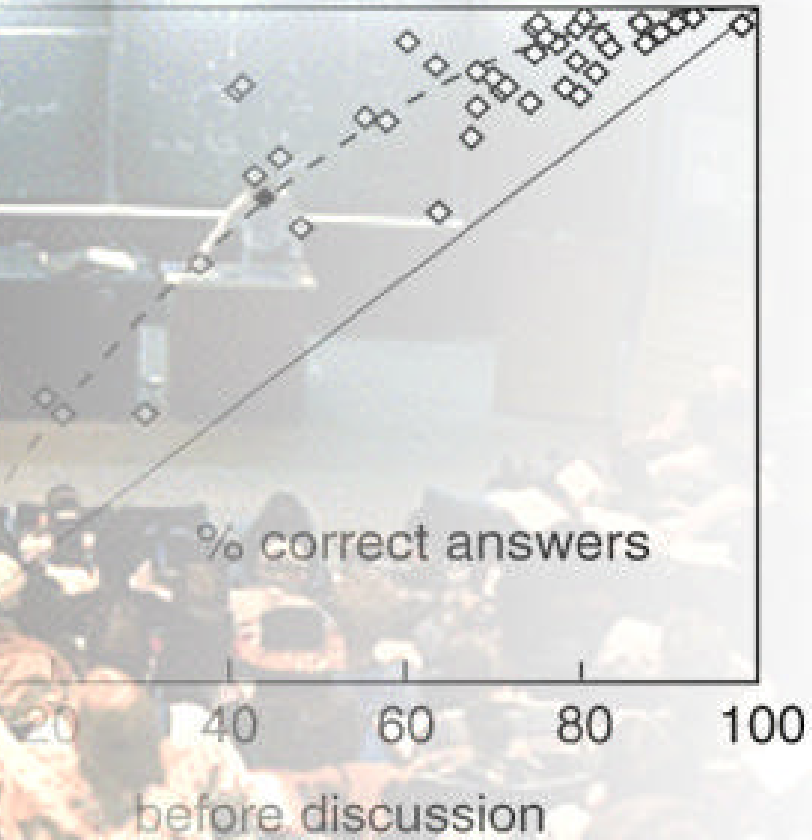
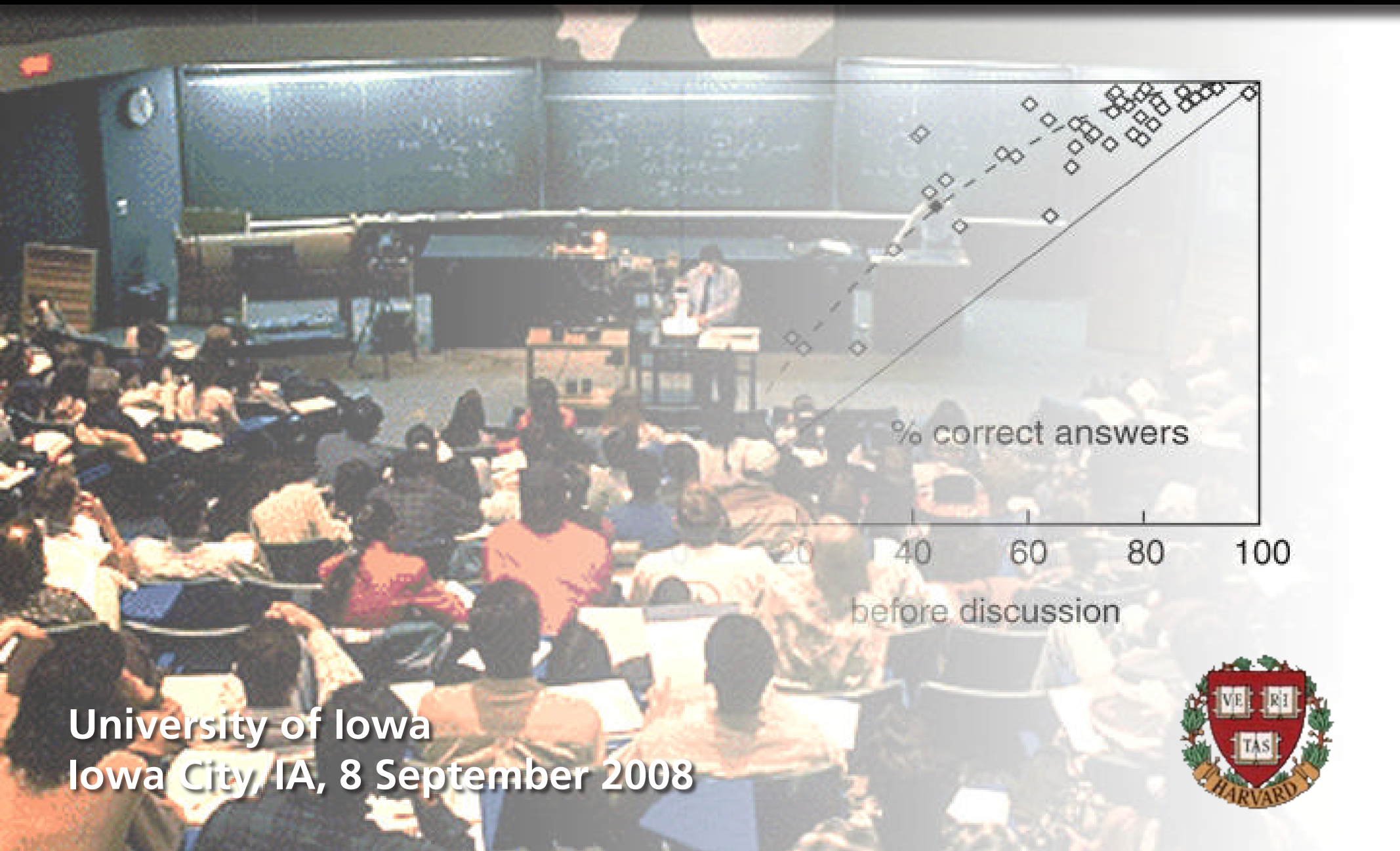


