The Future of Physics Education: New Methods for a New Generation

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UC SANTA BARBARA

Cartoon by Juanele (IG: @juaneletamal)

The Future of Physics Education:
New Methods for a New Generation

or

Physics Beyond the Standard Model

Education

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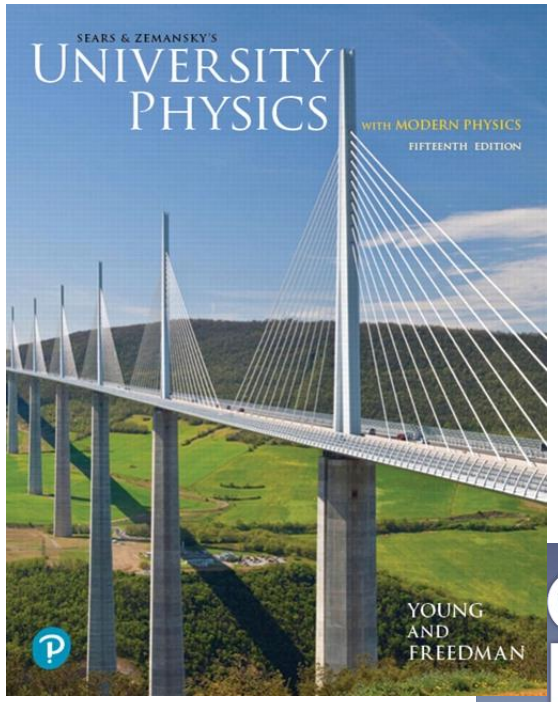
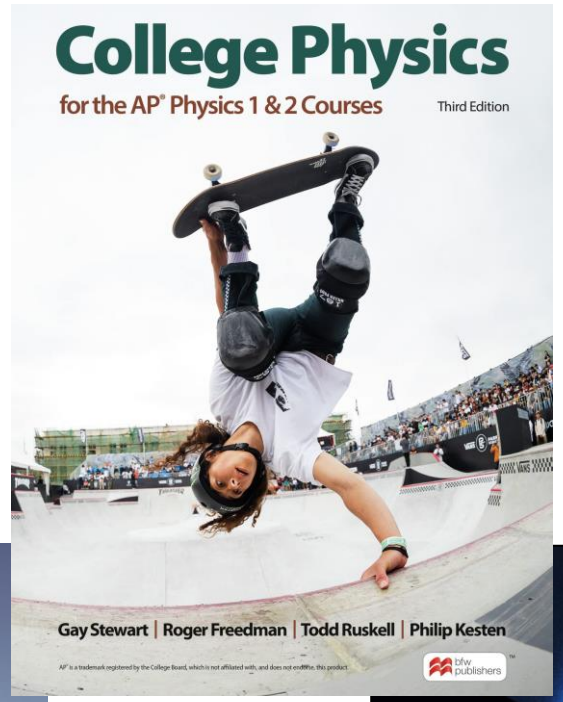

SEARS & ZEMANSKY'S
UNIVERSITY PHYSICS
WITH MODERN PHYSICS
FIFTEENTH EDITION
YOUNG
AND
FREEDMAN


College Physics
for the AP® Physics 1 & 2 Courses
Third Edition
Gay Stewart | Roger Freedman | Todd Ruskell | Philip Kesten
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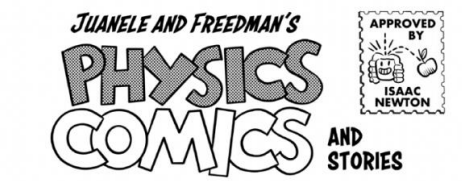
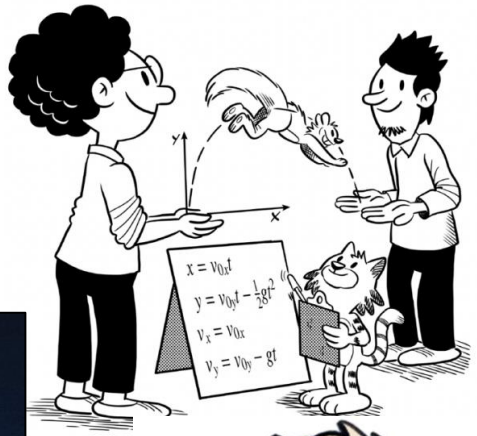
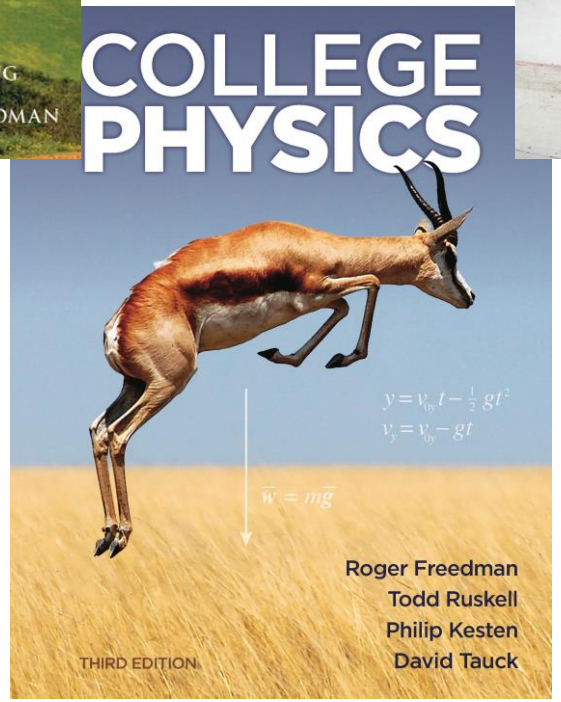

JUANELE AND FREEDMAN'S
PHYSICS COMICS
AND STORIES
APPROVED BY
ISAAC NEWTON


$x = v_{0x}t$
$y = v_{0y}t - \frac{1}{2}gt^2$
$v_x = v_{0x}$
$v_y = v_{0y} - gt$


COLLEGE
PHYSICS
$y = v_{0y}t - \frac{1}{2}gt^2$
$v_y = v_{0y} - gt$
$\vec{w} = m\vec{g}$
Roger Freedman
Todd Ruskell
Philip Kesten
David Tauck
THIRD EDITION


Eleventh Edition
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Last book that made you cry

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University Physics with Modern Physics 14th Edition by Hugh D. Young, Roger A. Freedman

1 3

Roger Freedman @RogerFreed... · 5h
No doubt tears of joy.

Physics Beyond the Standard Model

Education

Time evolution of a physics student's wave function

$$|\Psi_{student}(t)> = exp\left(-i\hat{\boldsymbol{H}}t/\hbar\right)|\Psi_{student}(0)>$$

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Time evolution of a physics student's wave function

Goal: an expert

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Time evolution of a physics student's wave function

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What is the initial state of your students?

