Improving College Physics Education Through Research

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Harvard University

University of Maryland
31 March 2000

We have a problem

"I took four years of science and four years of math…

A waste of my time,
a waste of the teacher's time,
and a waste of space…

You know,
I took *physics*.

For *what*?"

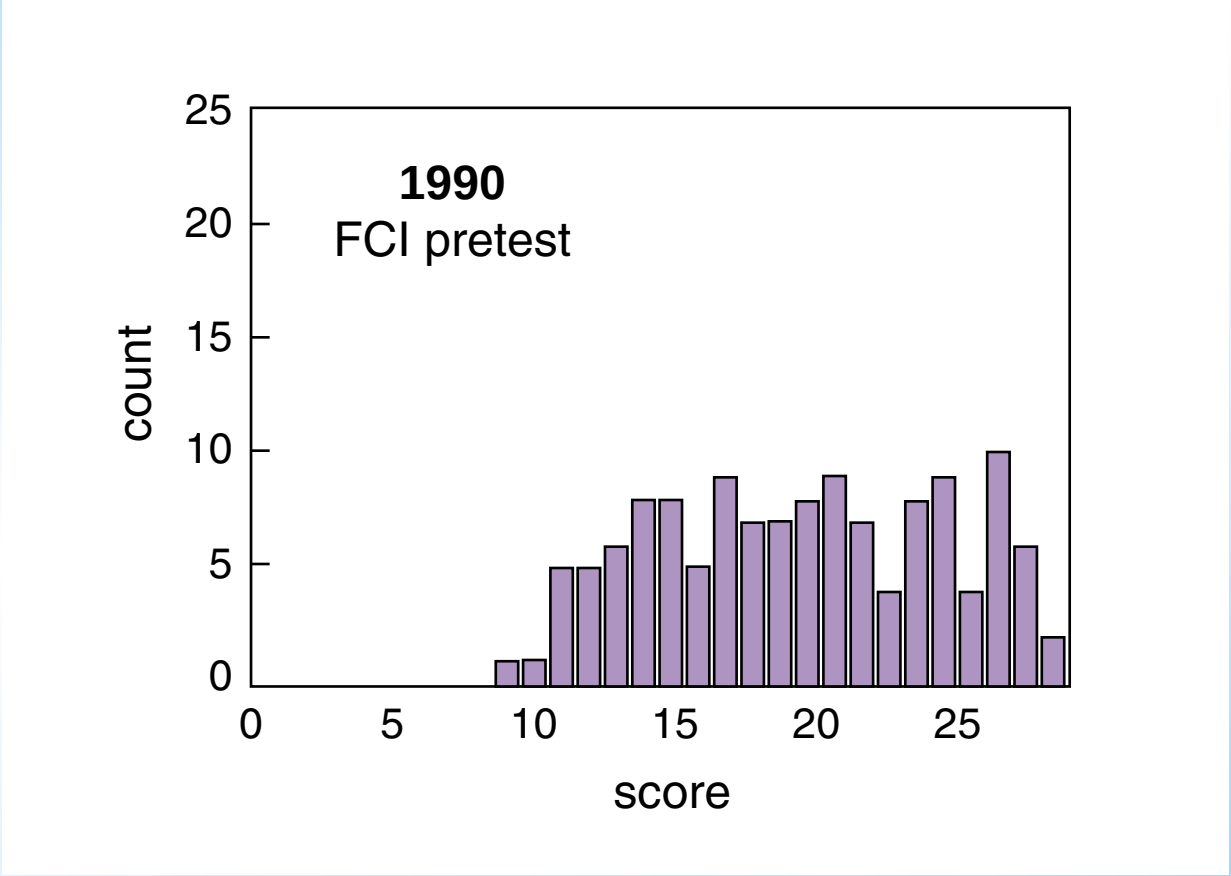

Why do we have this problem?

Why do we have this problem?

Lectures focus on transfer of information…

Why do we have this problem?

Force Concept Inventory data



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

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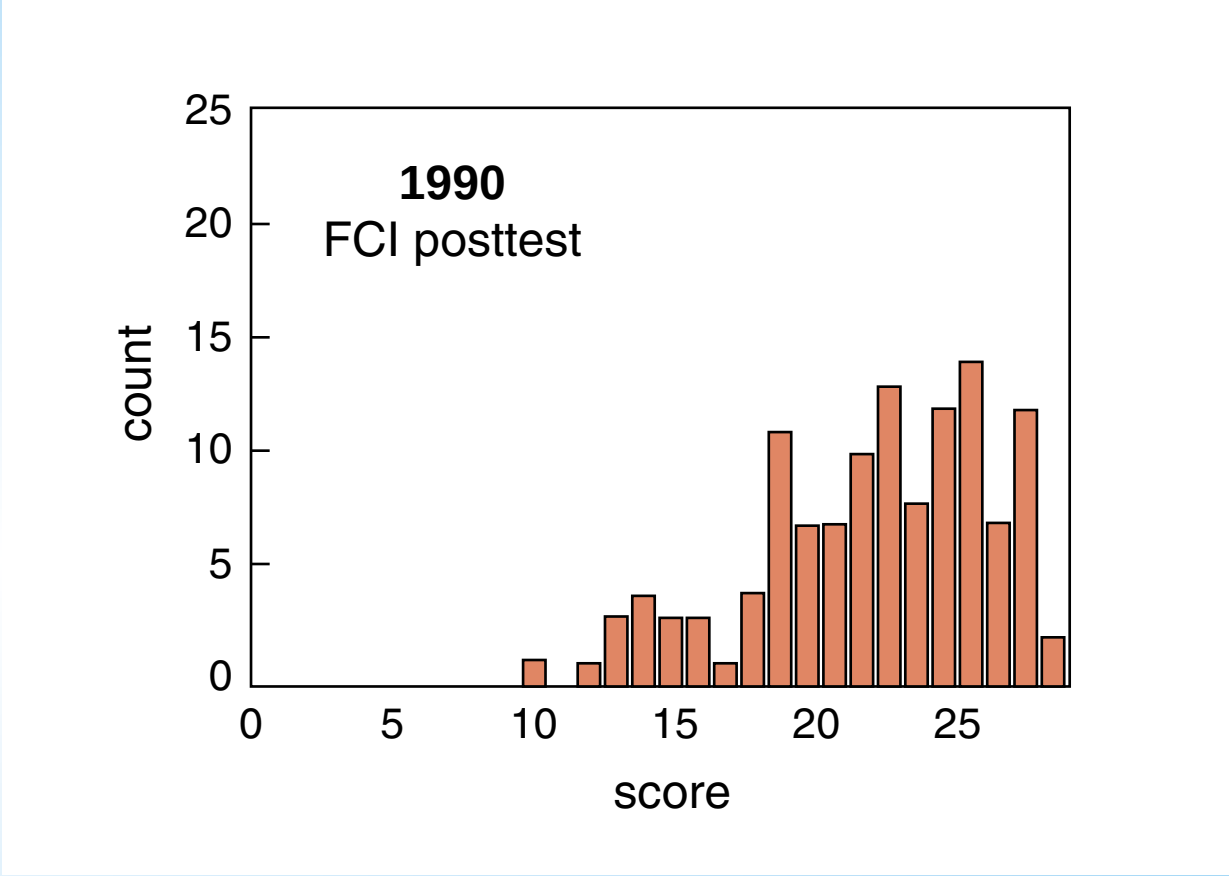

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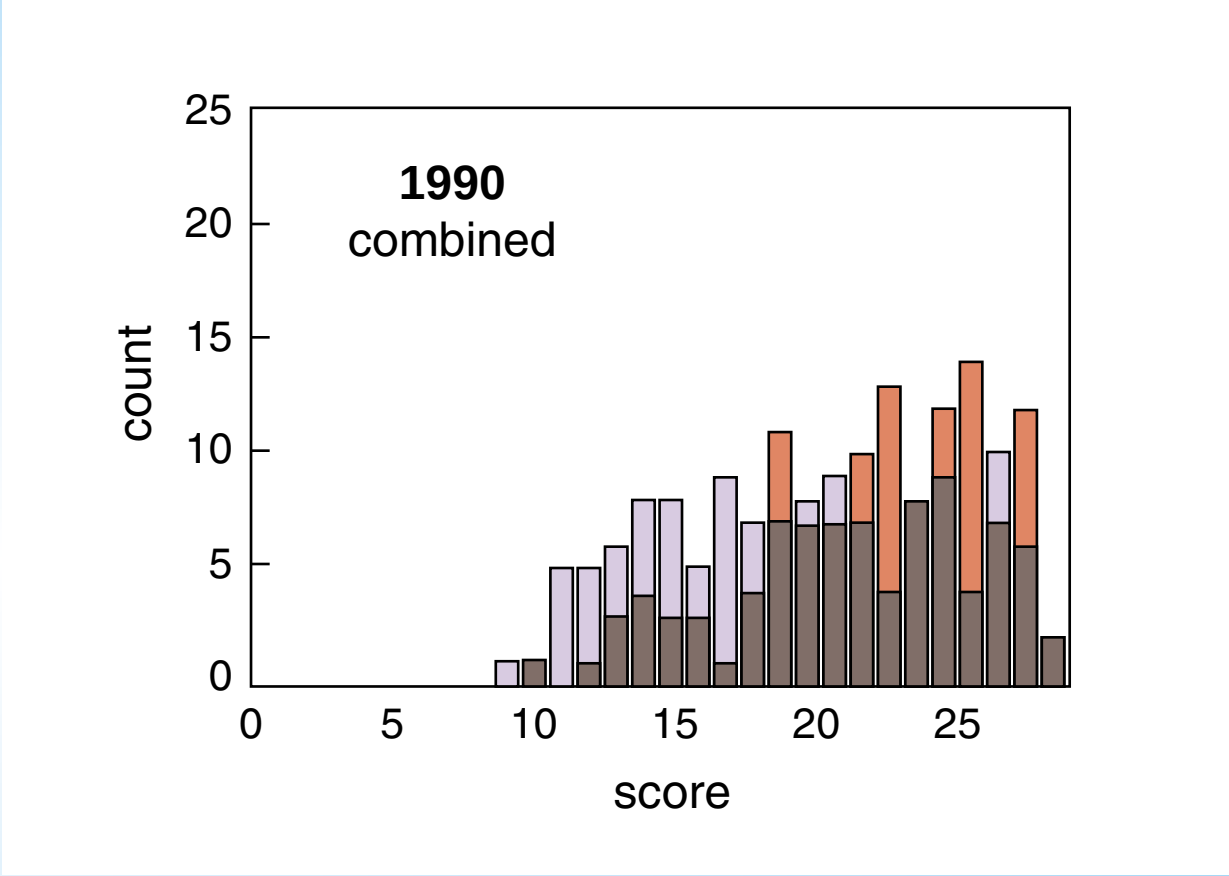

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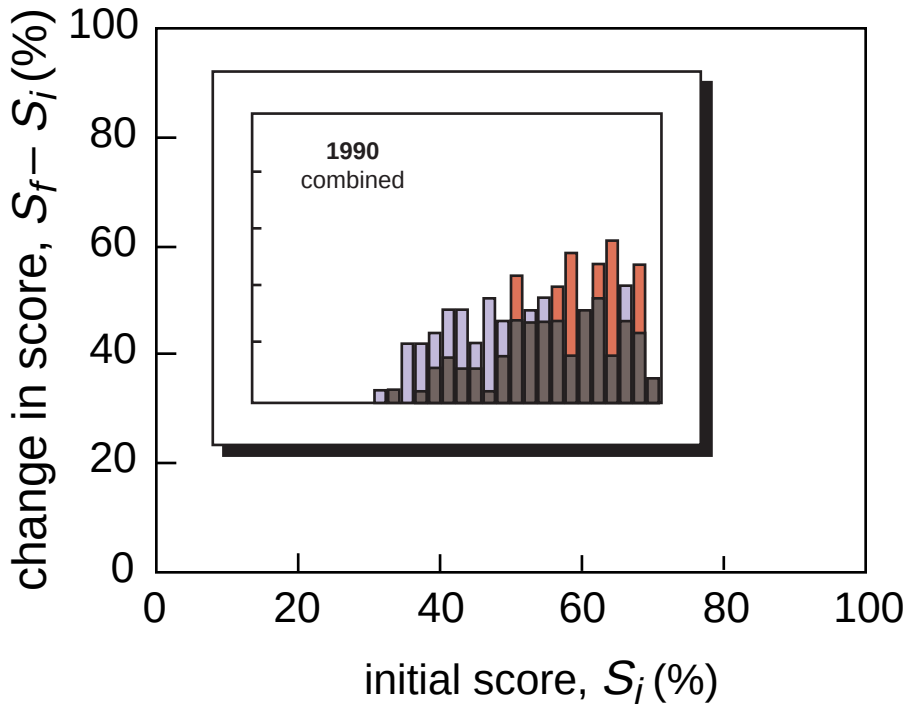

