IMPROVING EDUCATION THROUGH RESEARCH

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Paul Callan
Emily Fair Oster
Eric Mazur
Harvard University

Hong Kong University
21 October 1999

Peer Instruction

- **Move first exposure to the material out of the classroom…**

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- **Use class to deepen and broaden understanding**

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- **by identifying key ideas**

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- Move first exposure to the material out of the classroom: assign reading!
- Use class to deepen and broaden understanding
- by identifying key ideas
- and giving students opportunities to think

Reading

- **Web-based assignment due before class**

Reading

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- **Three questions (content and feedback)**

Reading

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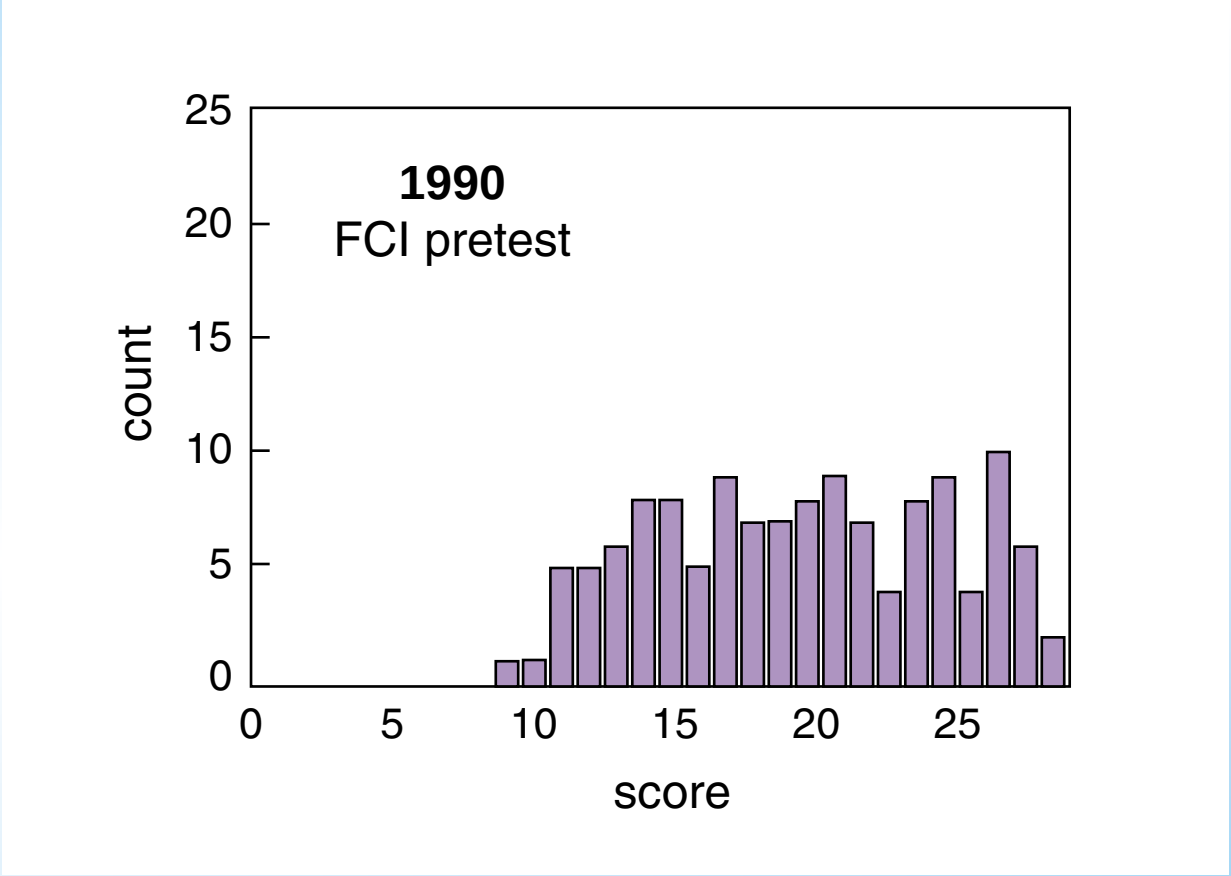
- **Graded on effort**

Reading

- **Web-based assignment due before class**
- **Three questions (content and feedback)**
- **Graded on effort**
- **5% of final grade**

Why use Peer Instruction?

Force Concept Inventory data



Hestenes, *et al.*, *TPT* 30, 141 (1992)

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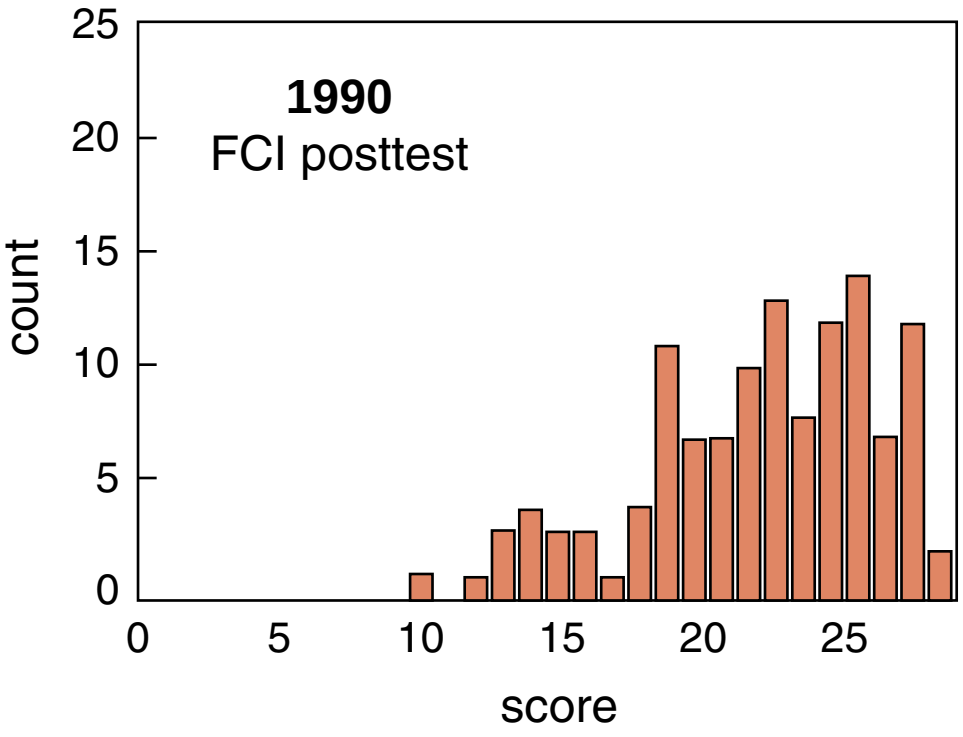

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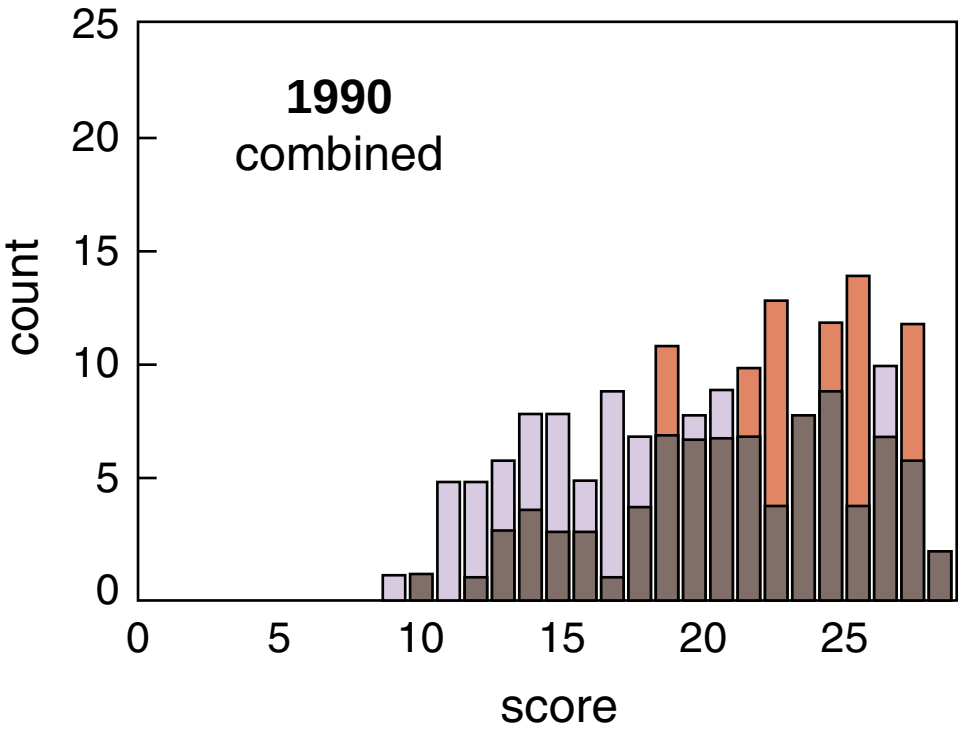

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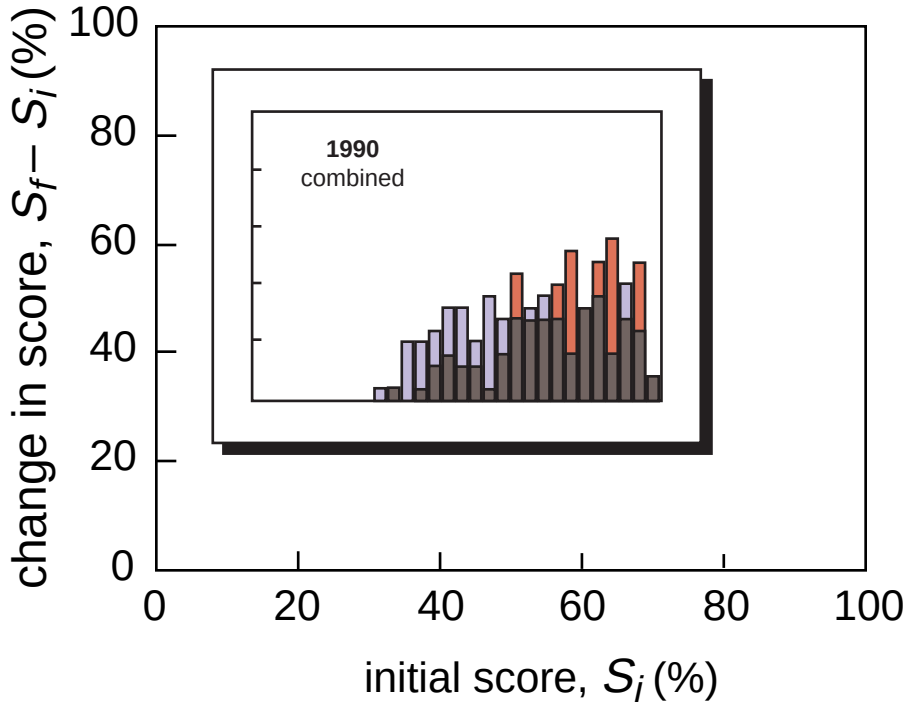

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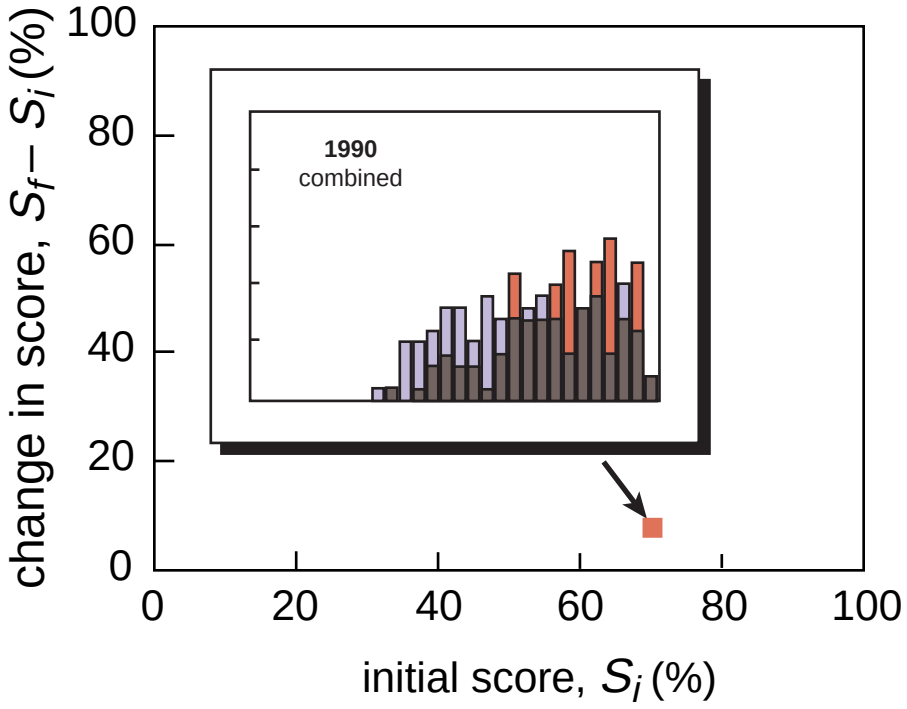

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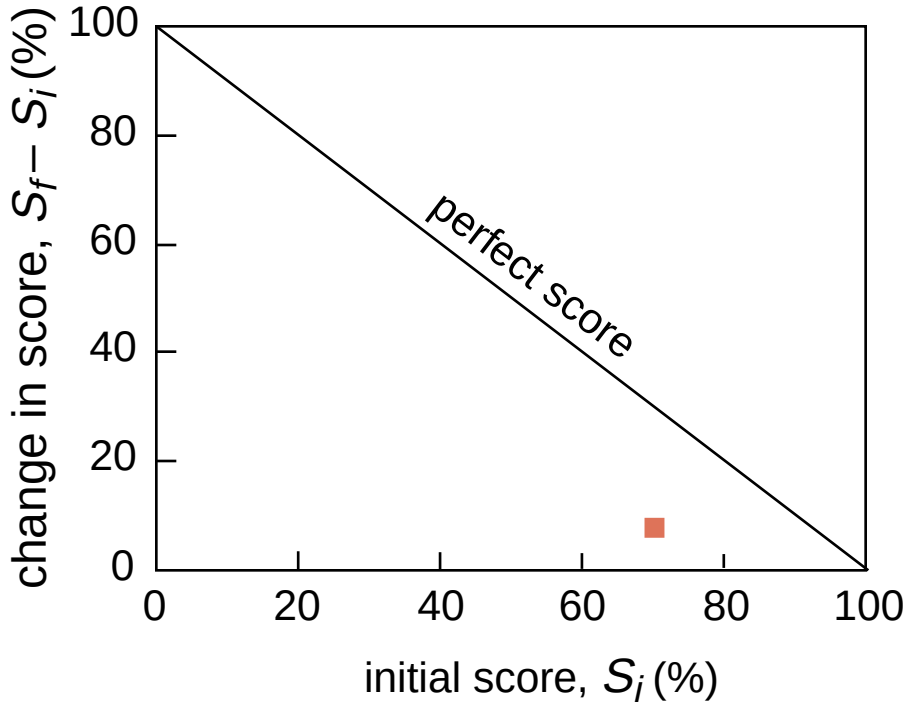

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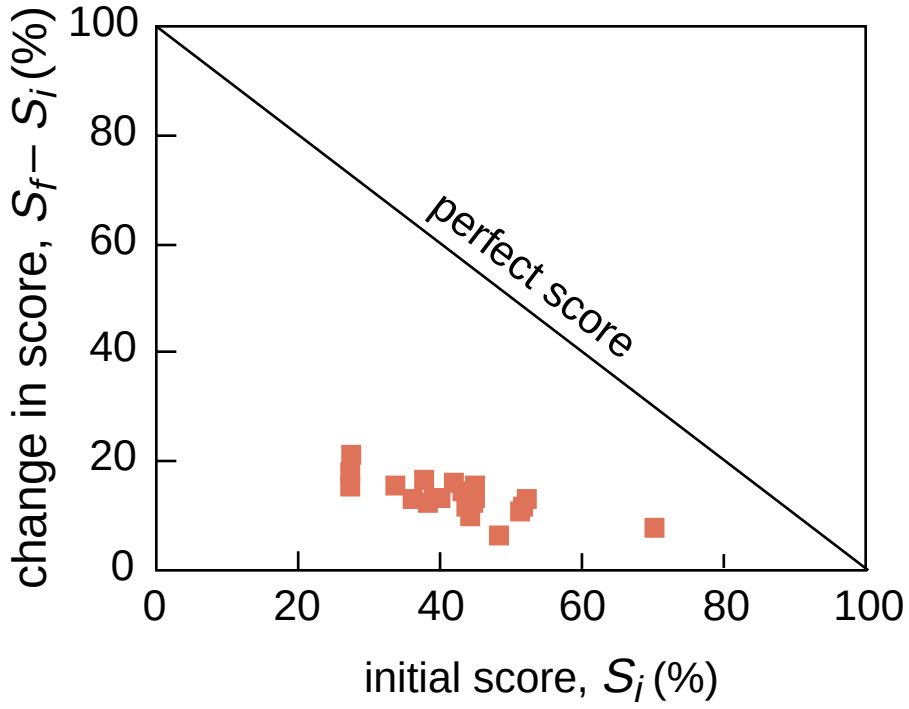