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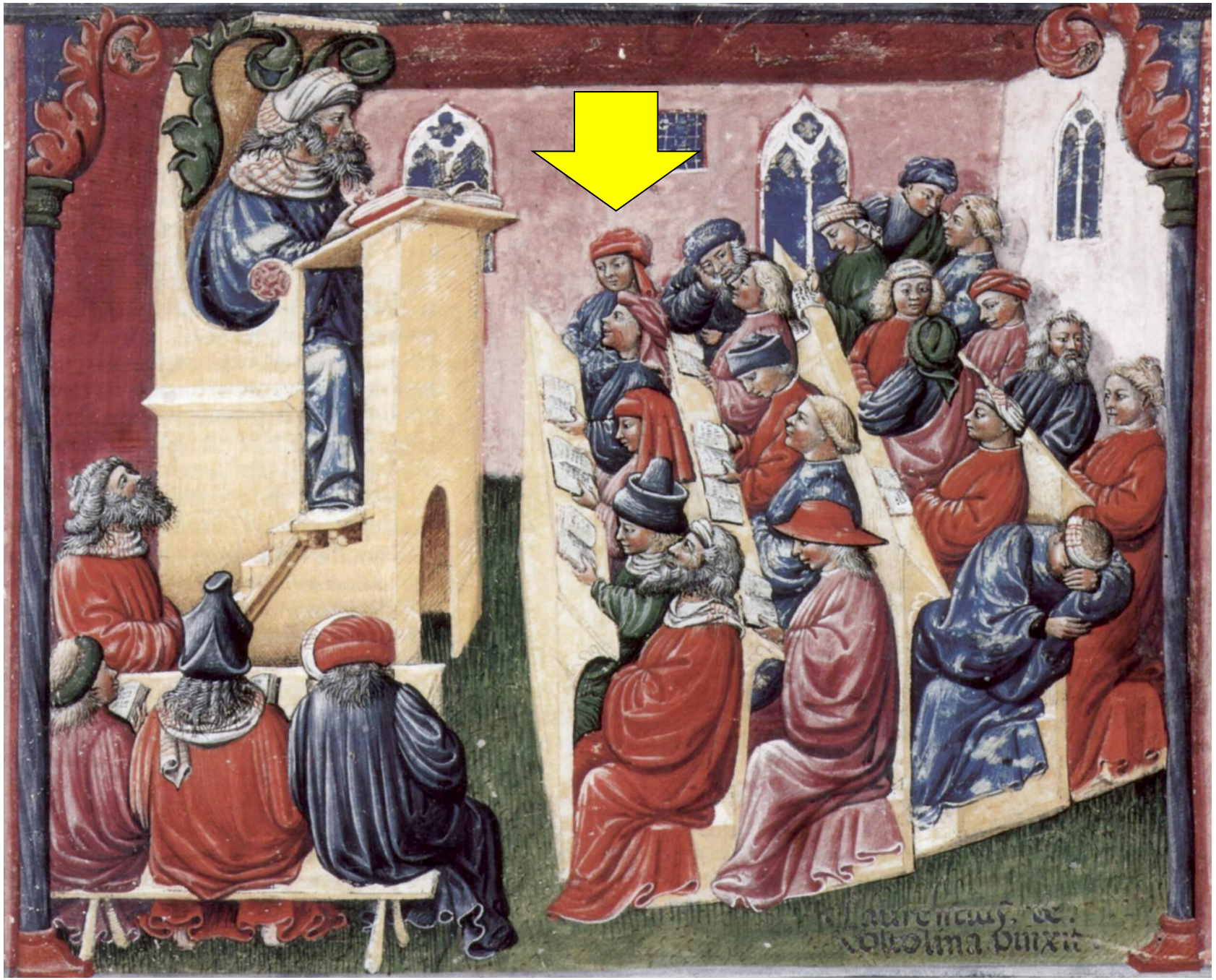
What Hamiltonian should you apply to get the desired final state?

The Standard Model of $\hat{H}_{instructor}$: Lecturing

Dr. Henry Walton "Indiana" Jones, Jr., Dept. of Archaeology, Marshall College

(University of Bologna, 2nd half of 14th century. Artist: Laurentius de Voltolina)

(University of Bologna, 2nd half of 14th century. Artist: Laurentius de Voltolina)



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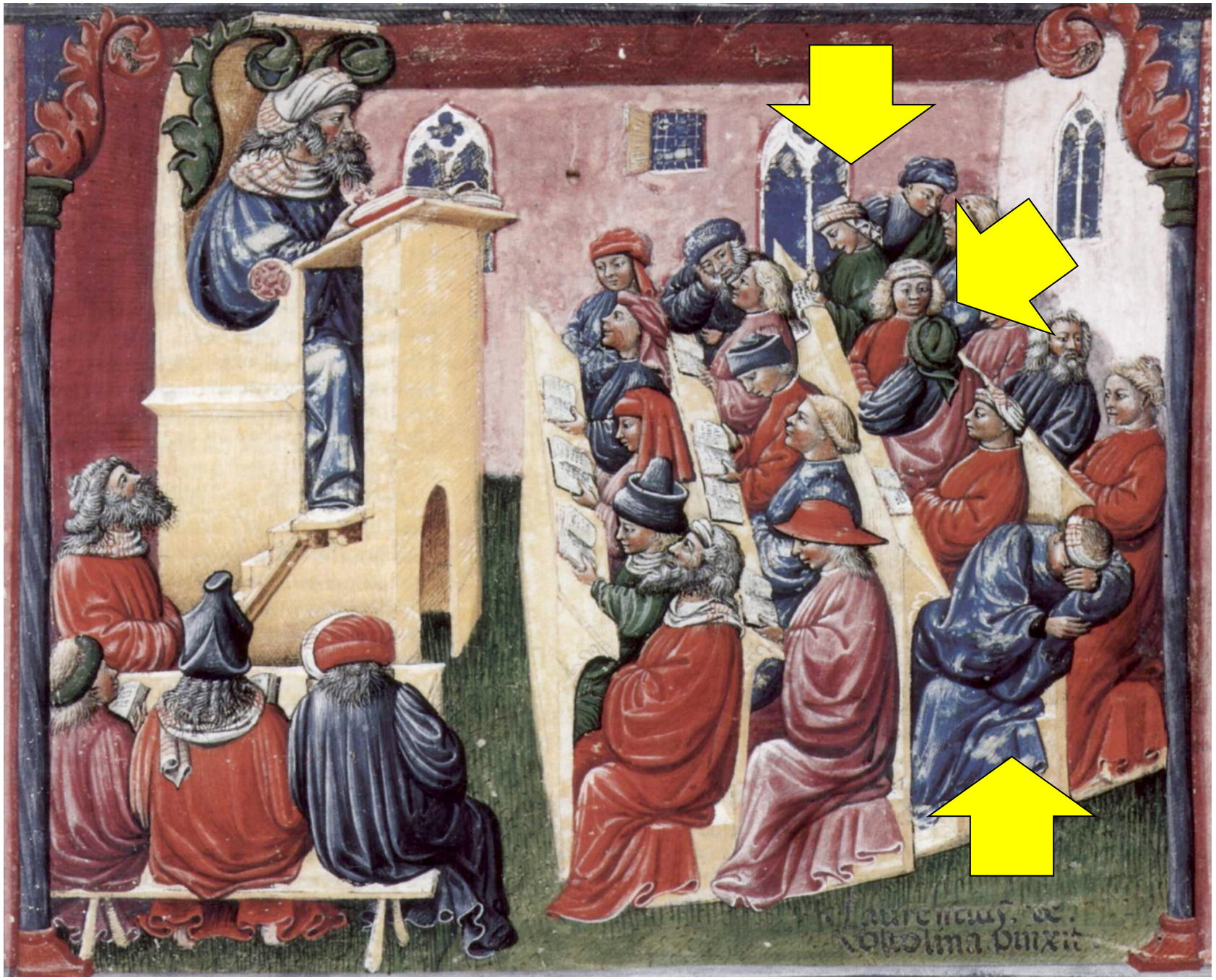