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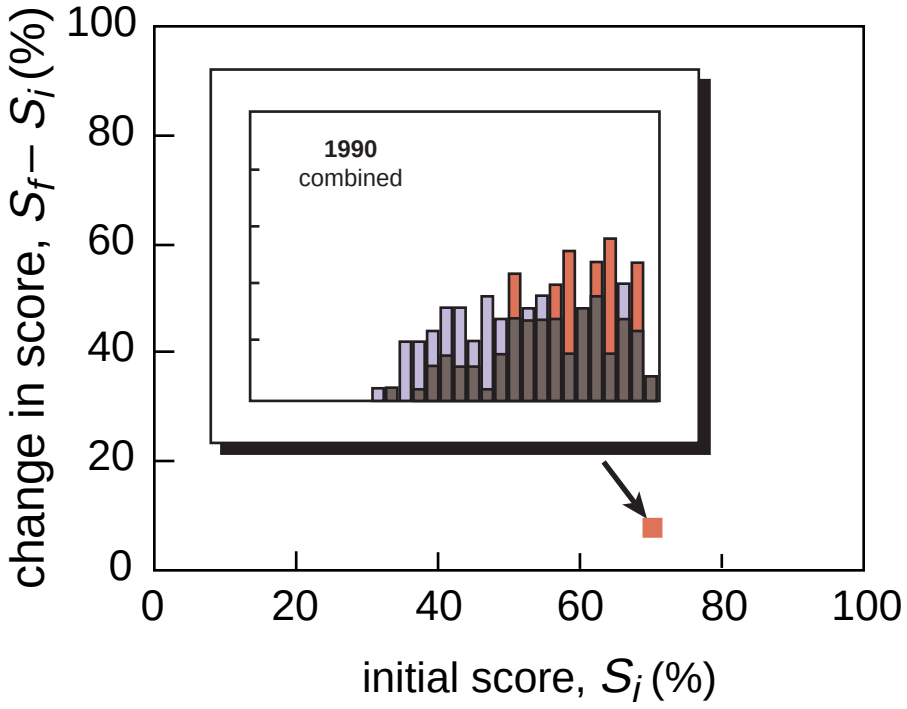

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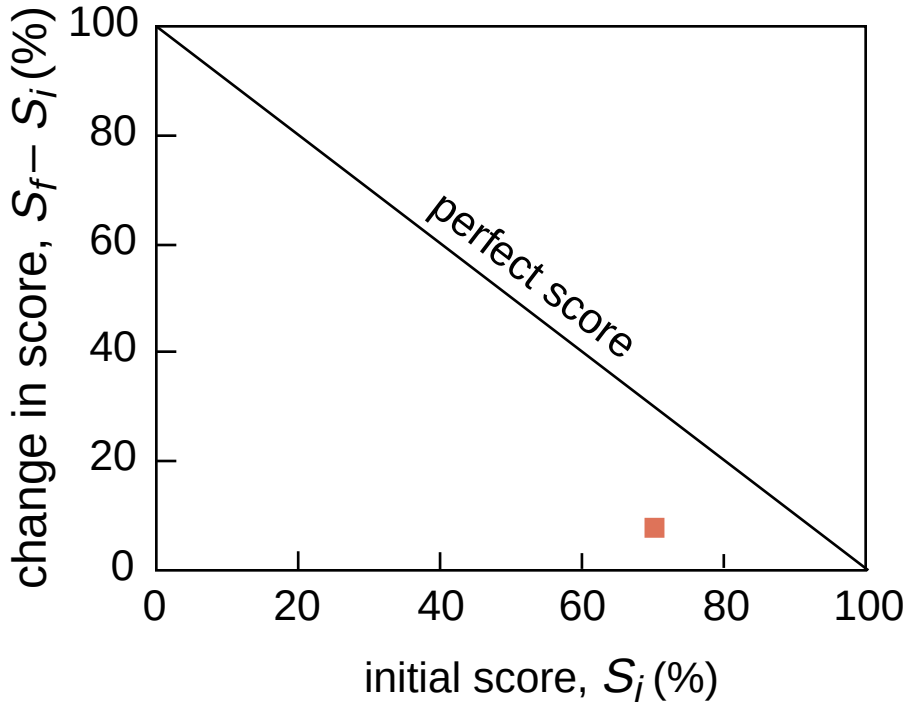

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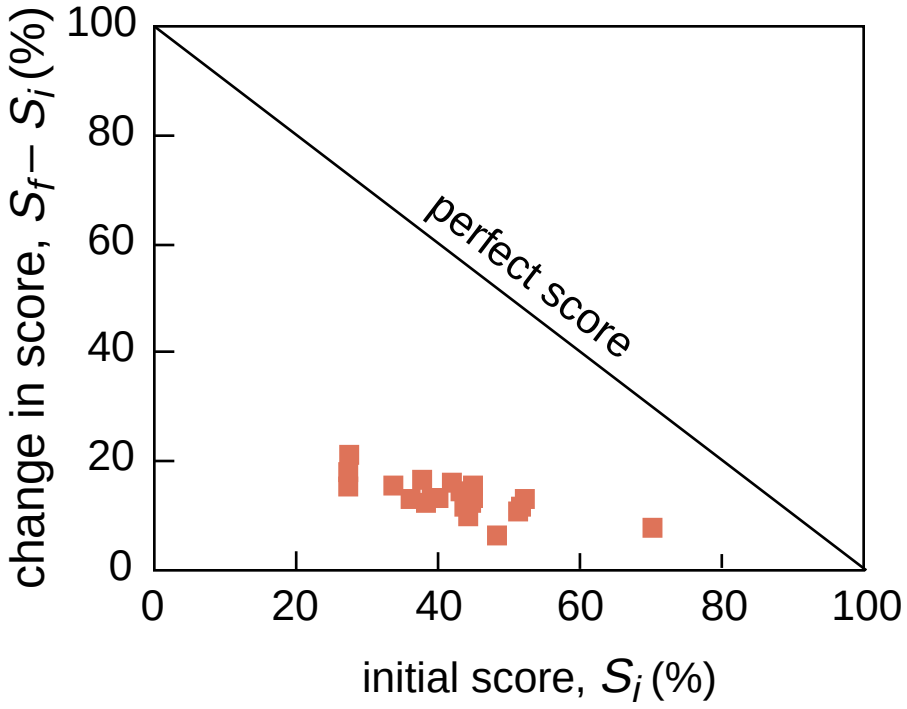

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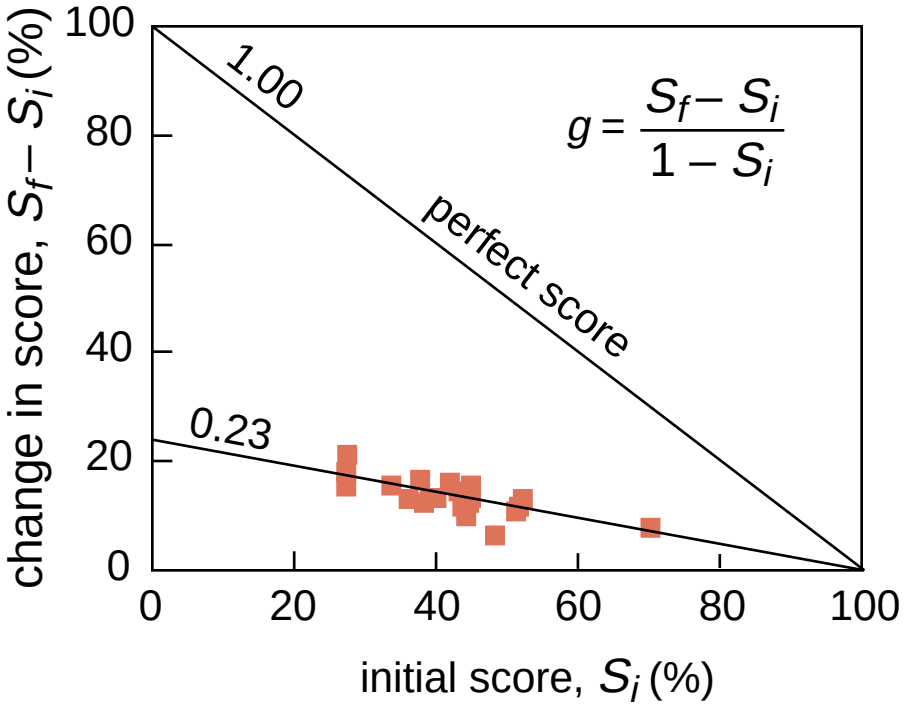

Why do we have this problem?

Conventional problems reinforce bad study habits

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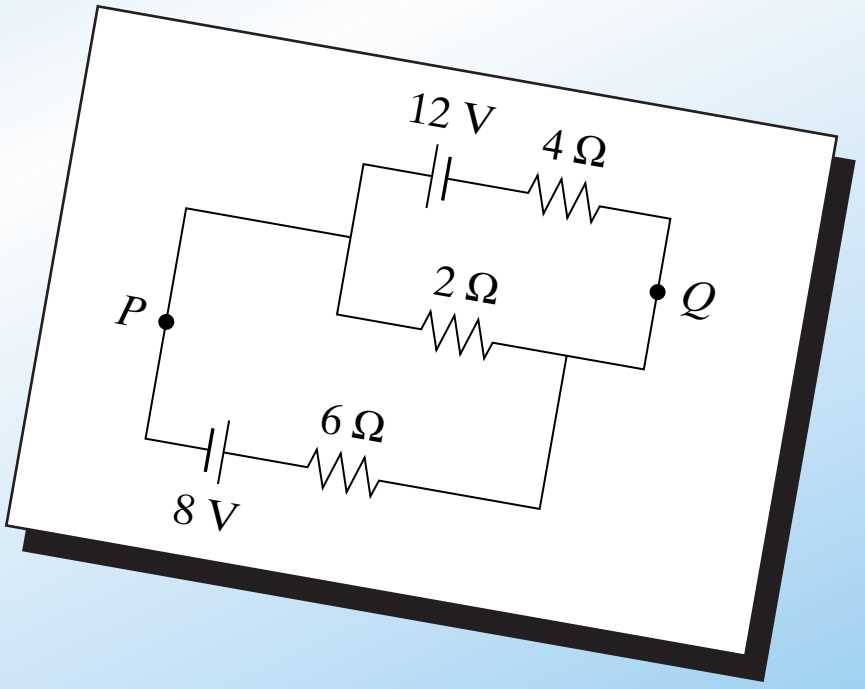

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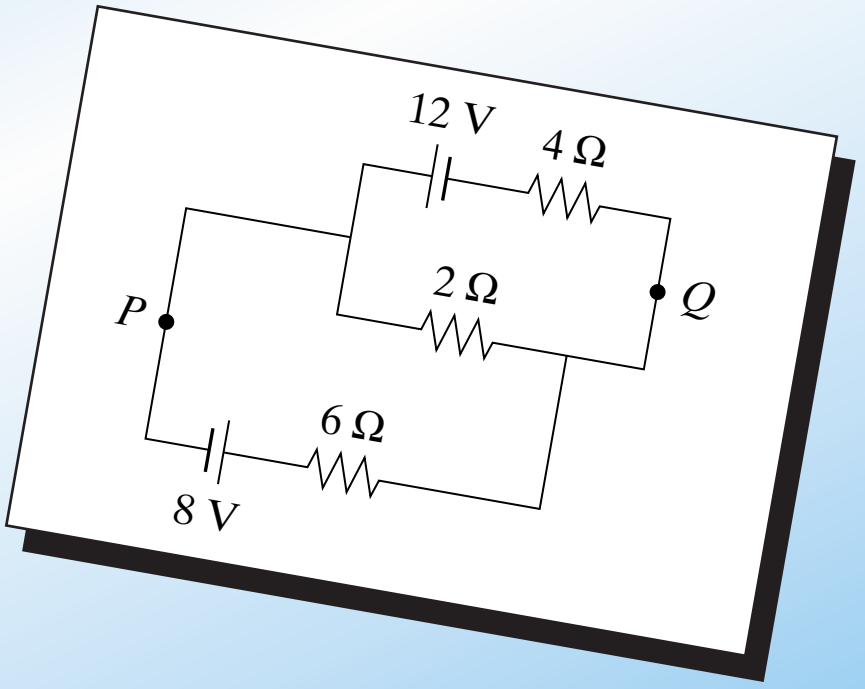
Calculate:

(*a*) the current in the 2-Ω resistor, and

(*b*) the potential difference between points *P* and *Q*



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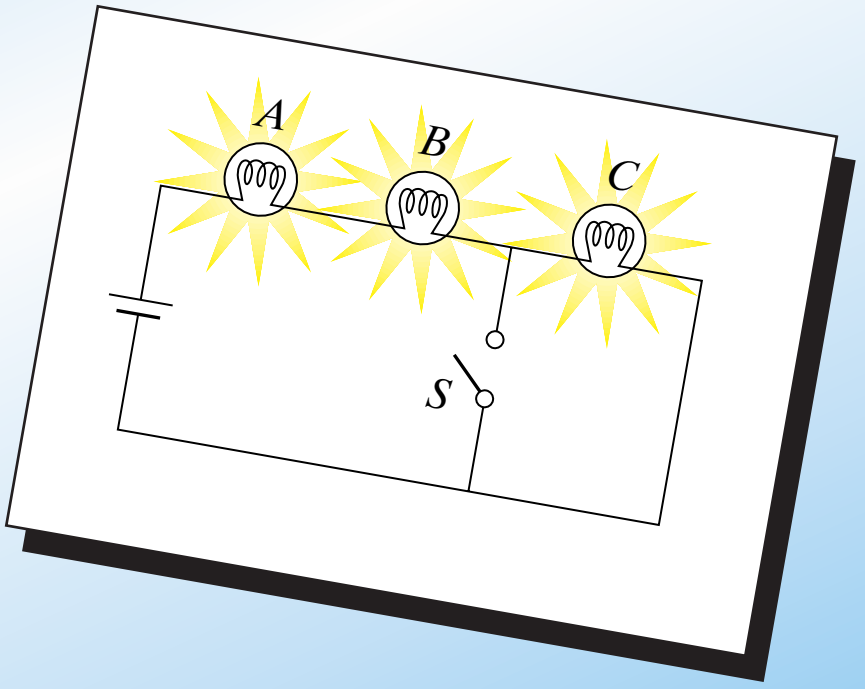
Are basic principles understood?



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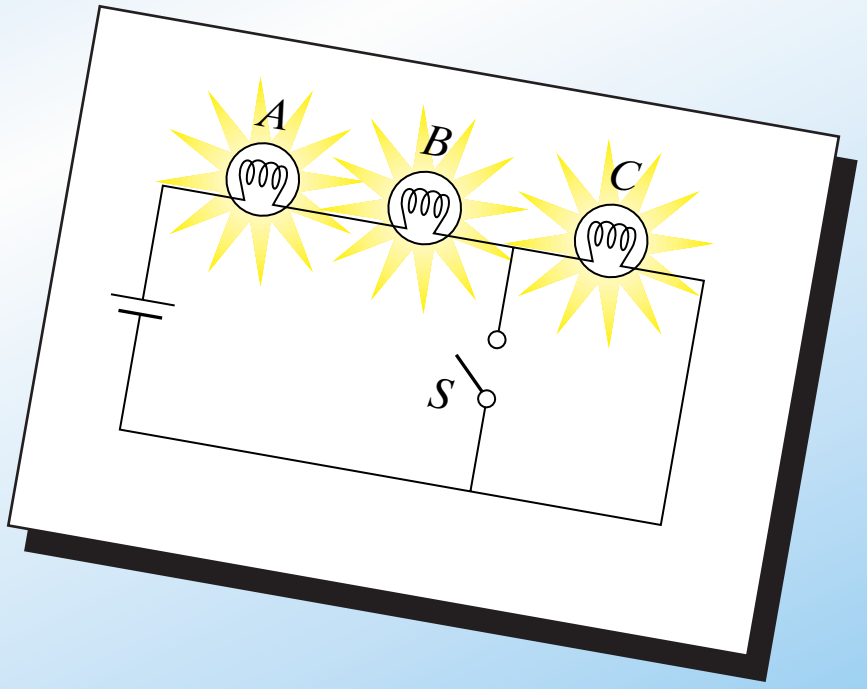
Are basic principles understood?

When *S* is closed, what happens to the:

(*a*) intensities of *A* and *B*?
(*b*) intensity of *C*?
(*c*) current through battery?
(*d*) voltage drop across *A*, *B*, and *C*?
(*e*) total power dissipated?



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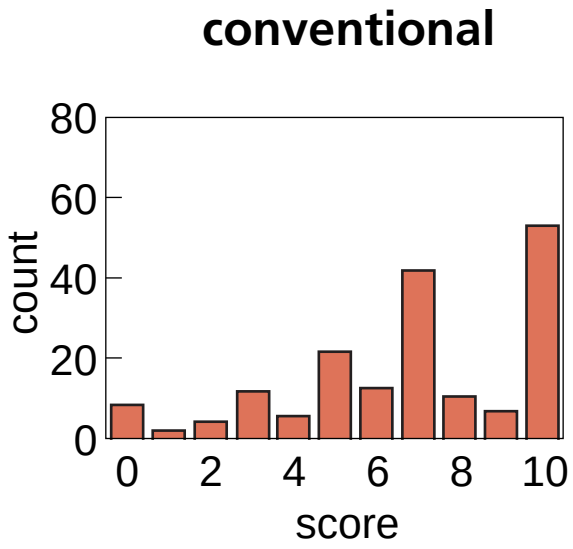

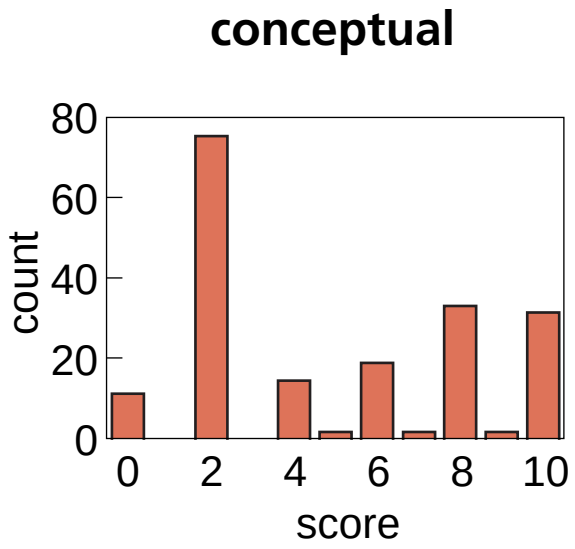

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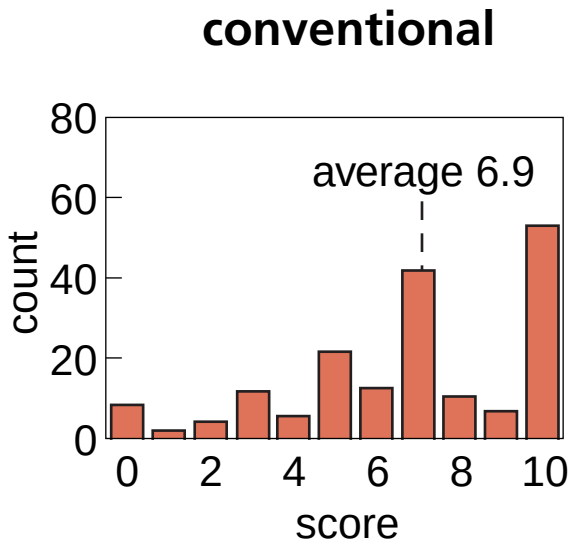

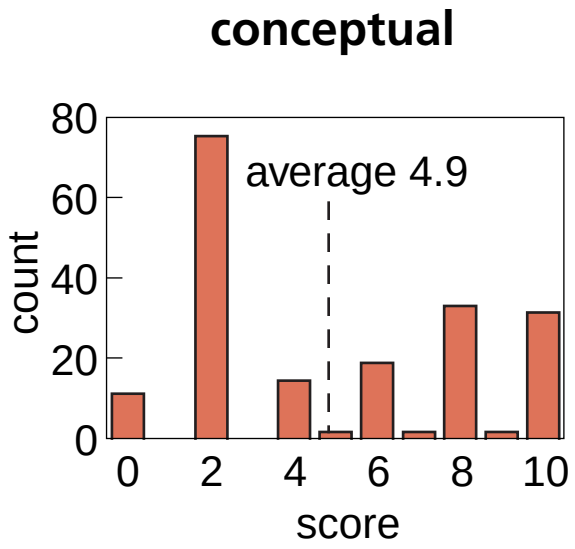

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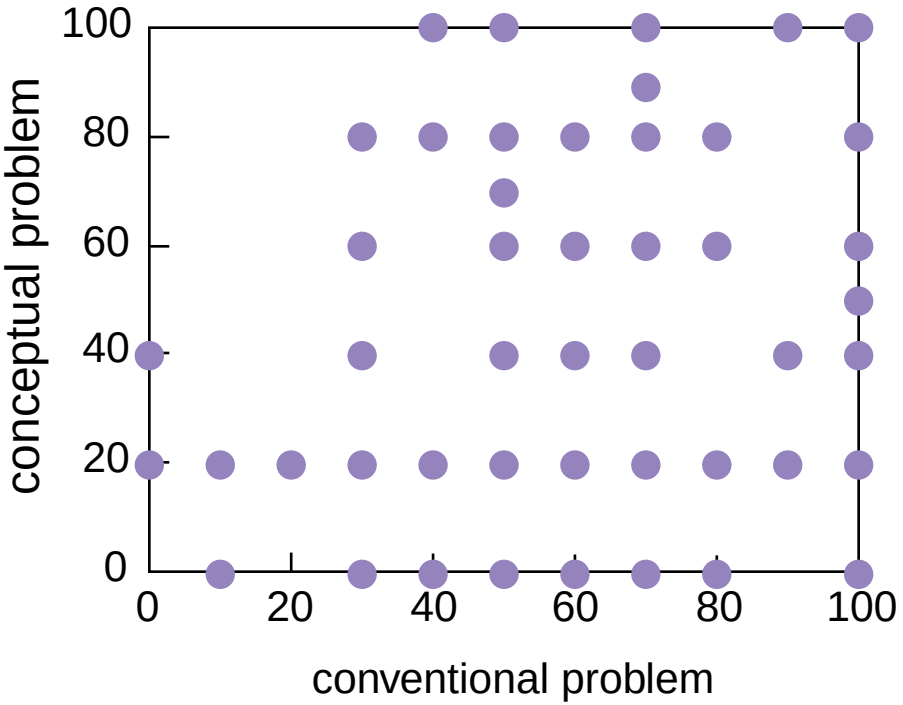

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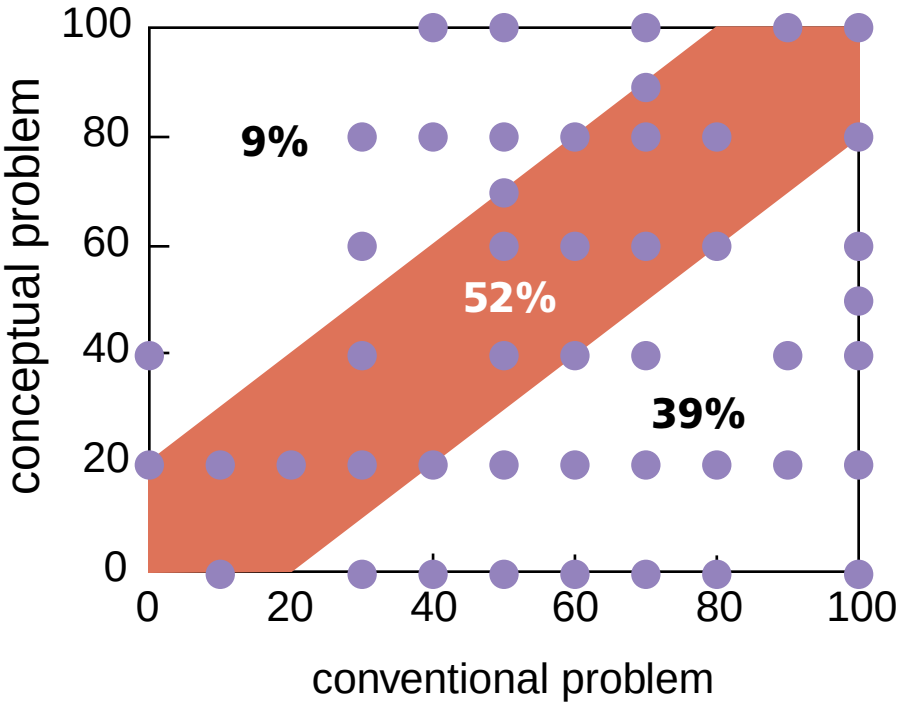



So what should we do?