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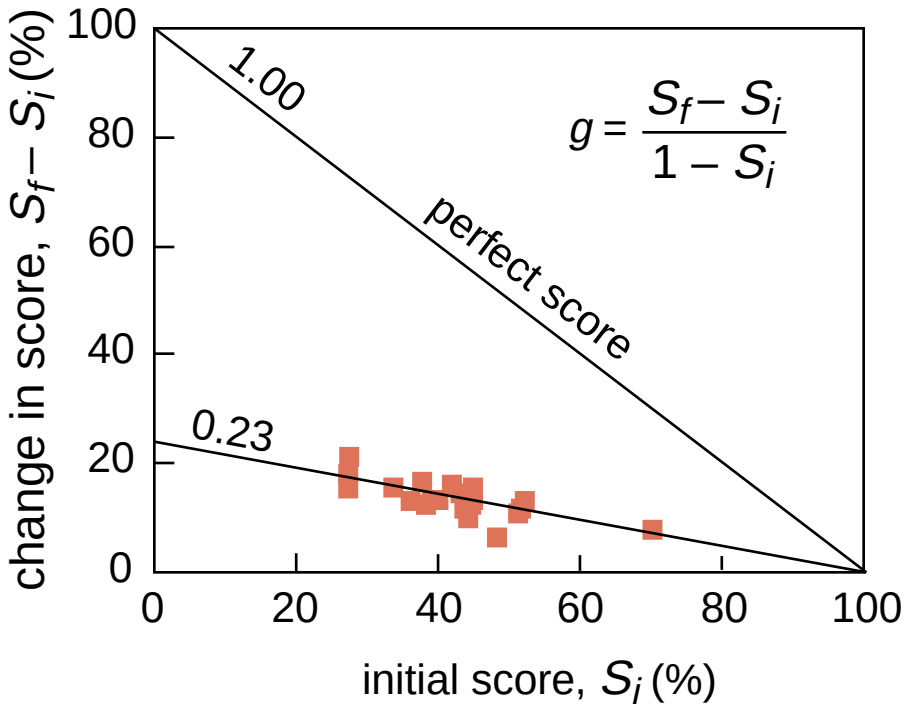
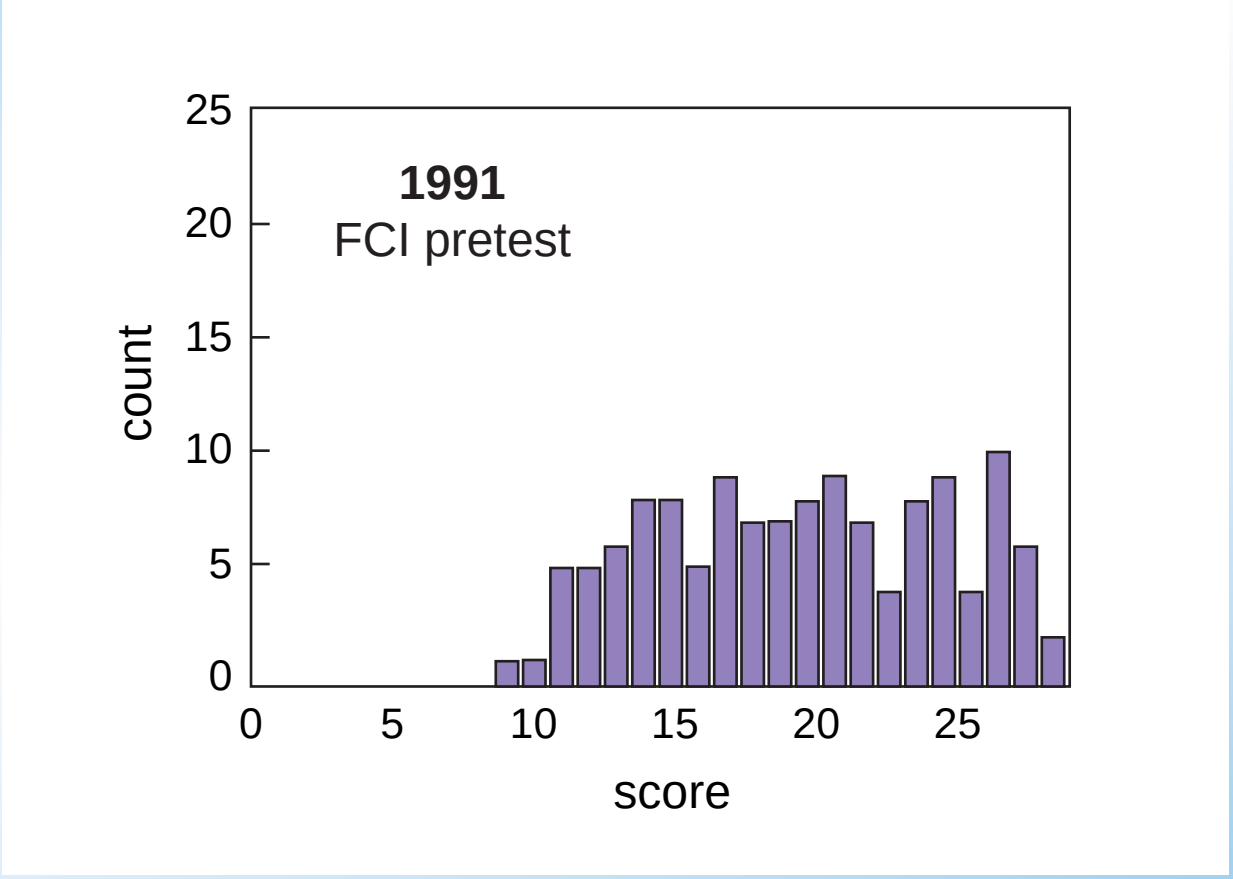


Results



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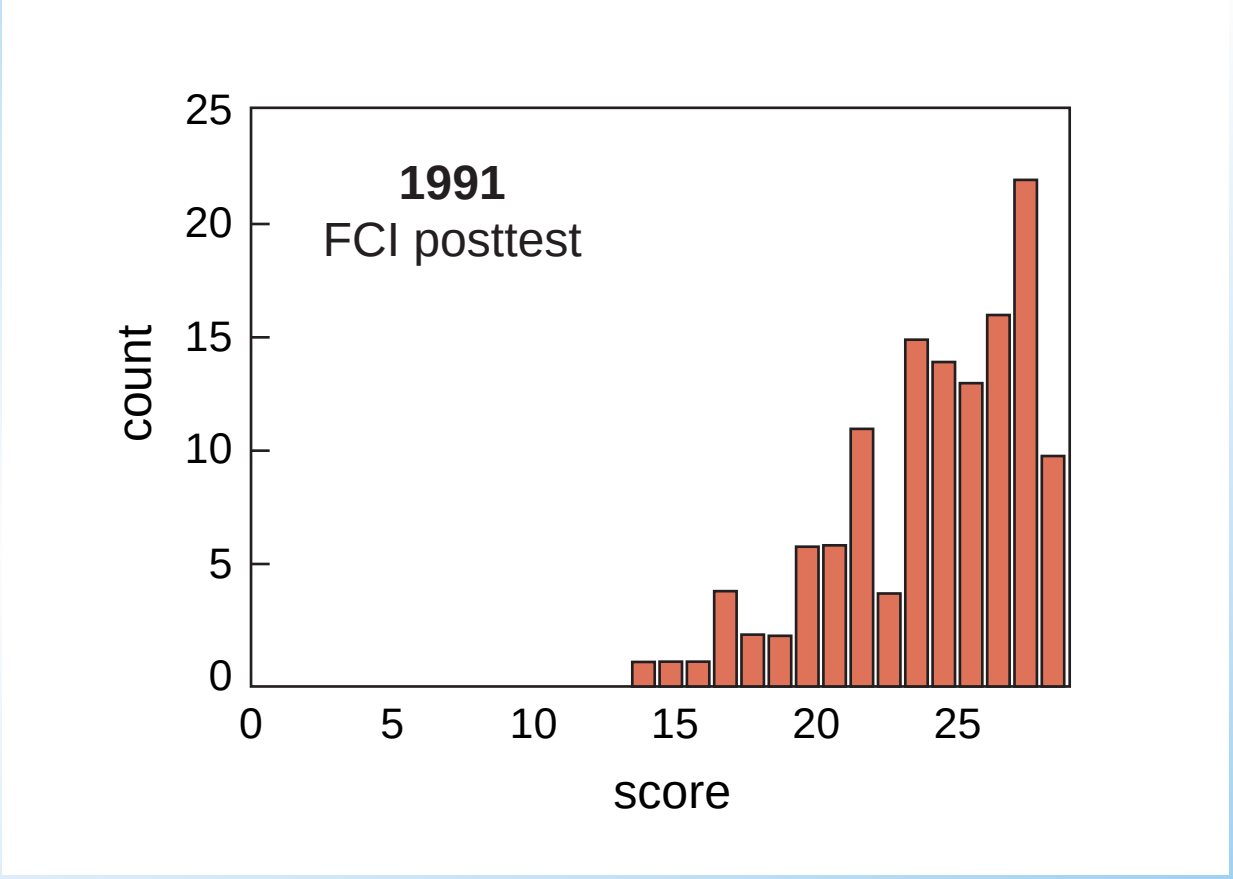

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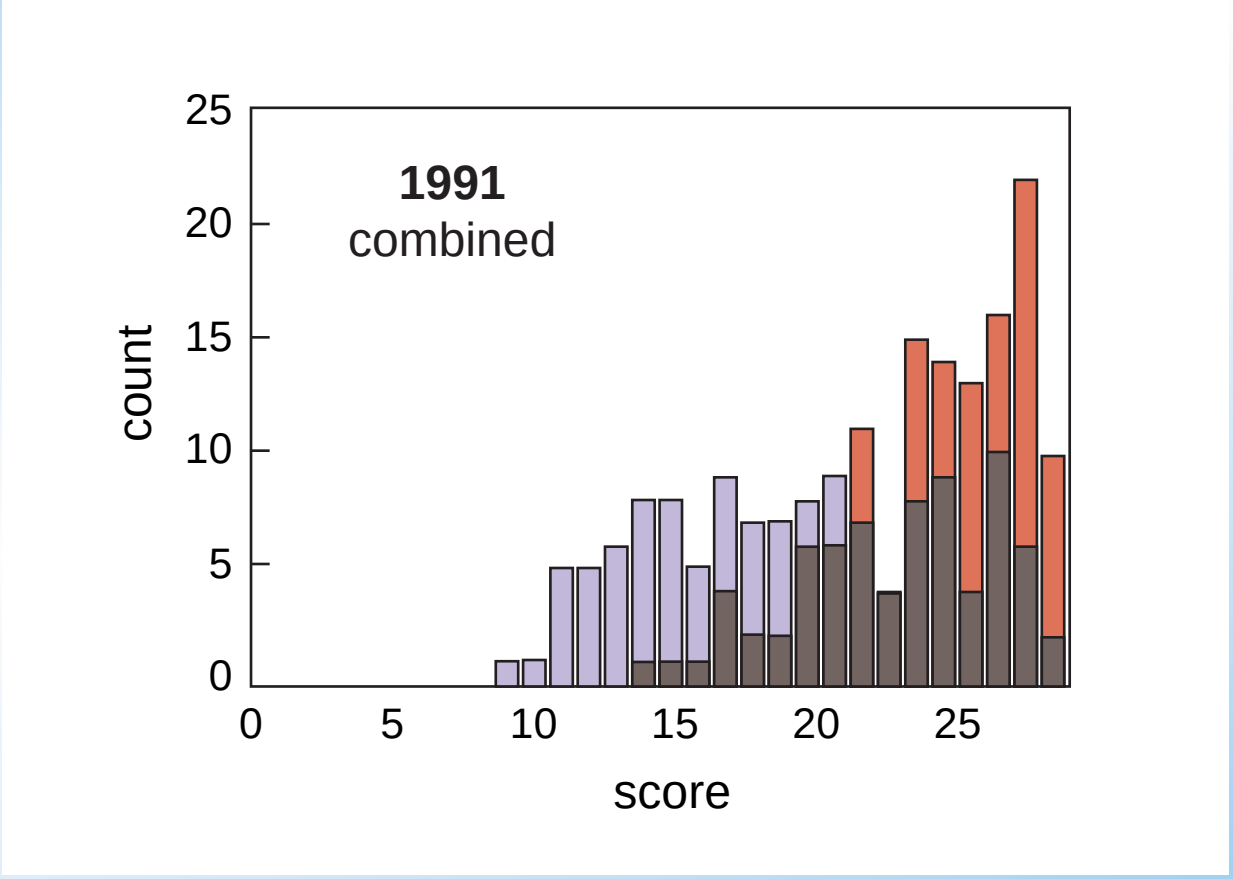

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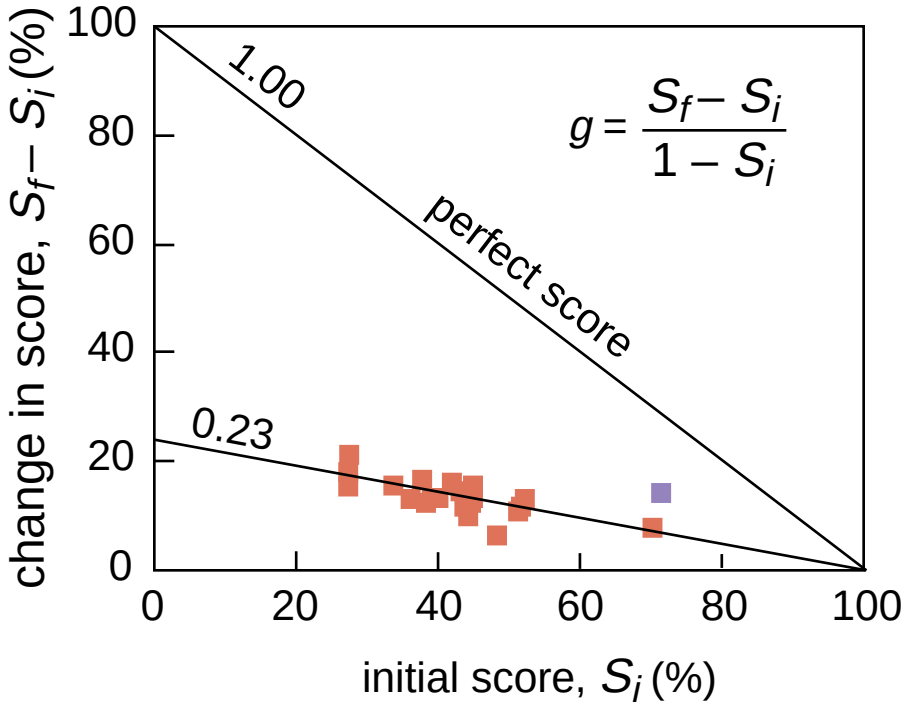
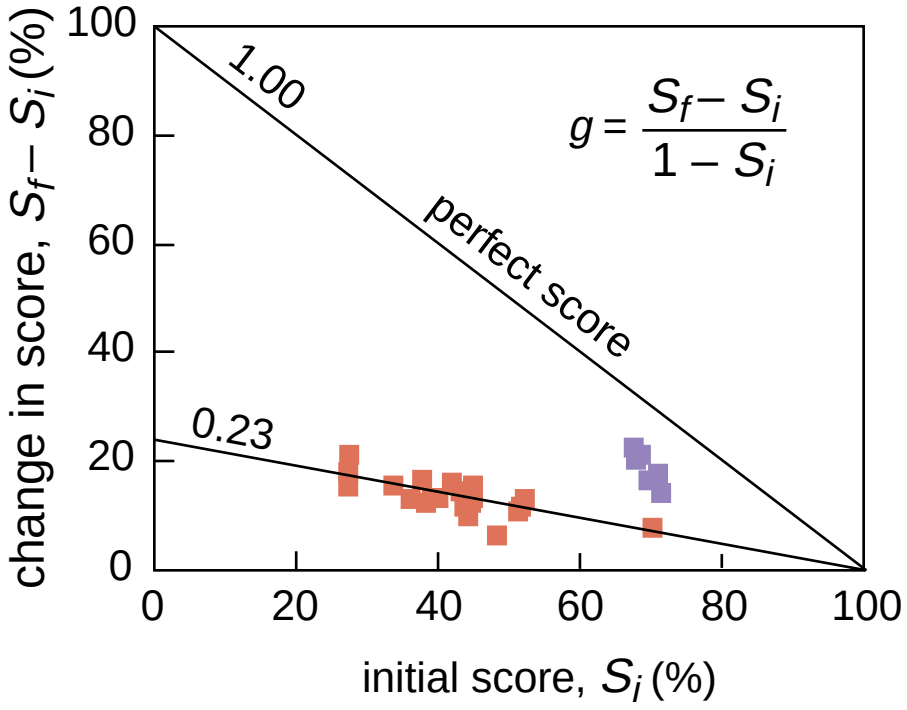

change in score, $S_f - S_i$ (%)
initial score, S_i (%)
0
20
40
60
80
100
1.00
perfect score
0.23
$g = \frac{S_f - S_i}{1 - S_i}$