# The scientific approach to teaching: research as a basis for course design



University of Iowa  
Iowa City, IA, 8 September 2008

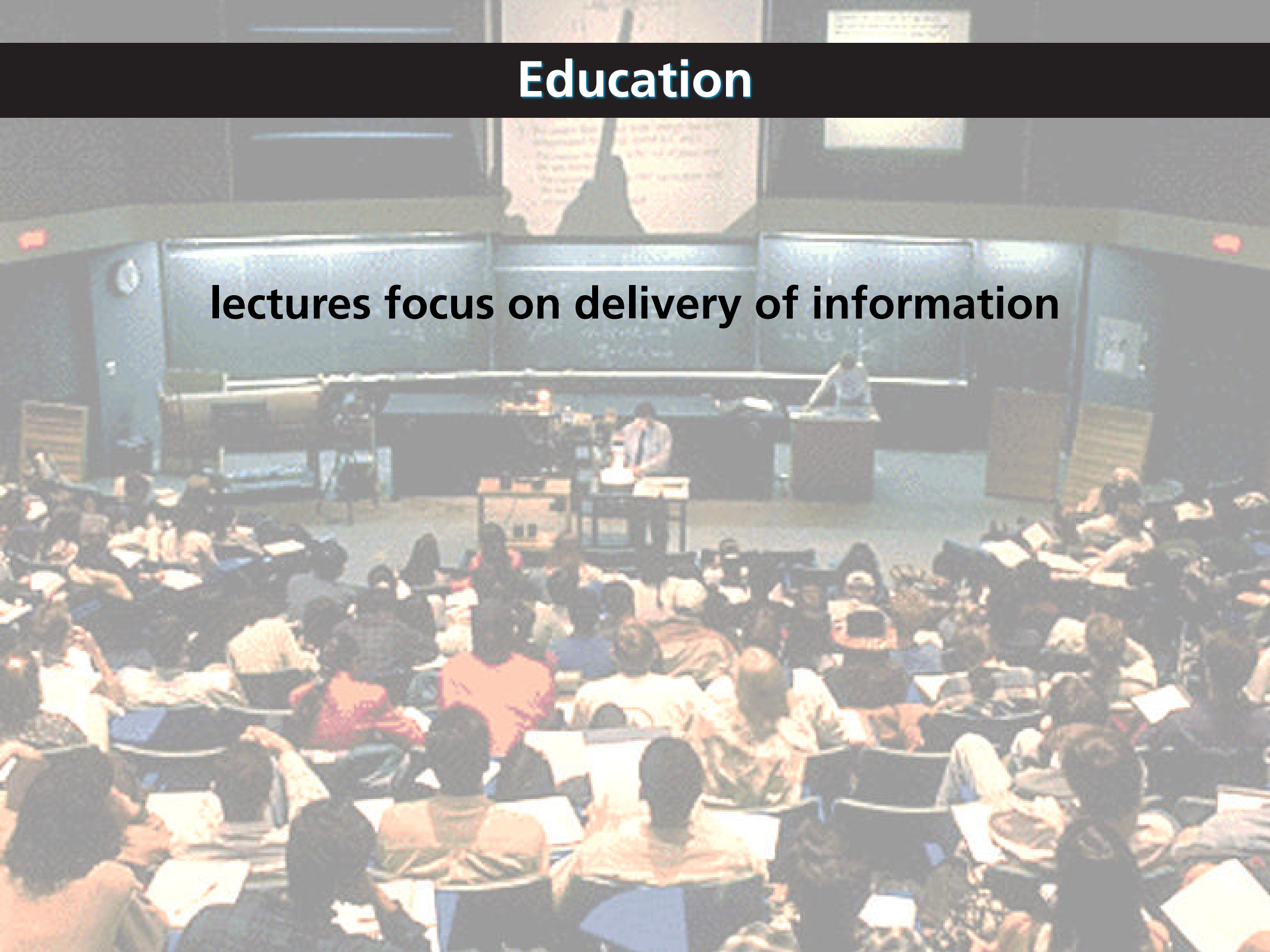


# Education



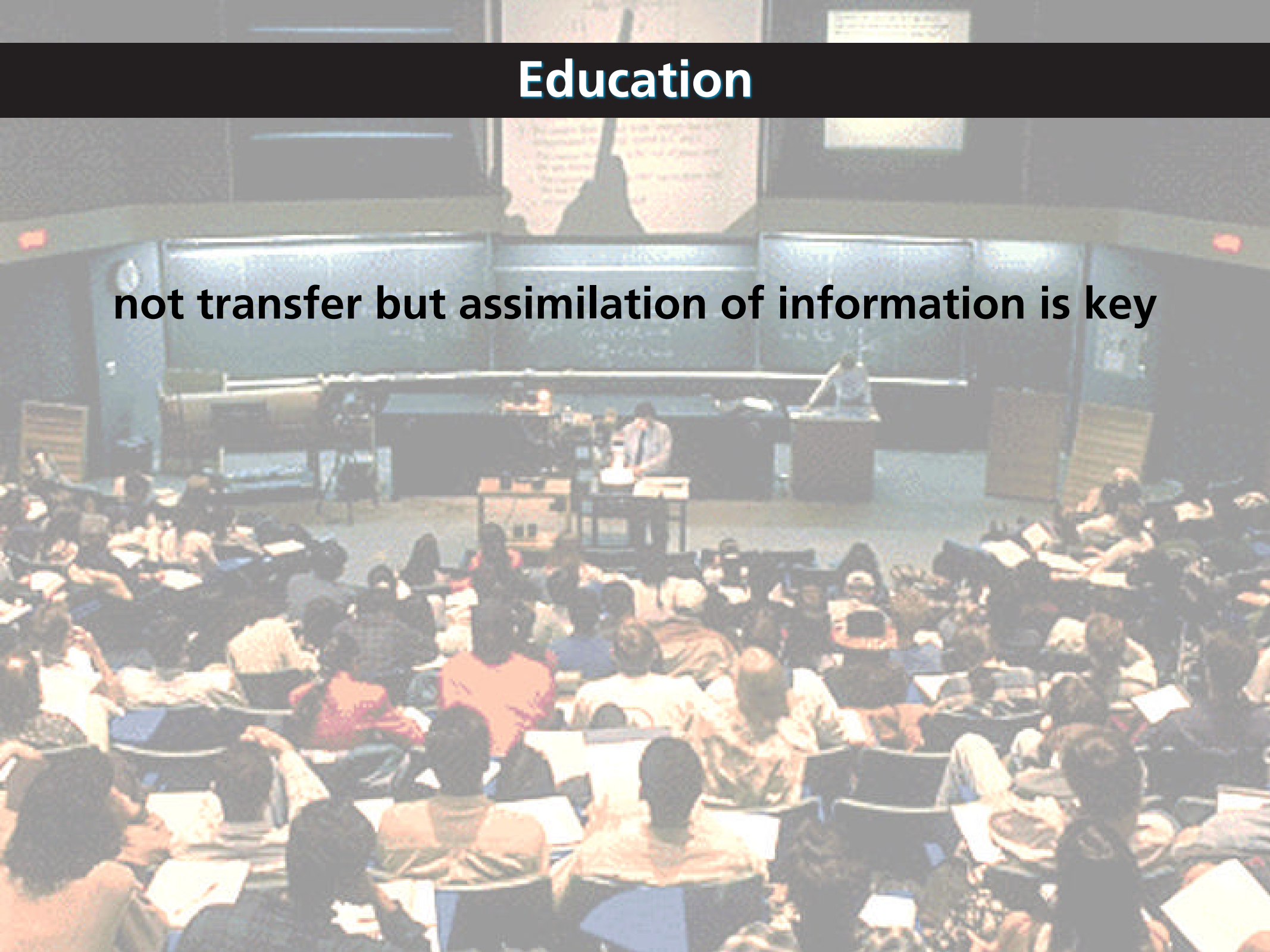
# Education

lectures focus on delivery of information



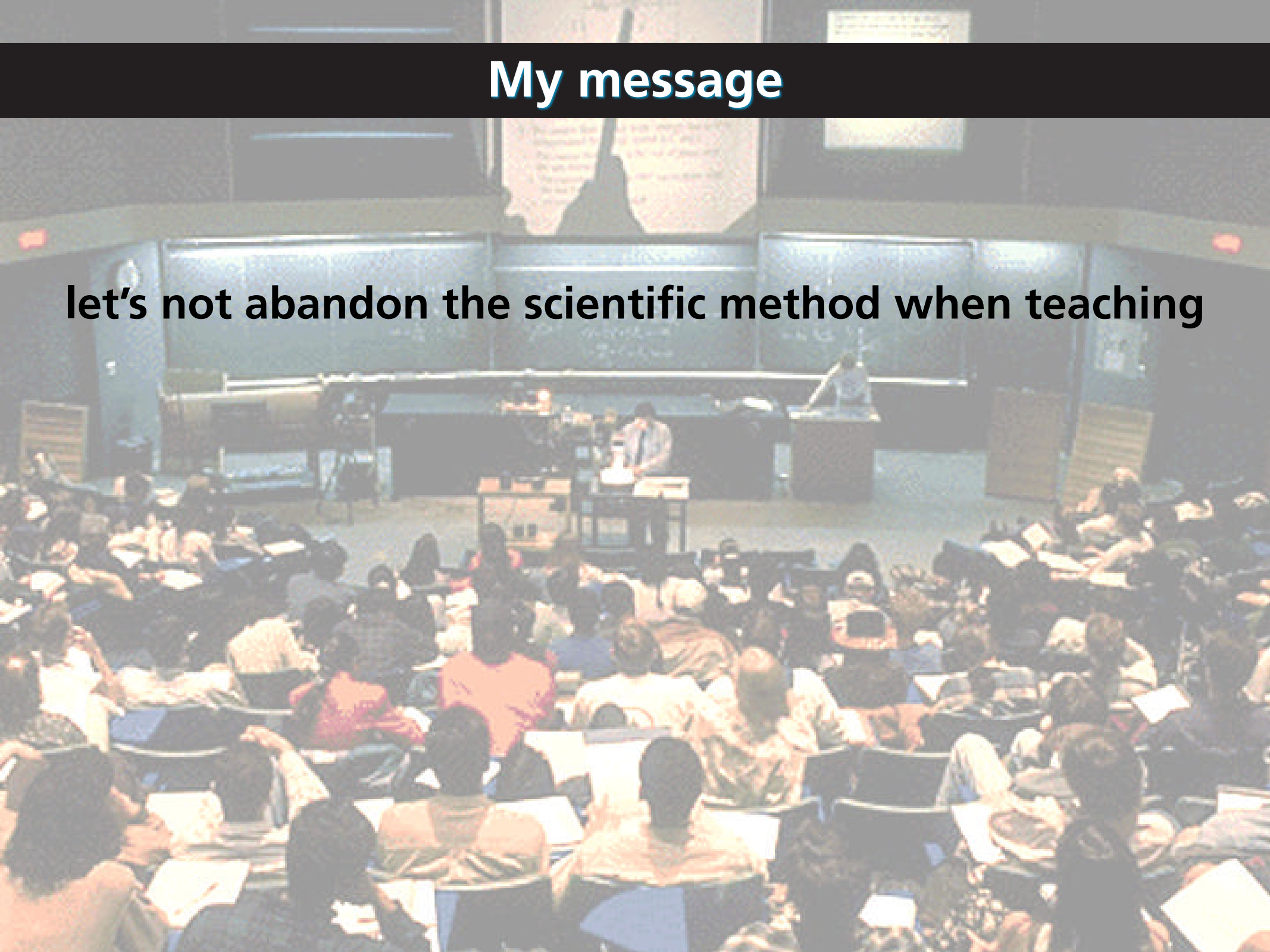
# Education

**not transfer but assimilation of information is key**



# My message

**let's not abandon the scientific method when teaching**

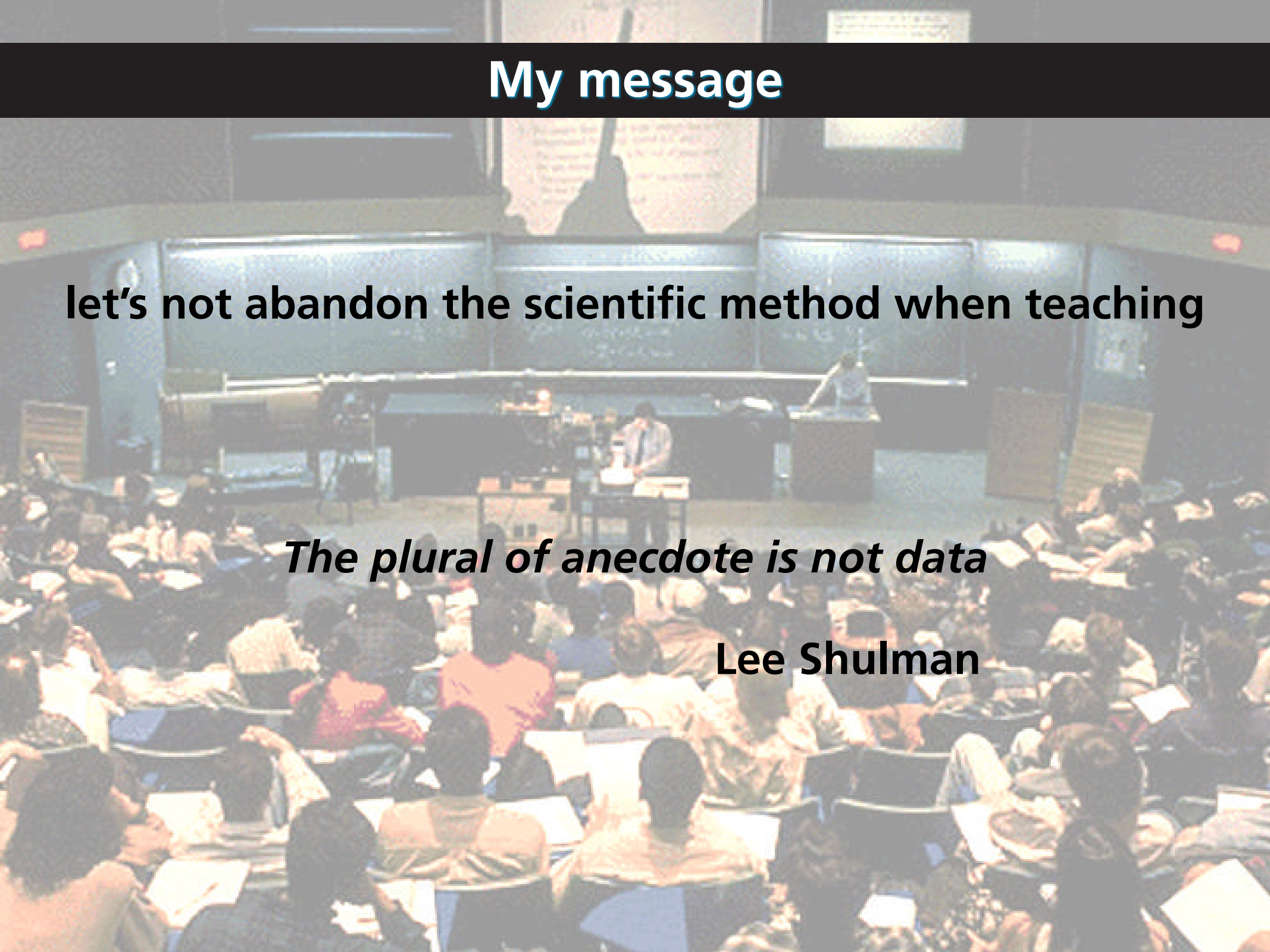


# My message

let's not abandon the scientific method when teaching

*The plural of anecdote is not data*

Lee Shulman



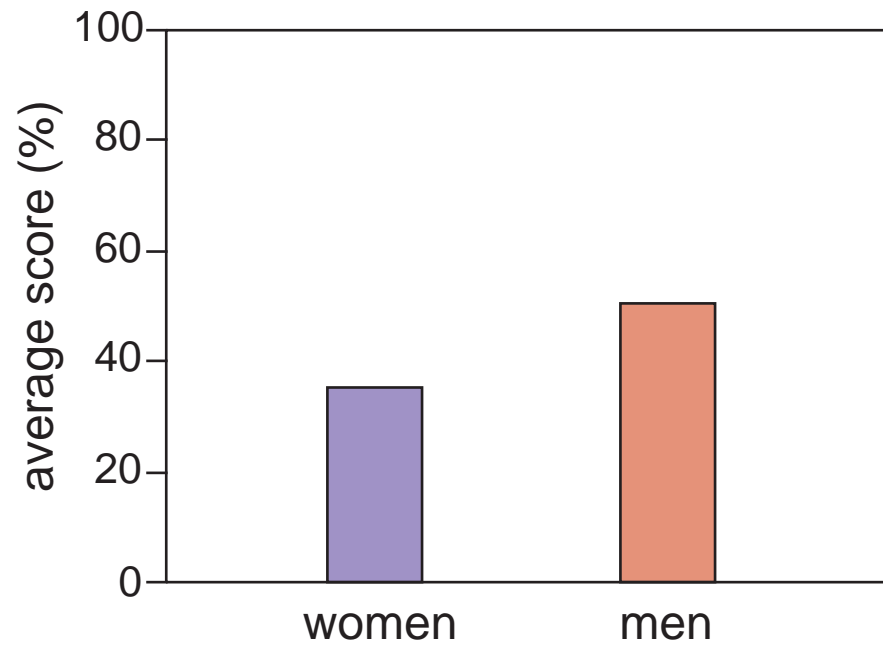
# Outline

- Gender issues
- Lecture demonstrations
- Confusion



# Gender issues

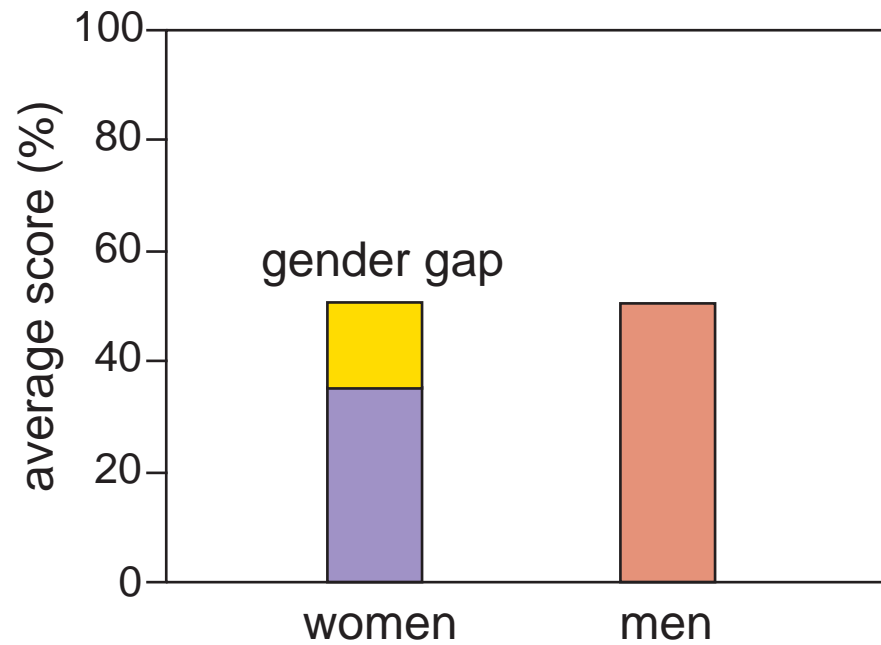
## Force Concept Inventory posttest scores