Peer Instruction

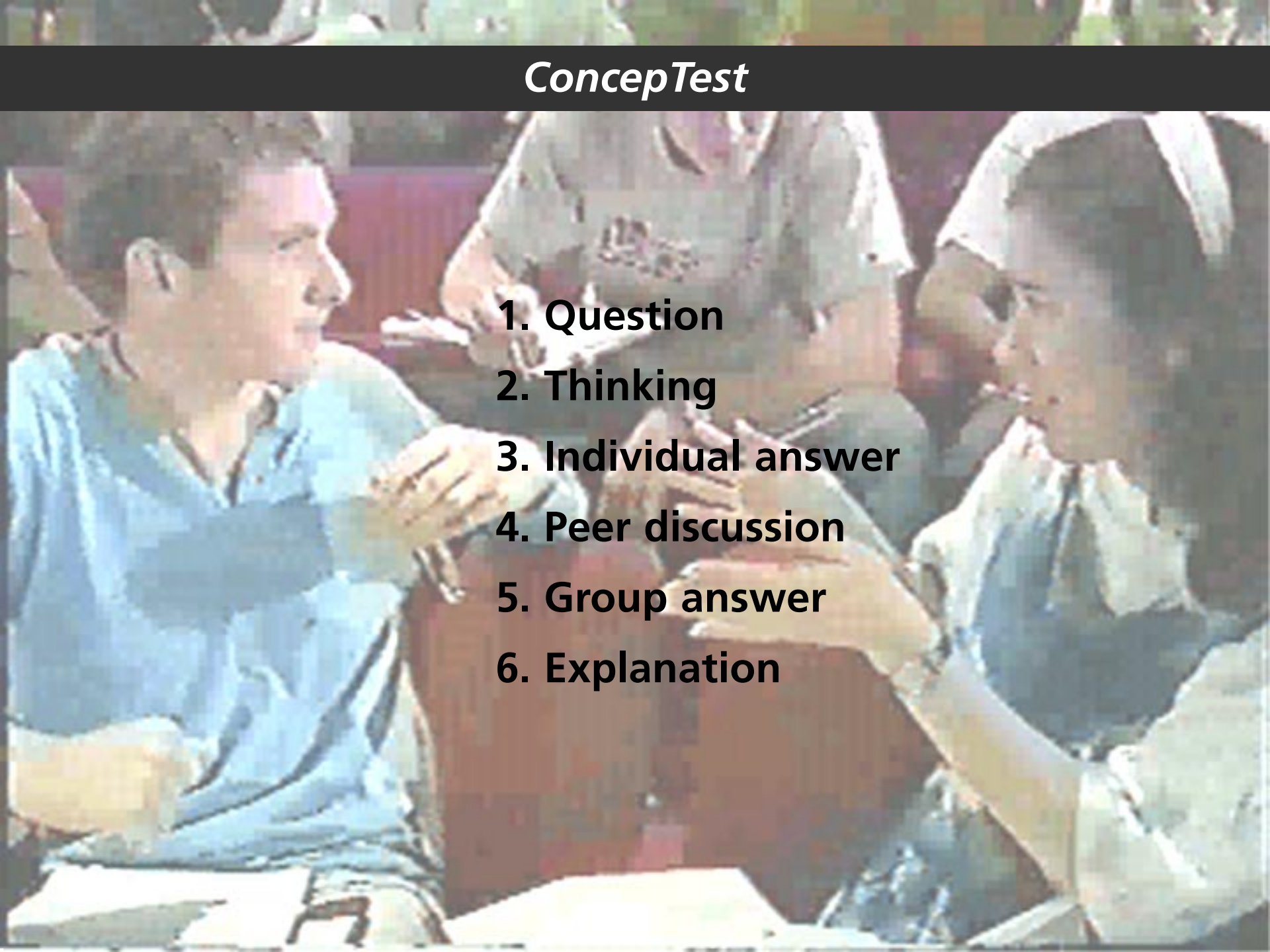
Help students take more responsibility for learning!

Peer Instruction

Main features:

- **Pre-class reading**
- **In class: depth, not coverage**
- **ConcepTests**

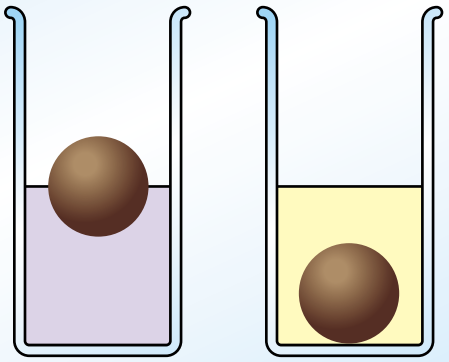
ConcepTest



1. Question
2. Thinking
3. Individual answer
4. Peer discussion
5. Group answer
6. Explanation

ConcepTest

Consider an object that floats in water but sinks in oil. When the object floats in water, half of it is submerged.



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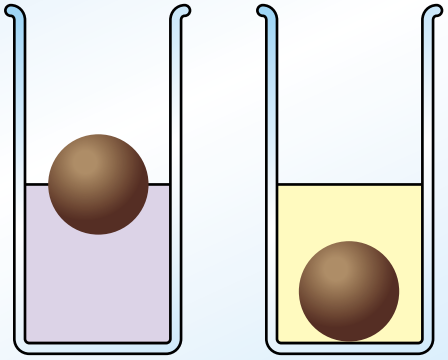
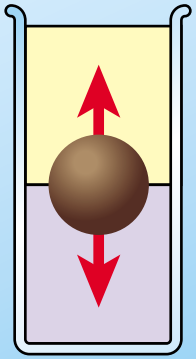


If we slowly pour oil on top of the water so it completely covers the object, the object

1. moves up.

2. stays in the same place.

3. moves down.



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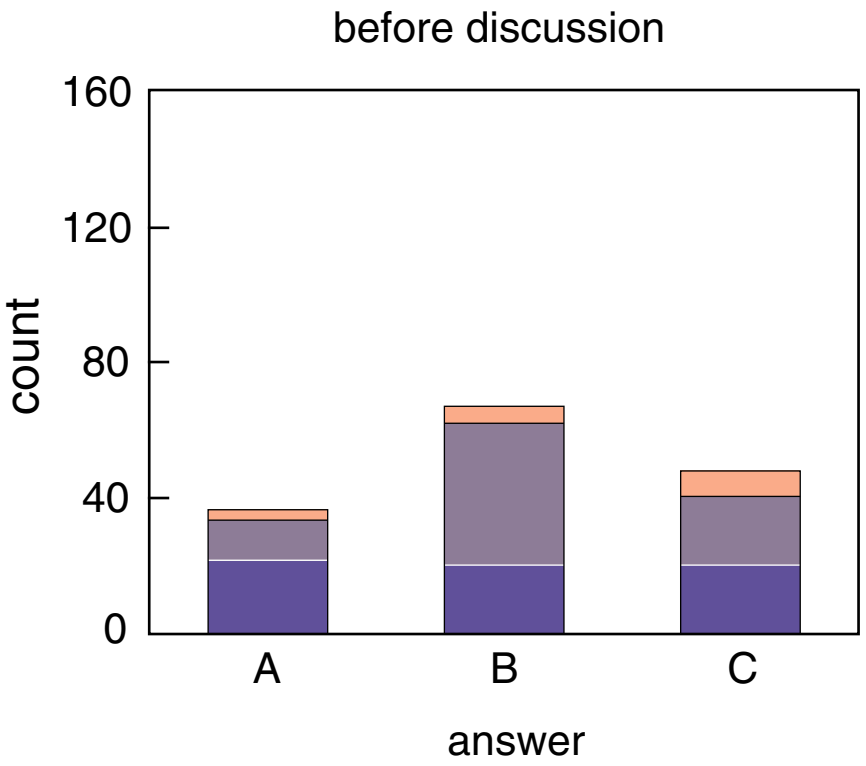

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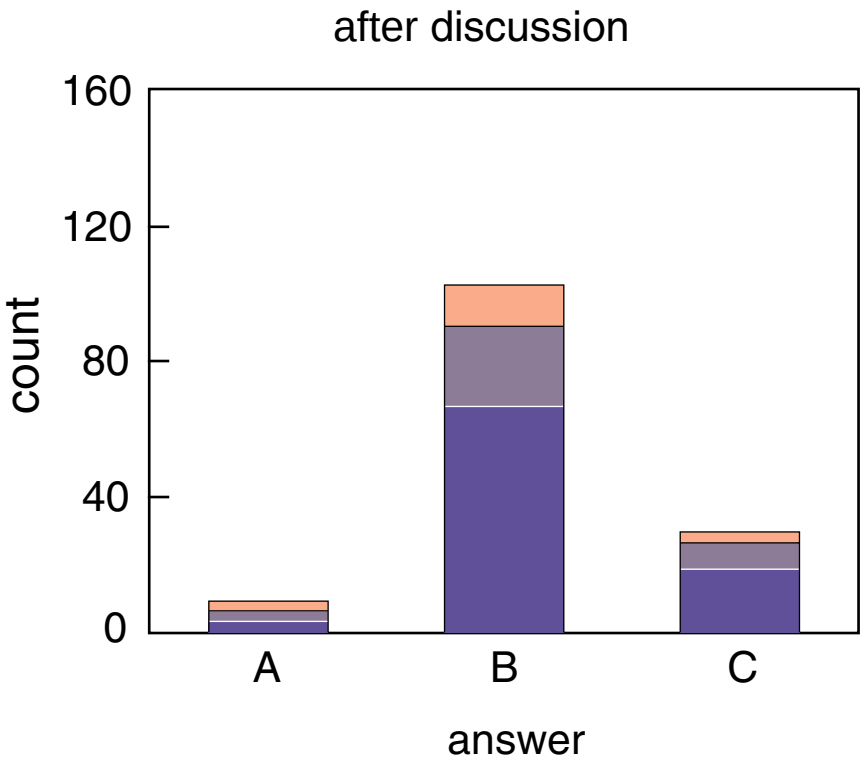

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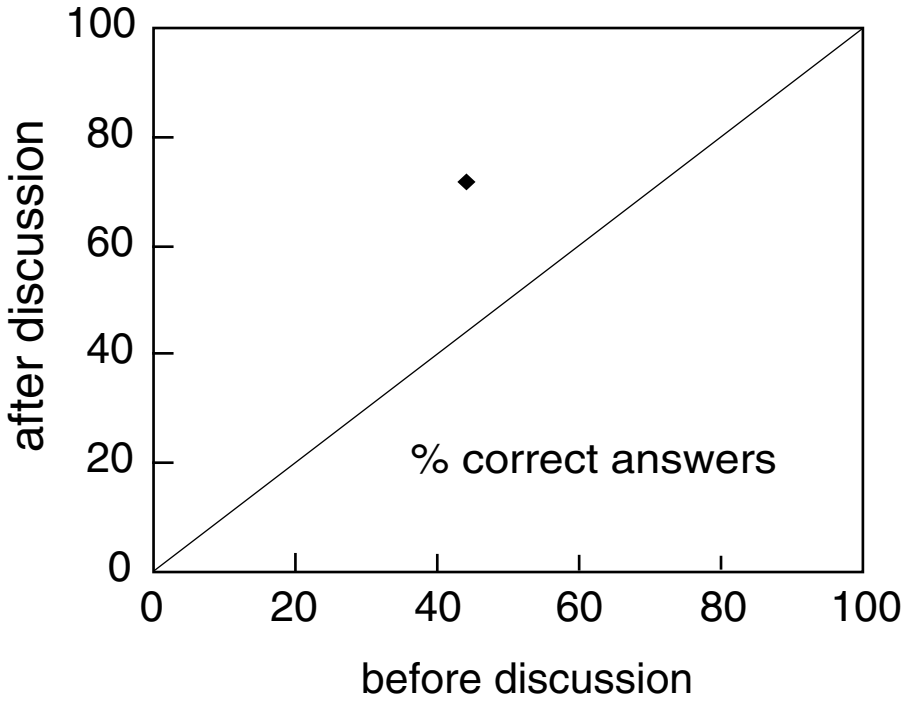