Results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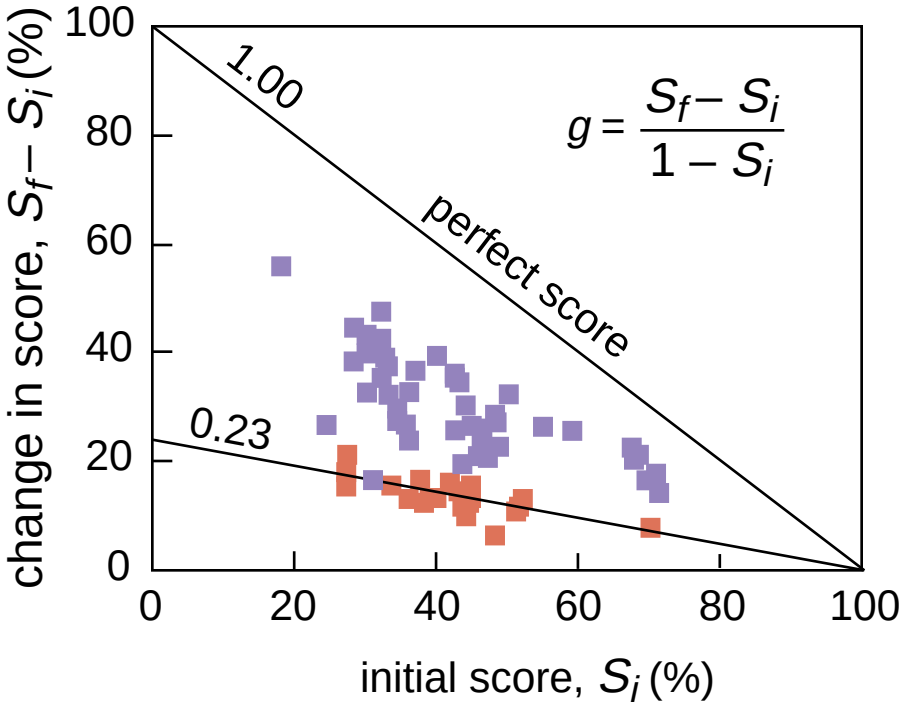
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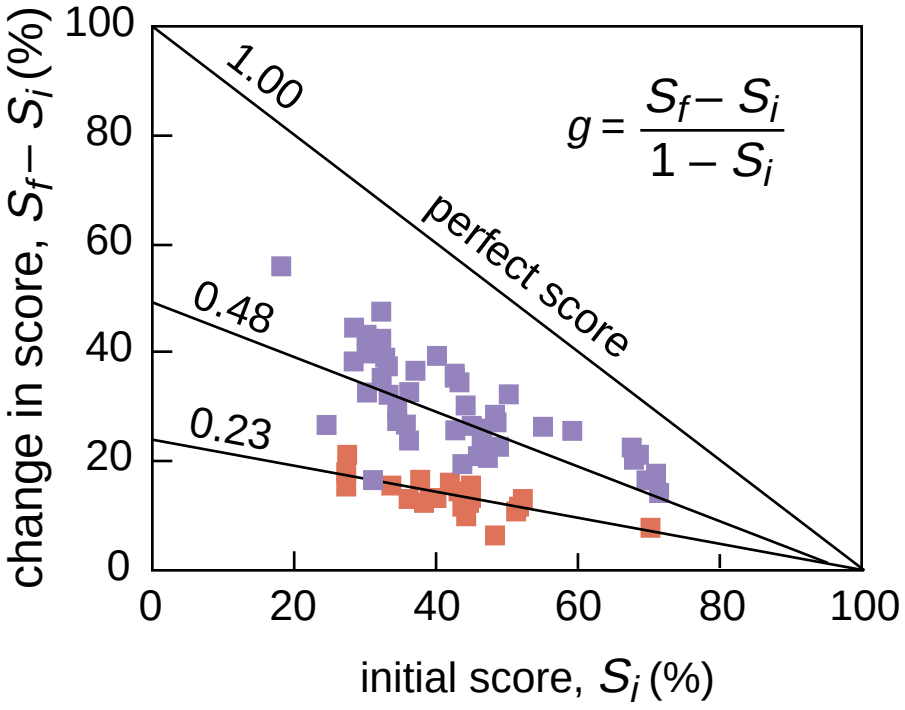
change in score, $S_f - S_i$ (%)
initial score, S_i (%)
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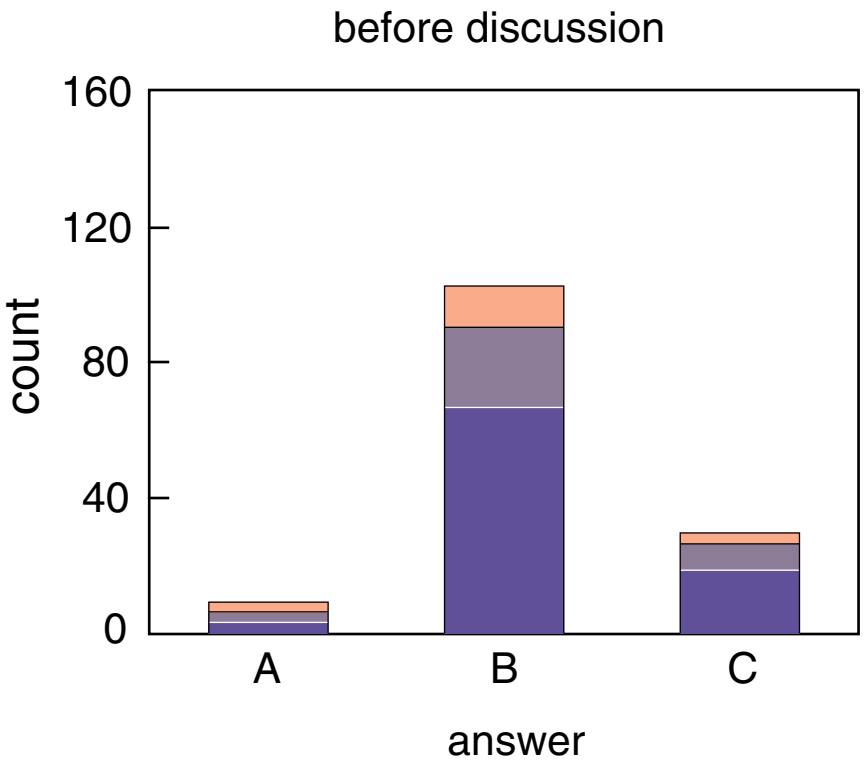
ConcepTest data



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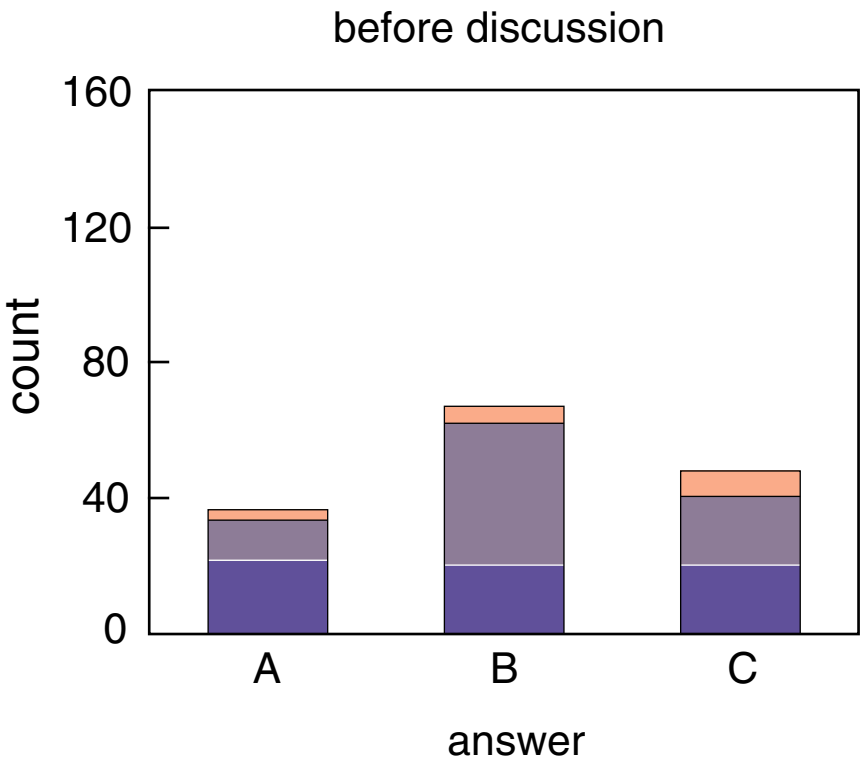

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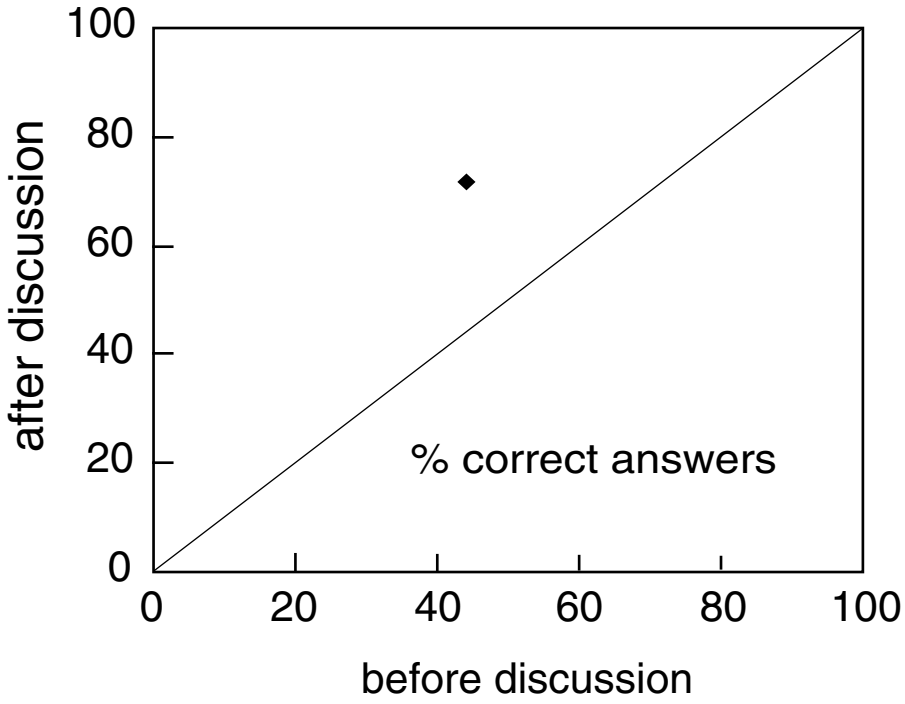

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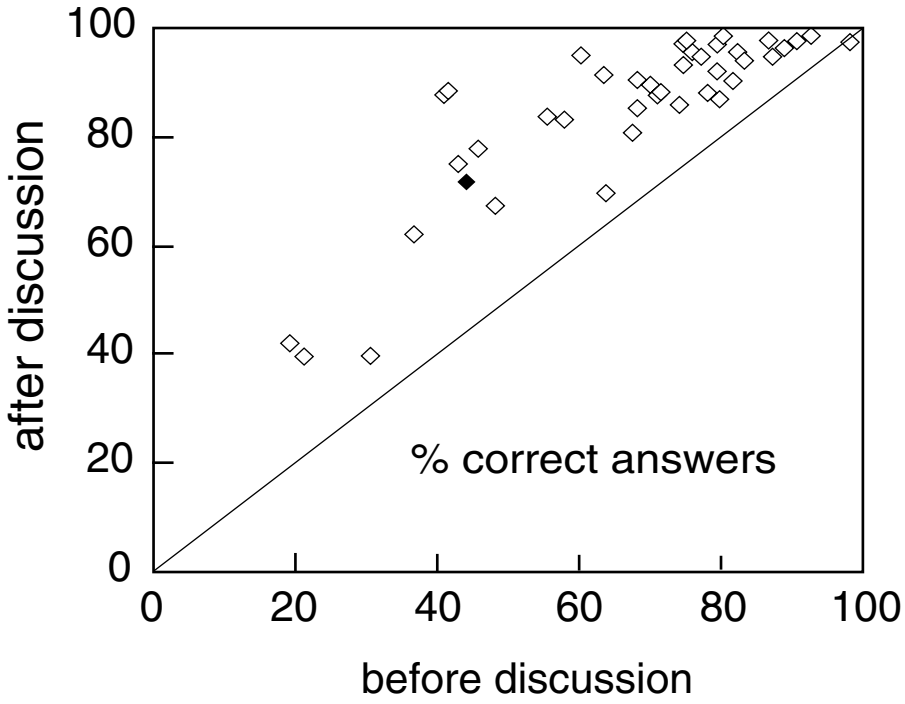

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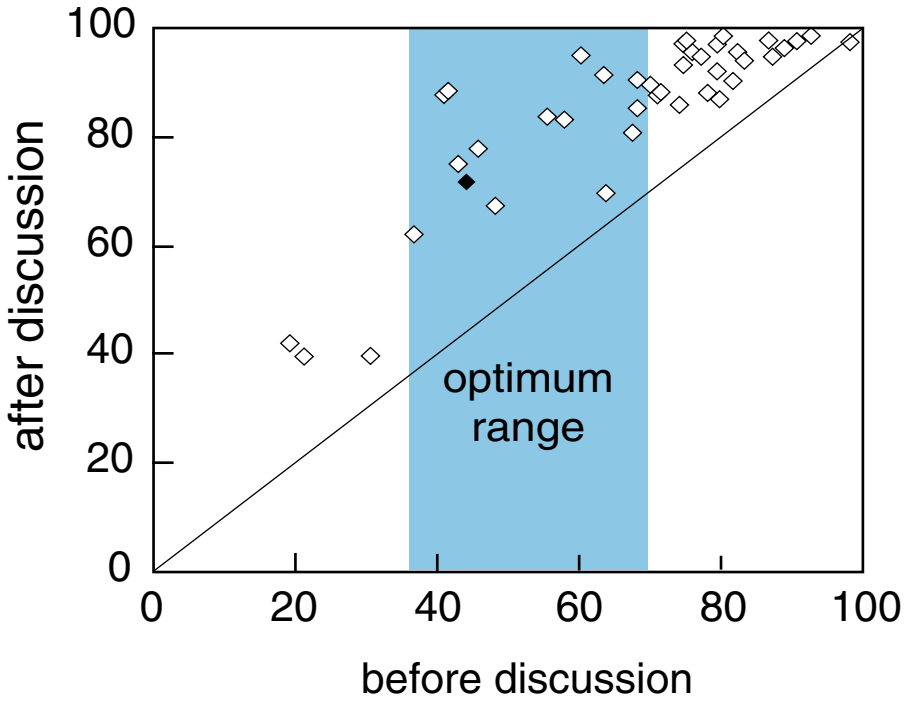

Research Sampler

- **Gender and physics**

Research Sampler

- **Gender and physics**
- **Demonstrations: entertainment or education?**

Research Sampler

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- **Confusion: how real is it?**

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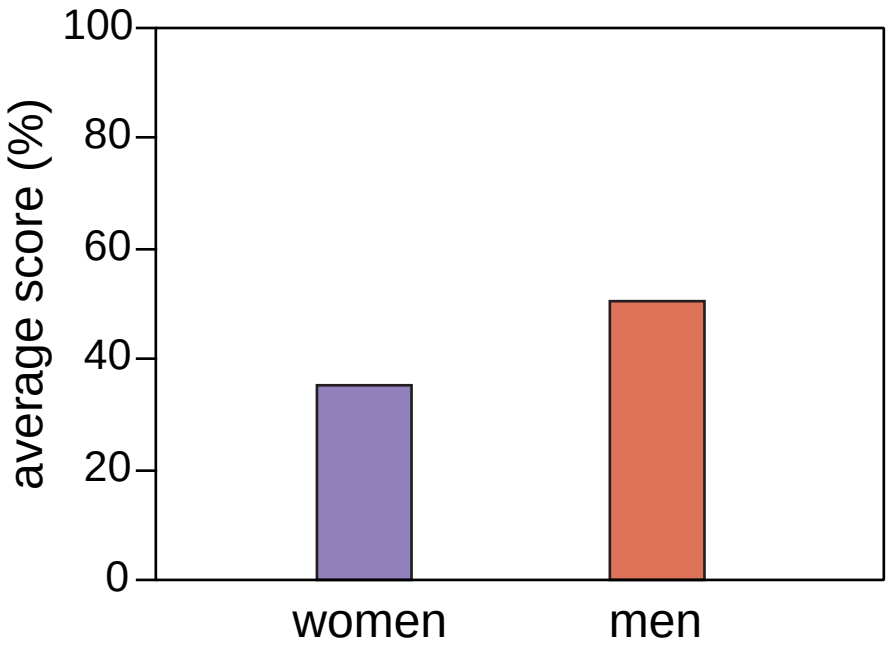
What is the gender gap?

Force Concept Inventory posttest scores



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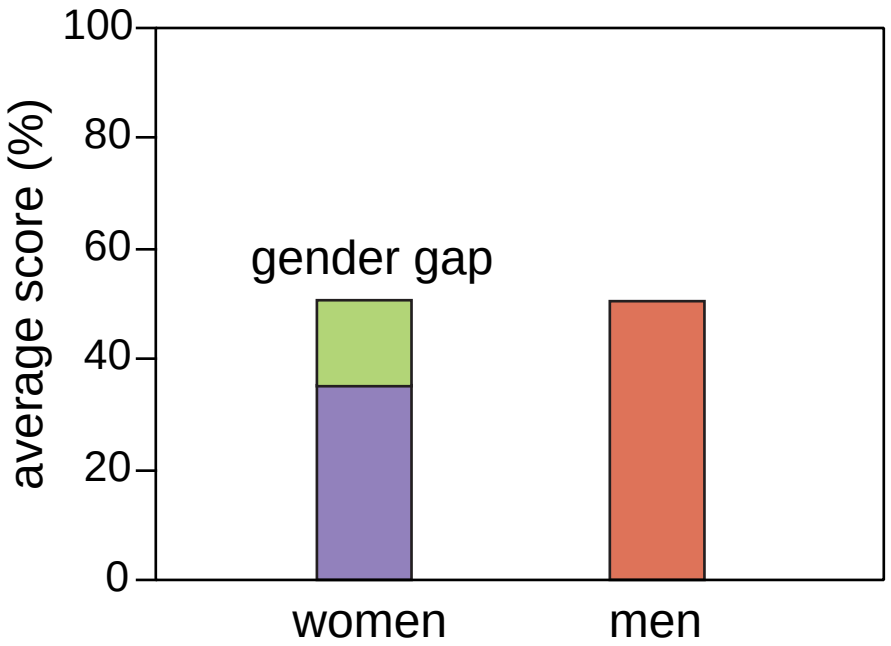

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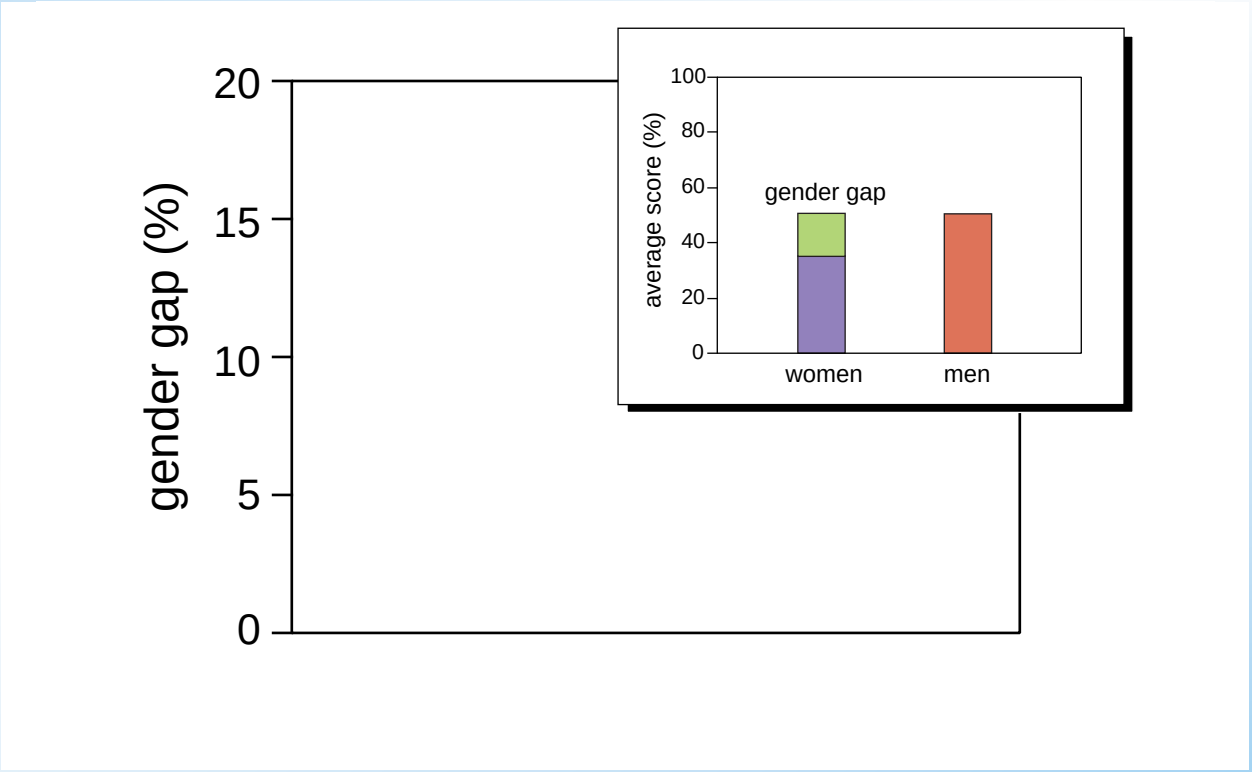