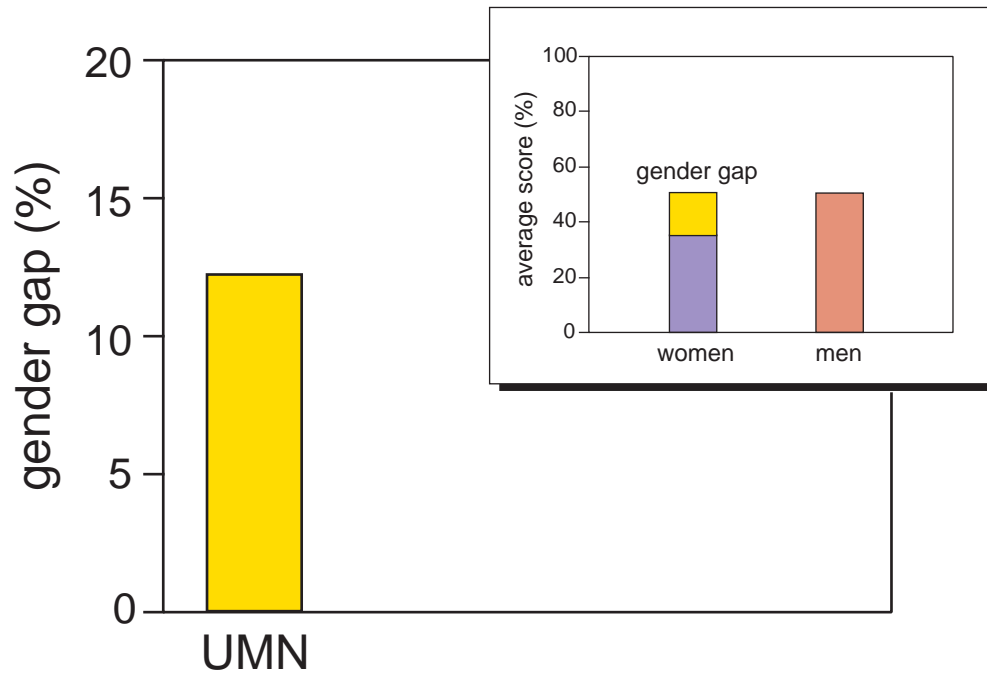
# Gender issues

## Force Concept Inventory posttest scores



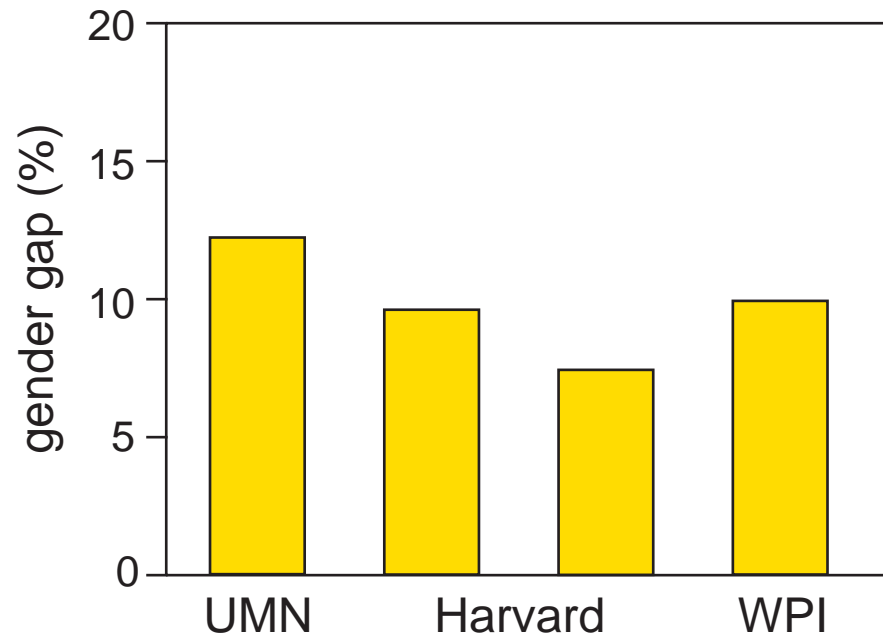
# Gender issues

## Force Concept Inventory posttest scores



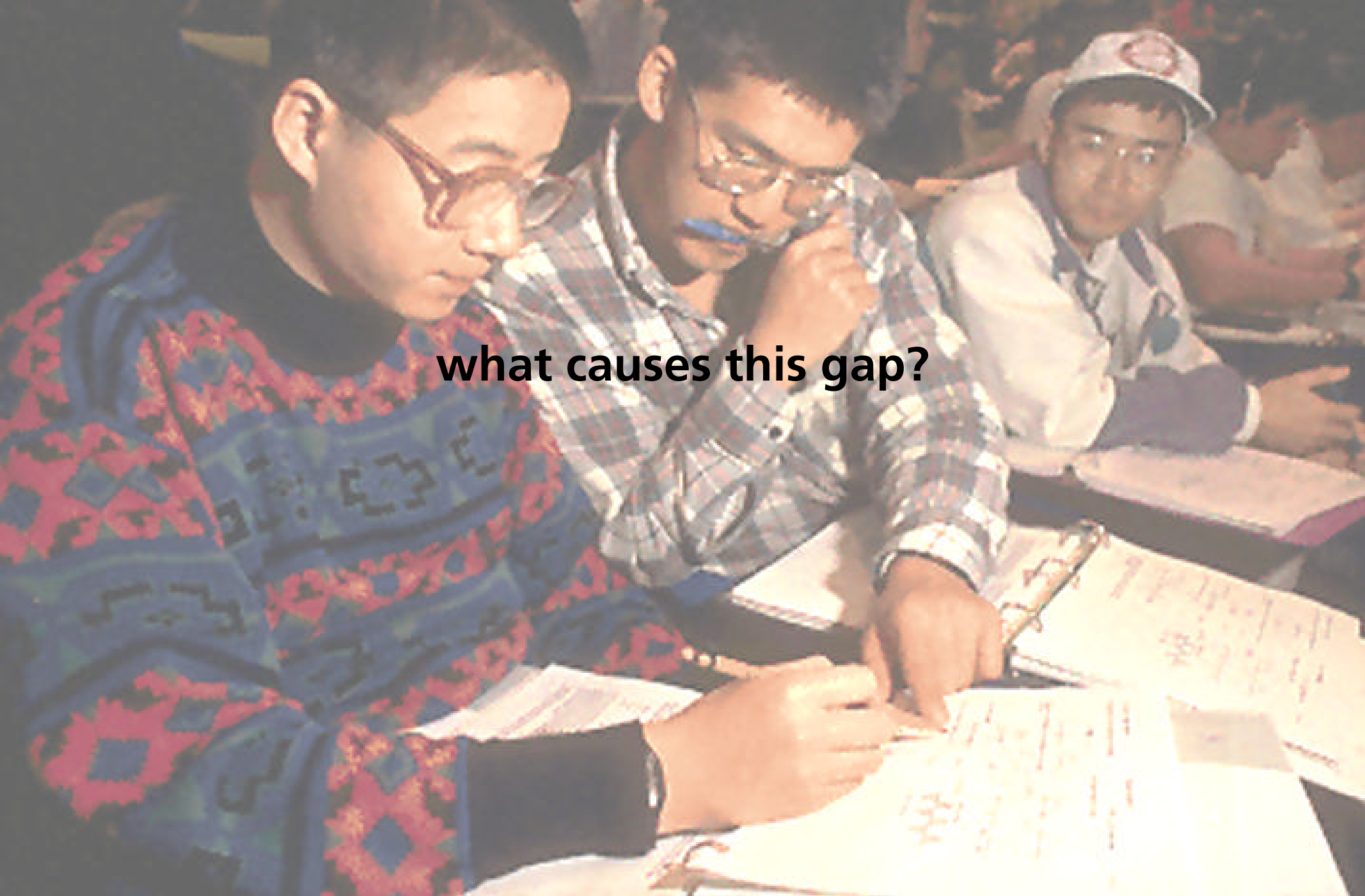
# Gender issues

## Force Concept Inventory posttest scores



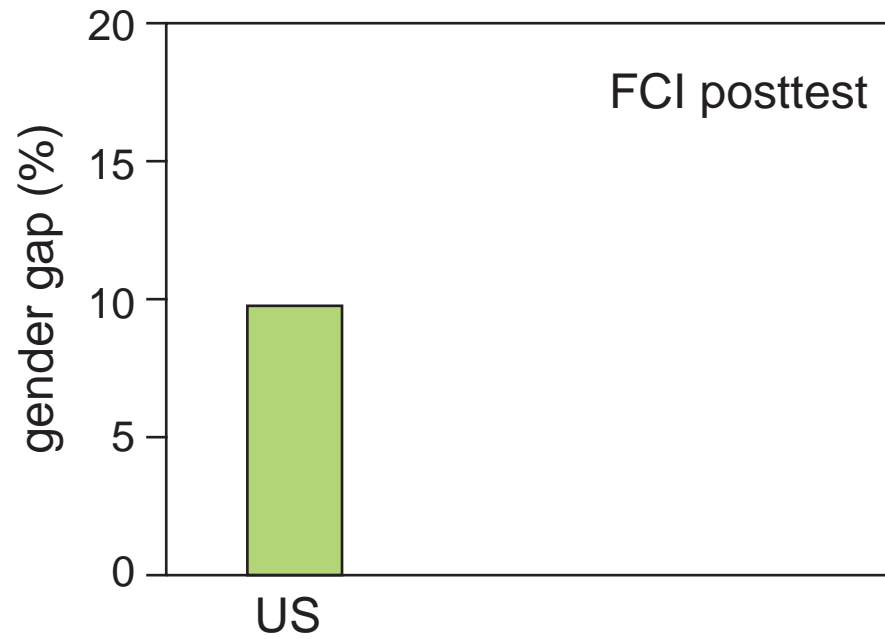
# Gender issues

what causes this gap?

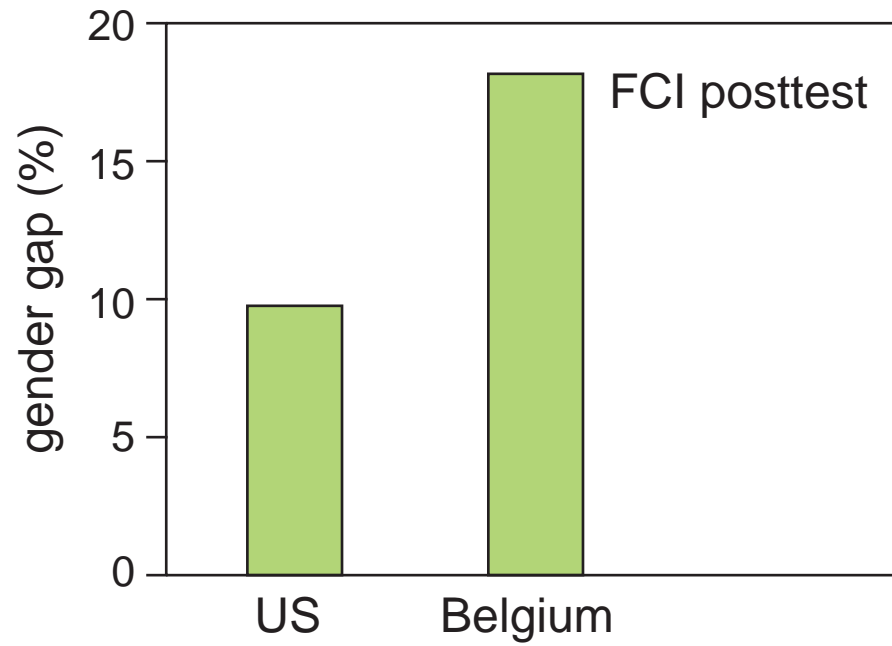


# Gender issues

is it cultural?