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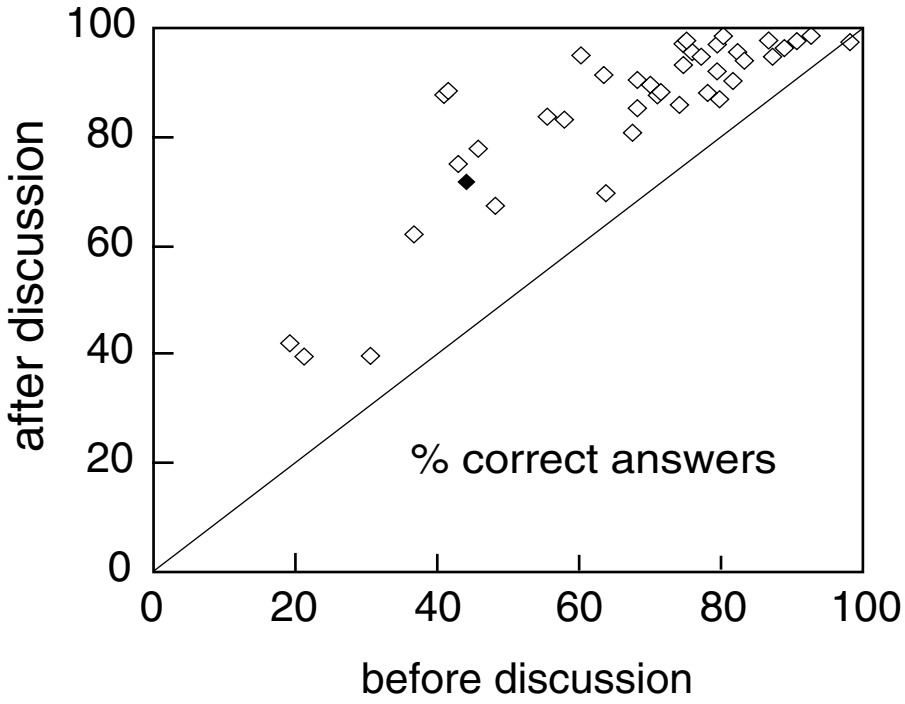

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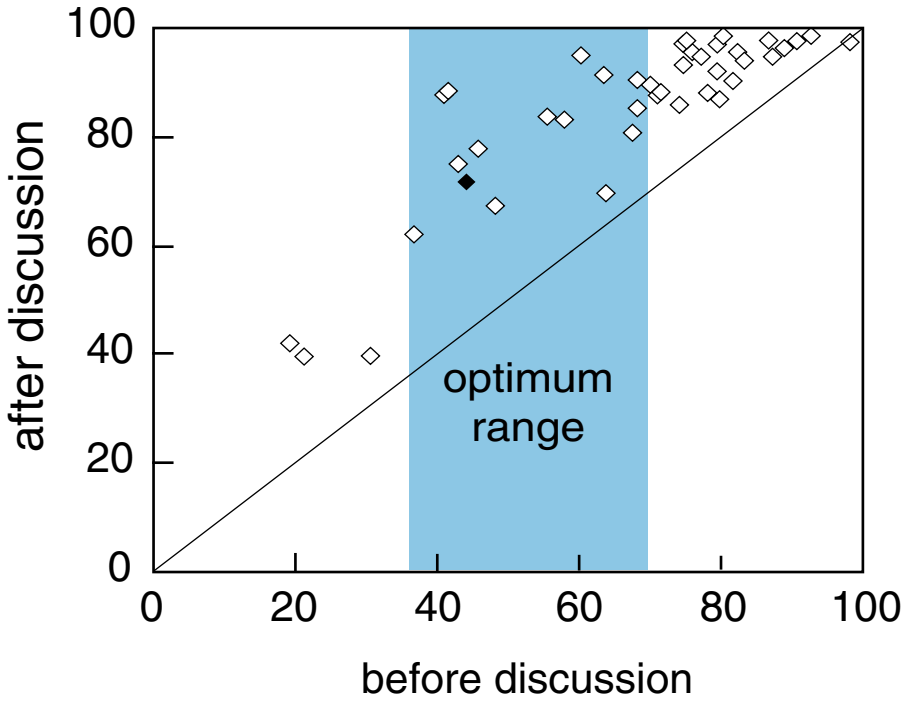

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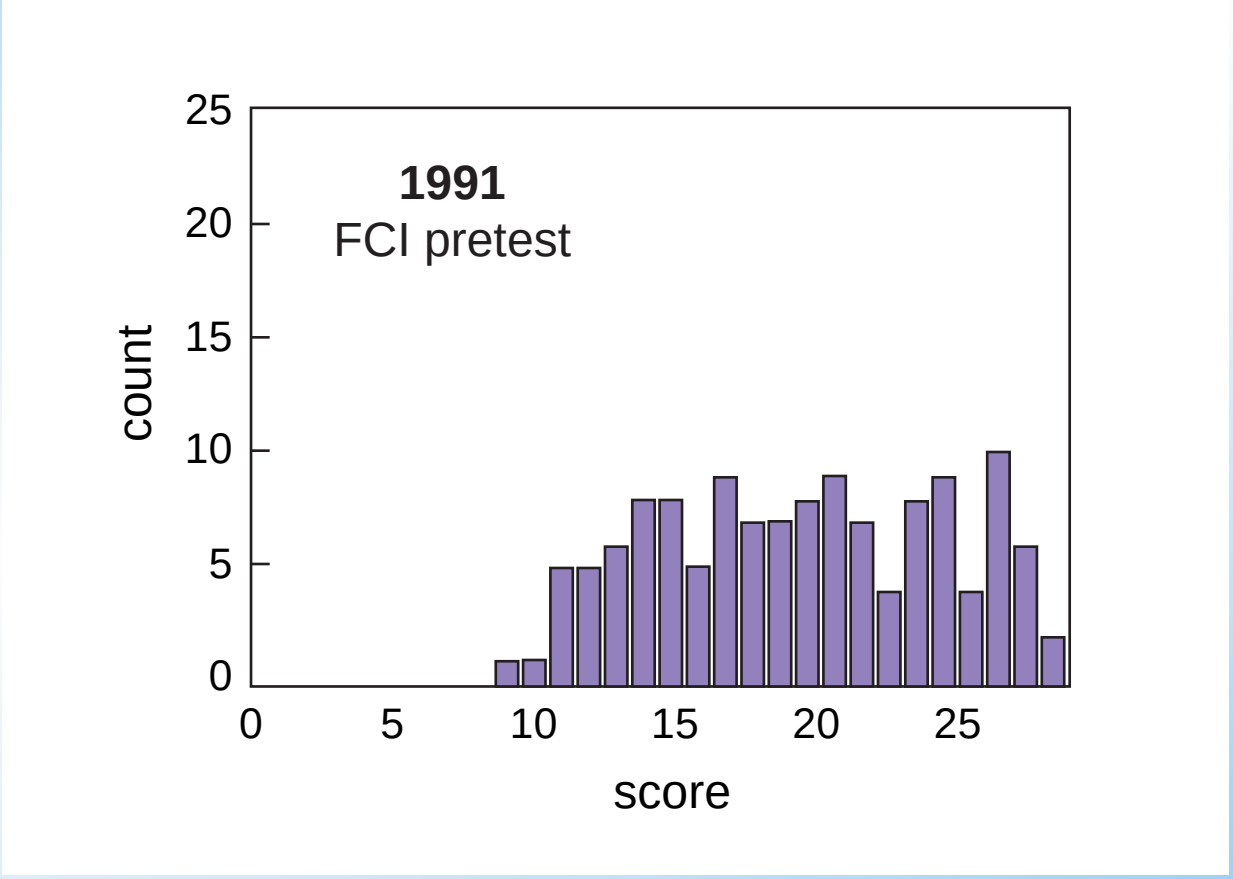

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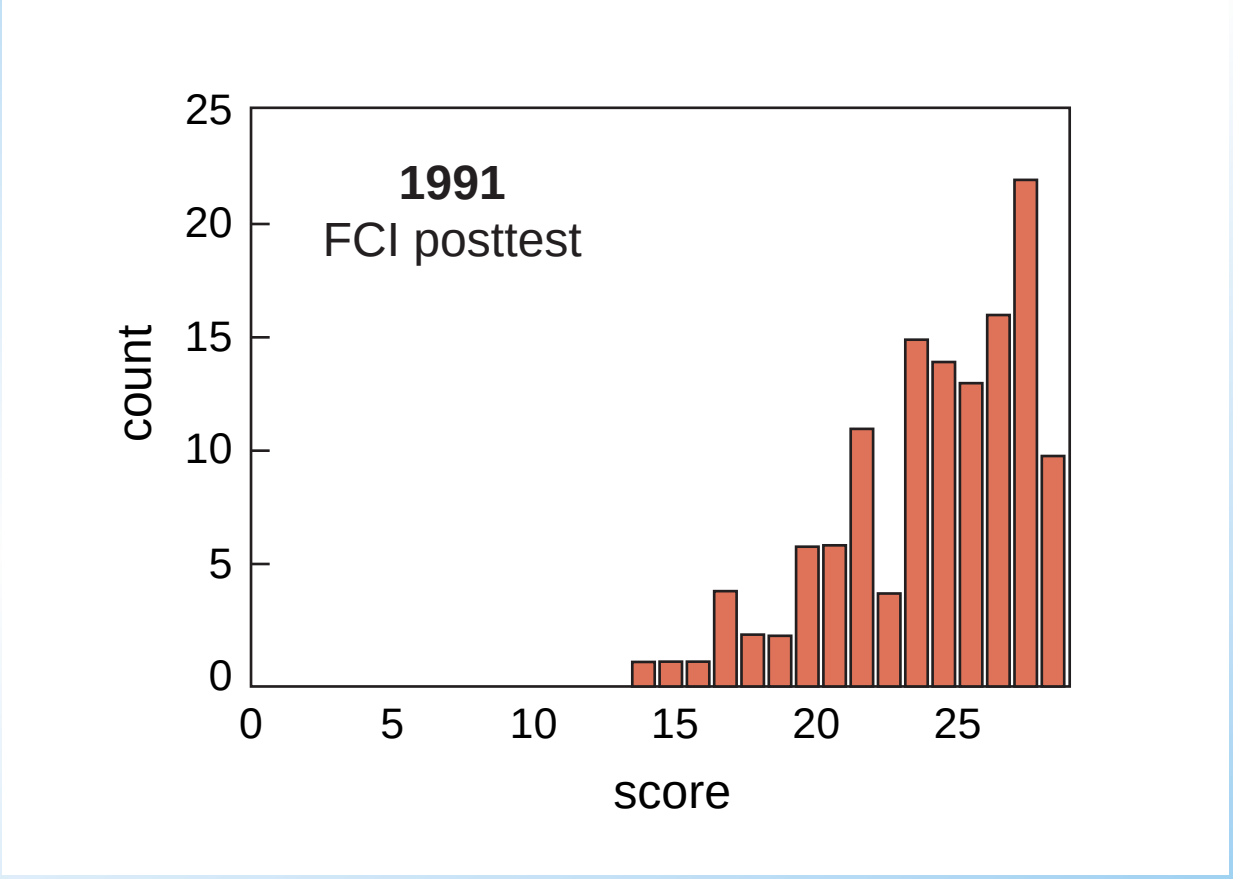