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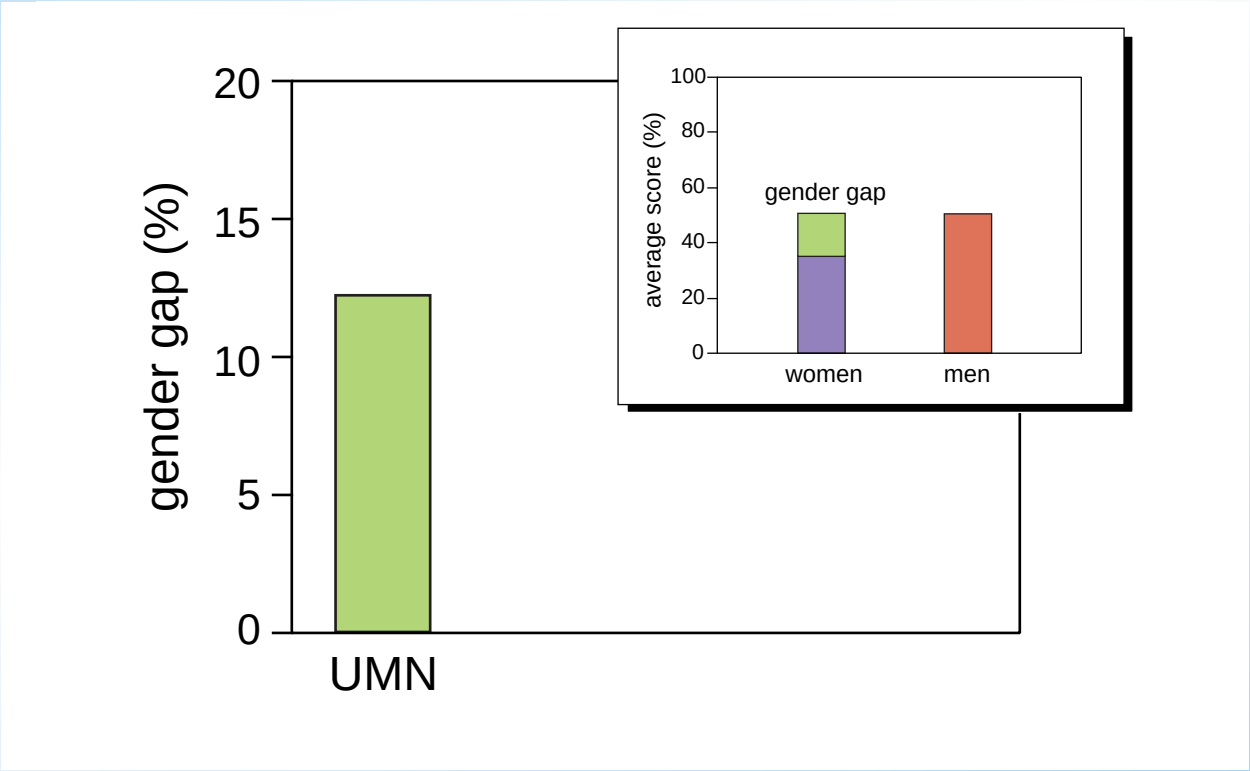
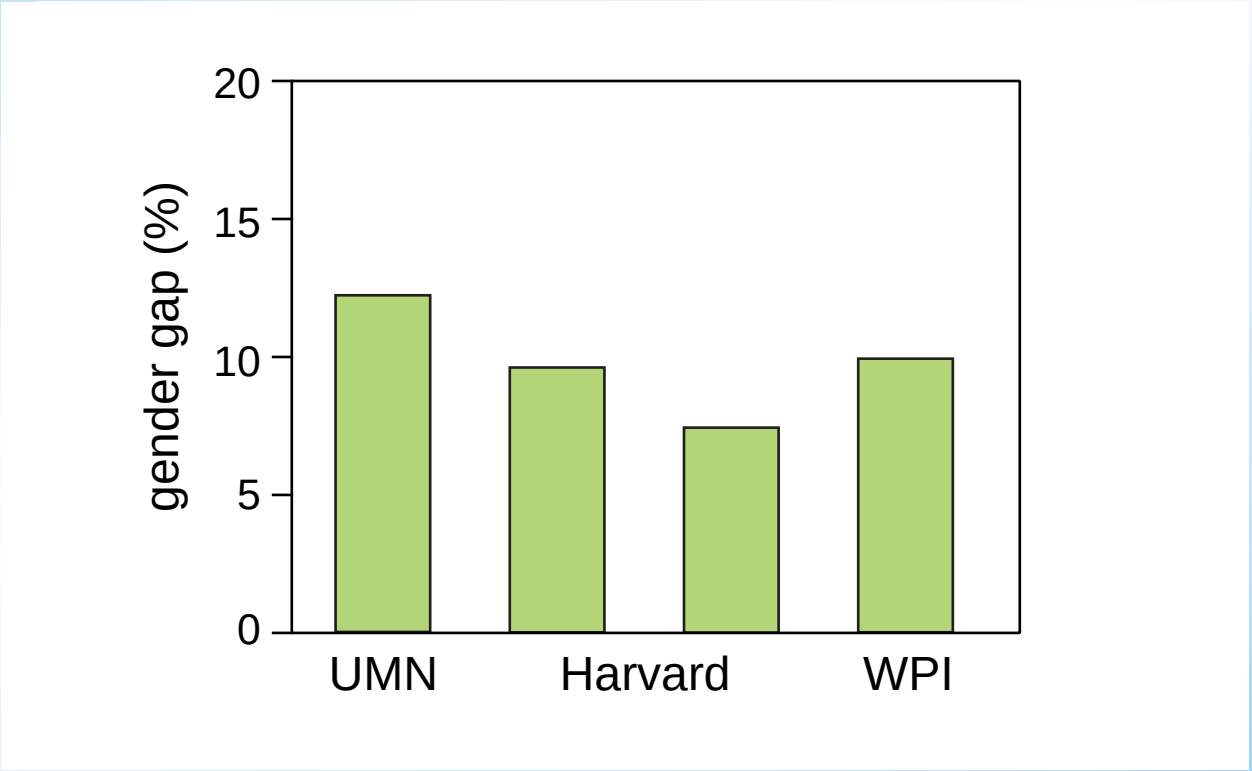
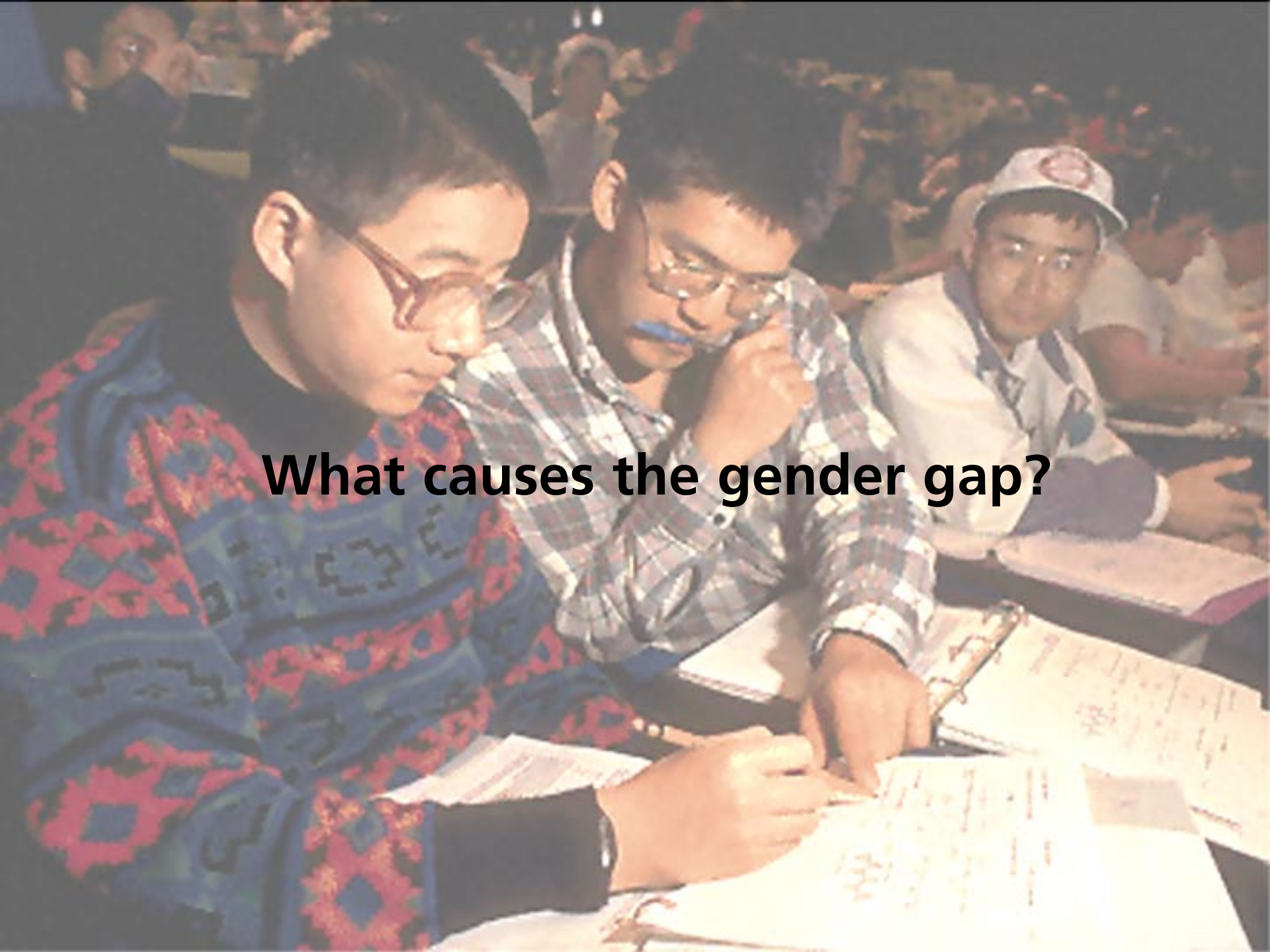


What is the gender gap?

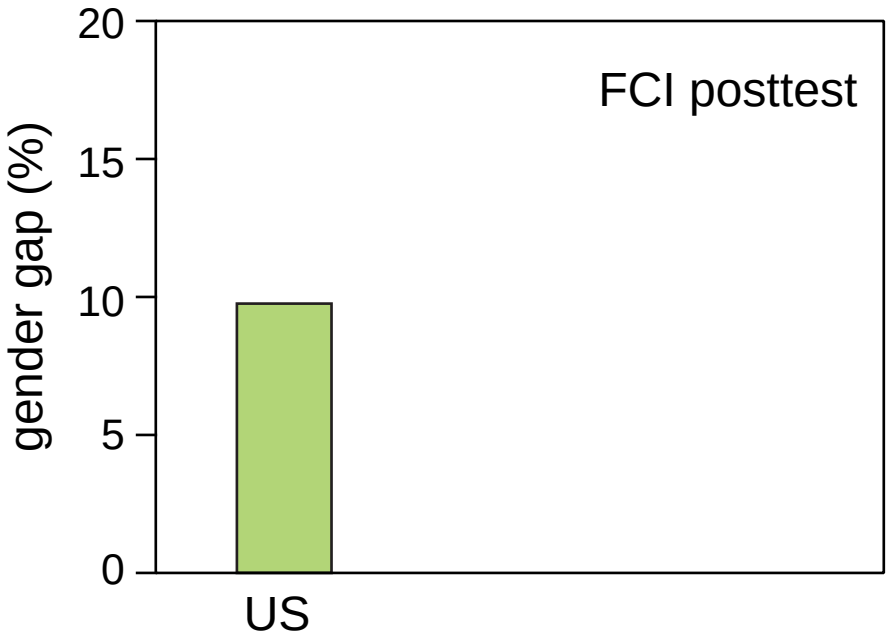
Gap is widespread




What causes the gender gap?

What causes the gender gap?

Is it cultural?



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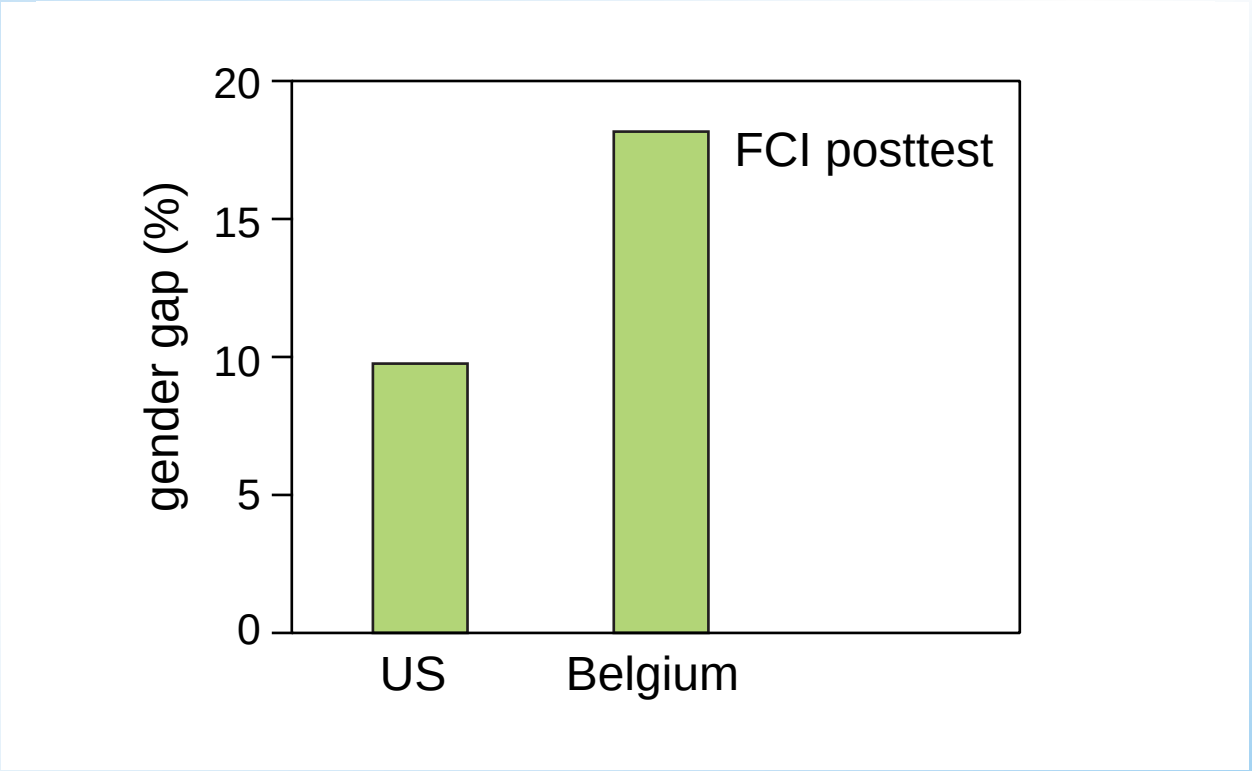
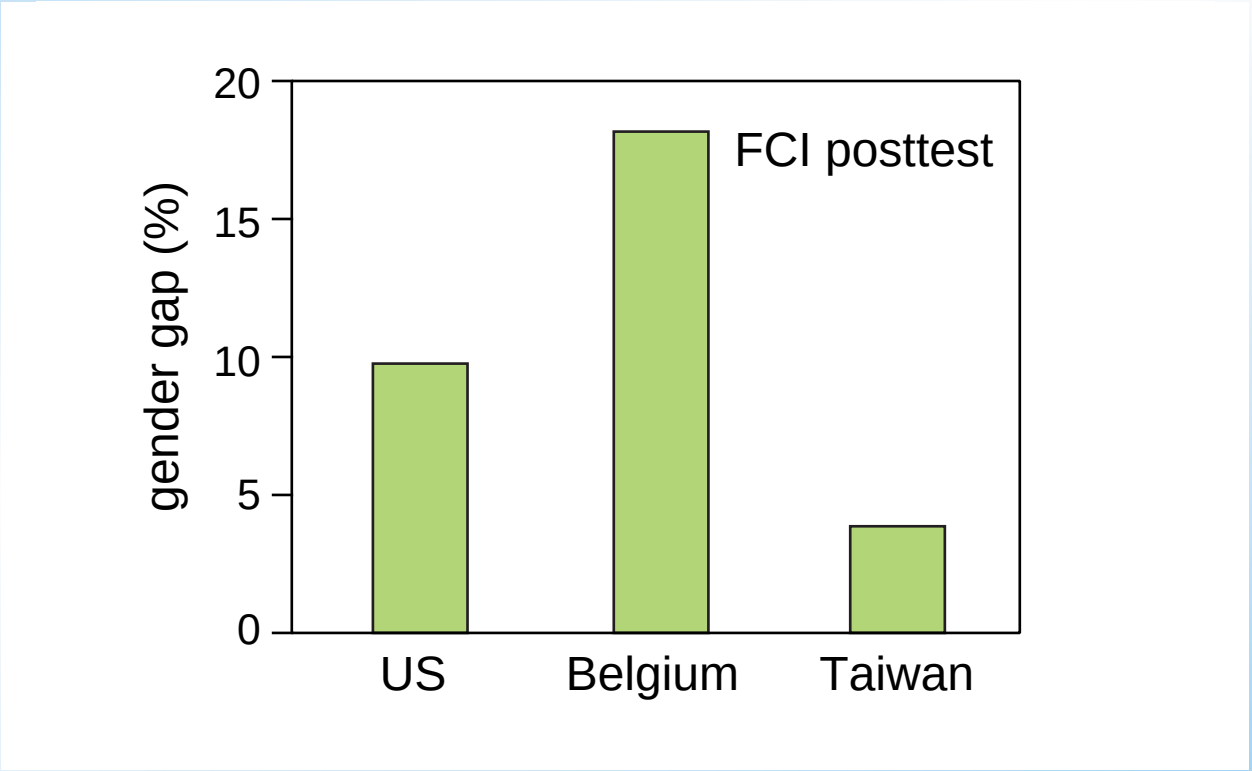