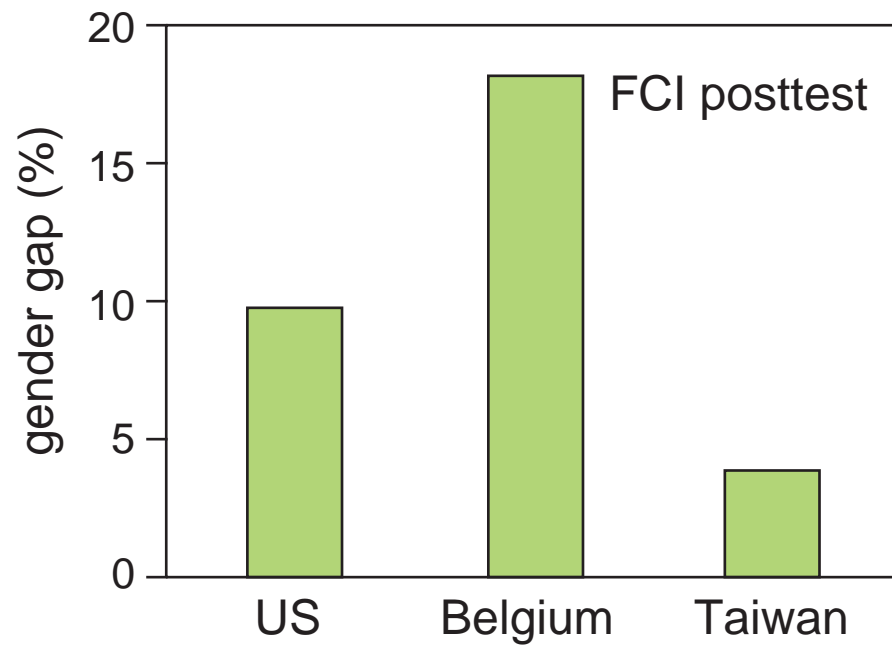


# Gender issues



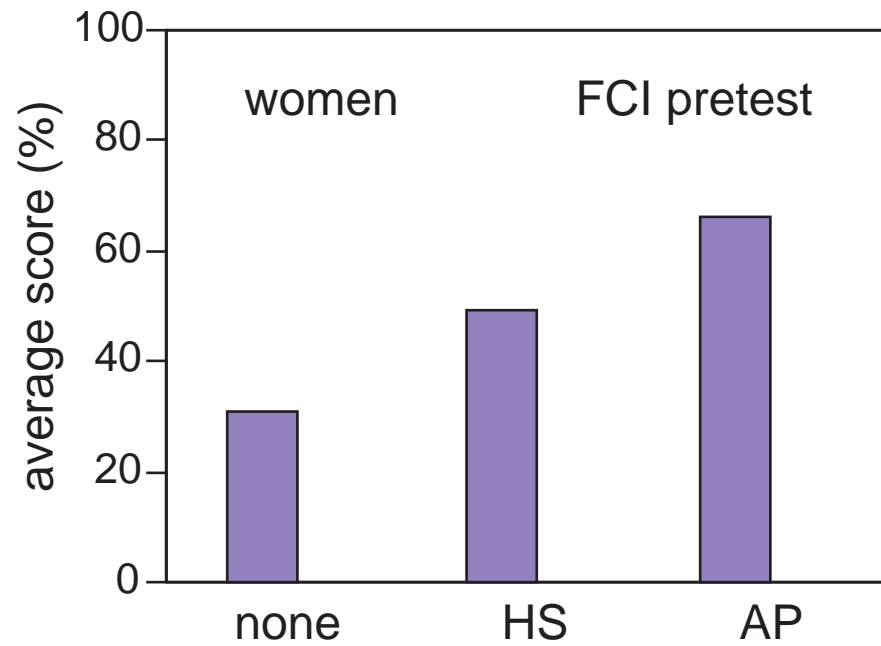
# Gender issues

**strong dependence on culture!**



# Gender issues

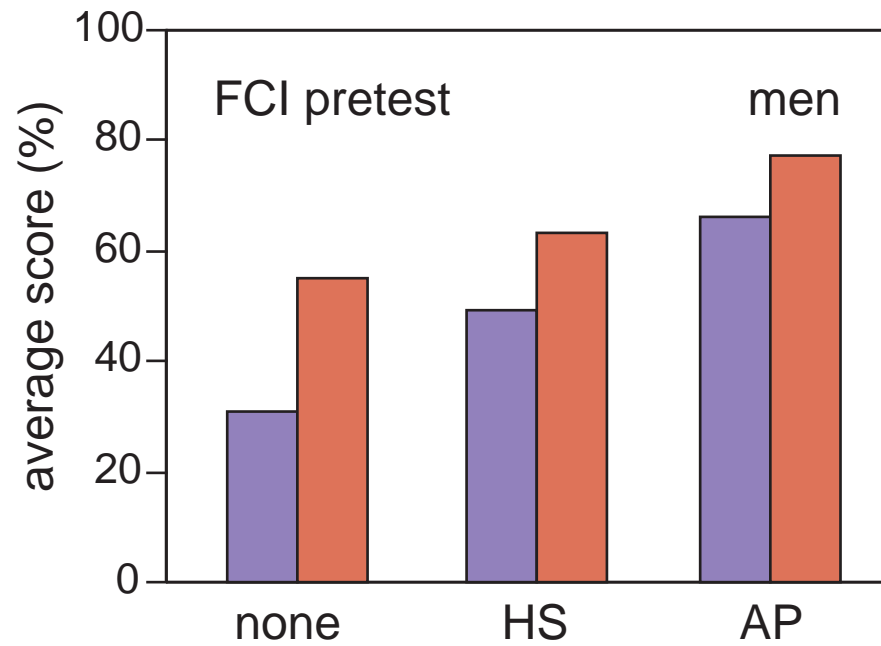
## effect of precollege education





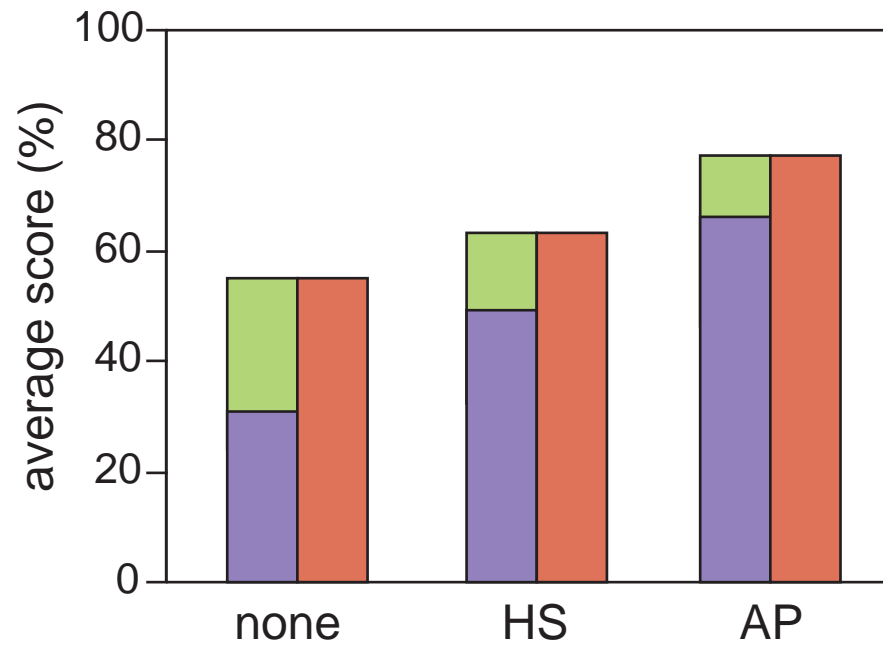
# Gender issues

everyone gains...



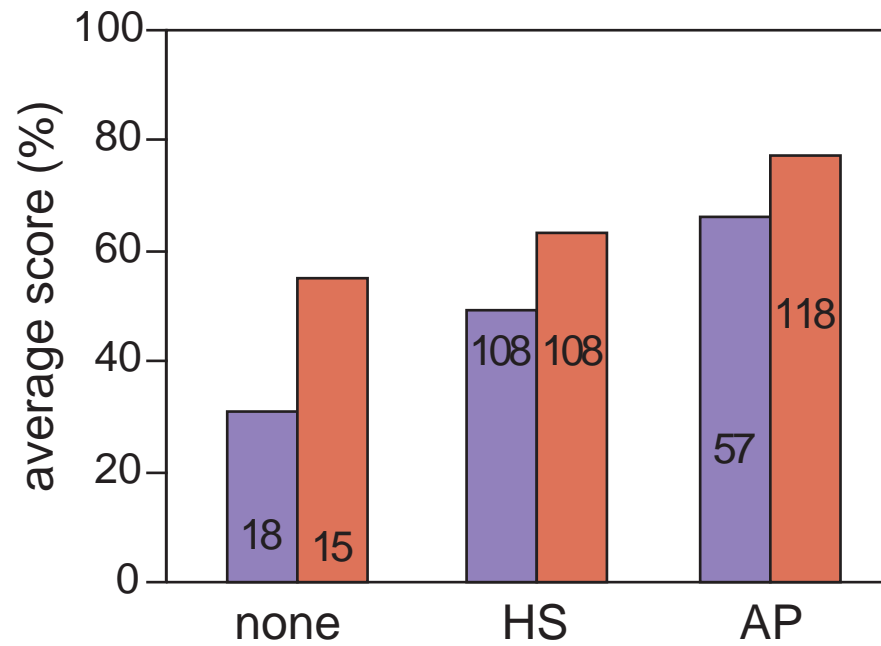
# Gender issues

...but gap persists...



# Gender issues

...and women underrepresented



# Gender issues

**what can we do?**

A group of women are seated around a table in what appears to be a meeting or workshop. They are looking at documents and talking. One woman in the center is wearing a red and orange patterned top and blue jeans. Another woman on the right is wearing a black top with a colorful patterned shawl. The setting is a room with green chairs and a dark table.

# Gender issues

**increase collaboration and interactivity**

A group of women are seated around a table in a meeting room, engaged in a collaborative activity. One woman on the left is pointing at a document on the table. Another woman in the center is looking at the document, and a third woman on the right is also looking towards the document. The room has green chairs and a patterned tablecloth. The text 'increase collaboration and interactivity' is overlaid on the image.

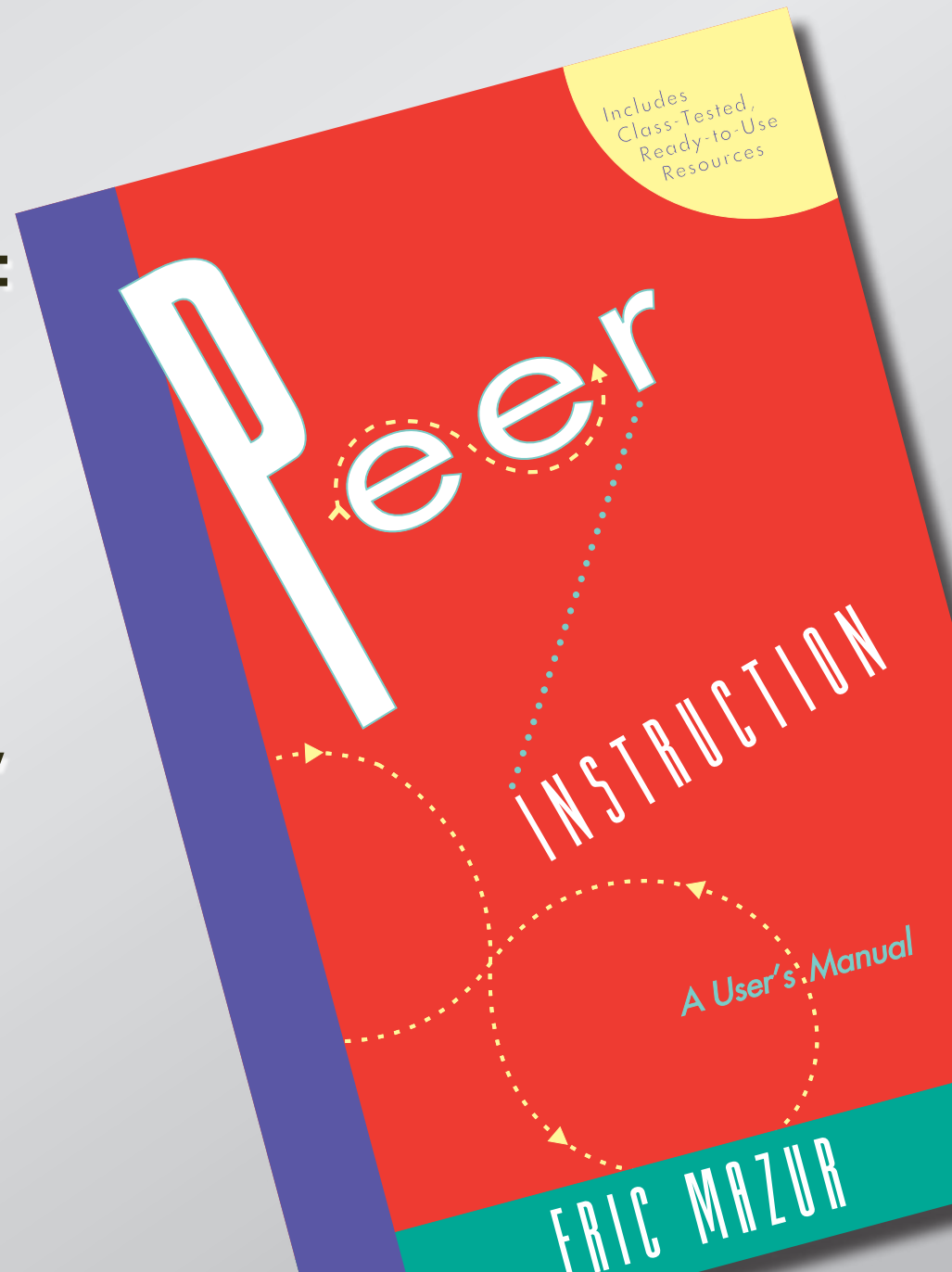
# Gender issues

Compare three pedagogies:

**T:** traditional lectures

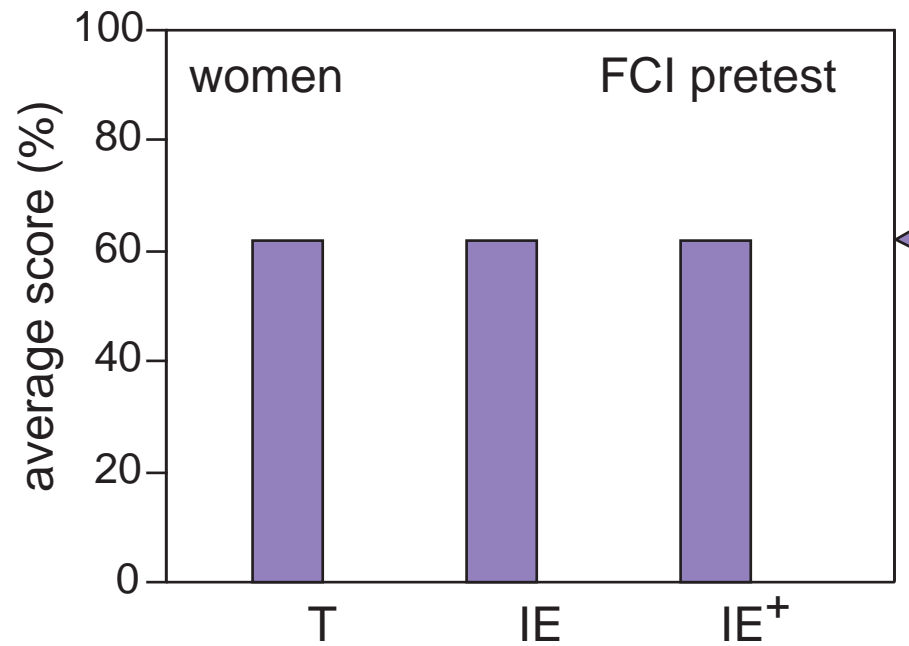
**I:** interactive lectures

**I<sup>+</sup>:** interactive assignments,  
lectures, and tutorials



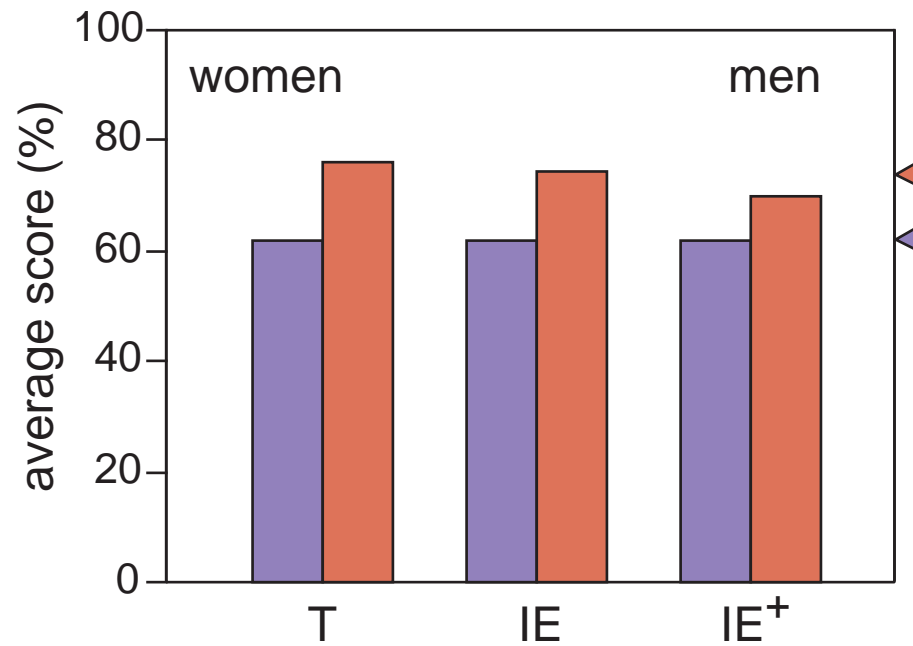
# Gender issues

does pedagogy help?