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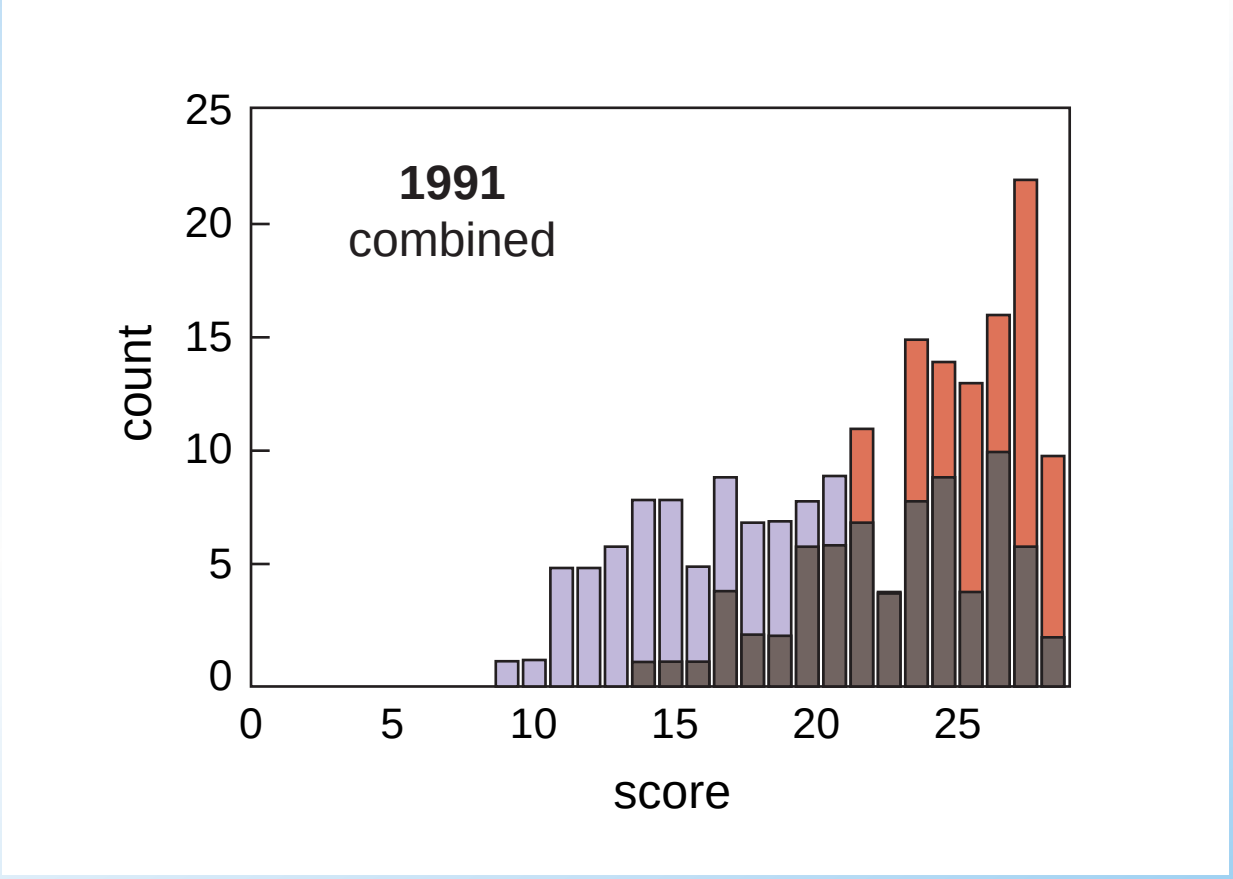

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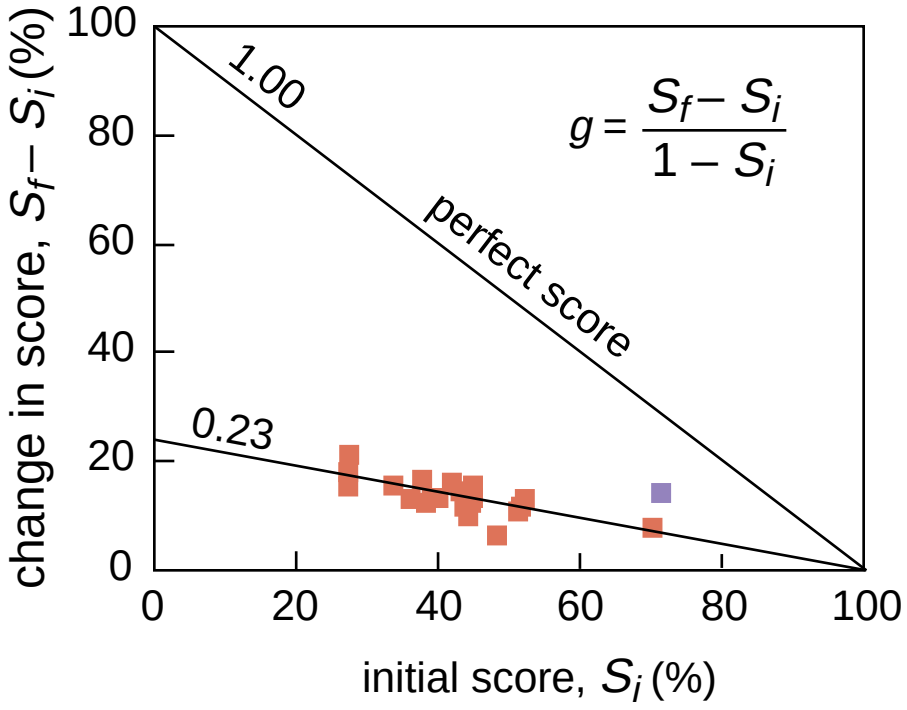
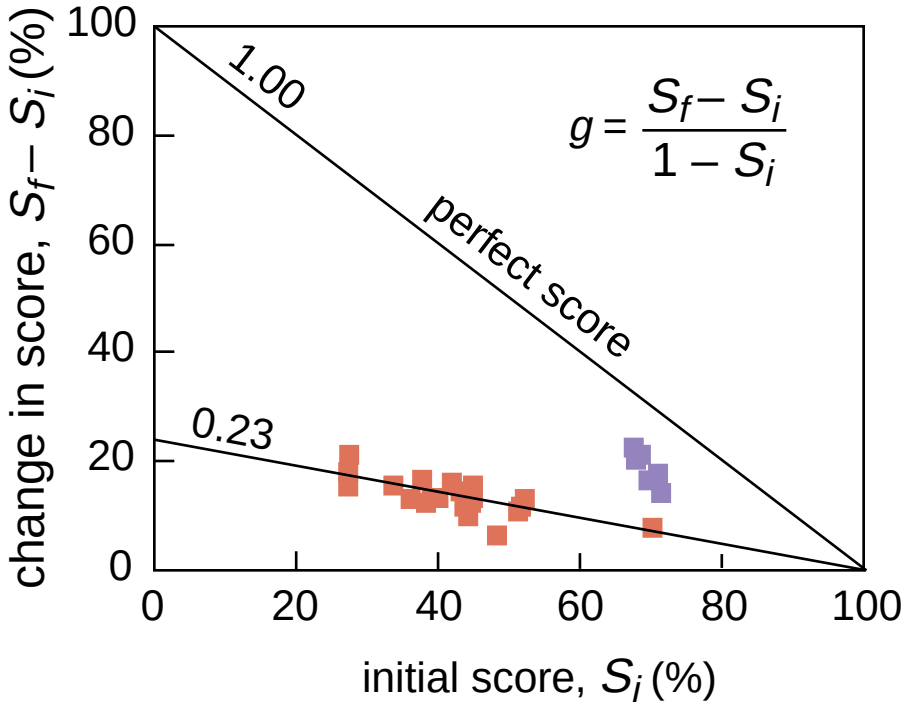

change in score, $S_f - S_i$ (%)
initial score, S_i (%)
0
20
40
60
80
100
1.00
perfect score
0.23
$g = \frac{S_f - S_i}{1 - S_i}$

Results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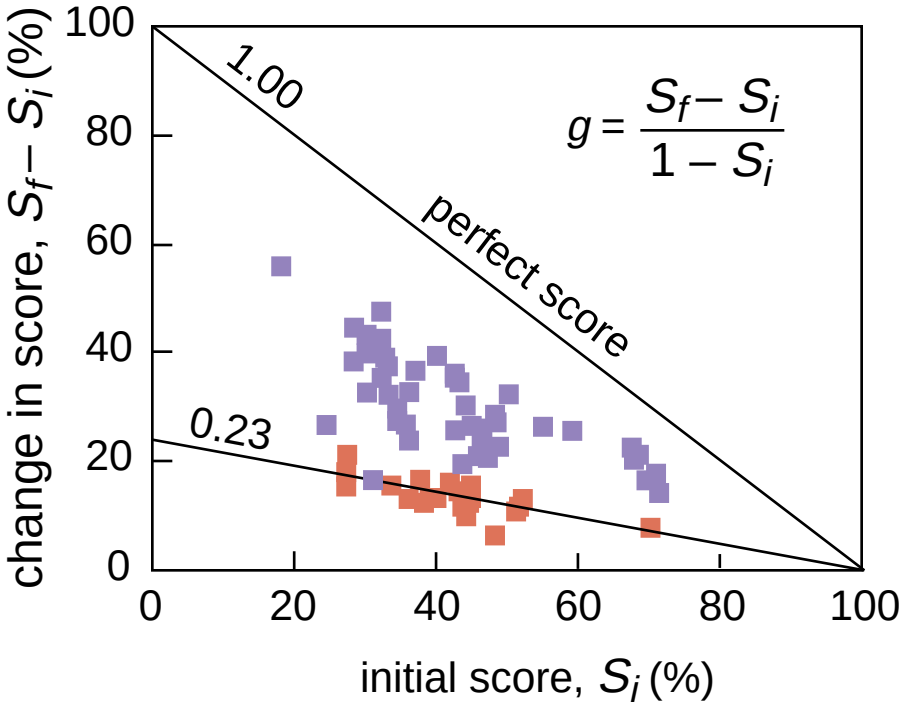
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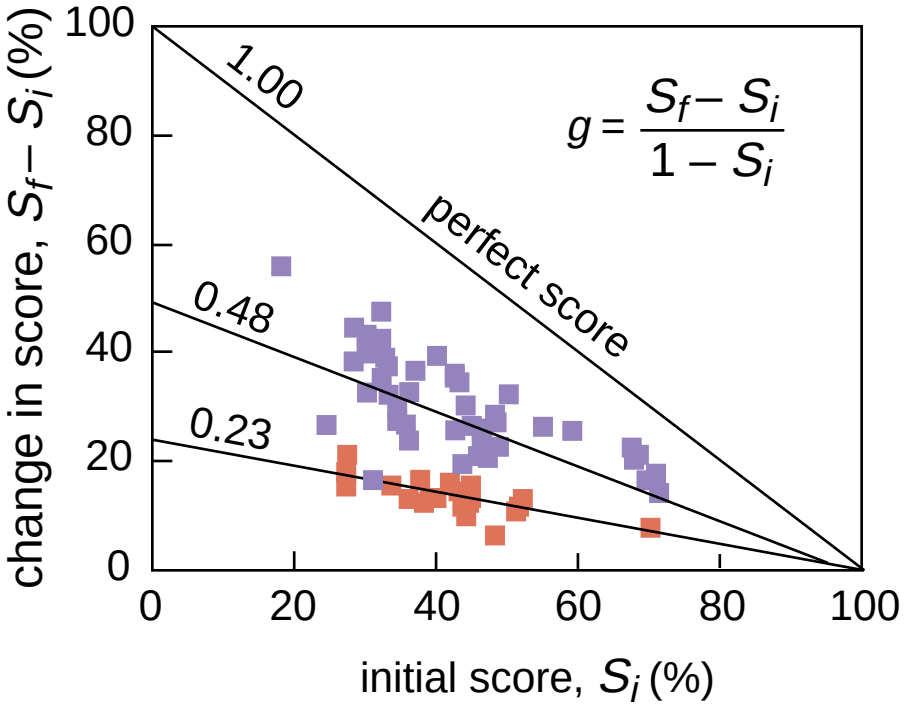
change in score, $S_f - S_i$ (%)
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0
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40
60
80
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1.00
perfect score
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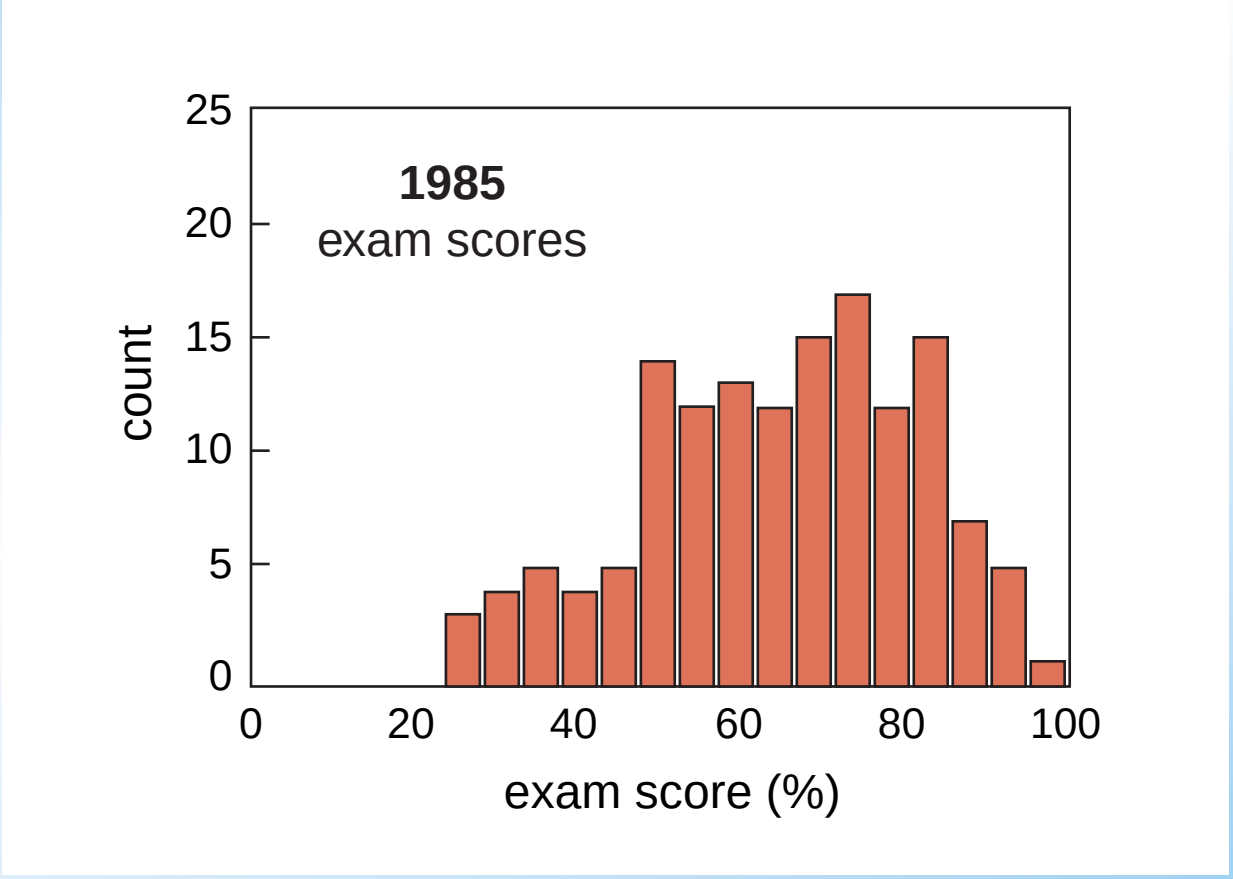
Results