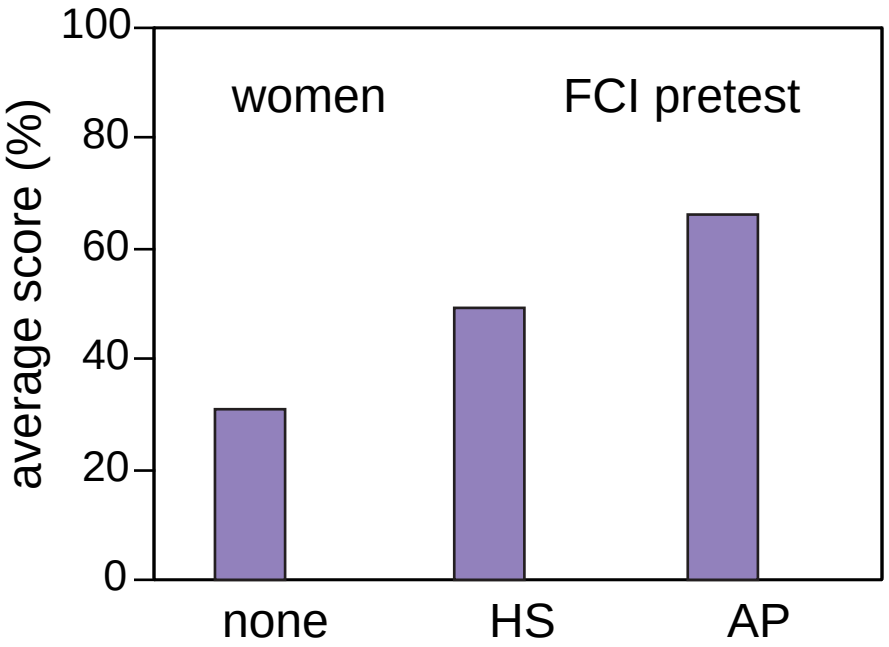
What causes the gender gap?

Strong dependence on culture!



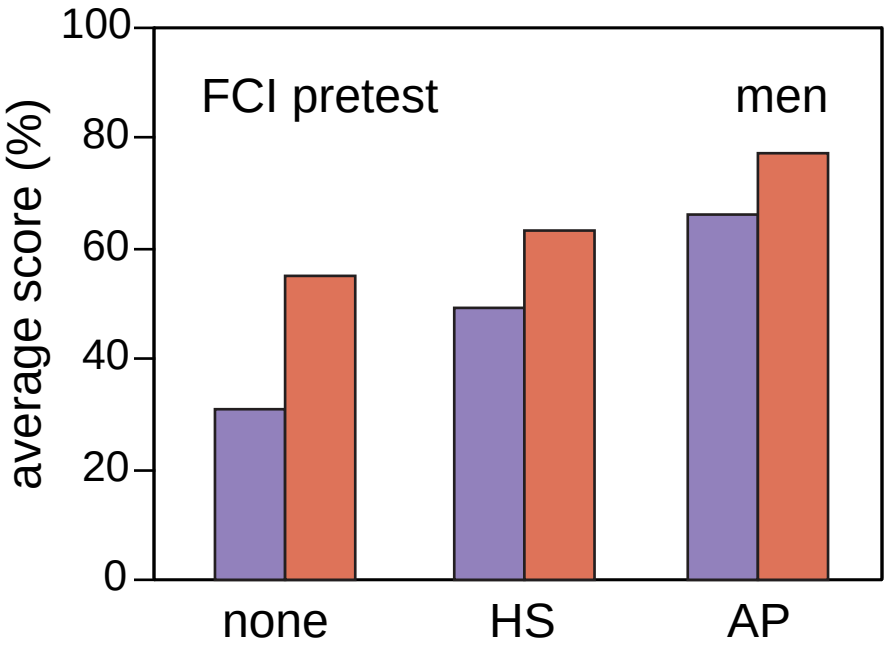
What causes the gender gap?

What is the effect of precollege education?



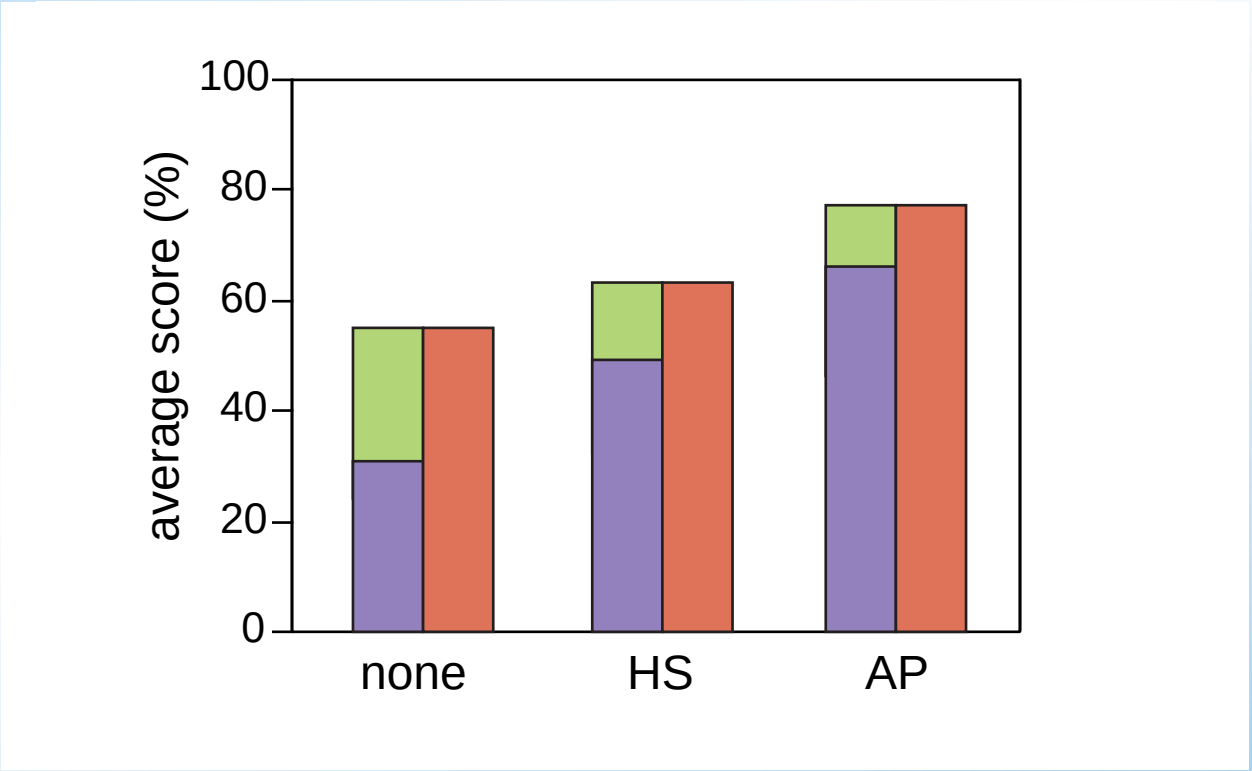
What causes the gender gap?

Everyone gains...



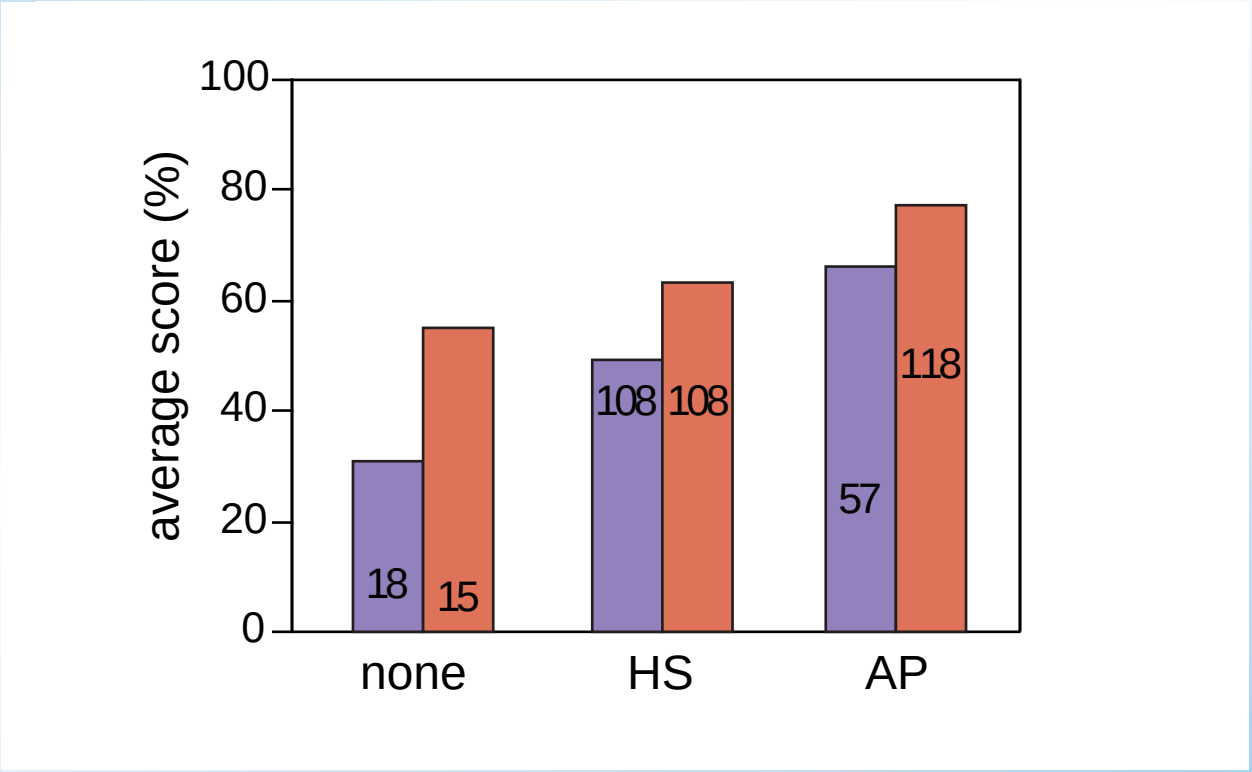
What causes the gender gap?

… but gap persists …



What causes the gender gap?

...and women underrepresented in AP courses




What can we do about the gender gap?

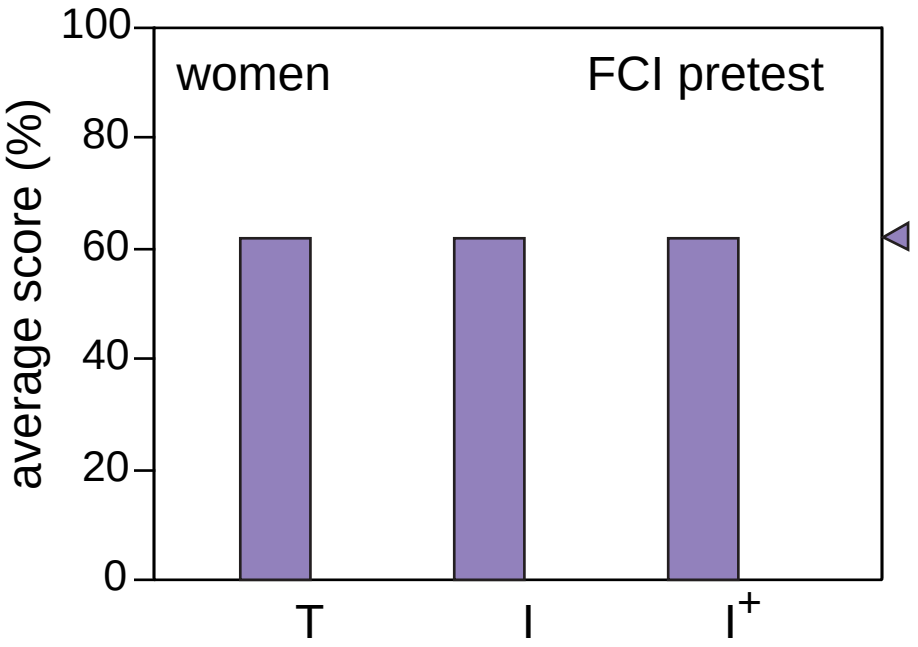
What can we do about the gender gap?

Compare three pedagogies:

- **Traditional lecture (T)**
- **Interactive lecture (I)**
- **Interactive lecture and sections, reading assignments (I^{+})**

What can we do about the gender gap?

Does pedagogy help?



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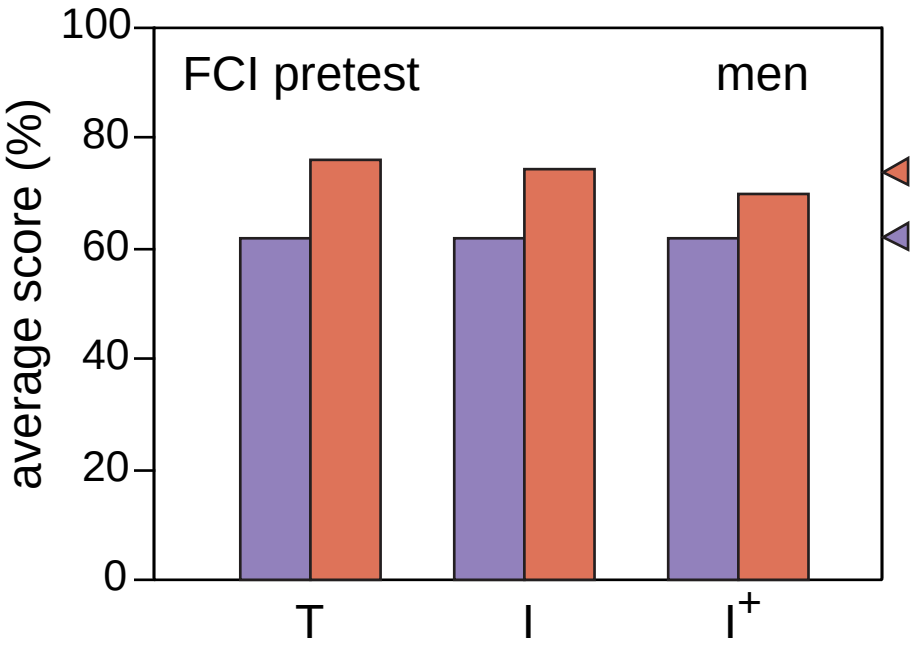

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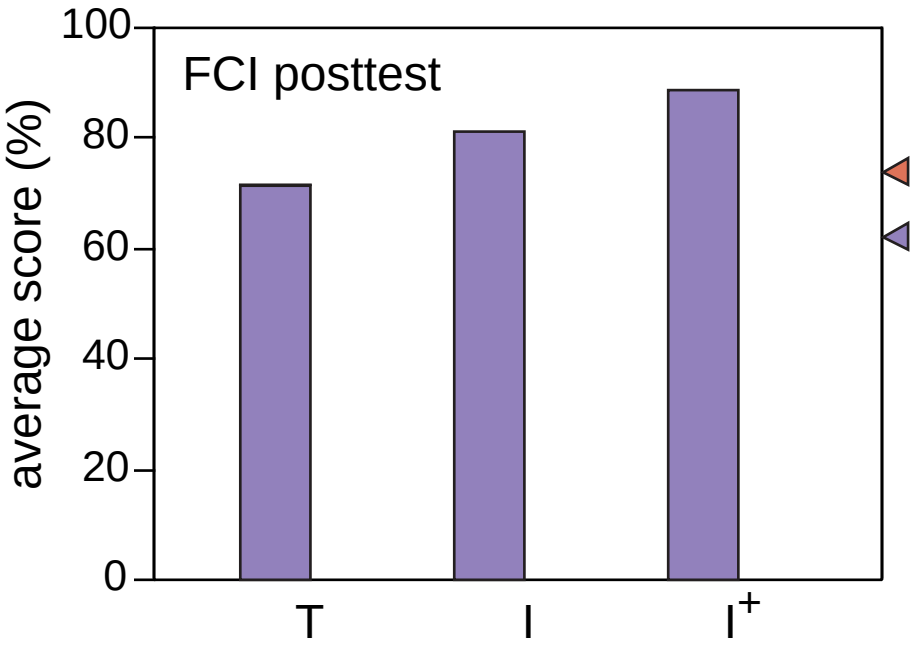
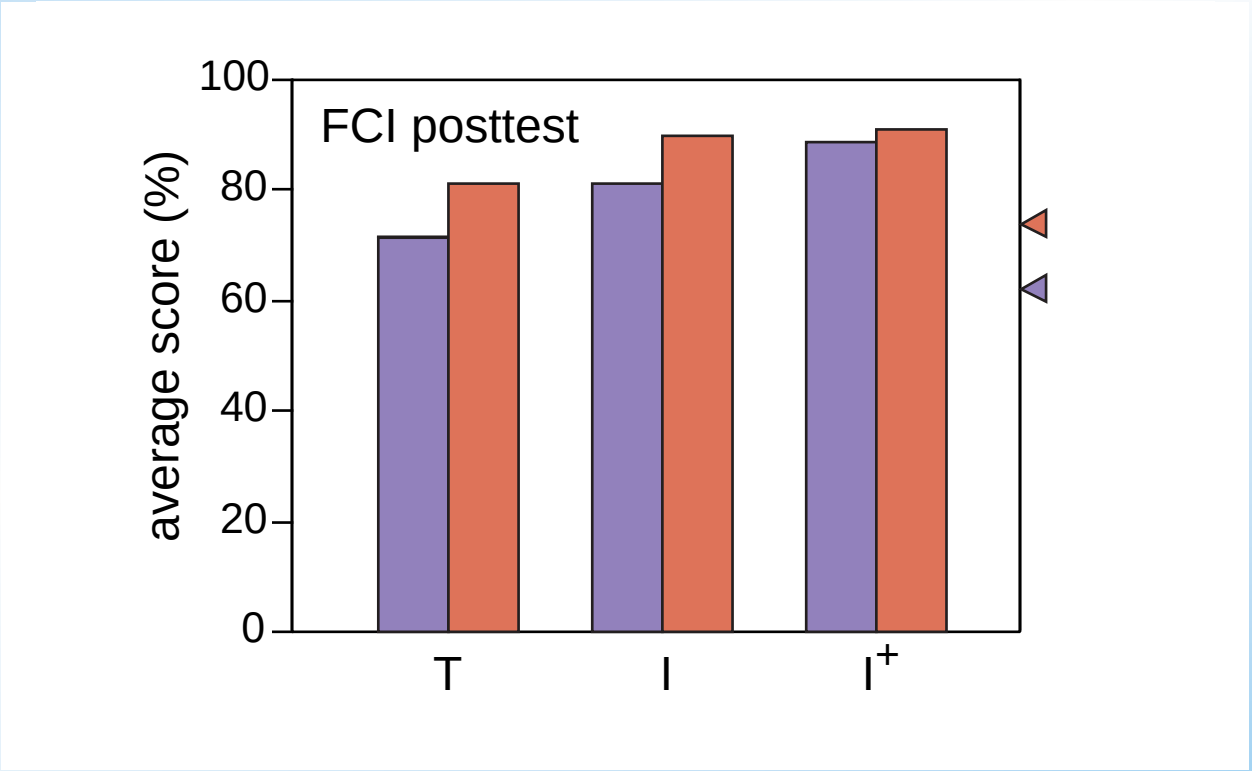