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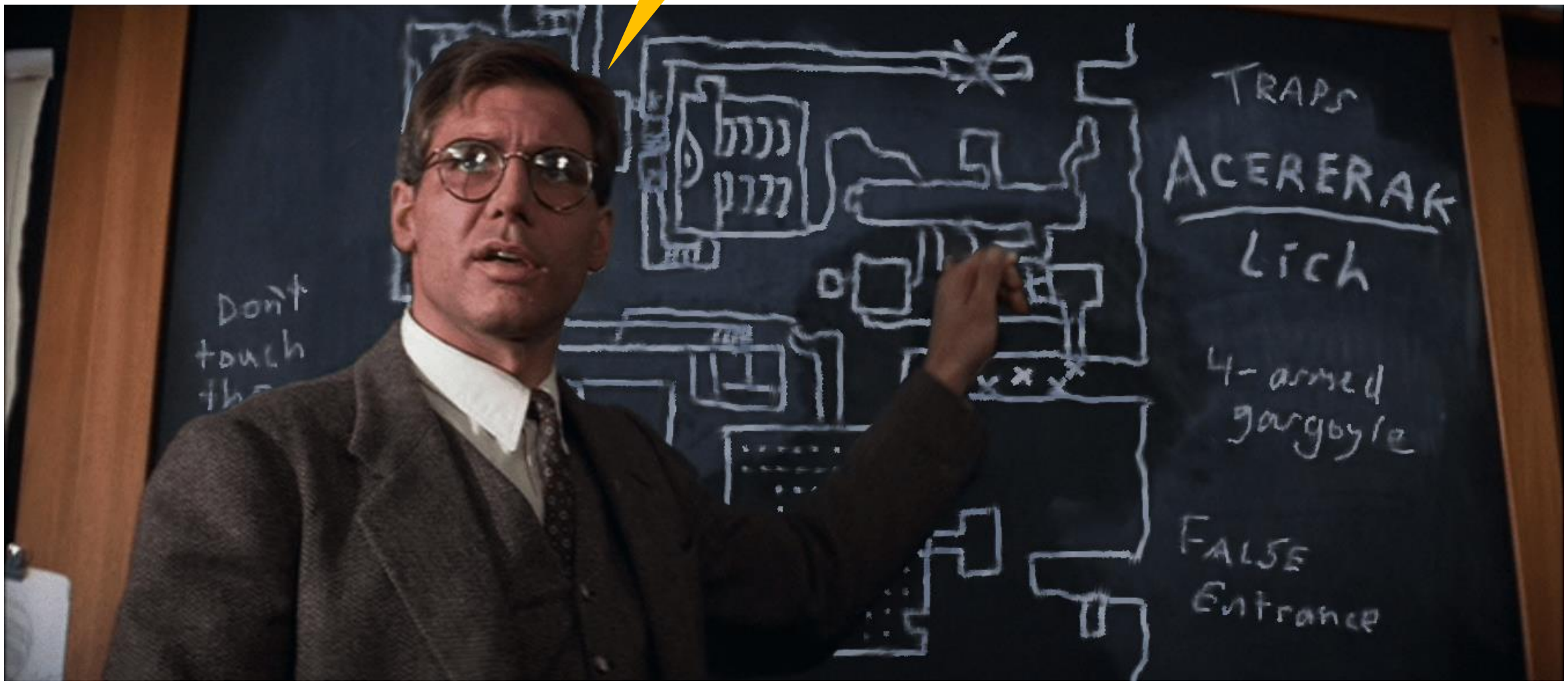
A better approach: Active learning

A better approach: Active learning

***Any* approach to instruction in which all students are asked to *engage* in the learning process**

What's so bad about lecturing?



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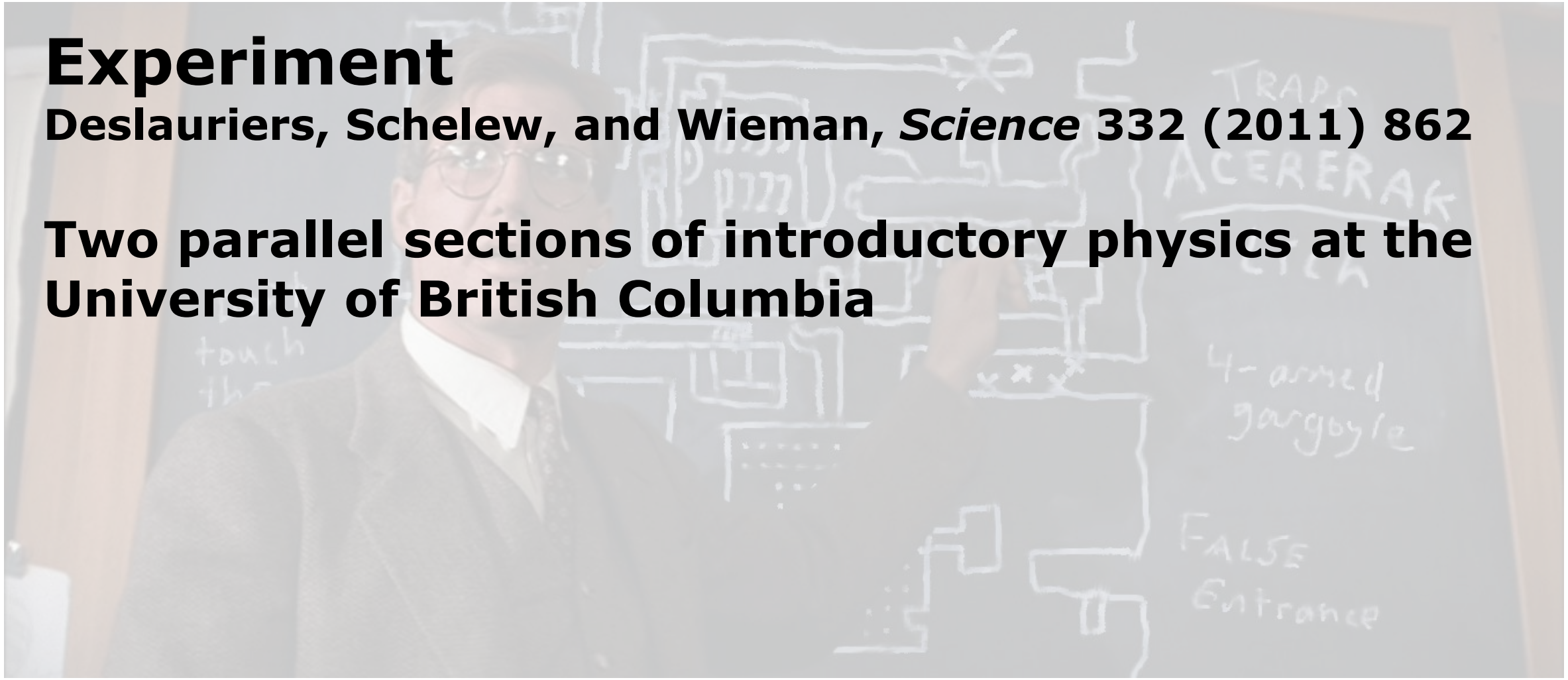

Experiment

Deslauriers, Schelew, and Wieman, *Science* 332 (2011) 862

Two parallel sections of introductory physics at the University of British Columbia

What's so bad about lecturing?

Experiment

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Two parallel sections of introductory physics at the University of British Columbia

Control section:
Taught by an experienced, highly rated instructor using conventional lecture