What about problem solving…?

Results


1985
exam scores
count
25
20
15
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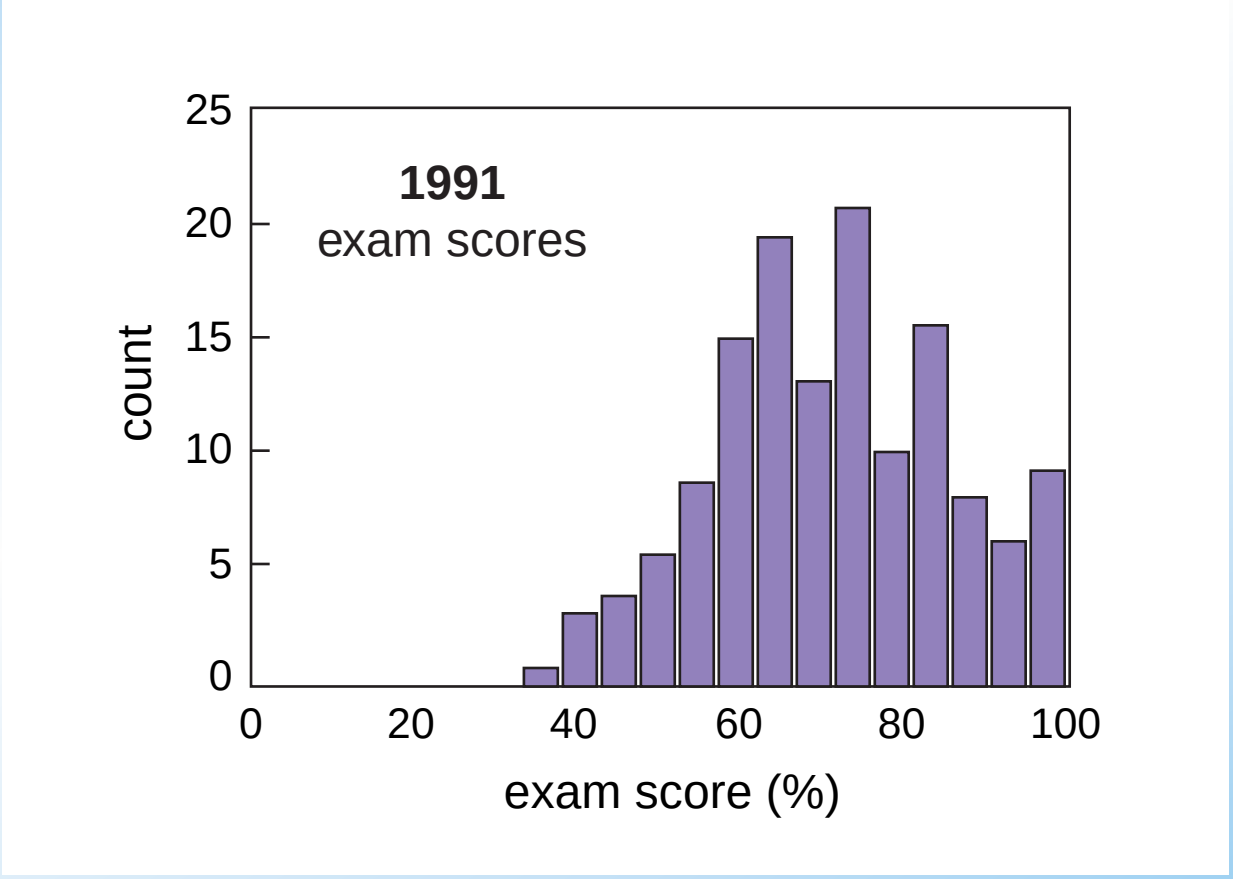
1991
exam scores
count
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100
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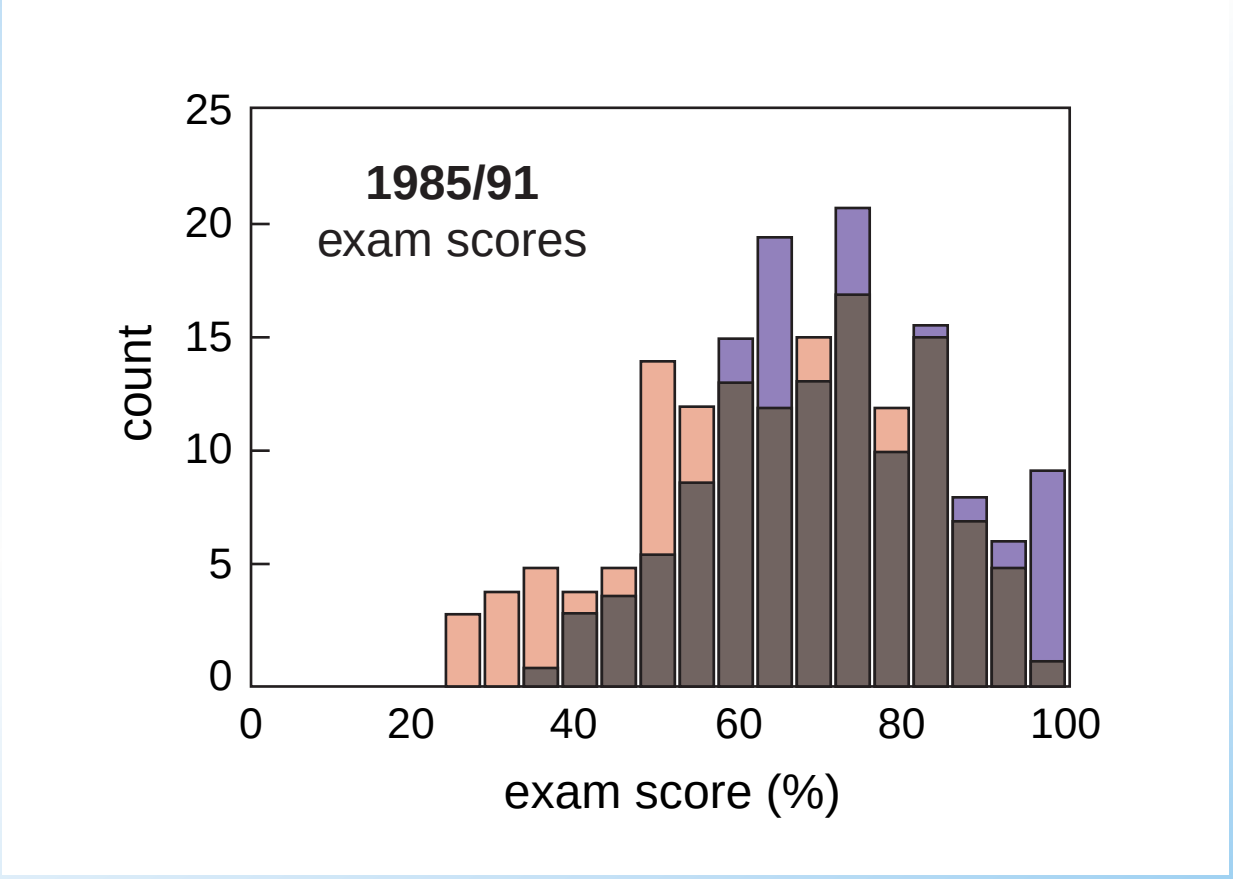
Results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Conclusion

So better understanding leads to better problem solving!

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(but “good” problem solving doesn’t always indicate understanding!)

Conclusion

Challenges:

- internal skepticism
- growing pains
- limited circle of influence

Conclusion

Rewards:

- **engagement**
- **improved understanding**
- **class is fun!**

Funding

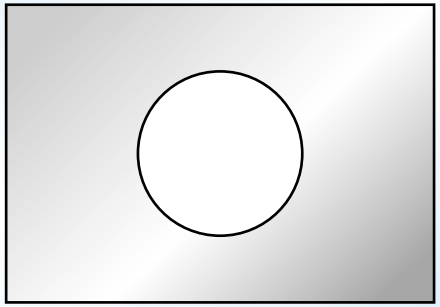
National Science Foundation

For a copy of this talk and additional information:

http://mazur-www.harvard.edu

Question 1

Consider a rectangular metal plate with a circular hole in it.



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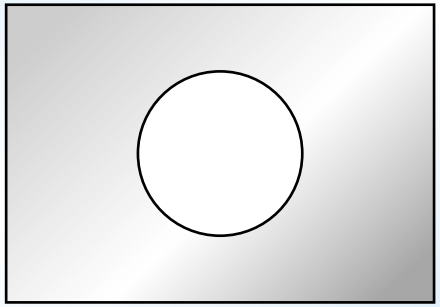

When the plate is uniformly heated, the diameter of the hole

1. increases

2. stays the same

3. decreases

Message 1

It's easy to fire up the audience!

Question 2

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks to the bottom of the lake.