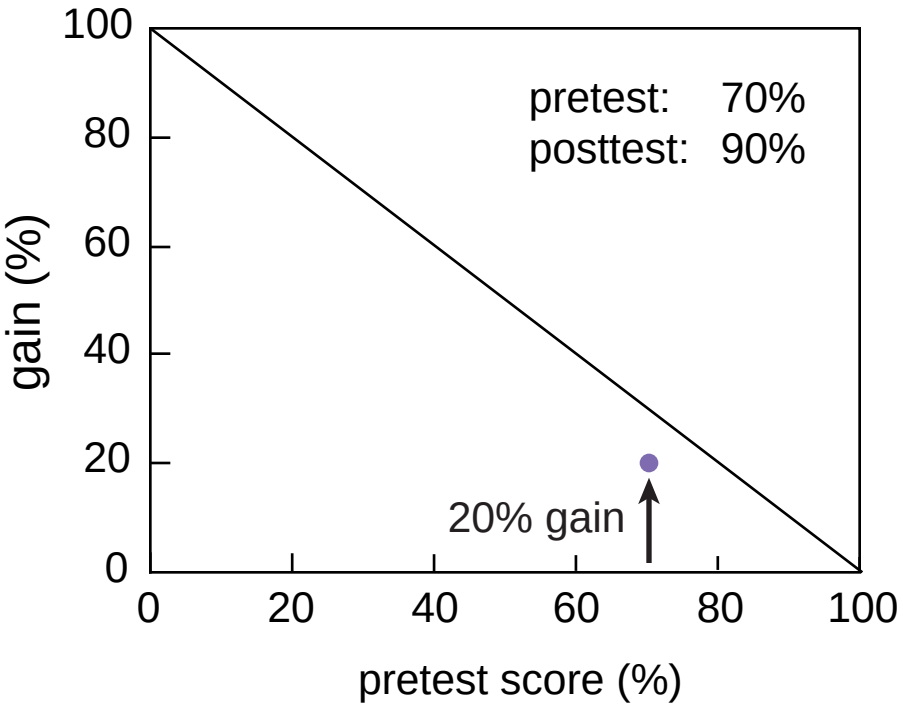
What can we do about the gender gap?

Yes, pedagogy narrows gap



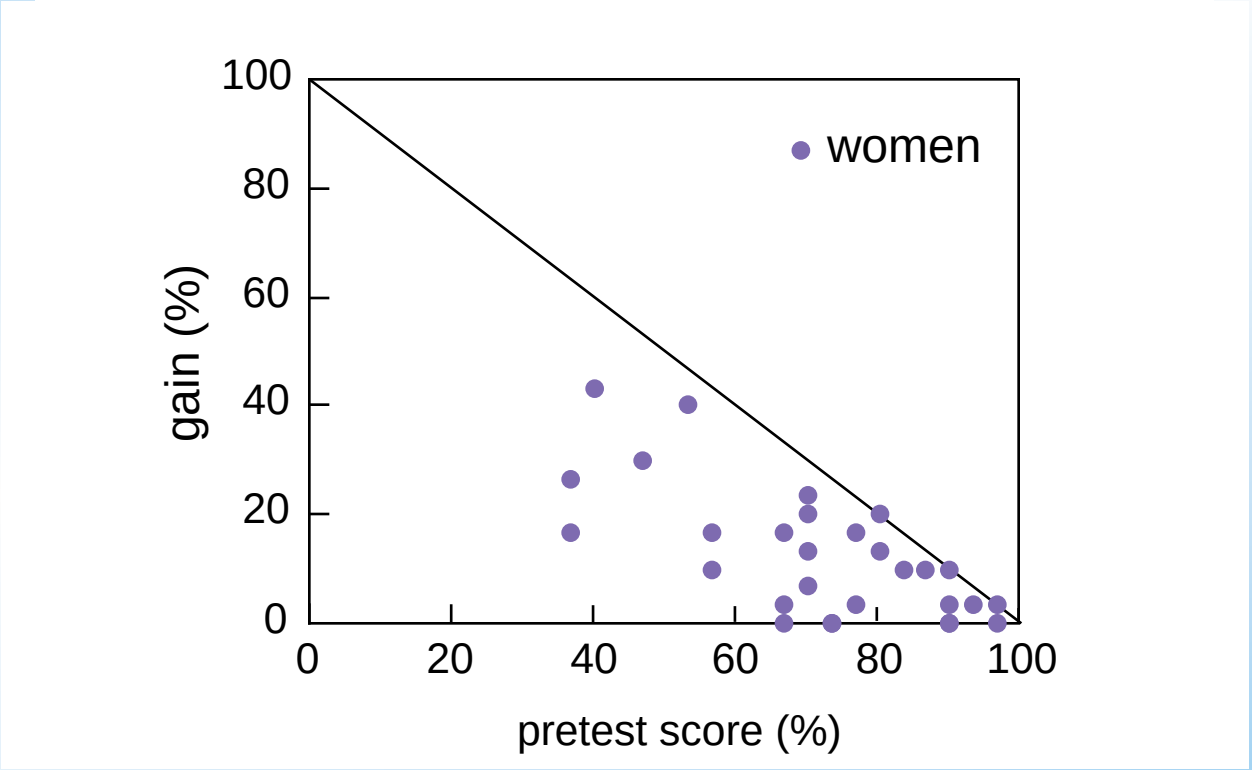
What can we do about the gender gap?

Who are the low-gain students?



What can we do about the gender gap?

Traditional class



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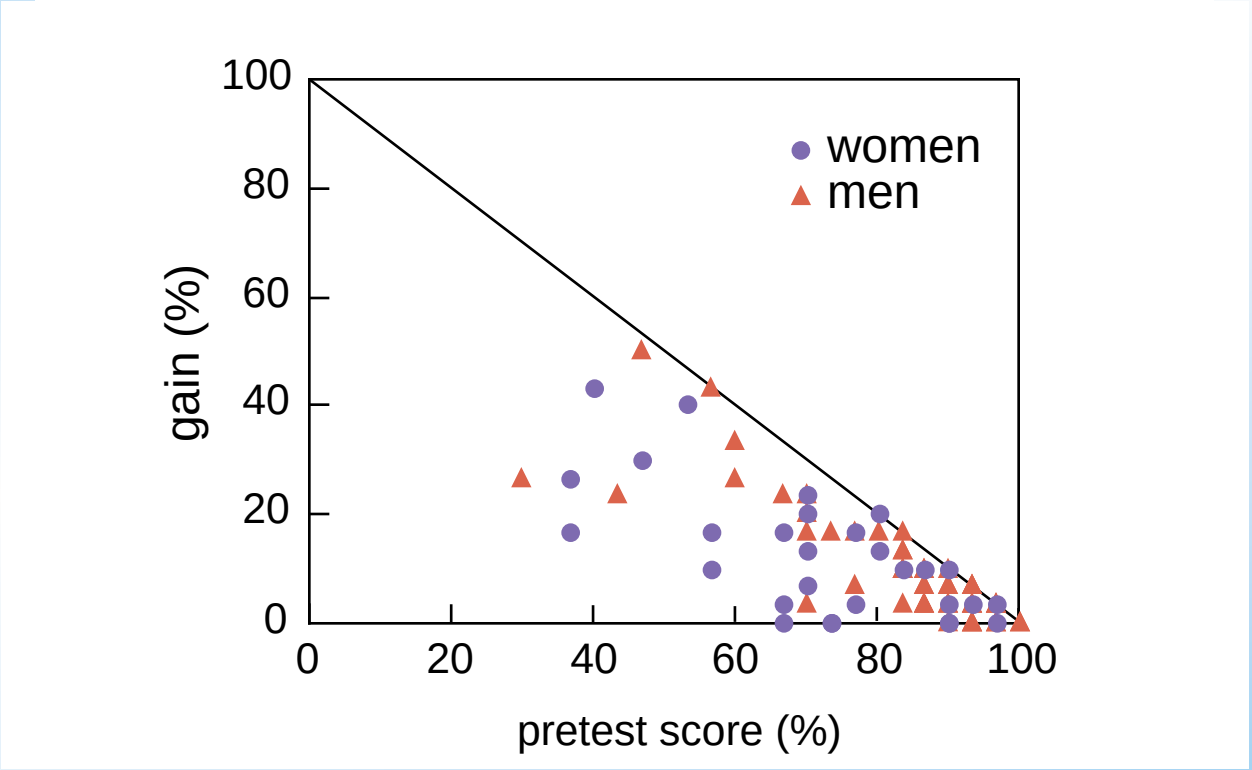
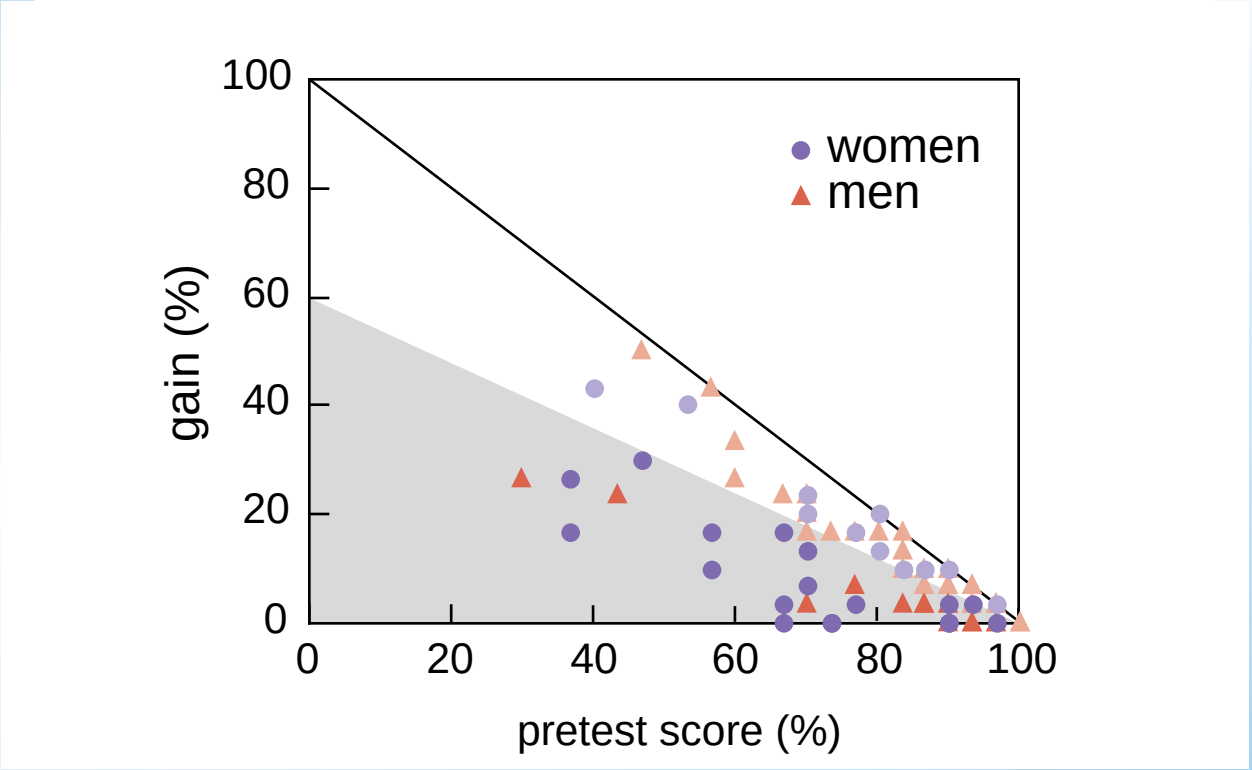


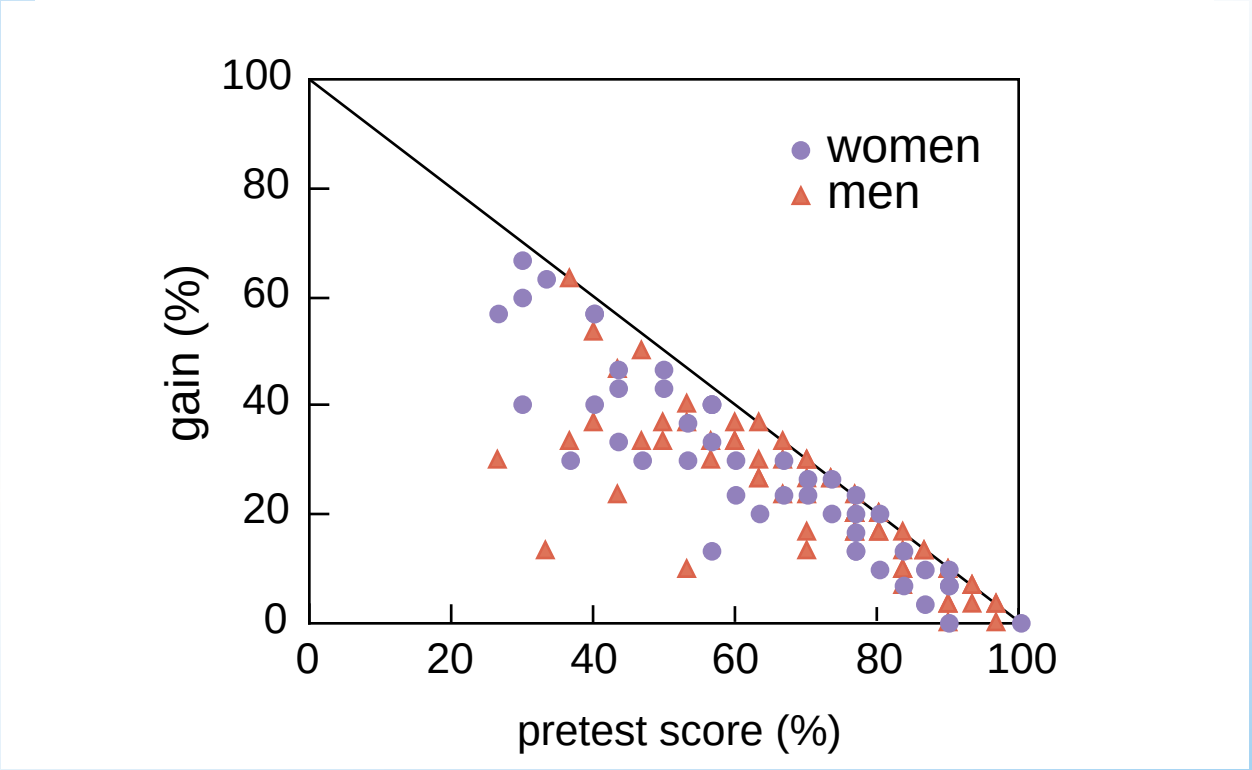
What can we do about the gender gap?

Traditional class: gender imbalance



What can we do about the gender gap?

Interactive class



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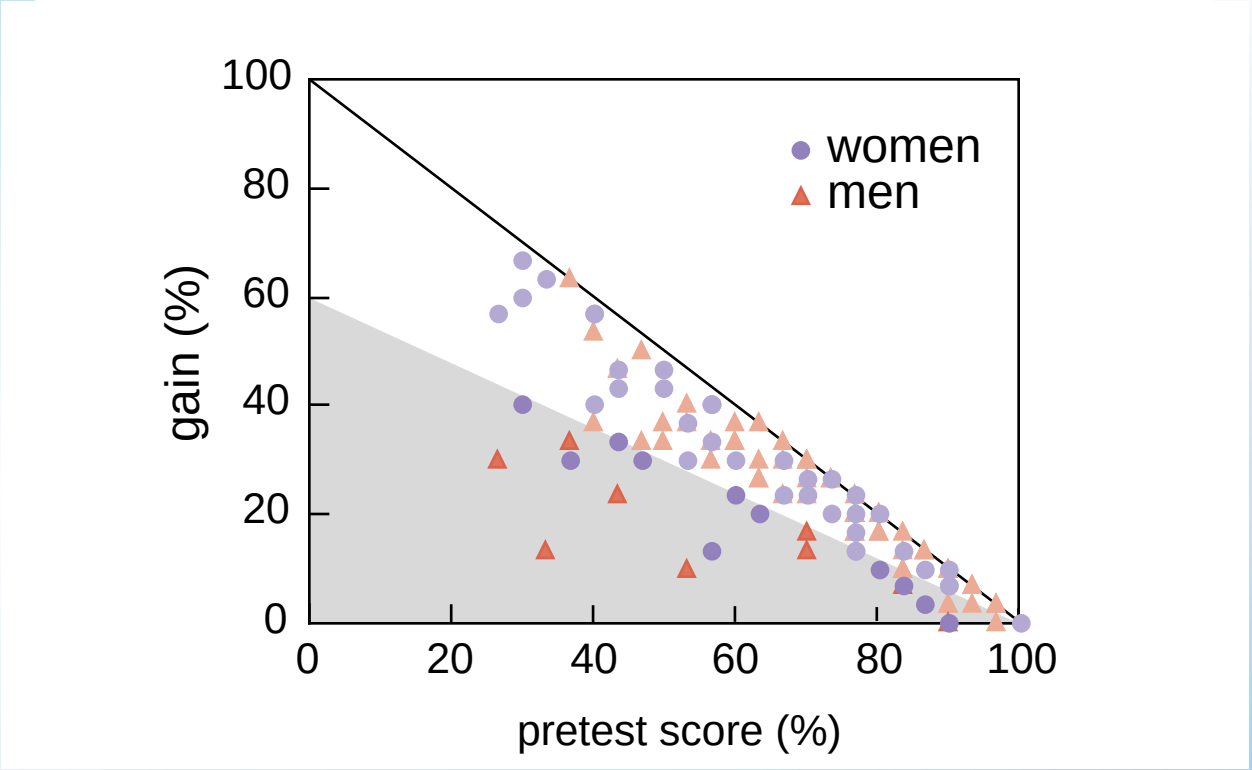
Interactive class: gender balance



Summary

- **Gap comes from culture and background**

Summary

- **Gap comes from culture and background**
- **Interaction makes a difference!**

Research Sampler

- Gender and physics
- **Demonstrations: entertainment or education?**
- Confusion: how real is it?