# Gender issues

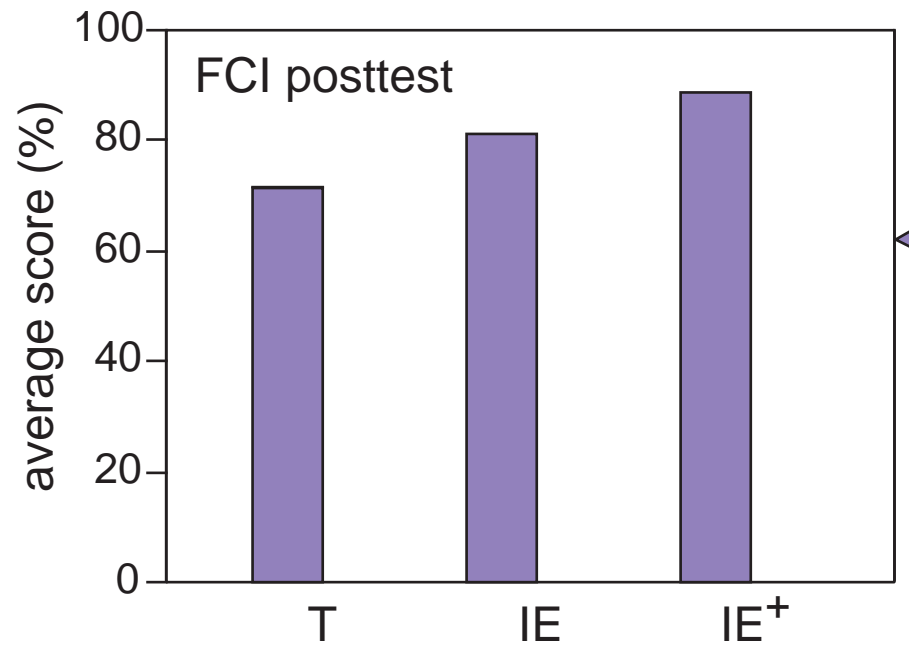
does pedagogy help?





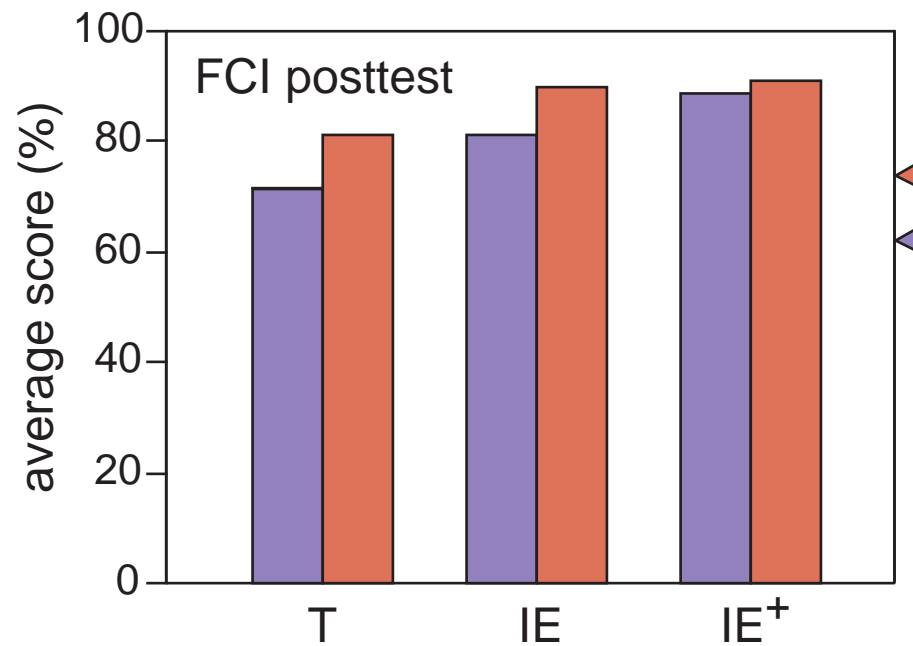
# Gender issues

does pedagogy help?



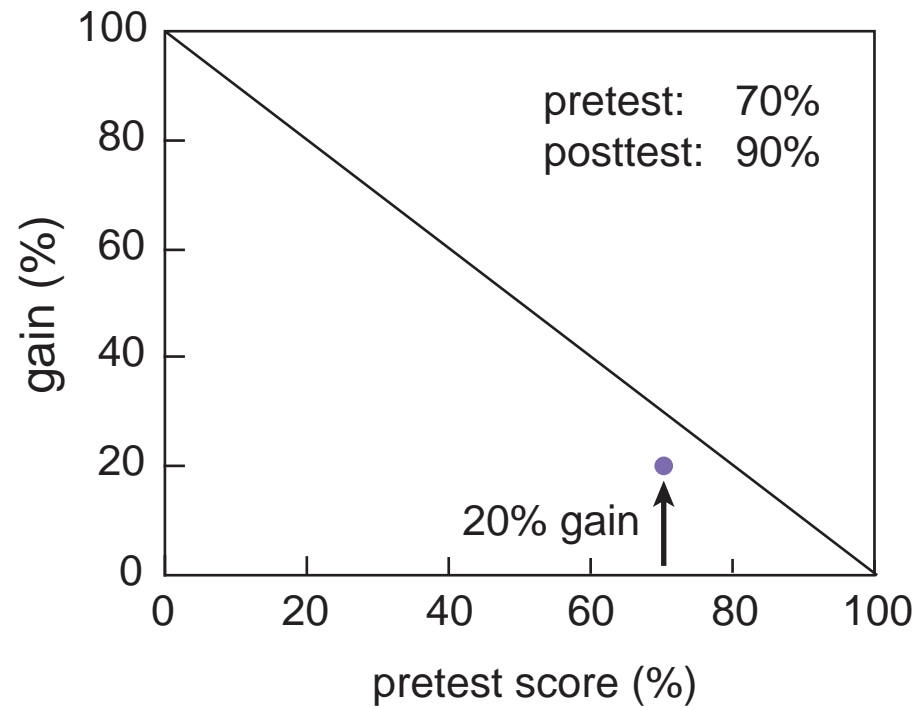
# Gender issues

yes, pedagogy can eliminate gap!



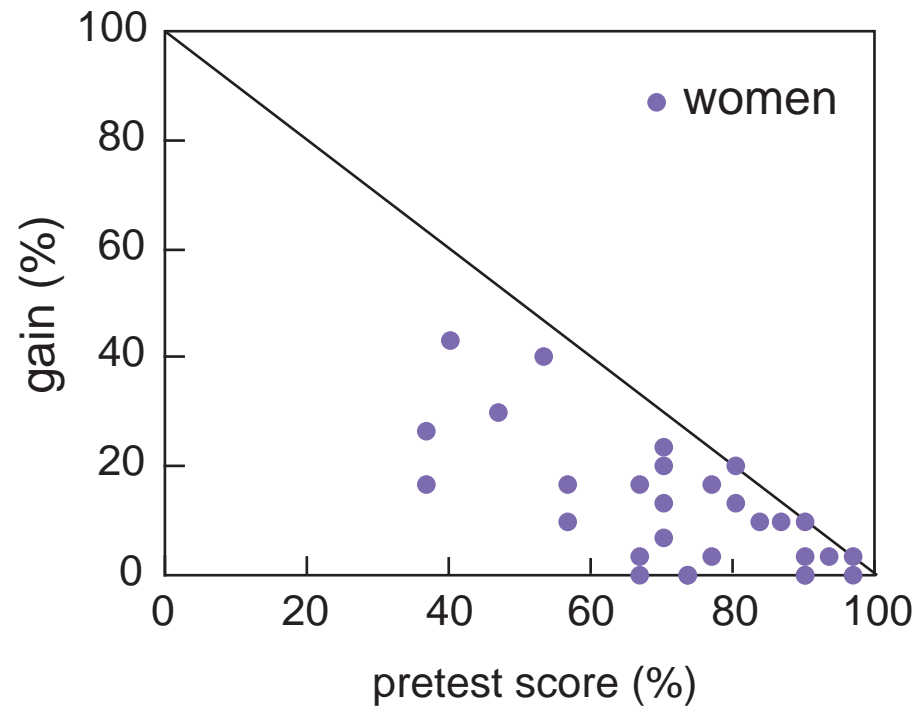
# Gender issues

who are the low-gain students?