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Experiment

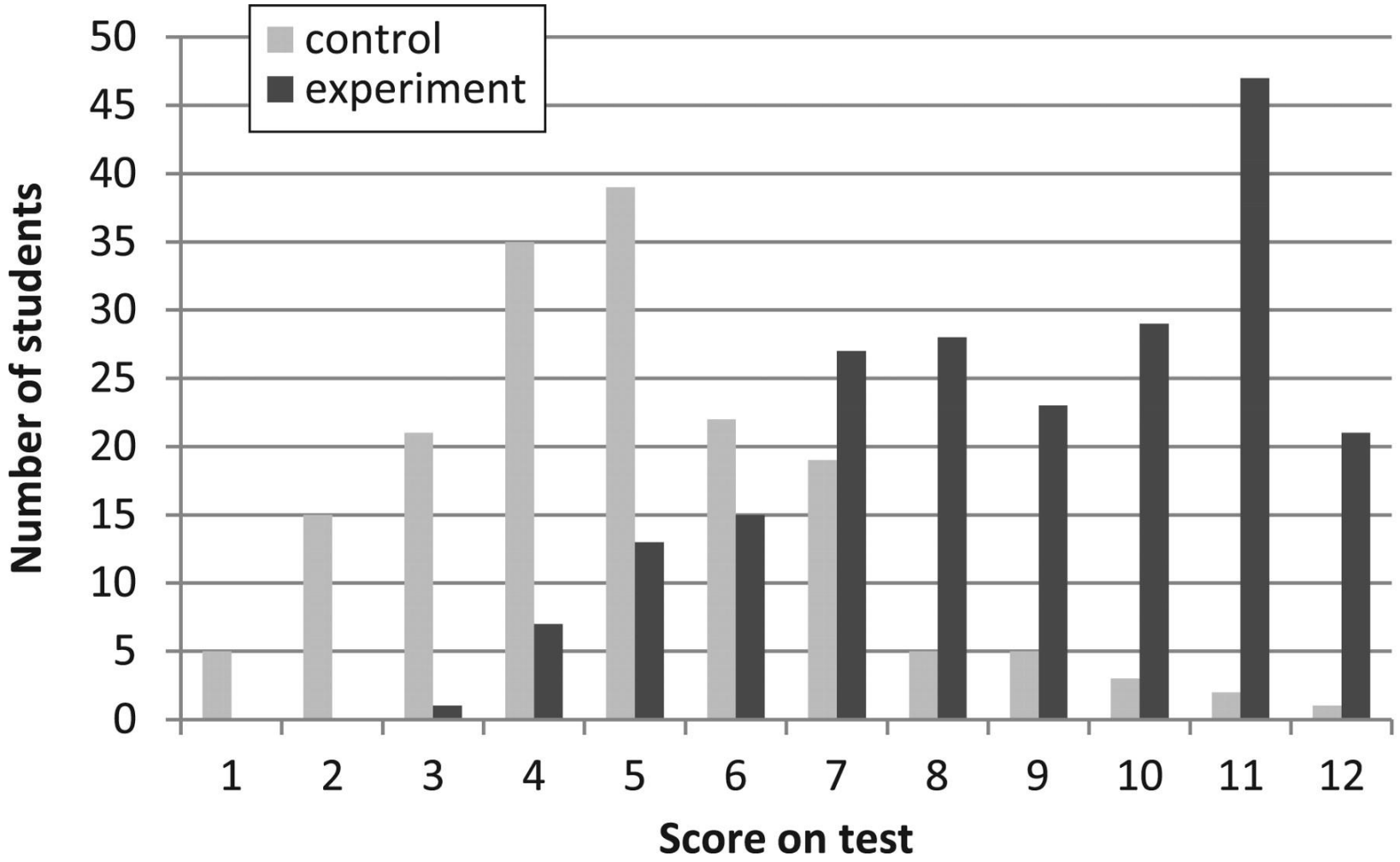
Deslauriers, Schelew, and Wieman, *Science* 332 (2011) 862

Two parallel sections of introductory physics at the University of British Columbia

Control section:
Taught by an experienced, highly rated instructor using conventional lecture

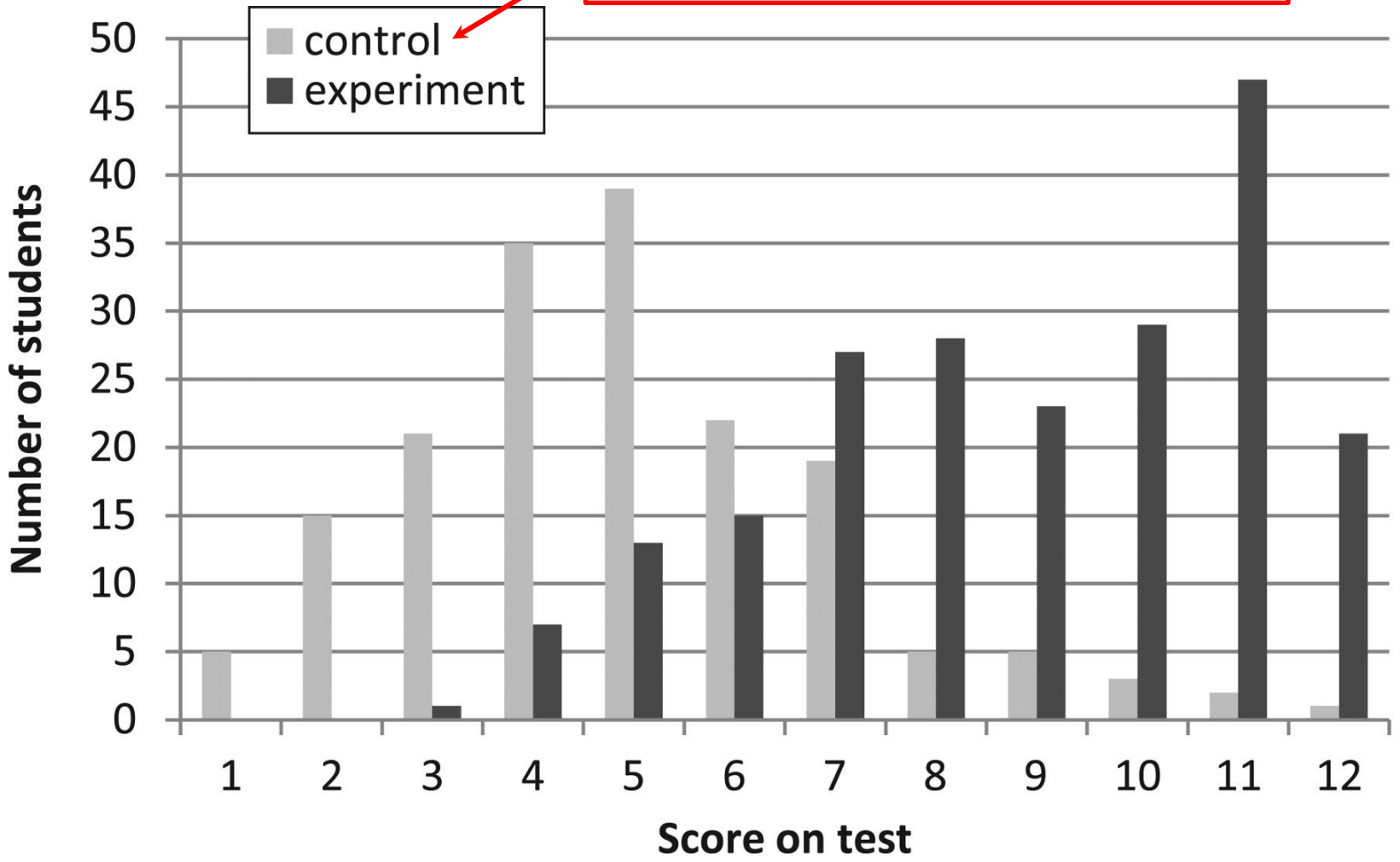
Experimental section:
Taught by an inexperienced instructor using active learning