Modes of Presentation

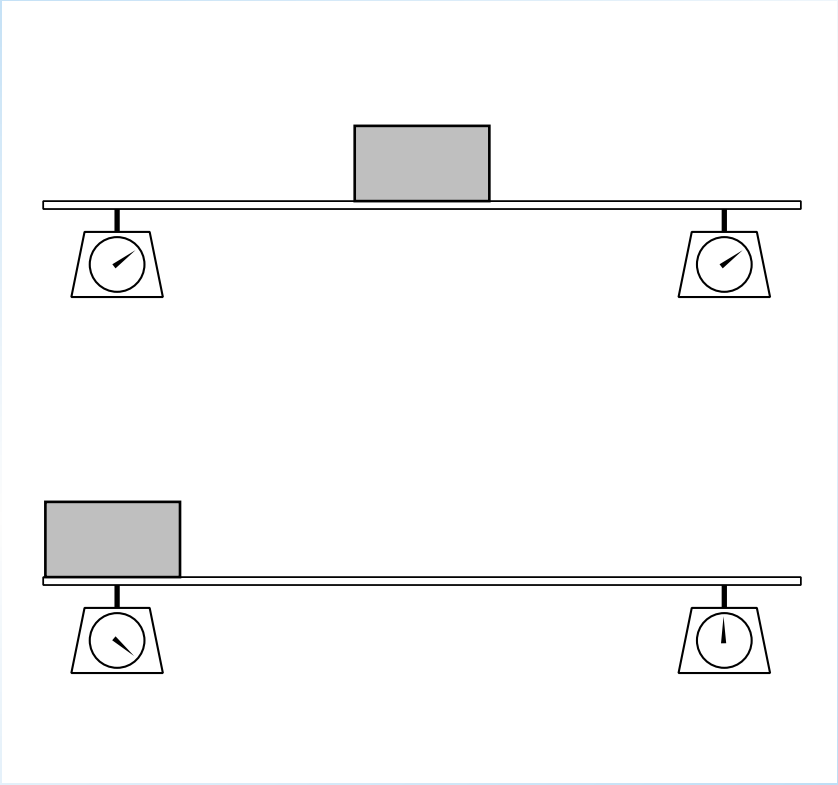
- no demo
- present
- predict
- discuss

Follow-up

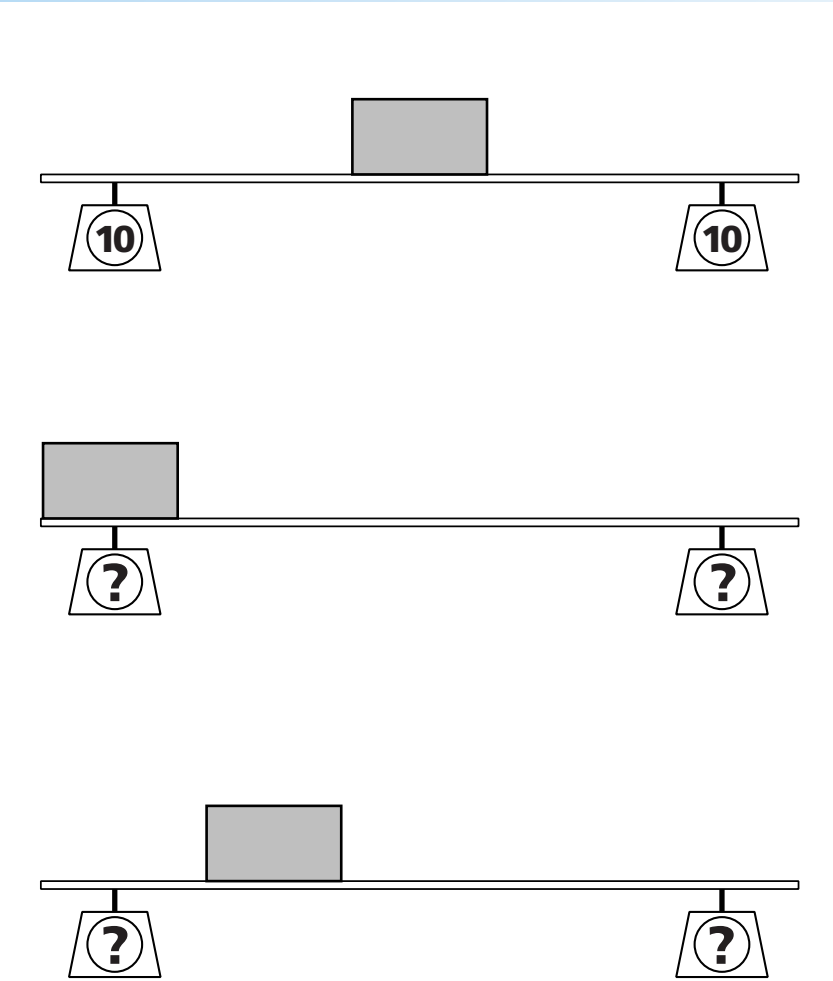
Web-based test (free response)

Final exam question

Loaded Beam Demo

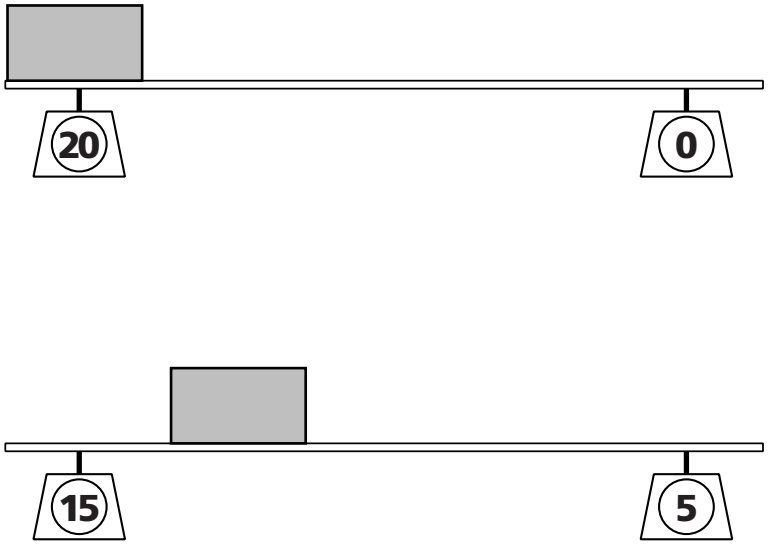


Web-based Test Question



Answers

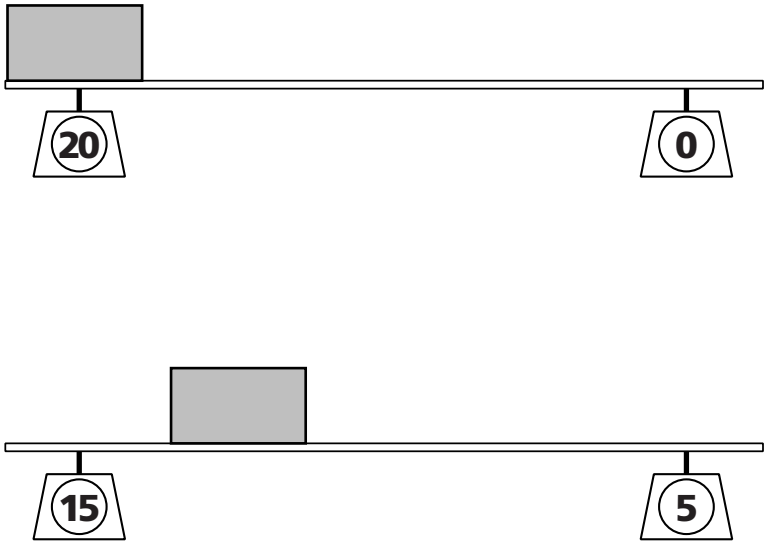
24% of students



correct (mentions torque)

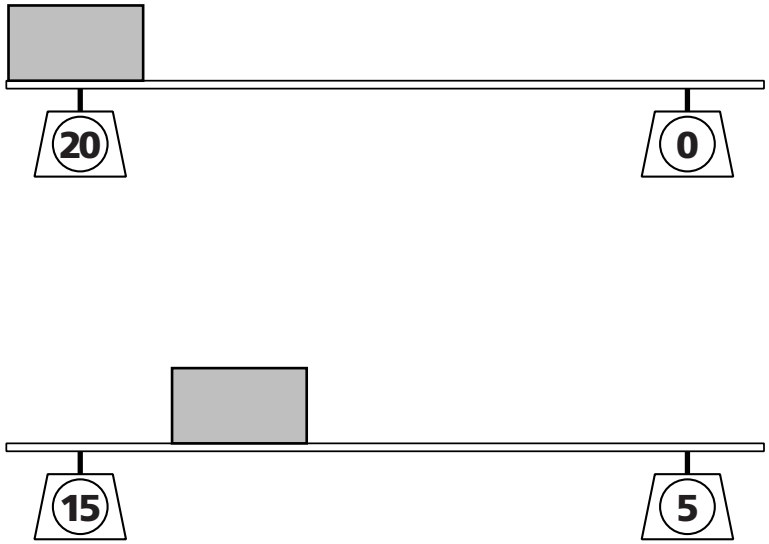
Answers

24% of students



correct (mentions torque)

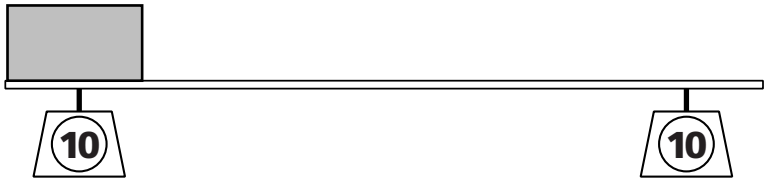
38% of students

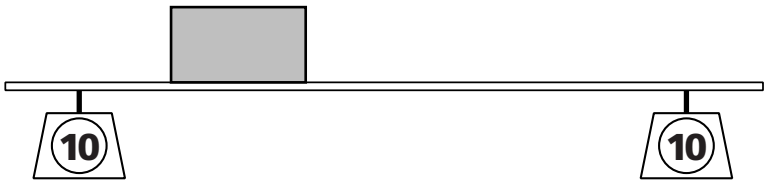


proportional reasoning

Answers

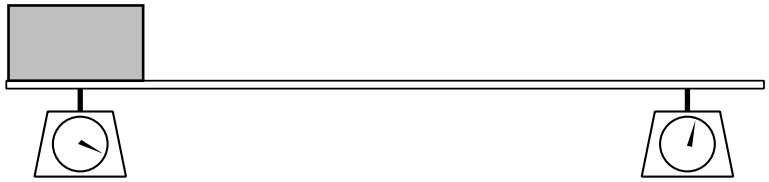
20% of students

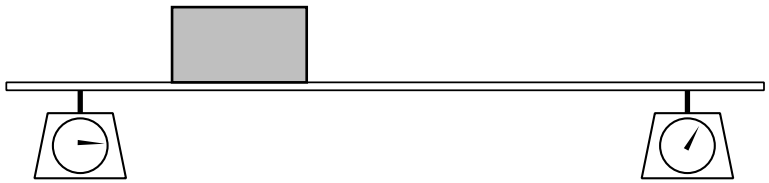




independent of position

10% of students





qualitative reasoning

6% of students do not balance forces
2% give other incorrect answers

‘Understanding’ affects Memory

“As demonstrated in lecture, both scales will read 10N, regardless of where the center of mass is located. The platform and the metal block form one unit that is being measured, so the scales show two evenly distributed readings, no matter where the metal block is placed along the platform.”

Preliminary Analysis

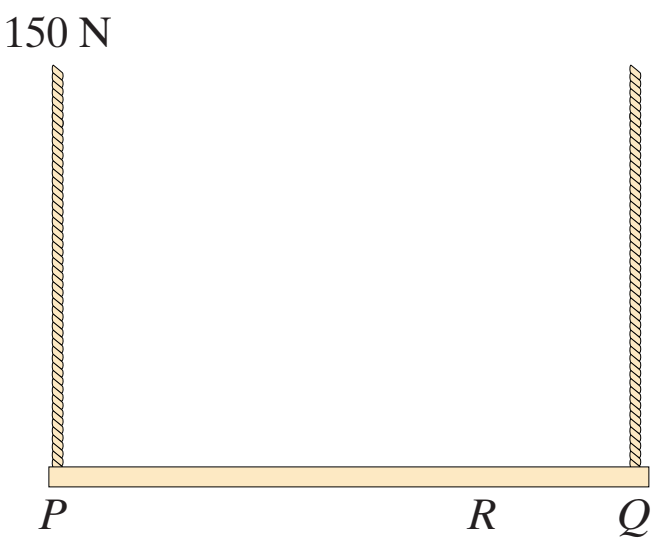
	correct	incorrect
no demo	30%	70%
present	18%	82%
predict	29%	71%
discuss	30%	70%

Preliminary Analysis

	correct	incorrect
no demo	30%	70%
present	**18%**	**82%**
predict	29%	71%
discuss	30%	70%

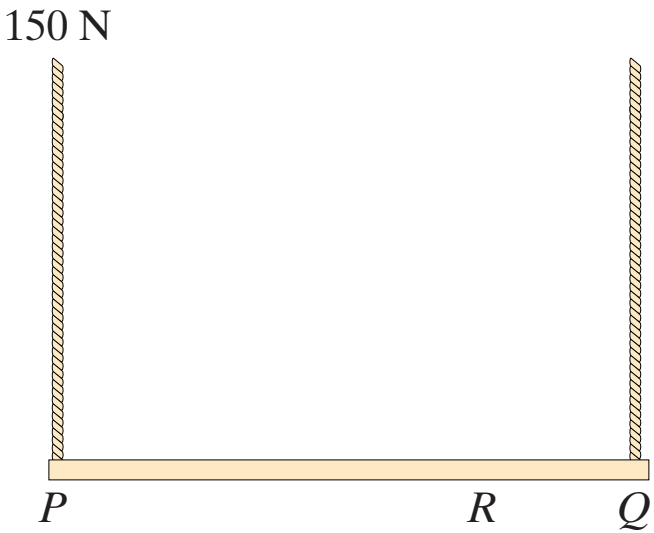
Just presenting harmful?

Exam Question

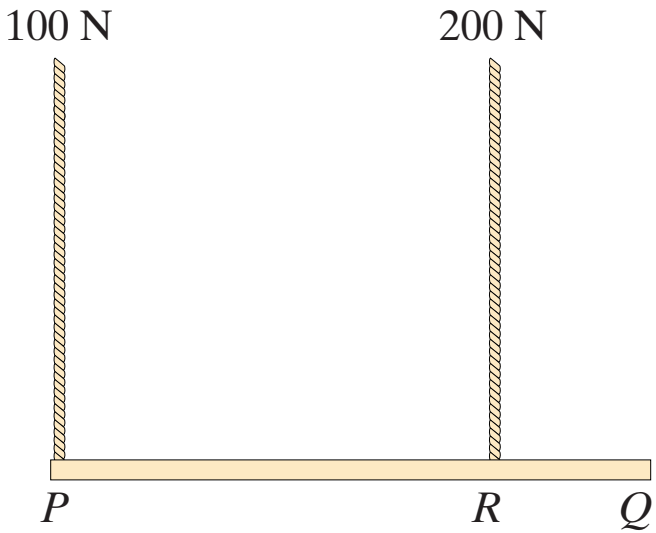


A uniform plank is supported by two ropes at points P and Q. The tension in the rope at P is 150 N. The point at which the other rope is attached to the plank is now moved to point R halfway between Q and the center of the plank. What are the tensions in the two ropes?