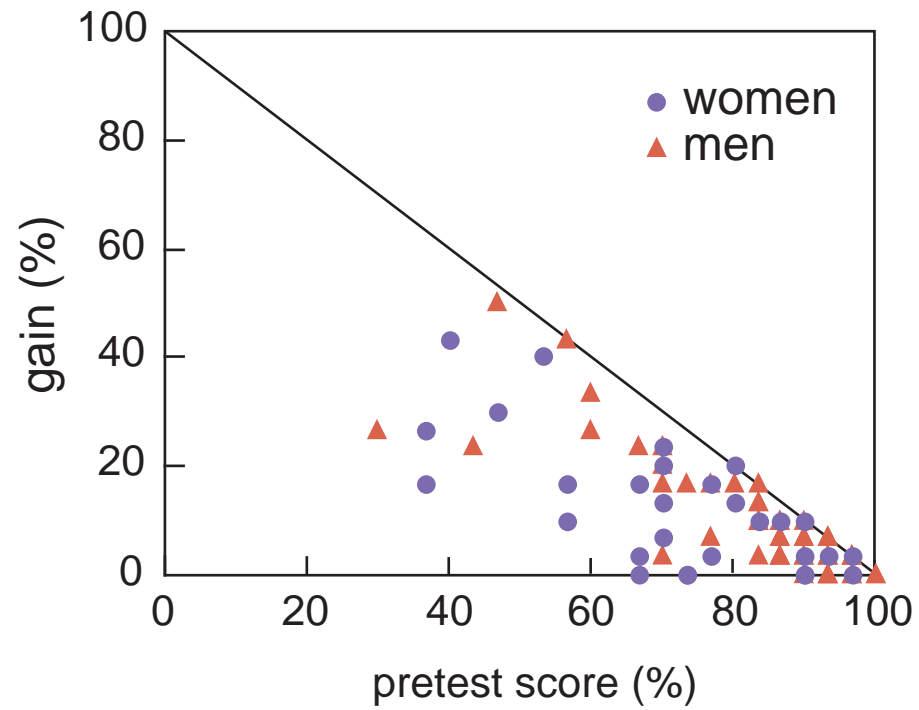
# Gender issues

## traditional class



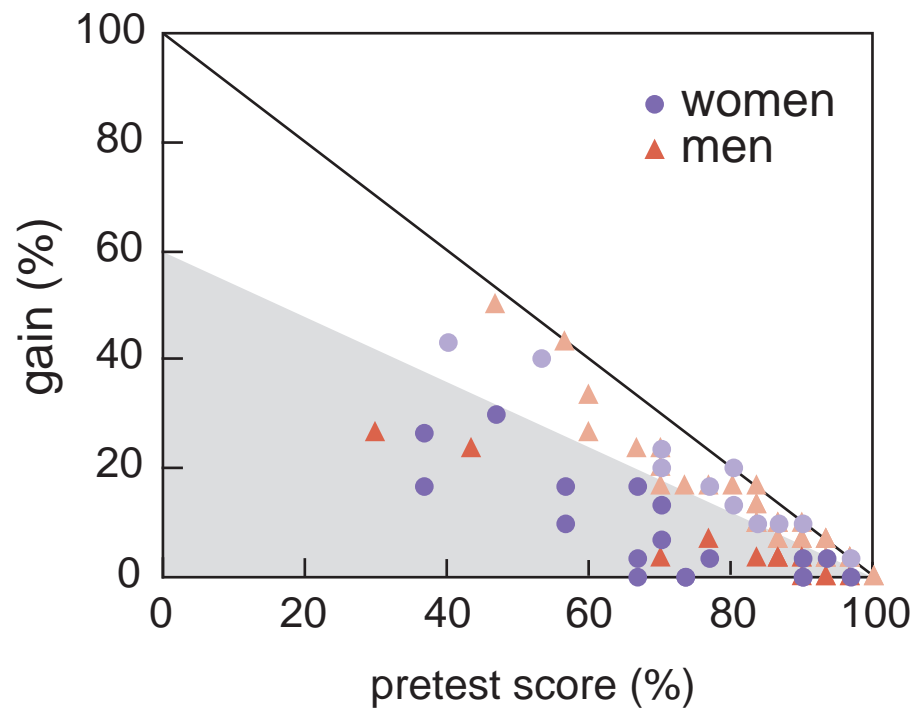
# Gender issues

## traditional class



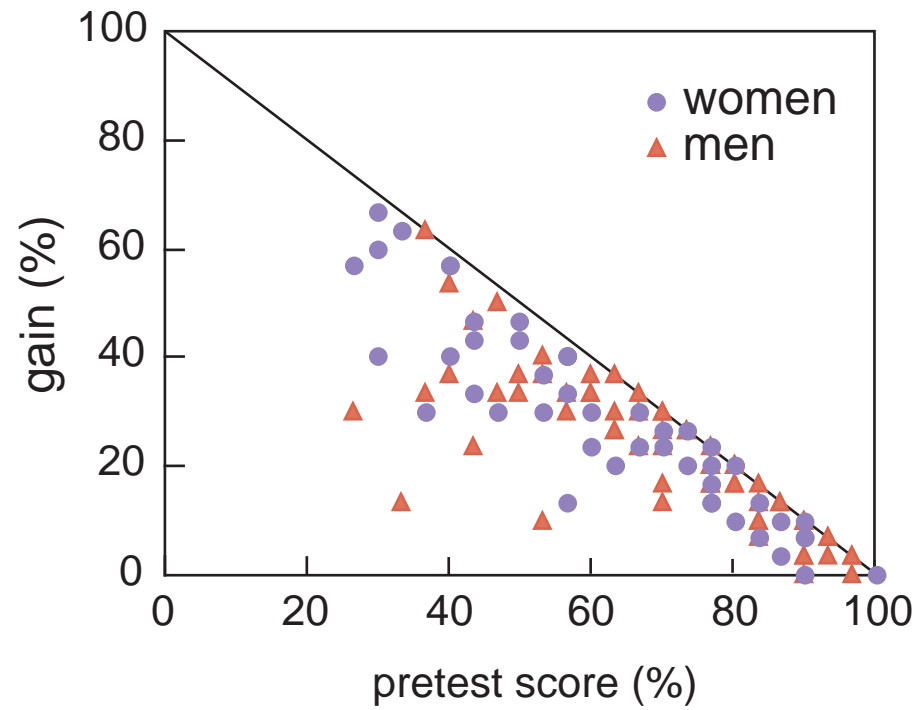
# Gender issues

traditional class: gender imbalance



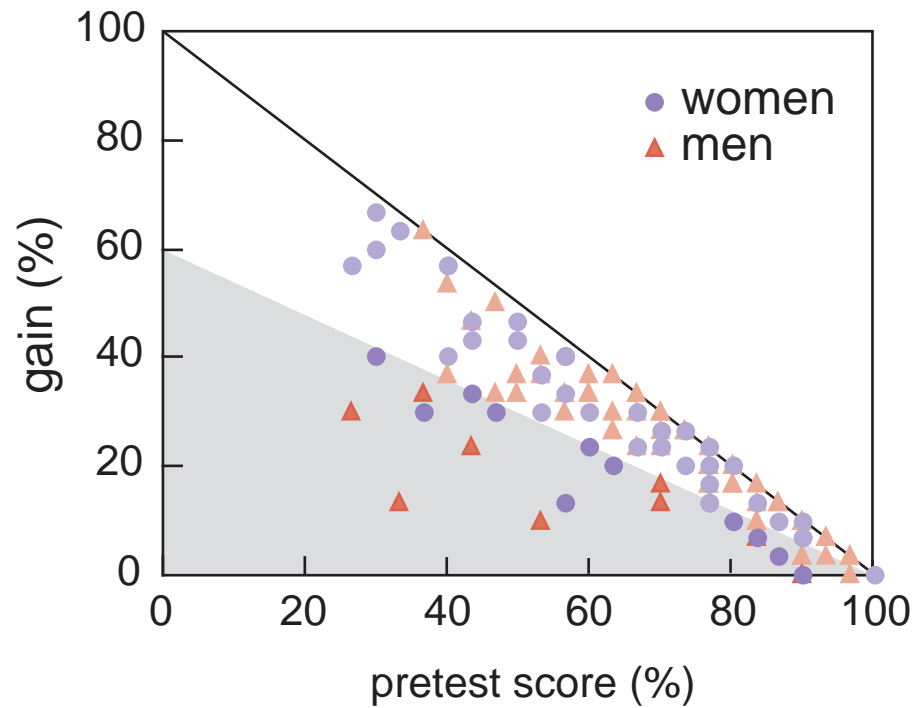
# Gender issues

## interactive class



# Gender issues

## interactive class: gender balance





# Gender issues

**Points to keep in mind:**

- **gap comes from culture and background**
- **interactivity makes a difference**

# Lecture demonstrations

how effective are lecture demonstrations?



# Lecture demonstrations

Carry out seven demonstrations in four “modes”:

- no demo (control)
- observe
- predict
- discuss

# Lecture demonstrations

Carry out seven demonstrations in four “modes”:

- no demo (control)
- observe
- predict (+2 mins.)
- discuss (+8 mins.)

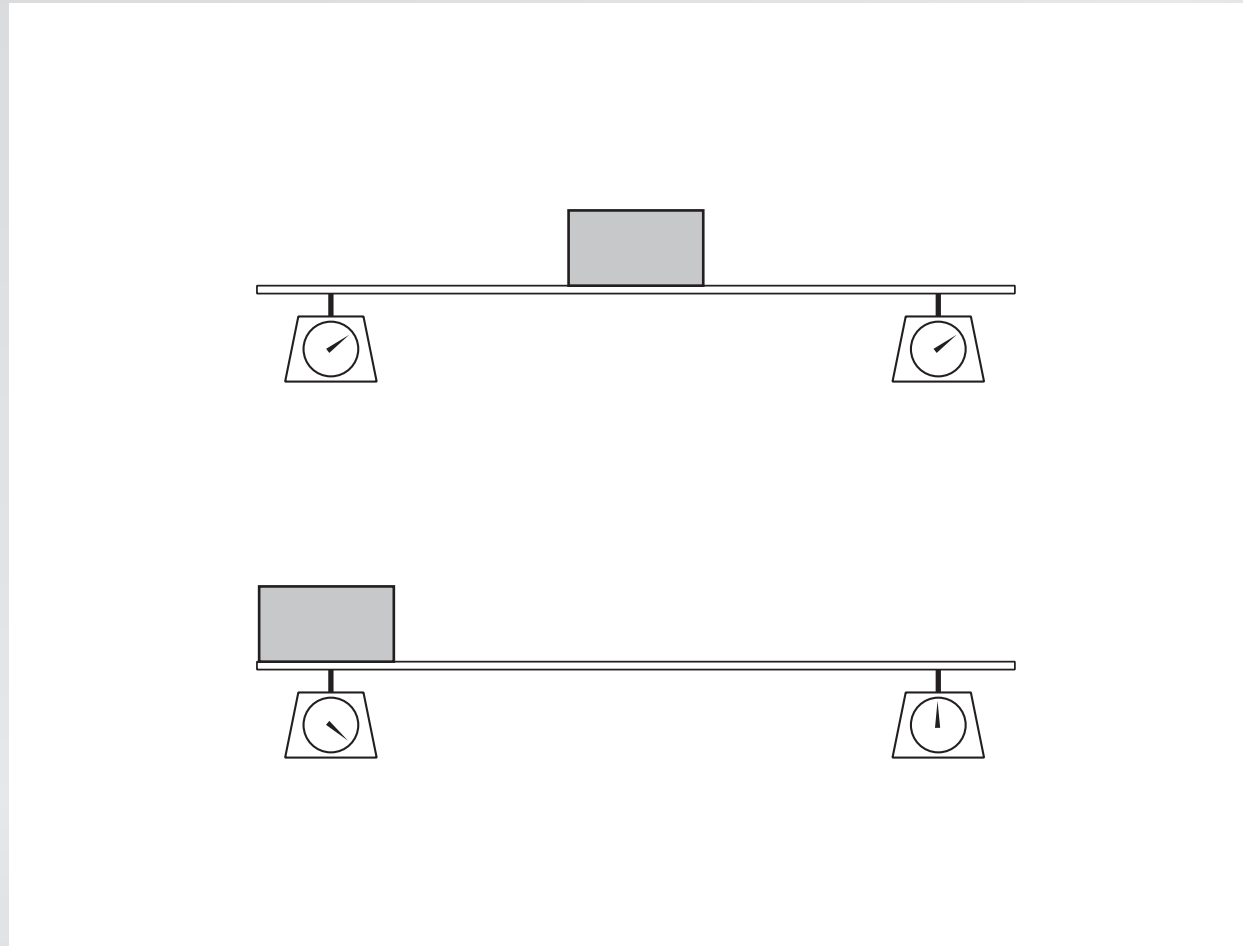
# Lecture demonstrations

**Follow up:**

- **free-response test (online)**
- **exam questions**

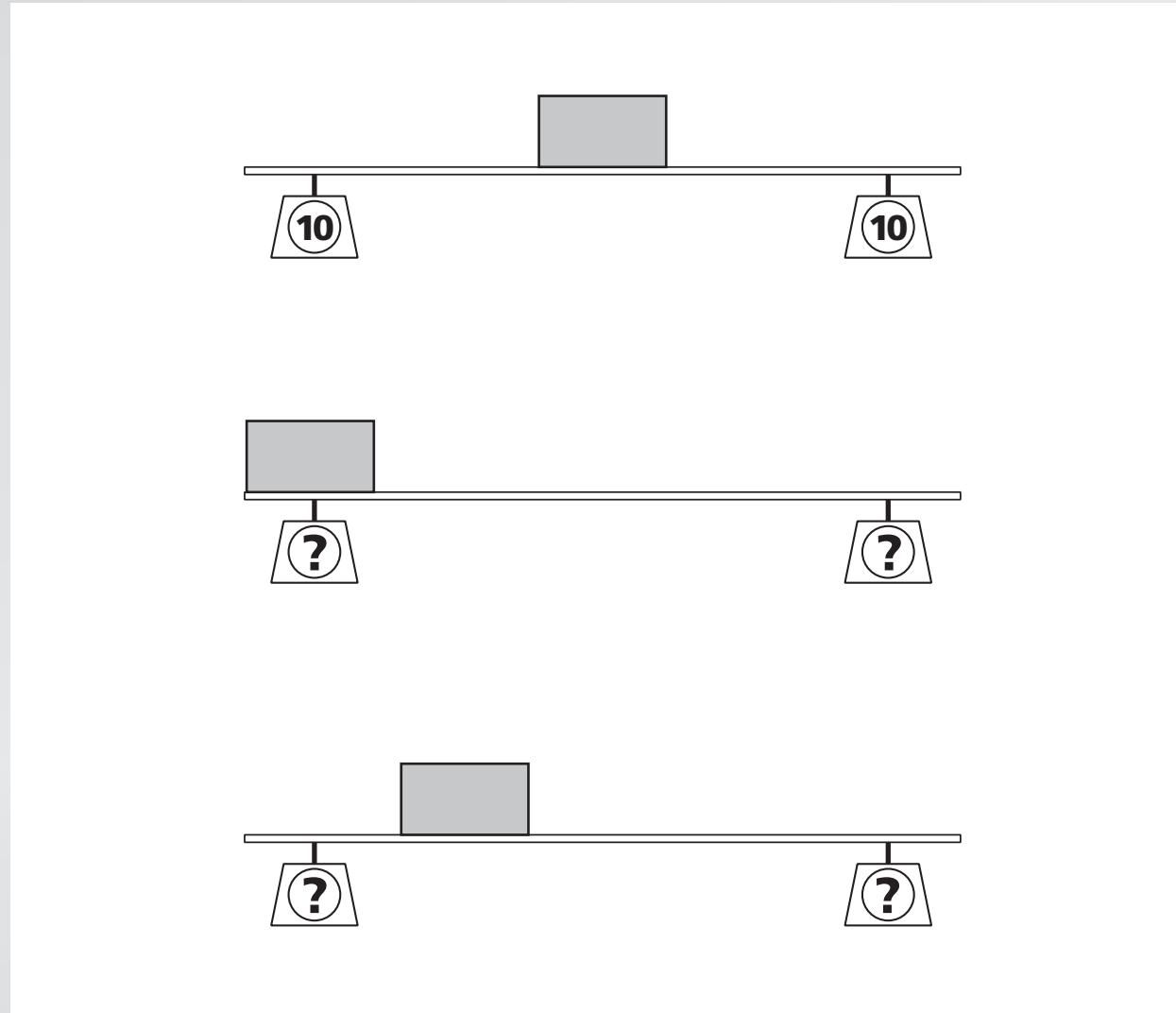
# Lecture demonstrations

## loaded beam demo



# Lecture demonstrations

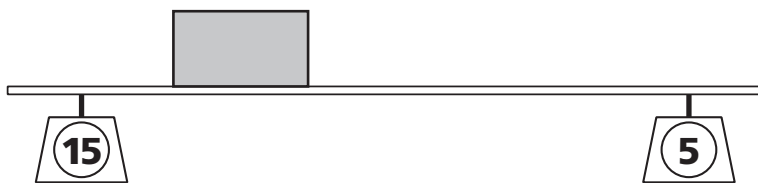
online test question



# Lecture demonstrations

answers given

24% of students



correct (mentions torque)