Experimental results



Experimental results

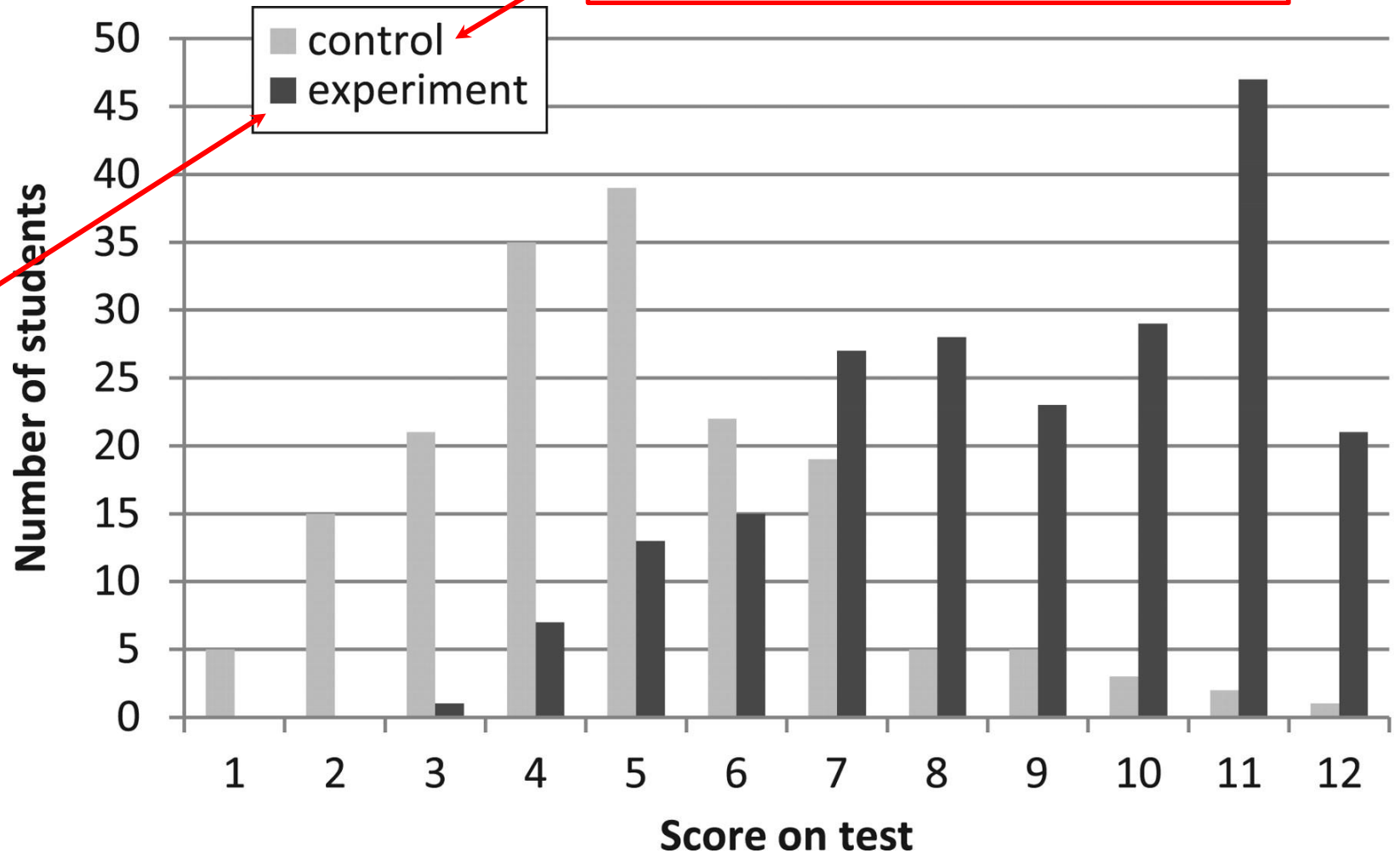
Experienced, highly rated instructor using conventional lecture
Avg. score: 41%



Experimental results

Experienced, highly rated instructor using conventional lecture Avg. score: 41%

Inexperienced instructor using active learning Avg. score: 74%



Experimental results

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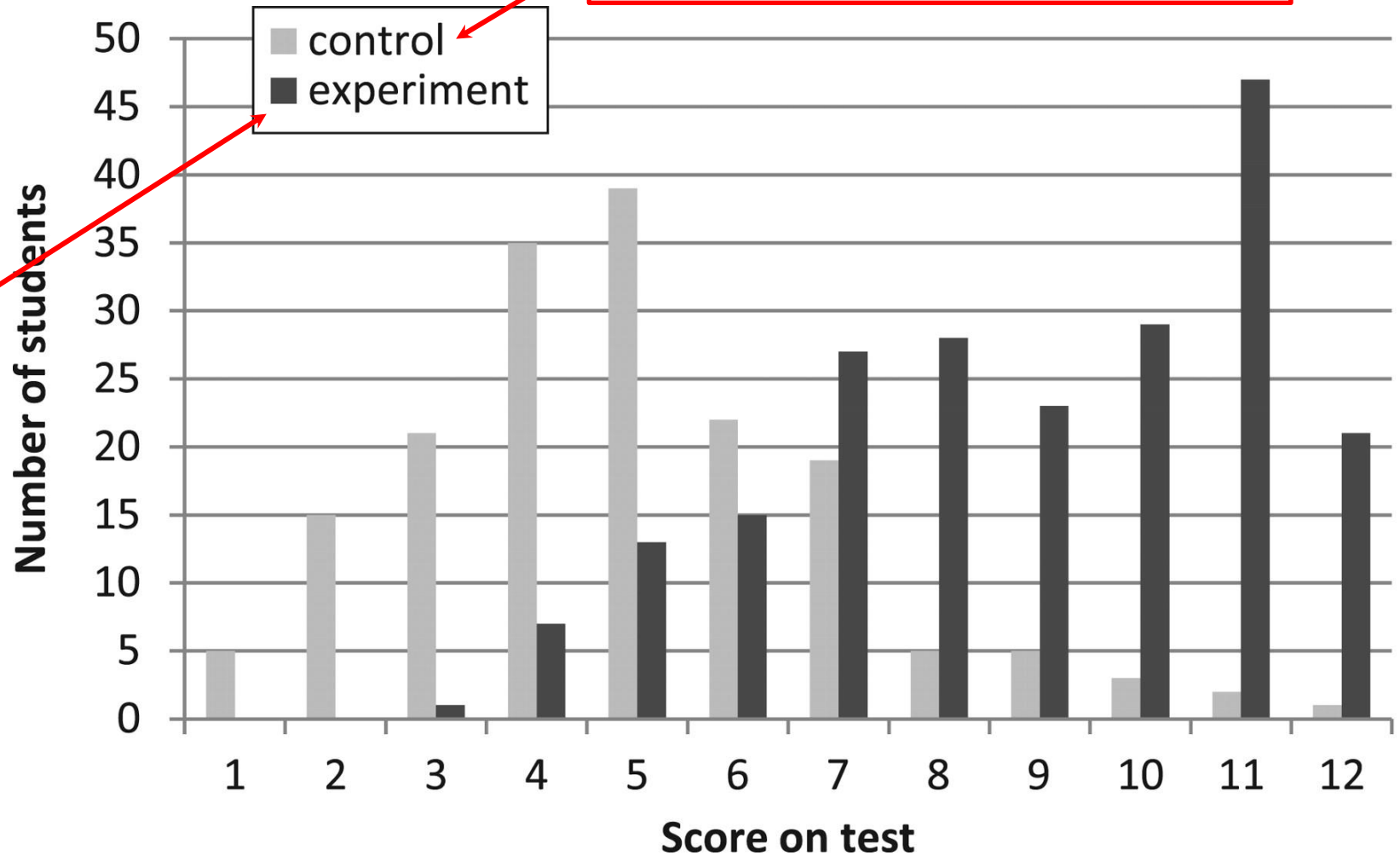
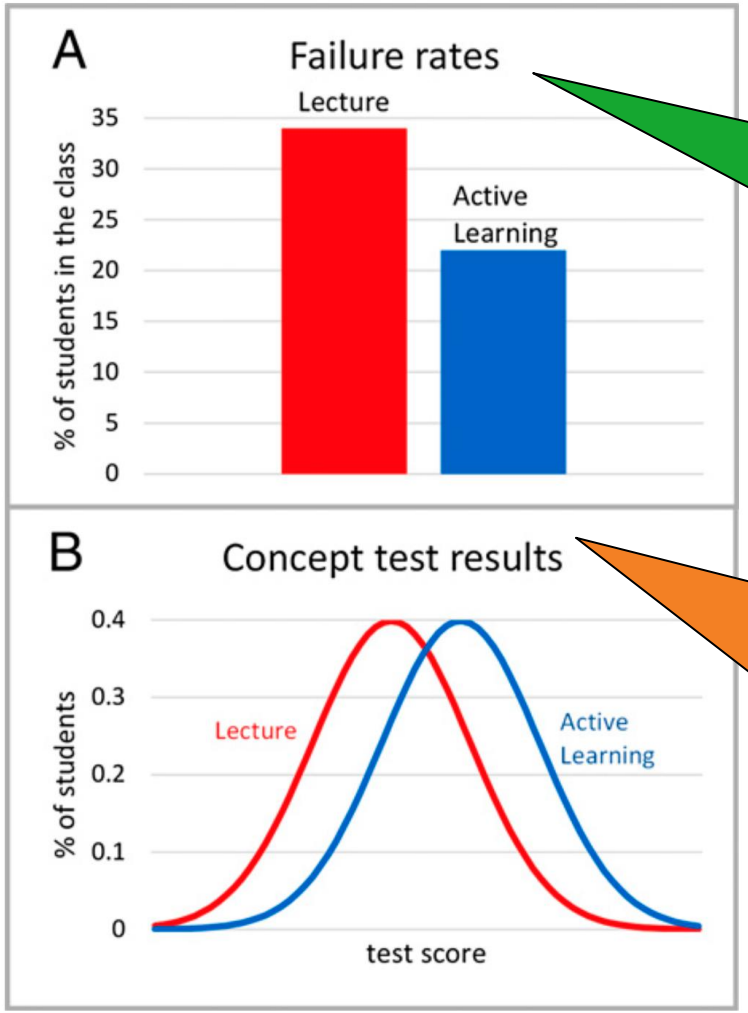