Correct Answer



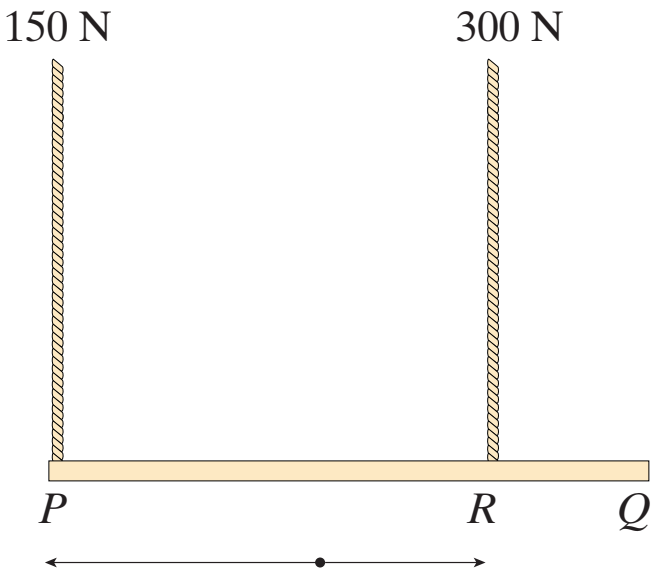
36% of students
(30% w. corr. reasoning)



considerable improvement from web test

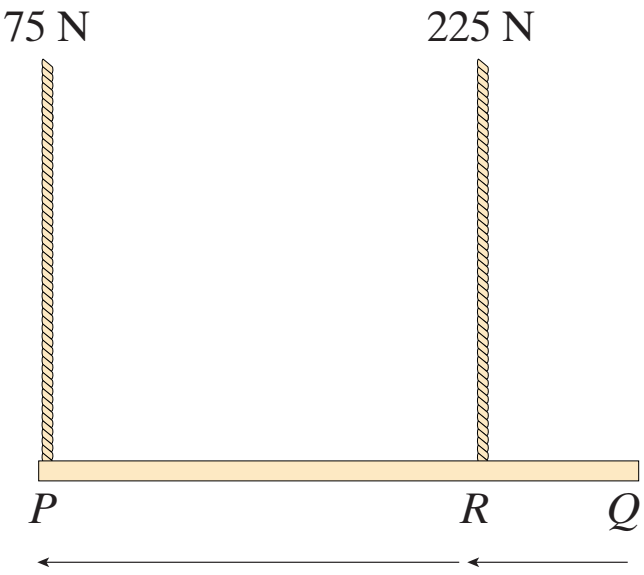
Incorrect Answers

13% of students



moment arm for Q reduced by factor of 2

12% of students

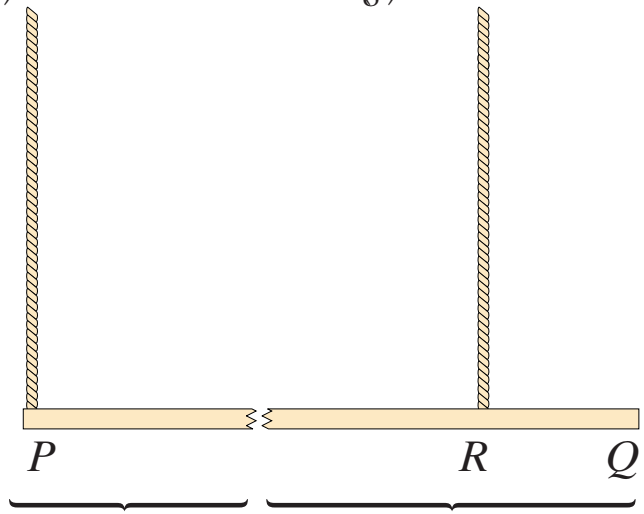


moment arms compare as 1:3

Incorrect Answers

8% of students

$\left(\frac{3}{8}\right)$ 300 N = 112.5 N $\left(\frac{5}{8}\right)$ 300 N = 187.5 N

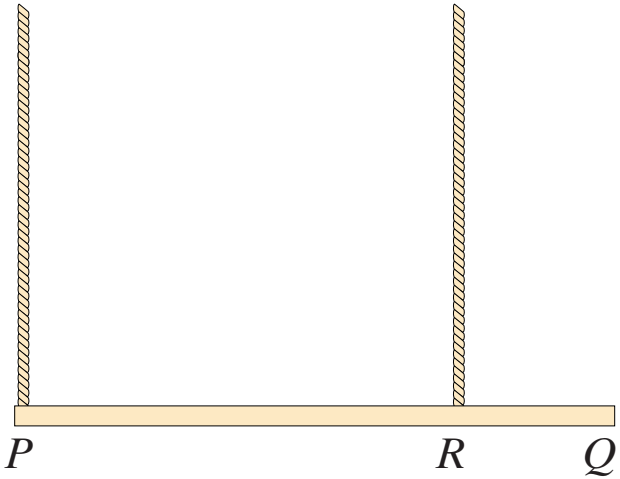


rope supports $\frac{3}{8}$ of the plank

rope supports $\frac{5}{8}$ of the plank

1% of students

112.5 N 112.5 N



ropes only need to support $\frac{3}{4}$ of plank

Analysis

	correct	balances torques	no clear reasoning
no demo	31%	53%	42%
present	42%	55%	42%
predict	41%	65%	32%
discuss	46%	85%	15%

Conclusion

Demonstration without engagement not very helpful

Much more data to be analyzed!

Research Sampler

- Gender and physics
- Demonstrations: entertainment or education?
- **Confusion: how real is it?**

Questions

What do students get out of their reading assignments?

Questions

What do students get out of their reading assignments?

What confuses them?

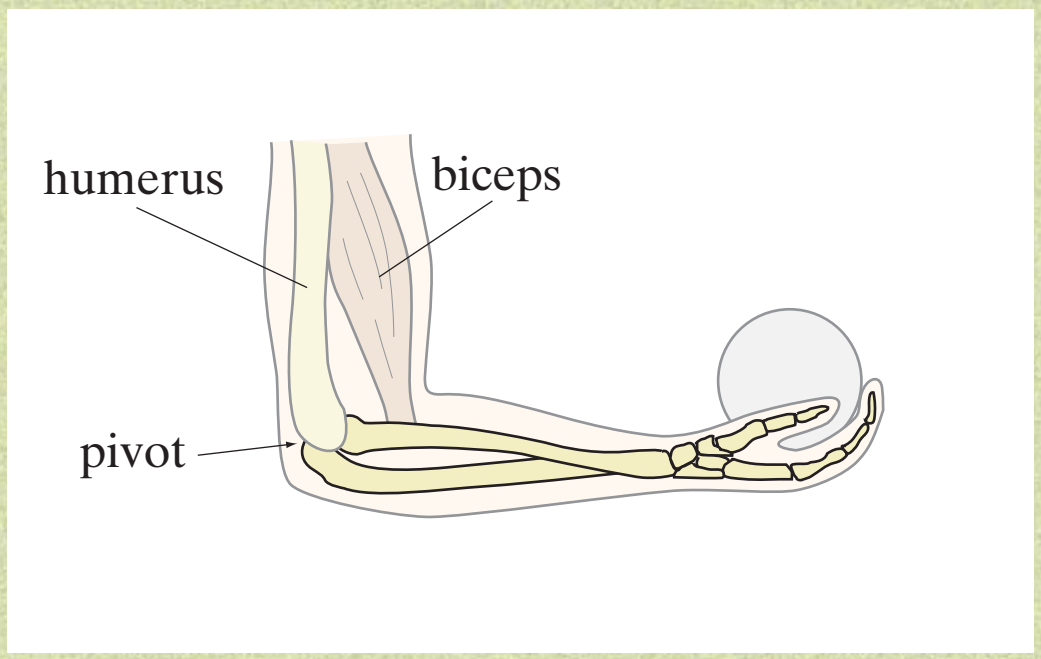
Questions

What do students get out of their reading assignments?

What confuses them?

How real is this confusion?

Reading Assignment Question

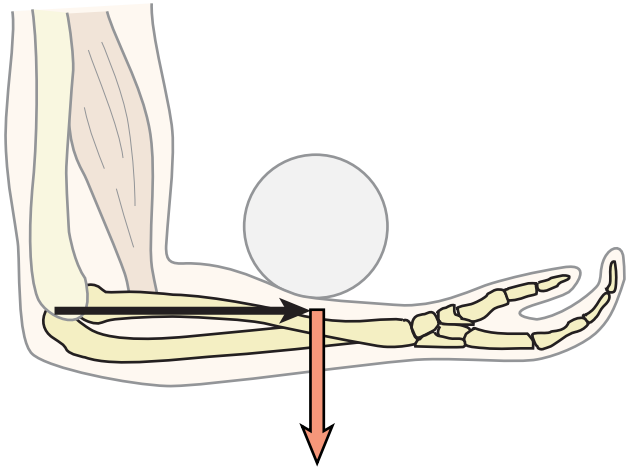


In the figure below, if you were to put the ball not in the palm of your hand as shown, but on your forearm, halfway between your elbow and your hand, would it be harder, equally hard, or easier to lift it? Explain briefly.

Coding of Responses

1. answer
2. conceptual model
3. degree of confusion expressed
4. length of answer

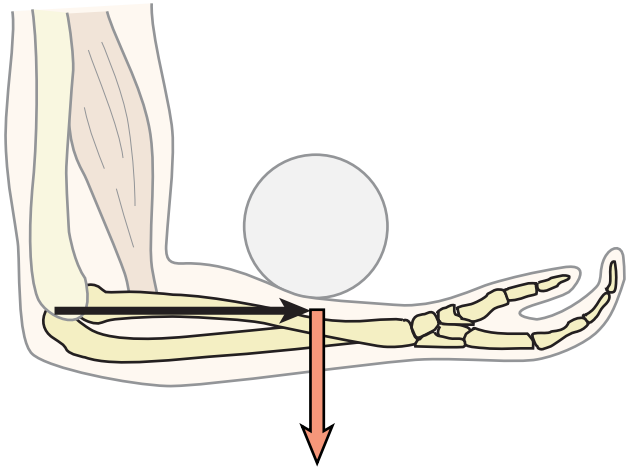
Correct Answers



less torque exerted by ball on arm

Correct Answers

38% of students



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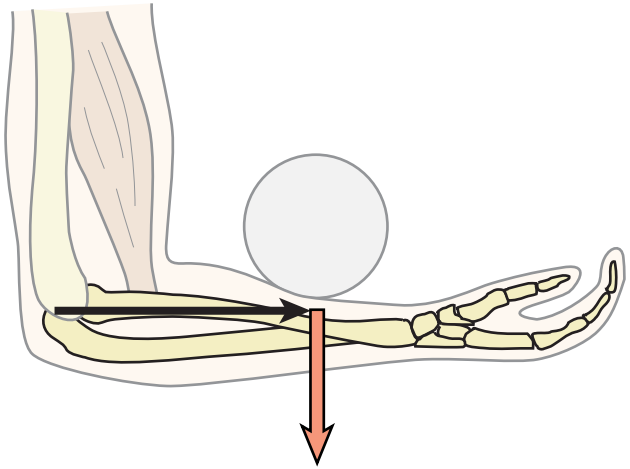
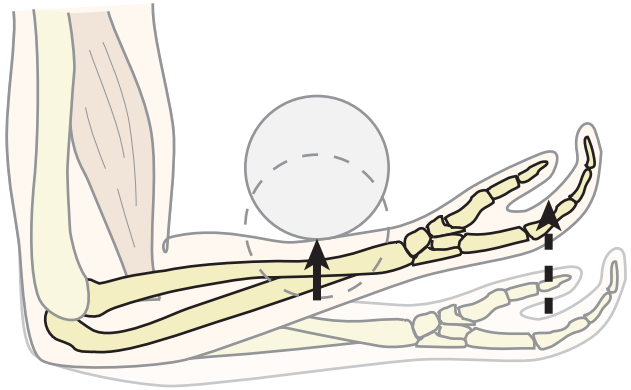


less torque exerted by ball on arm

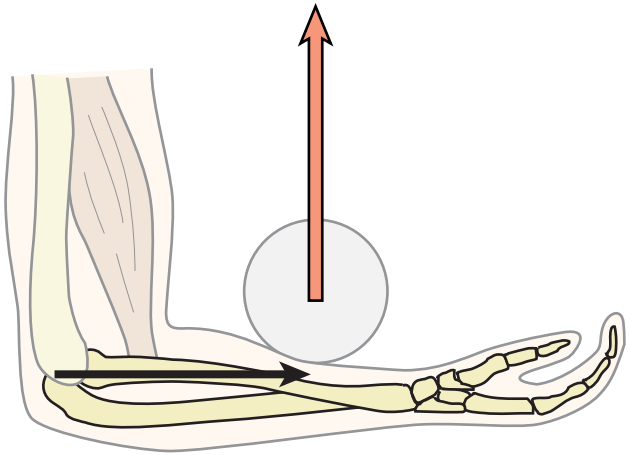
6% of students



smaller distance raised: less work required
(or: mechanical advantage of lever arm)

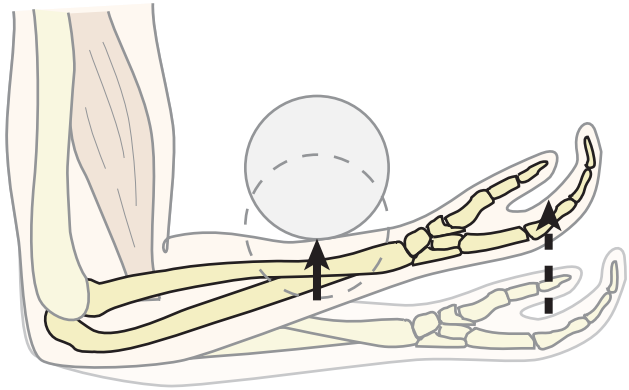
Incorrect Answers

27% of students



smaller moment arm: need larger force

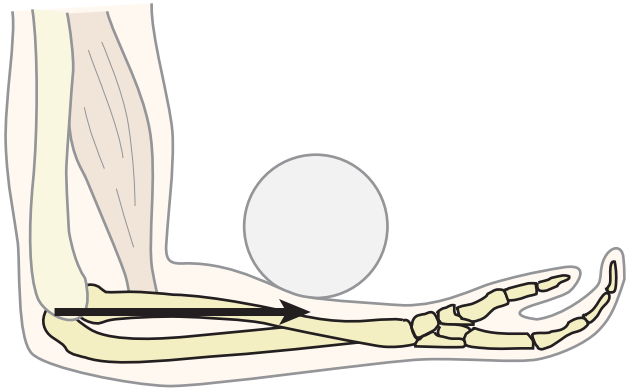
8% of students



smaller distance raised: greater force required to do same work

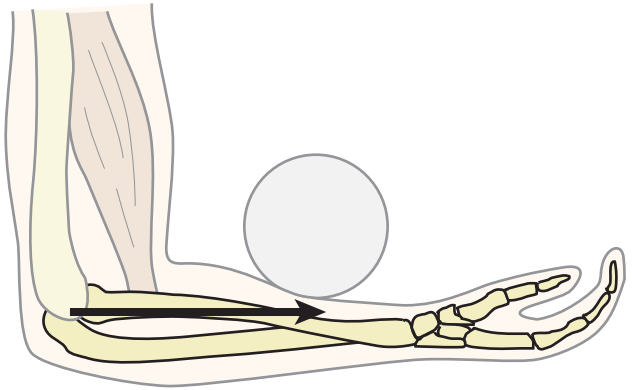
Incorrect Answers

6% of students



distance to pivot smaller:
easier/harder (no reasoning)

3% of students



smaller rotational inertia

6% of students give other incorrect answers
6% do not answer question

Correlation to Physics Background

	torque	other
none	26%	74%
high school	36%	64%
AP/college	46%	54%

Confusion

Which students claim being confused?

Confusion

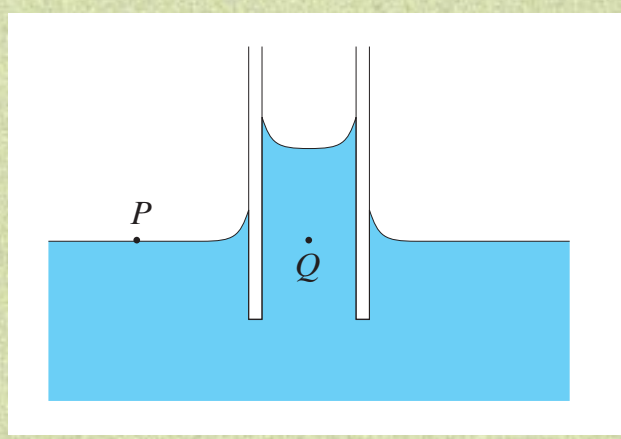
Which students claim being confused?

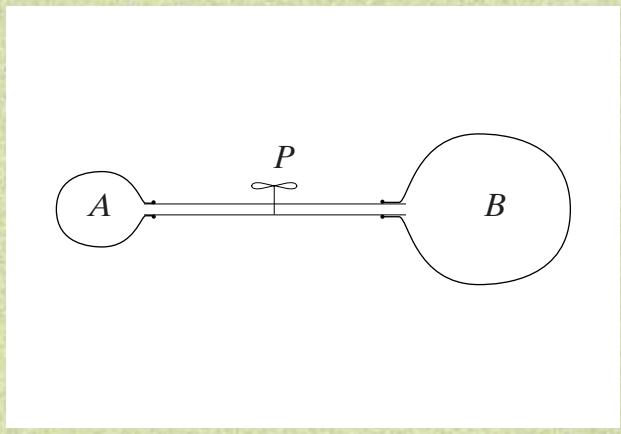
2/3 of students with correct answers, but only

1/2 of students with incorrect answer!

Reading Assignment Questions

Consider the capillary rise of a liquid in a glass tube. How does the pressure at point *P* at the surface of the liquid compare to the pressure at point *Q* at equal height?





Two identical balloons are connected to a tube as shown below. Balloon *B* is inflated more than balloon *A*. Which way does the air flow when valve *P* is opened?

Sample Response

1. Capillary action is due to the cohesion between water molecules, and the adhesion of water to the surface of the glass tube. Negative pressures can result from the cohesive forces of water. At the same height, the pressure inside the tube is much less due to negative pressures.

2. The air flows from high pressure to low pressure. The fully blown up balloon has higher pressure than the 1/2 blown up balloon. So the air flows from the fully blown balloon to the half filled balloon.

3. Nothing was difficult or confusing. The sections on the surfactant in the lungs and the heart as a pump were interesting because they relate physics to biology.

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WRONG

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Another Response

1. The water rises because of an interaction between the water and the walls of the tube. This interaction creates an upward force which causes the water to rise. The force is due to surface tension between the water and the walls of the tube. The pressure at the point inside the tube must be the same as the pressure at the point of equal height outside the tube, because if there was a pressure difference, then there would be a net flow of water, into or out of the tube, until the pressure difference was equalized.

2. Laplace's law tells us that it requires a greater pressure difference to maintain a small sphere than a larger one. So, the pressure in the small balloon must be greater, and the air will flow from the small balloon into the large one.

3. I found the explanation of Laplace's law to be inadequate, and while I can understand the conclusion drawn, I don't understand the reasoning which led to the conclusion.

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YES!

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Coding of Responses

1. correct/incorrect answer
2. confusion on topic of question

Result

capillarity	correct	incorrect
confused	44%	56%
not confused	25%	75%

Laplace	correct	incorrect
confused	49%	51%
not confused	21%	79%

Conclusion

Confusion is not a bad thing…

but it can be a serious obstacle to education reform.

Funding

National Science Foundation

For a copy of this talk and additional information:

http://mazur-www.harvard.edu