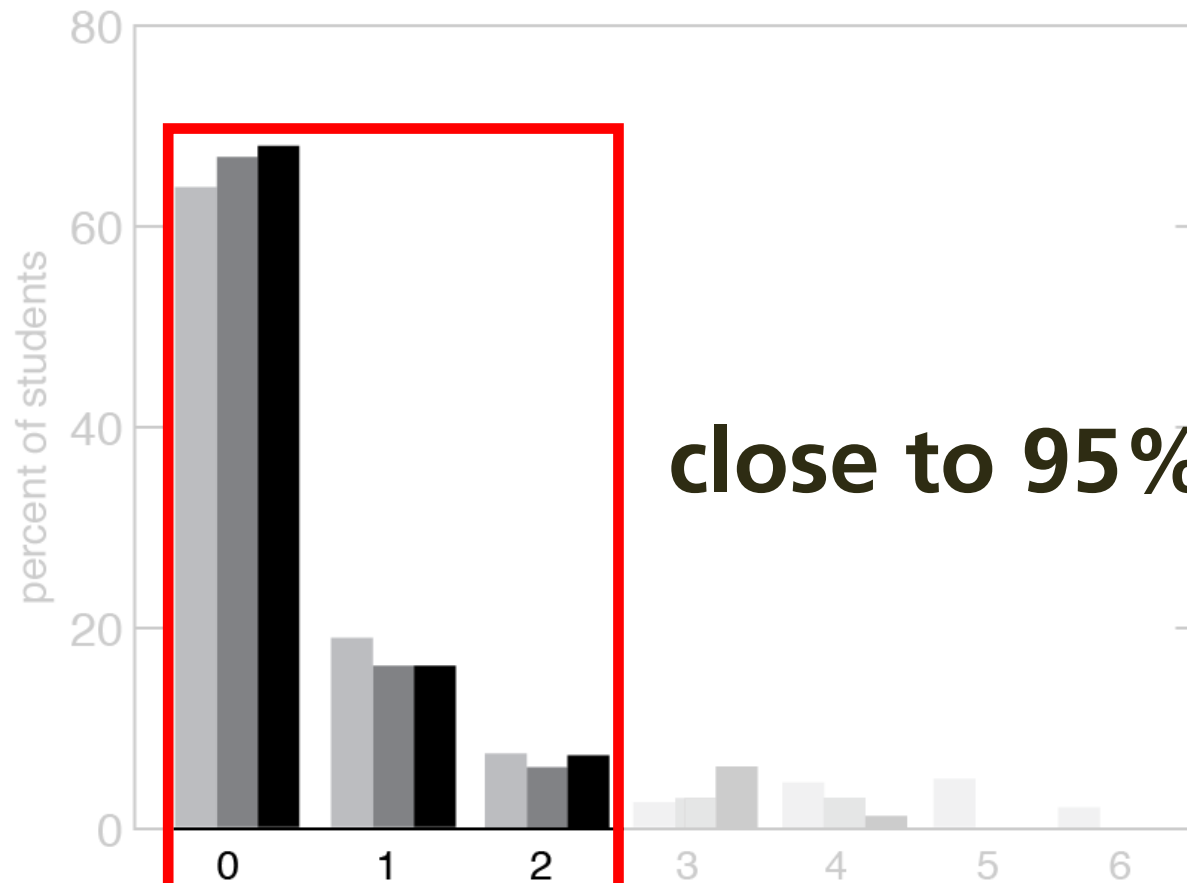
\vec{F}

\vec{F}_1

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close to 95%!

number of chapters missed before class

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A group of four students are gathered around a wooden box containing electronic components. A female student with glasses is leaning over the box, pointing at a component. Another female student is looking on, and a male student is standing behind her, smiling. A fourth student, a female with short blonde hair, is sitting in front of the box, looking up at the others. The box contains a breadboard with red and yellow jumper wires, a blue bowl, and other electronic parts. The background shows a classroom setting with windows and other students.

**social engagement
in & out of classroom a must**

- 
- A photograph of four students in a laboratory or workshop setting. A woman with long dark hair and glasses is leaning over a wooden box, using a tool to work on a circuit board. She is smiling. Behind her, another woman with long dark hair is also smiling. To the right, a man with short blonde hair, wearing a plaid shirt and yellow pants, is standing and smiling. In the foreground, a woman with short blonde hair, wearing a maroon hoodie, is sitting and smiling. The wooden box they are working on contains various electronic components, including a circuit board with many red and yellow LEDs, a blue bowl, and other tools. The background shows a bright room with windows and some laboratory equipment.
- **overwhelming evidence**
 - **research data is essential**

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