Active learning FTW!

Active learning across STEM

Metaanalysis of 225 studies

S. Freeman *et al*., *PNAS* 111 (2014) 8410



Active learning gives lower failure rates than conventional lecturing

Active learning improves scores on concept inventories compared to conventional lecturing (B– to B, B to B+…)

Q: What active learning exercises can you do in your classes at all levels?

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A: Clicker questions

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...no technology required!

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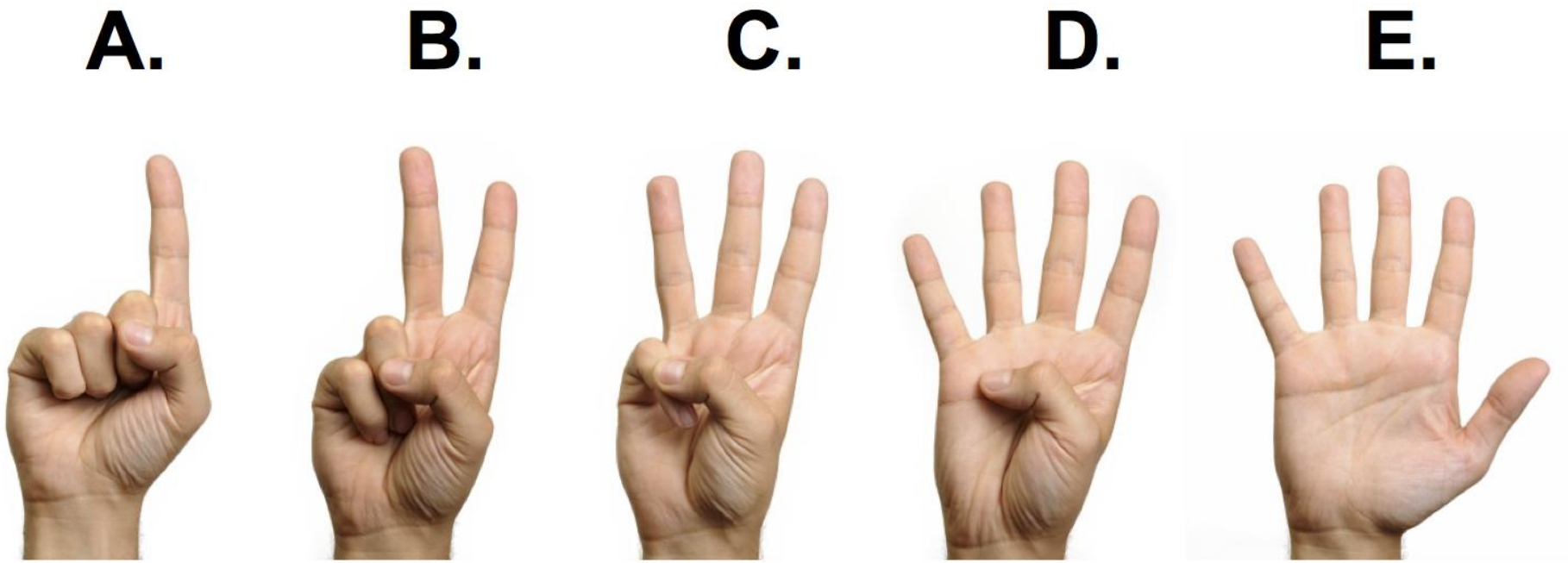
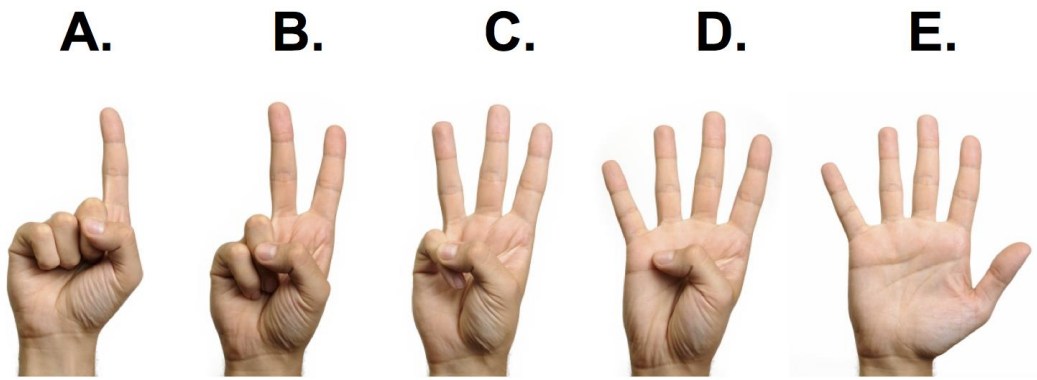


Q: What active learning exercises can you do in your classes at all levels?

A: Clicker questions

- **Good clicker questions focus on important concepts, involve challenging ideas, have multiple plausible answers, reveal student confusion, and generate spirited discussion.**



Clicker questions give insight into the initial state of your students…

$$|\Psi_{student}(t)> = exp\left(-i\hat{H}t/\hbar\right)|\Psi_{student}(0)>$$

$$\hat{H} = \hat{H}_{instructor} + \hat{H}_{TA} + \hat{H}_{other\ students} + \hat{H}_{student\ themself}$$

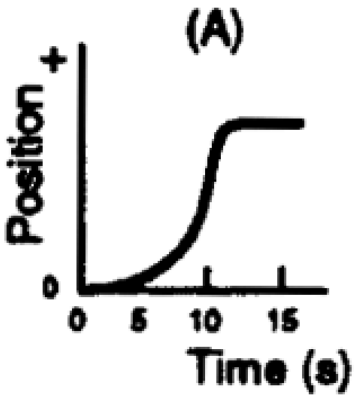
…and provide extra terms in the Hamiltonian

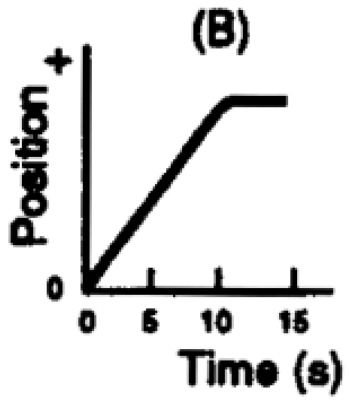
Before answering these questions, please discuss with others!