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A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks to the bottom of the lake.

Does the level of the water in the lake (with respect to the shore)

1. go up,

2. go down, or

3. stay the same?

Message 2

We all make mistakes!

Message 3

It's easy to make simple demonstrations fascinating!

Question 4

When we hold a page of printed text in front of a mirror, the text on the image in the mirror runs from right to left:

The New York Times

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When we hold a page of printed text in front of a mirror, the text on the image in the mirror runs from right to left:

The New York Times

Why is it that right and left are interchanged and not top and bottom? Because

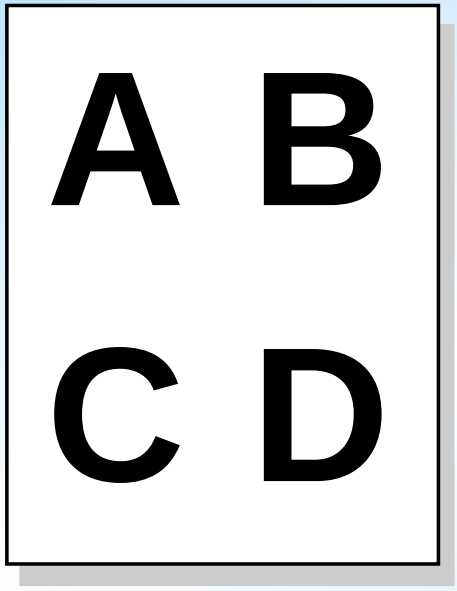
1. **the mirror is oriented vertically,**
2. **we have two eyes in the horizontal plane,**
3. **the Earth's gravitation is directed downward,**
4. **a habit we have when looking at images in a mirror,**
5. **It only *appears* to run from left to right.**

Message 4

It's "simple" only if you know the answer

Feedback

Flashcards: simple and effective!



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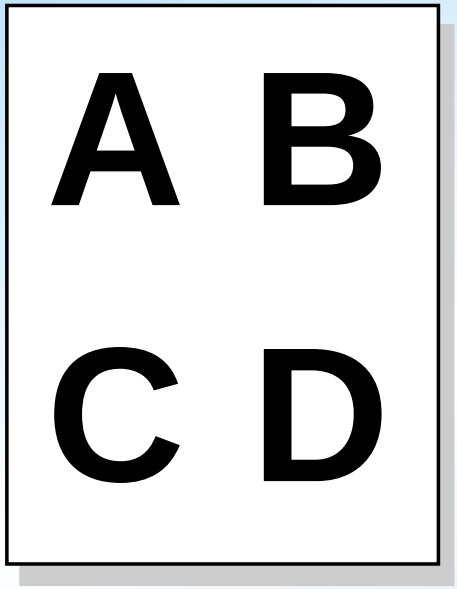

Problem with problems

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Requires assumptions
Requires developing a model
Requires applying that model

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Requires applying a (new) model

Problem with problems

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area where people are known to shop, on average, for two hours. You circle around, but there are no empty spots. You decide to wait at one end of the lot, where you can see (and command) about 20 spaces.

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Requires using a calculator

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Essential elements

- **Reading (before class)**
- **Participation (during class)**
- **Problem-solving (after class)**
- **Appropriate testing/assessment**

Coverage

traditional	
coverage	encyclopedic
retention	disappointing

Coverage

	traditional	interactive
coverage	encyclopedic	less?
retention	disappointing	more!

Coverage

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coverage	encyclopedic	less?
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"What counts is not how much is covered, but how much is uncovered"

Viki Weisskopf

Reading

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

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

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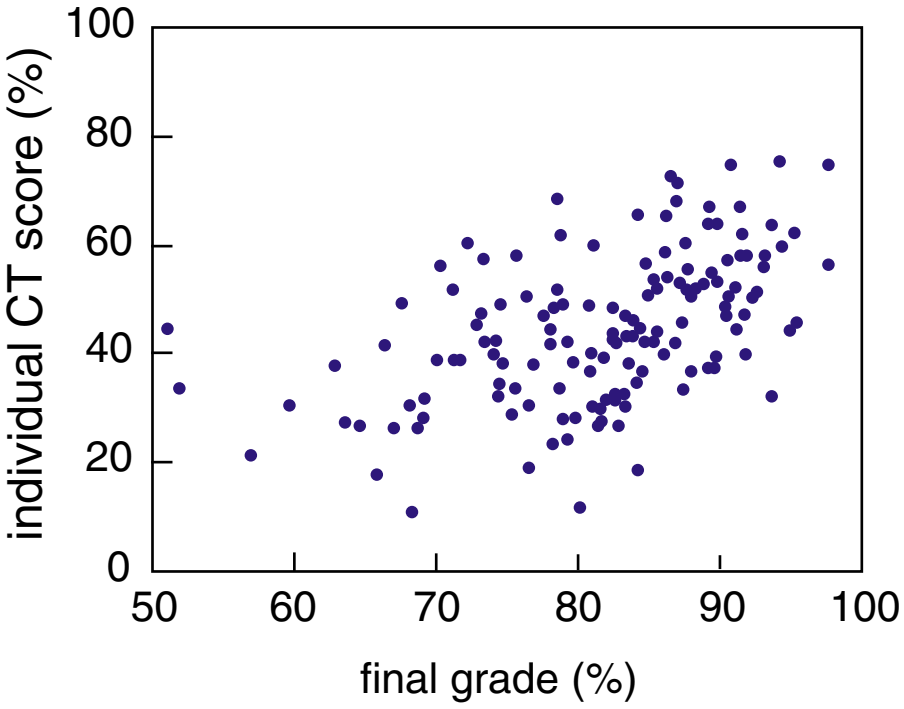
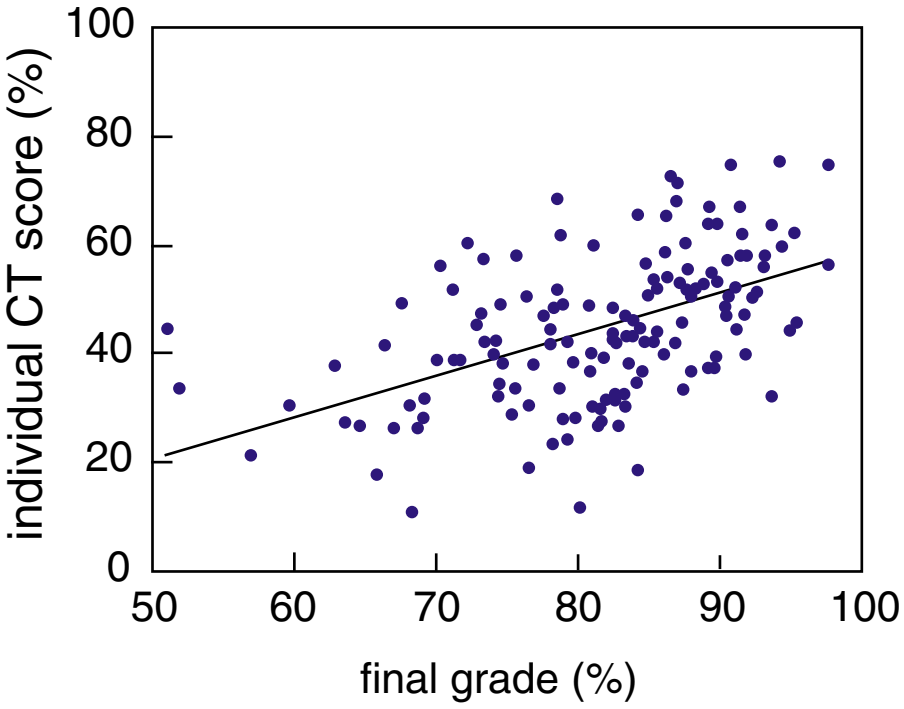
- **Graded on effort**
- **5% of final grade**

Who benefits?

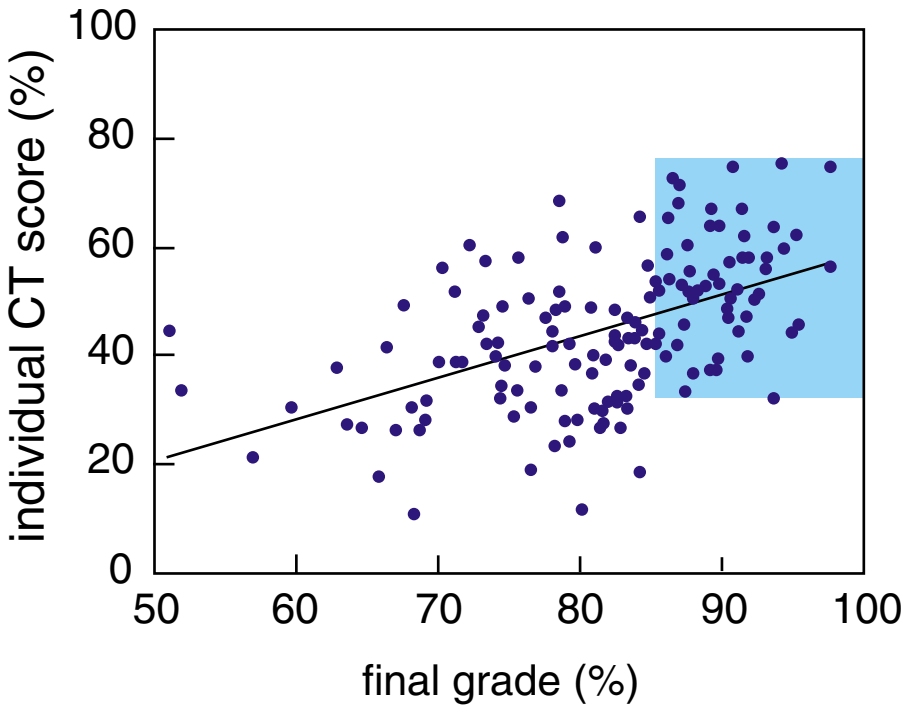


Who benefits?



Who benefits?

even best students are challenged!



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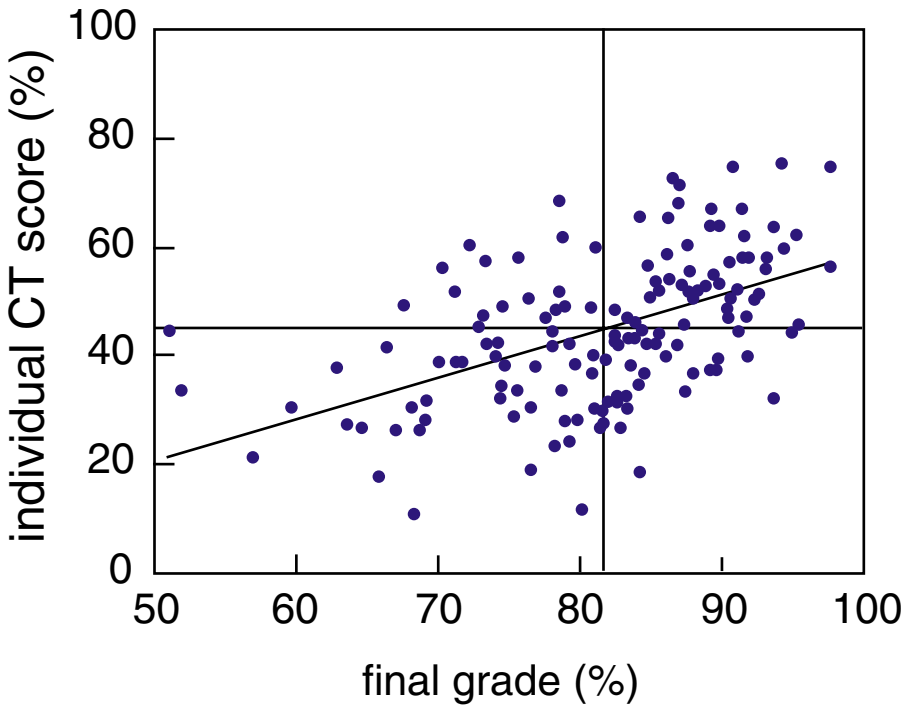

Resources

Peer Instruction: A User's Manual **(Prentice Hall, 1997)**

http://galileo.harvard.edu

Funding

National Science Foundation

For a copy of this talk and additional information:

http://mazur-www.harvard.edu