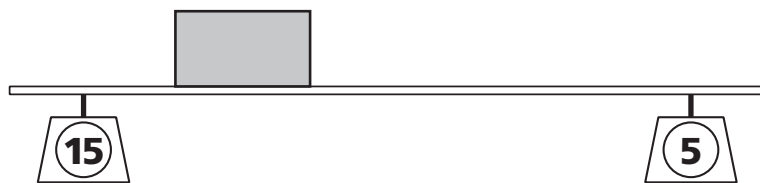
# Lecture demonstrations

answers given

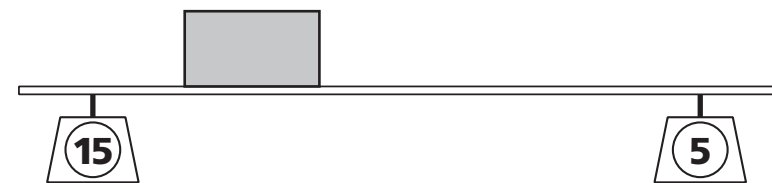
24% of students



38% of students



correct (mentions torque)



proportional reasoning

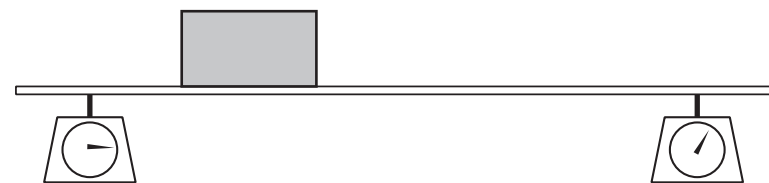
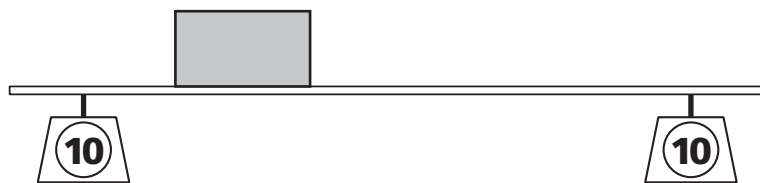
# Lecture demonstrations

answers given

20% of students



10% of students



independent of position

qualitative reasoning

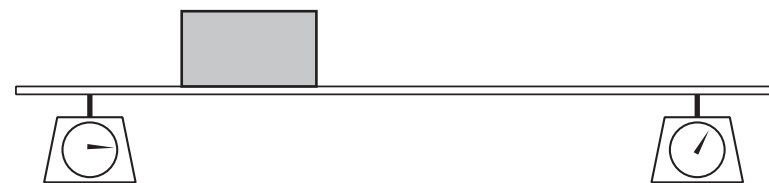
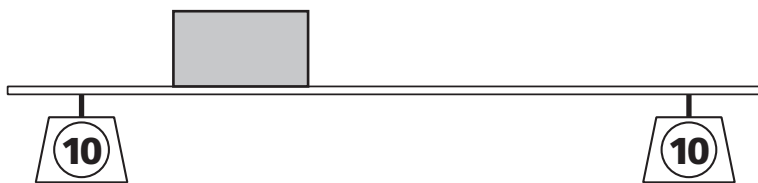
# Lecture demonstrations

answers given

20% of students



10% of students



independent of position

qualitative reasoning

6%: forces not balanced; 2%: other incorrect

# Lecture demonstrations

---

<b>mode</b>	<b>correct</b>	<b>incorrect</b>
<b>no demo</b>	<b>30%</b>	<b>70%</b>
<b>observe</b>	<b>18%</b>	<b>82%</b>
<b>predict</b>	<b>29%</b>	<b>71%</b>
<b>discuss</b>	<b>30%</b>	<b>70%</b>

---

# Lecture demonstrations

---

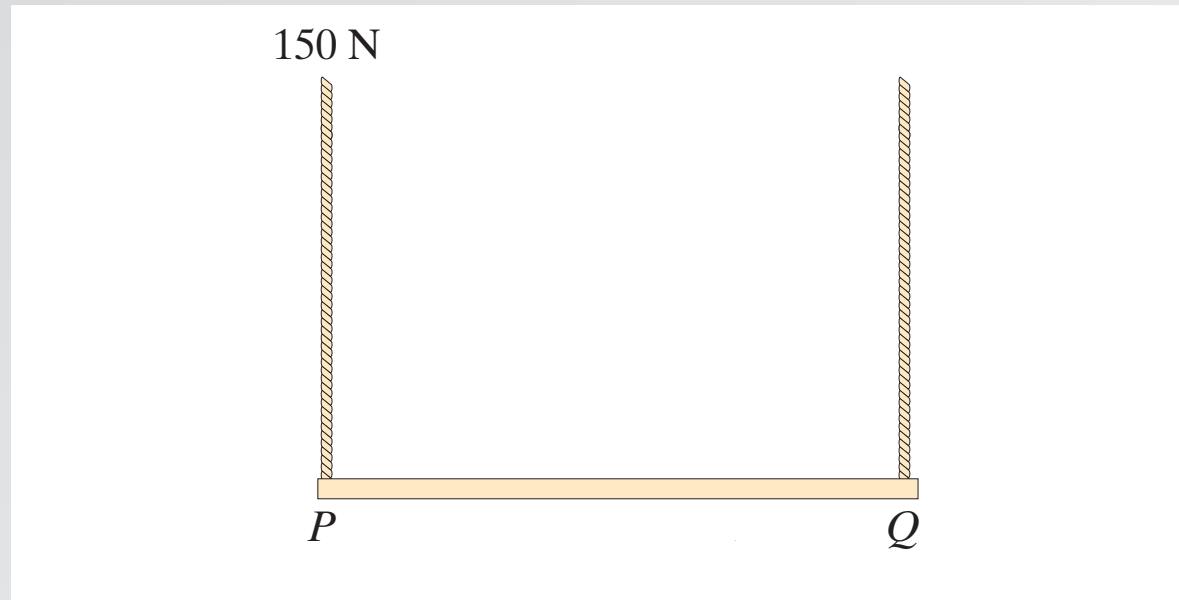
mode	correct	incorrect
no demo	30%	70%
<b>observe</b>	<b>18%</b>	<b>82%</b>
predict	29%	71%
discuss	30%	70%

---

**just presenting harmful?**

# Lecture demonstrations

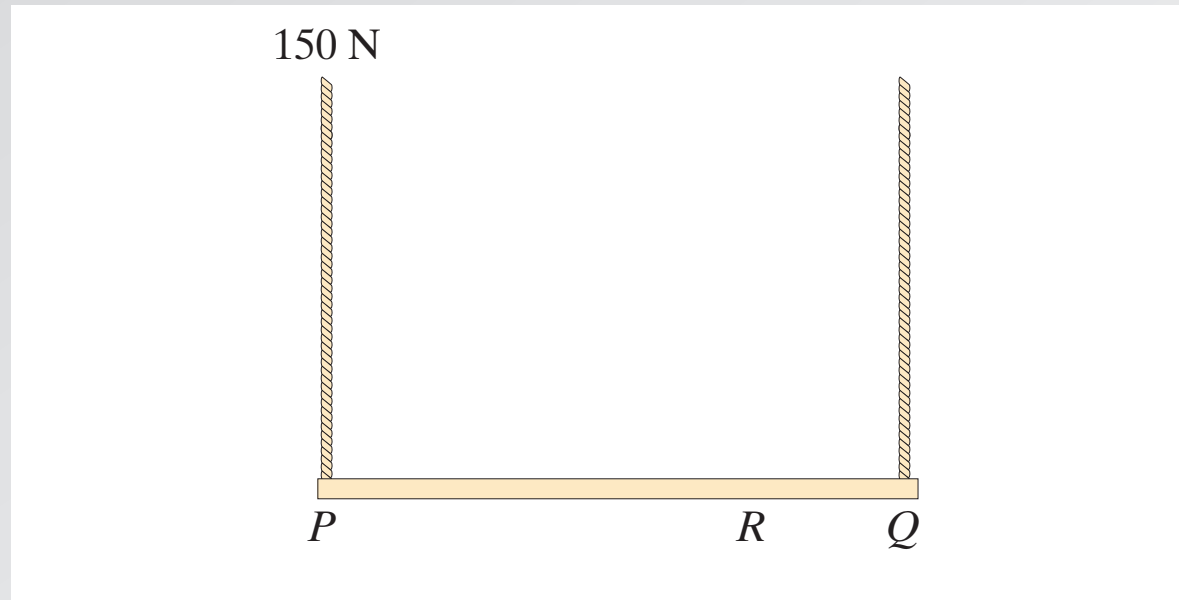
## exam question



A uniform plank is supported by two ropes at points  $P$  and  $Q$ . The tension in the rope at  $P$  is  $150\text{ N}$ .

# Lecture demonstrations

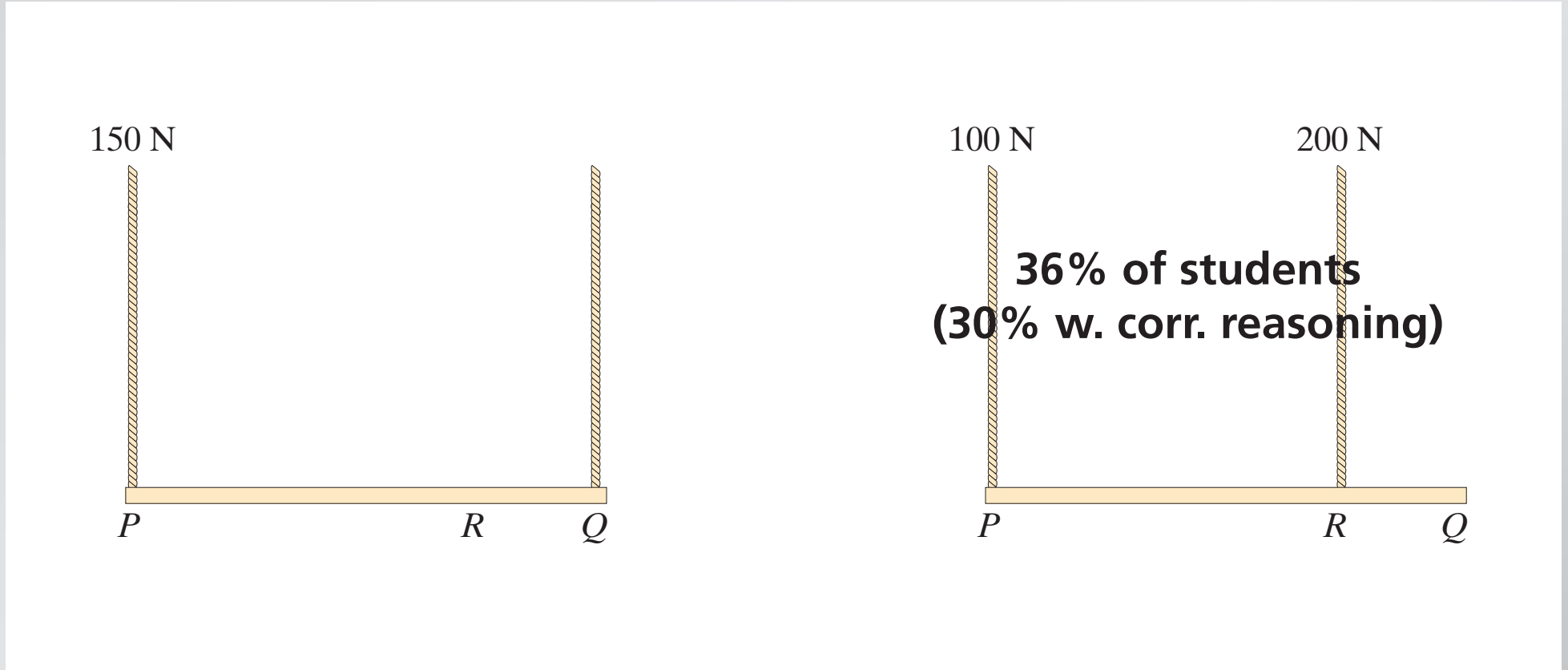
## exam question



A uniform plank is supported by two ropes at points  $P$  and  $Q$ . The tension in the rope at  $P$  is  $150\text{ N}$ . 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?