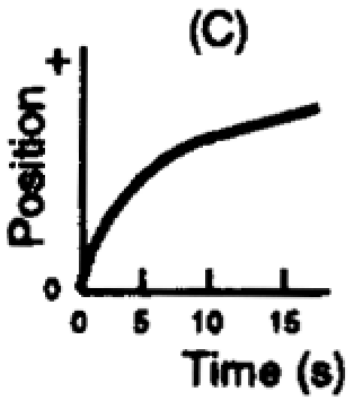
A question for you

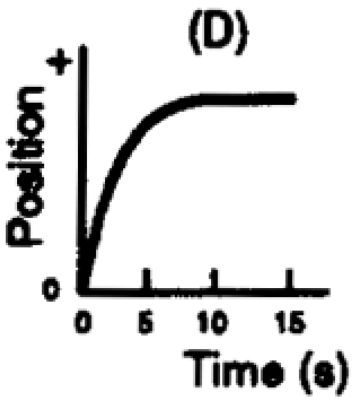
Choose the **correct answer** to this problem.

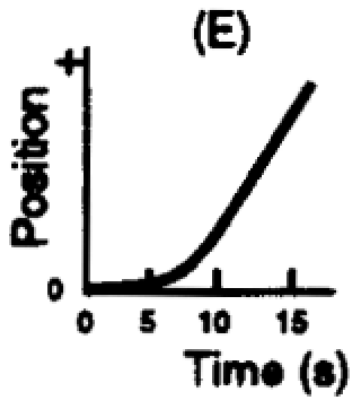
An object starts from rest and undergoes a constant, positive acceleration for ten seconds. It then continues on with constant velocity. Which of the following position-time graphs correctly describes this situation?









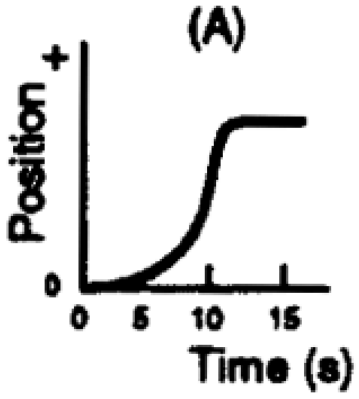


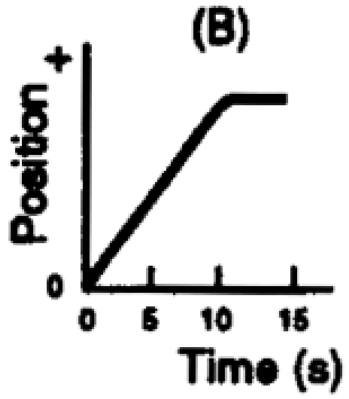
Beichner Q9

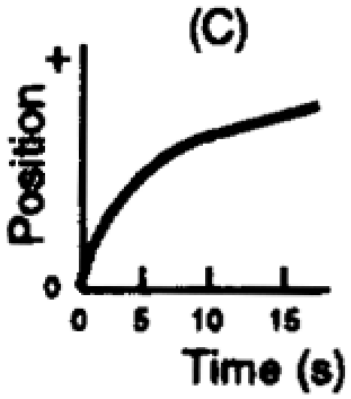
Answer

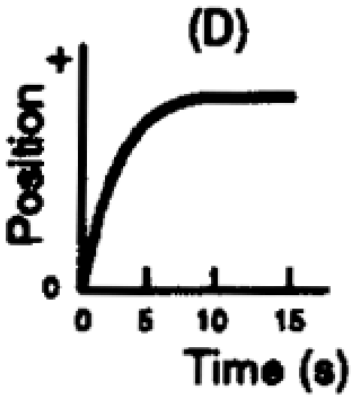
Choose the **correct answer** to this problem.

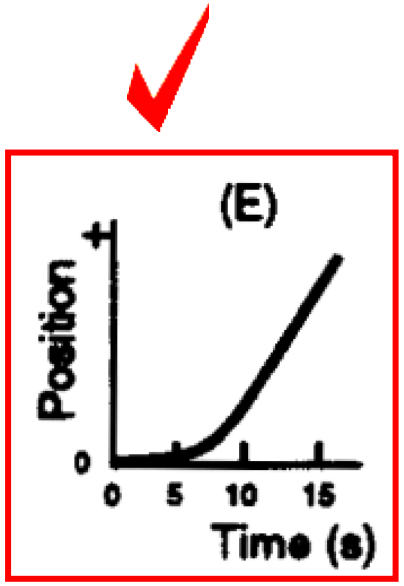
An object starts from rest and undergoes a constant, positive acceleration for ten seconds. It then continues on with constant velocity. Which of the following position-time graphs correctly describes this situation?











A question for you

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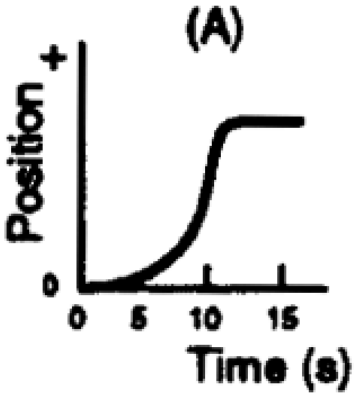

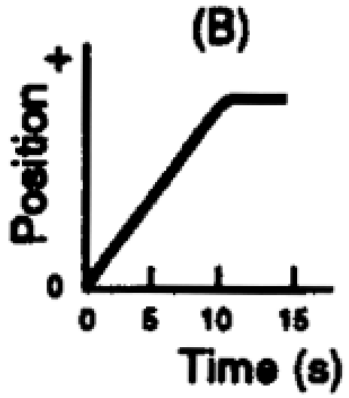

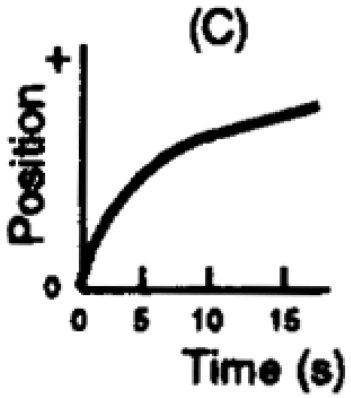

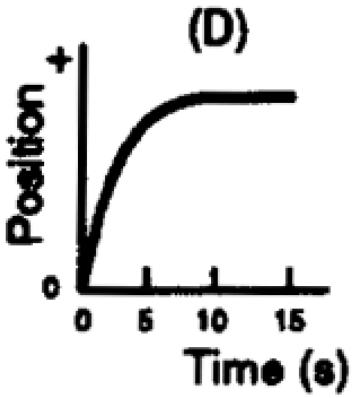

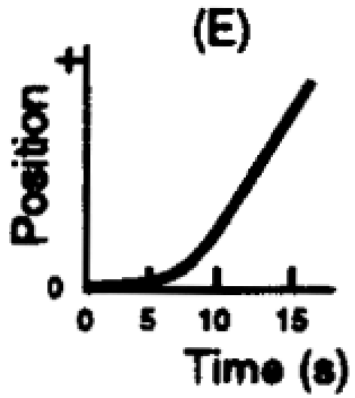

Beichner Q9

Answer

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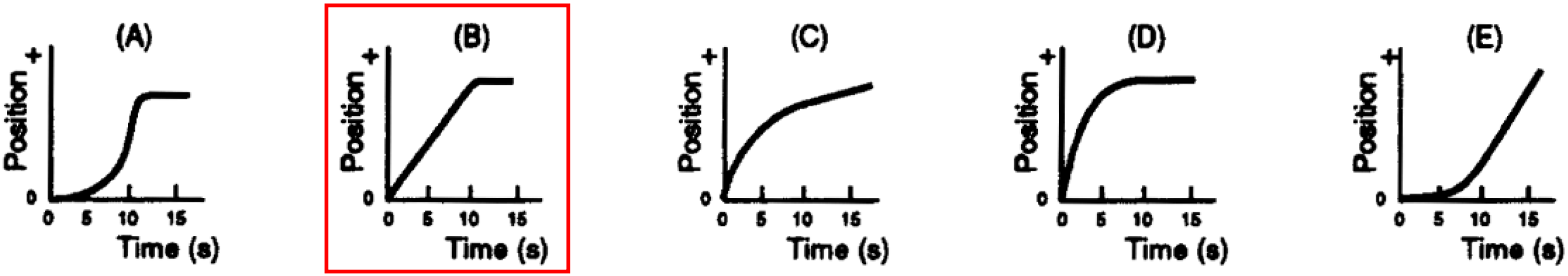
✓ **57% of students gave this answer**



What were they thinking?

Beichner Q9

A question for you

Choose the **correct answer** to this problem.

Which of the following statements are *true*?

(1) The stationary states refer to the eigenstates of any operator corresponding to a physical observable.

(2) If at time $t = 0$ a system is in an eigenstate of any operator that corresponds to a physical observable, it stays in that state unless an external perturbation is applied.

(3) If at time $t = 0$ a system is in an energy eigenstate, it stays in the energy eigenstate unless an external perturbation is applied.

A. 1 only B. 3 only C. 1 and 3 only D. 2 and 3 only E. all of 1., 2., and 3.

Answer

Choose the **correct answer** to this problem.

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50% of students gave this answer

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Zhu and Singh Q1

Answer

Choose the **most common incorrect answer given by students.**

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50% of students gave this answer

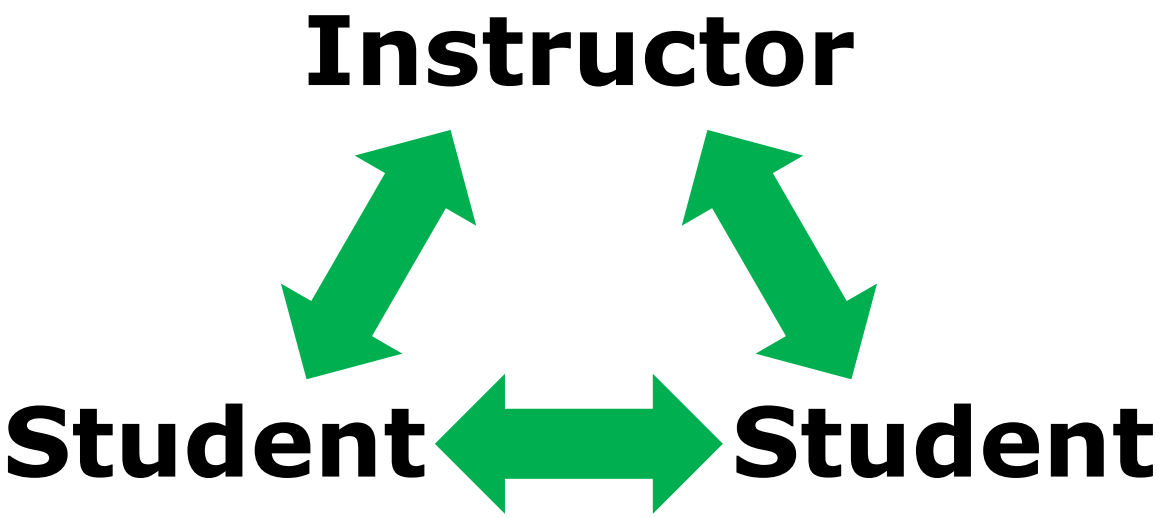
A. 1 only B. 3 only C. 1 and 3 only D. 2 and 3 only E. all of 1., 2., and 3.

0% gave the correct answer

What were they thinking?

Zhu and Singh Q1

Clicker questions and other active learning techniques provide feedback…



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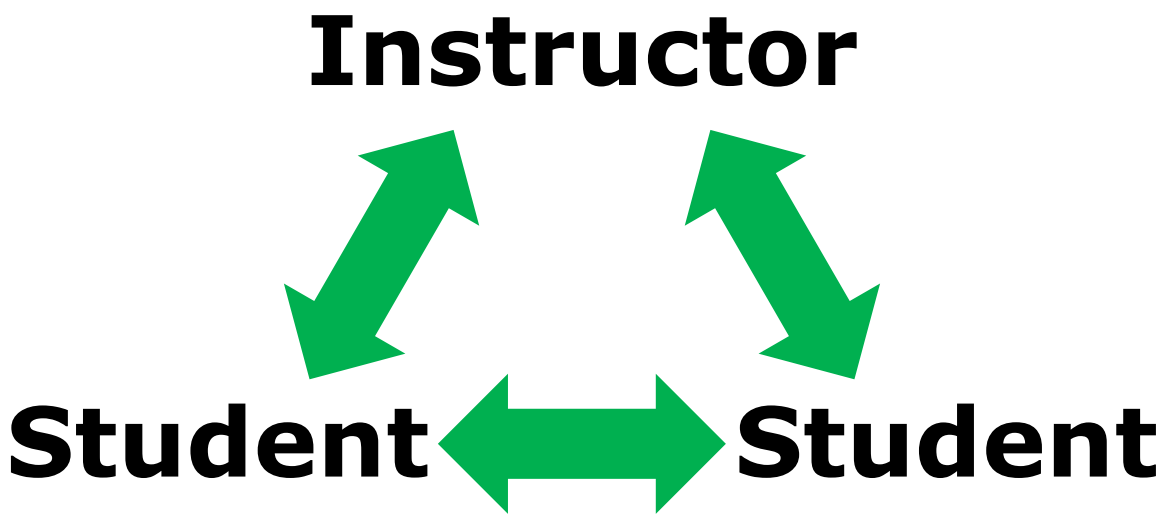
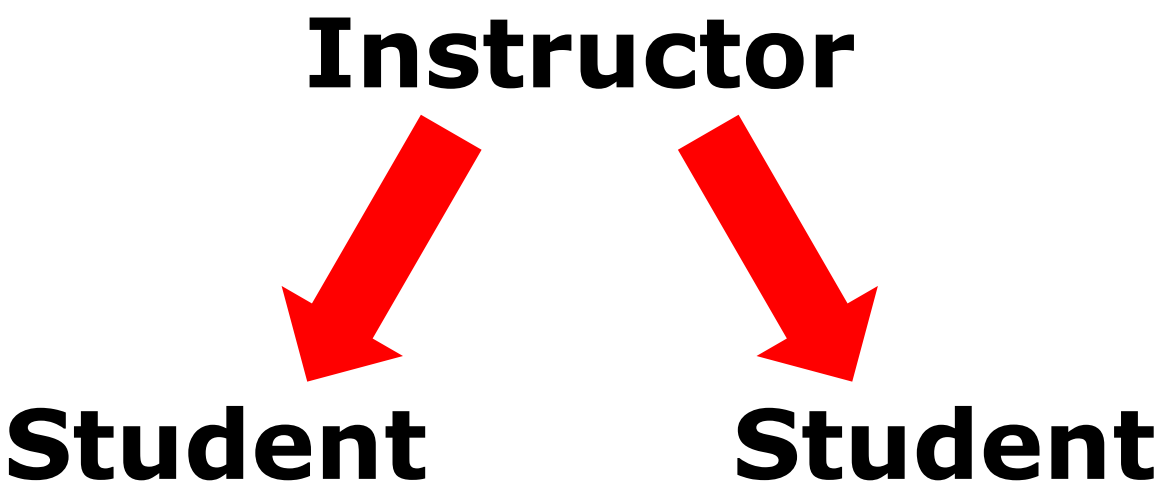


…lecturing does not!



Physics Beyond the Standard Model

Education

Please try active learning in your courses at any level!

Consult your campus center for teaching and learning for best practices.

Physics Beyond the Standard Model

Education

Thank you!

Roger Freedman
airboy@ucsb.edu
IG: @airboy1952
Bluesky: @rogerfreedman.bsky.social