# Lecture demonstrations

correct answer

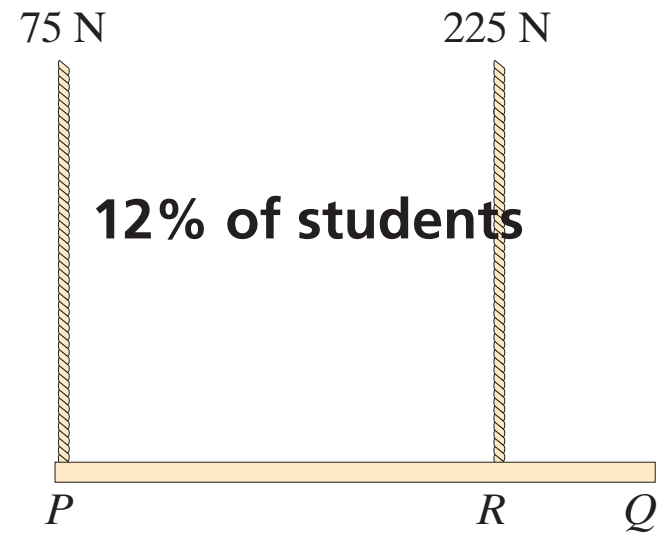
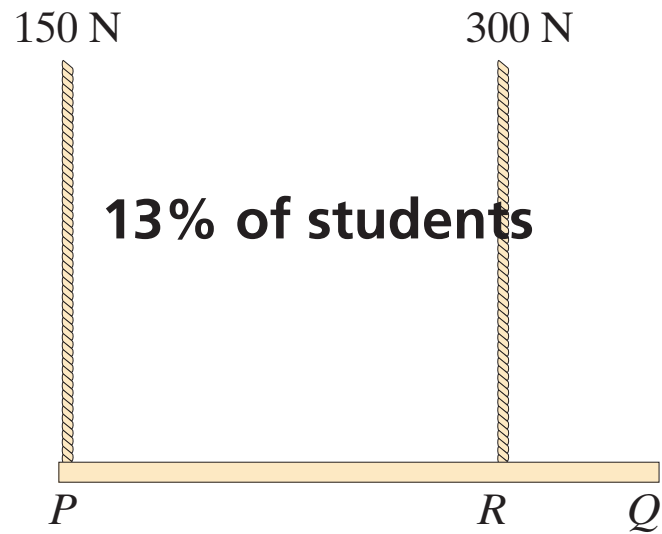


considerable improvement from online test



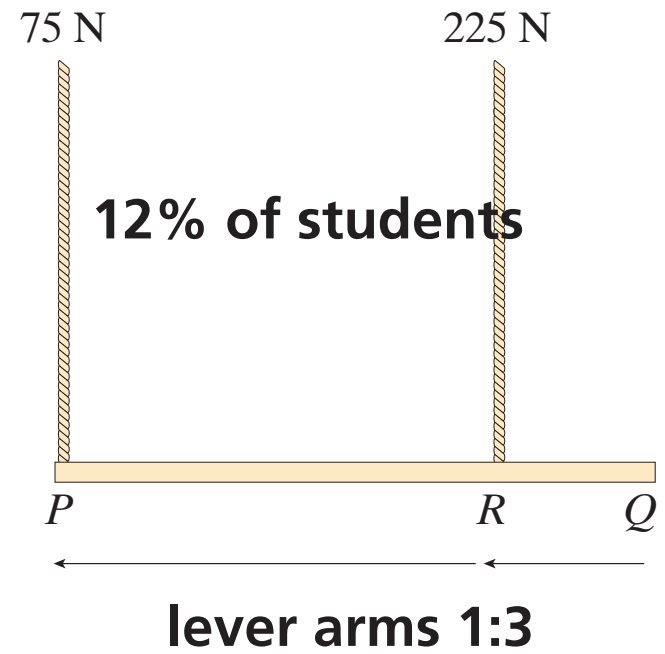
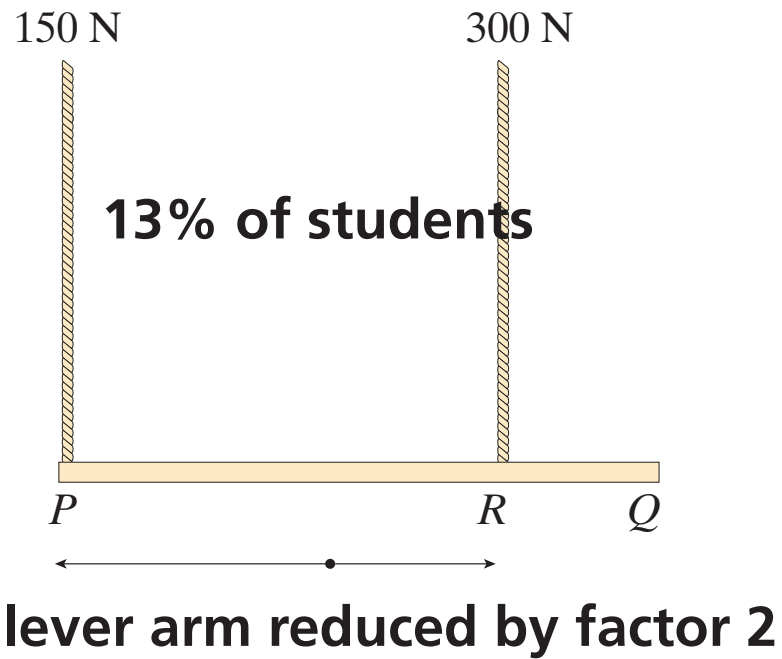
# Lecture demonstrations

incorrect answers



# Lecture demonstrations

incorrect answers

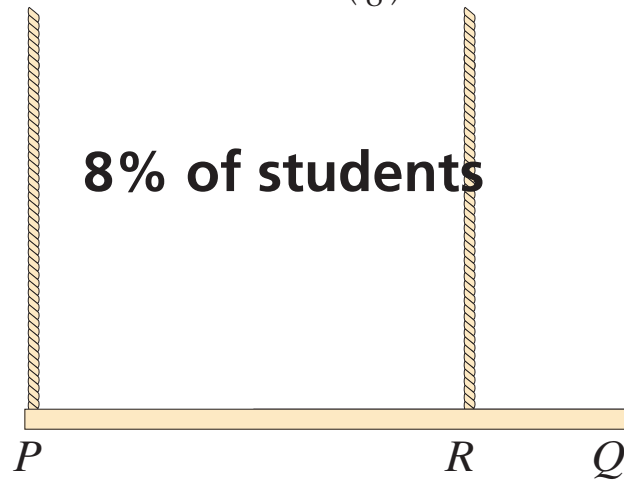


# Lecture demonstrations

## incorrect answers

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

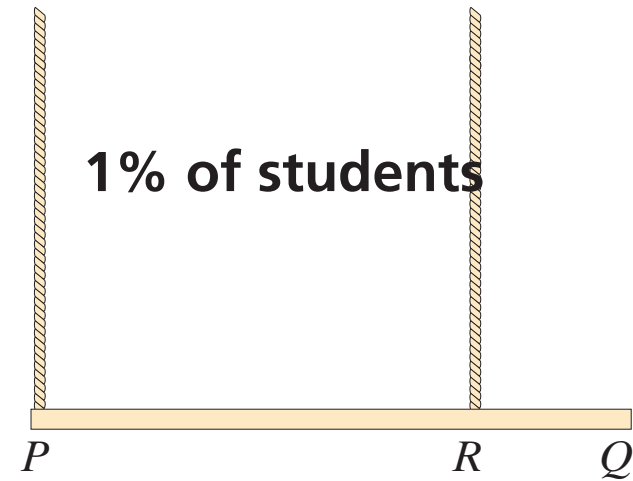
**8% of students**



$$112.5 \text{ N}$$

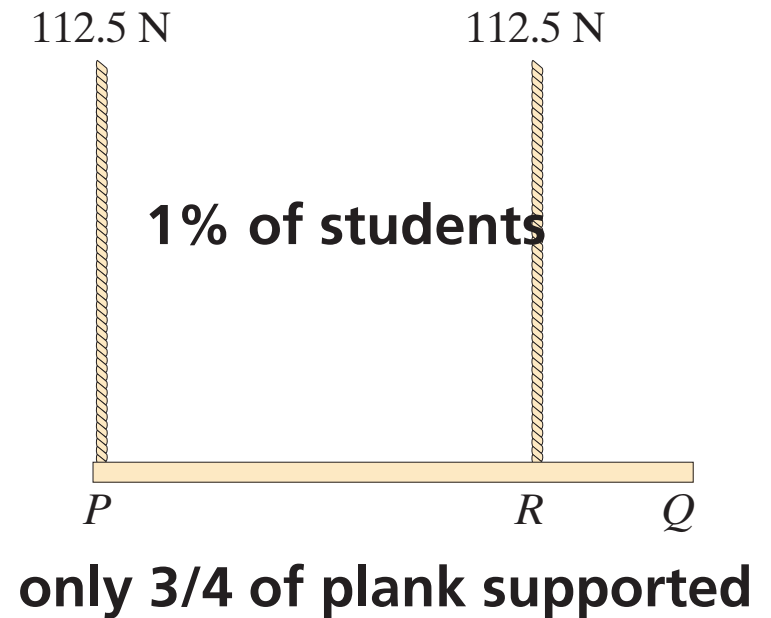
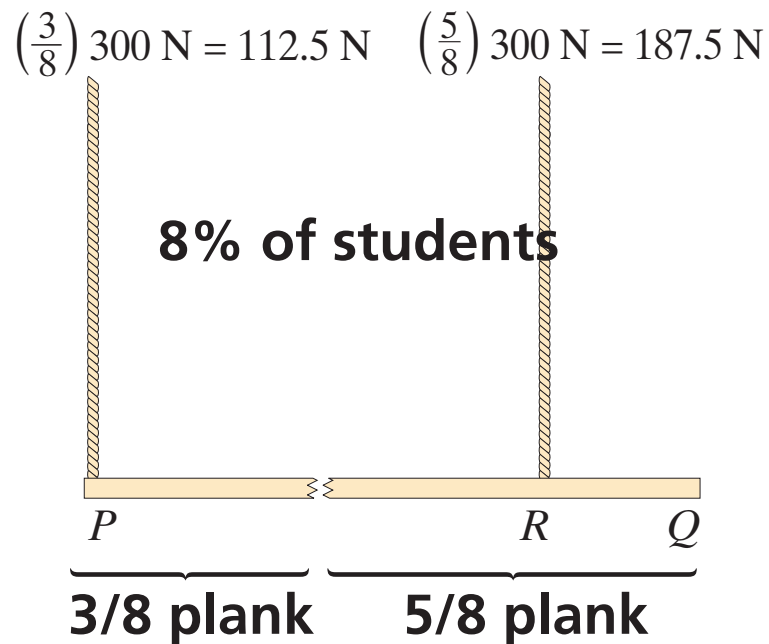
$$112.5 \text{ N}$$

**1% of students**



# Lecture demonstrations

incorrect answers



who would have thought??

# Lecture demonstrations

---

<b>mode</b>	<b>correct</b>	<b>balances torques</b>	<b>no clear reasoning</b>
<b>no demo</b>	<b>31%</b>	<b>53%</b>	<b>42%</b>
<b>observe</b>	<b>42%</b>	<b>55%</b>	<b>42%</b>
<b>predict</b>	<b>41%</b>	<b>65%</b>	<b>32%</b>
<b>discuss</b>	<b>46%</b>	<b>85%</b>	<b>15%</b>

---

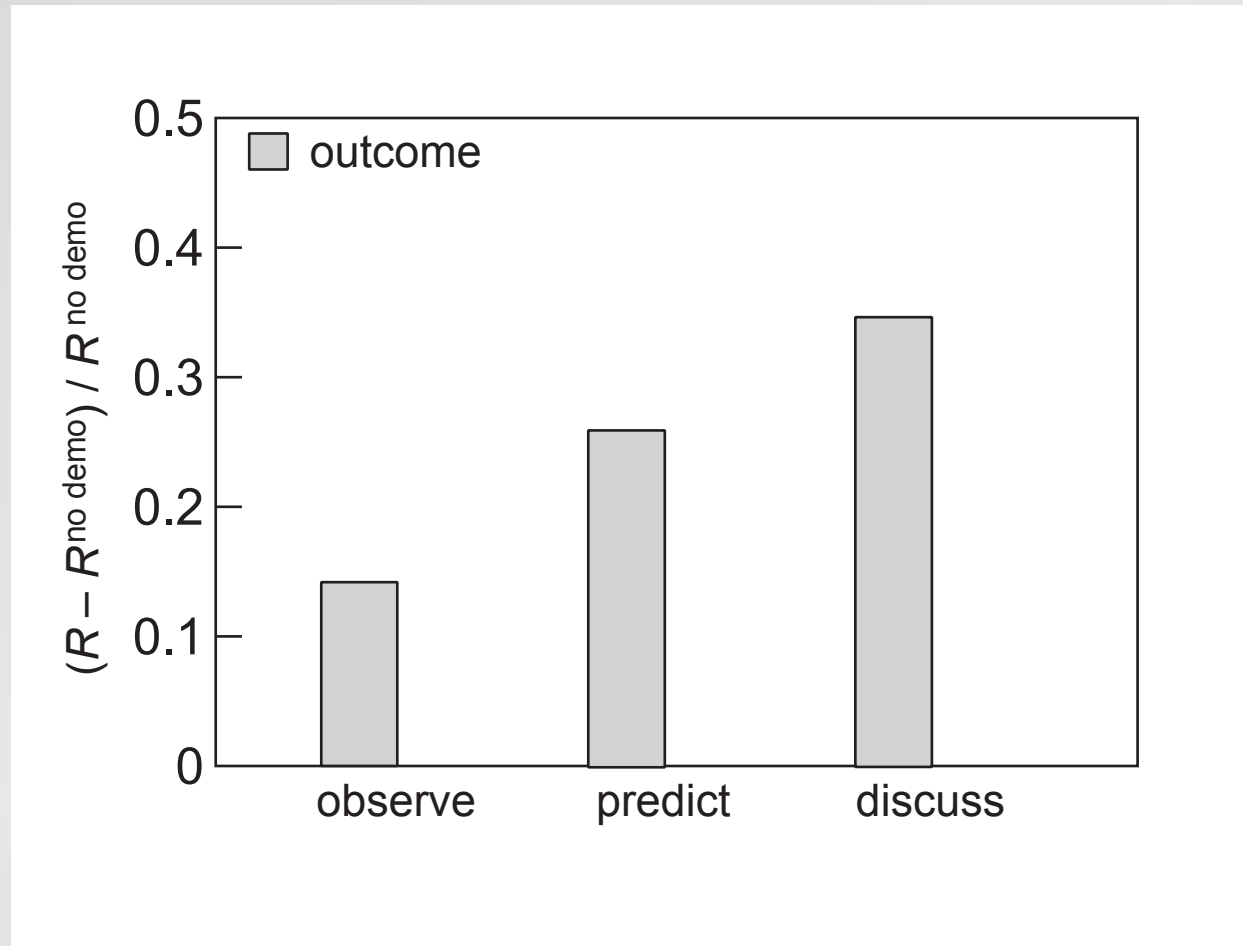
# Lecture demonstrations

aggregate results for seven demonstrations

mode	$N$	$R_{\text{outcome}}$	$R_{\text{explanation}}$
no demo	297	61%	22%
observe	220	70%	24%
predict	179	77%	30%
discuss	158	82%	32%

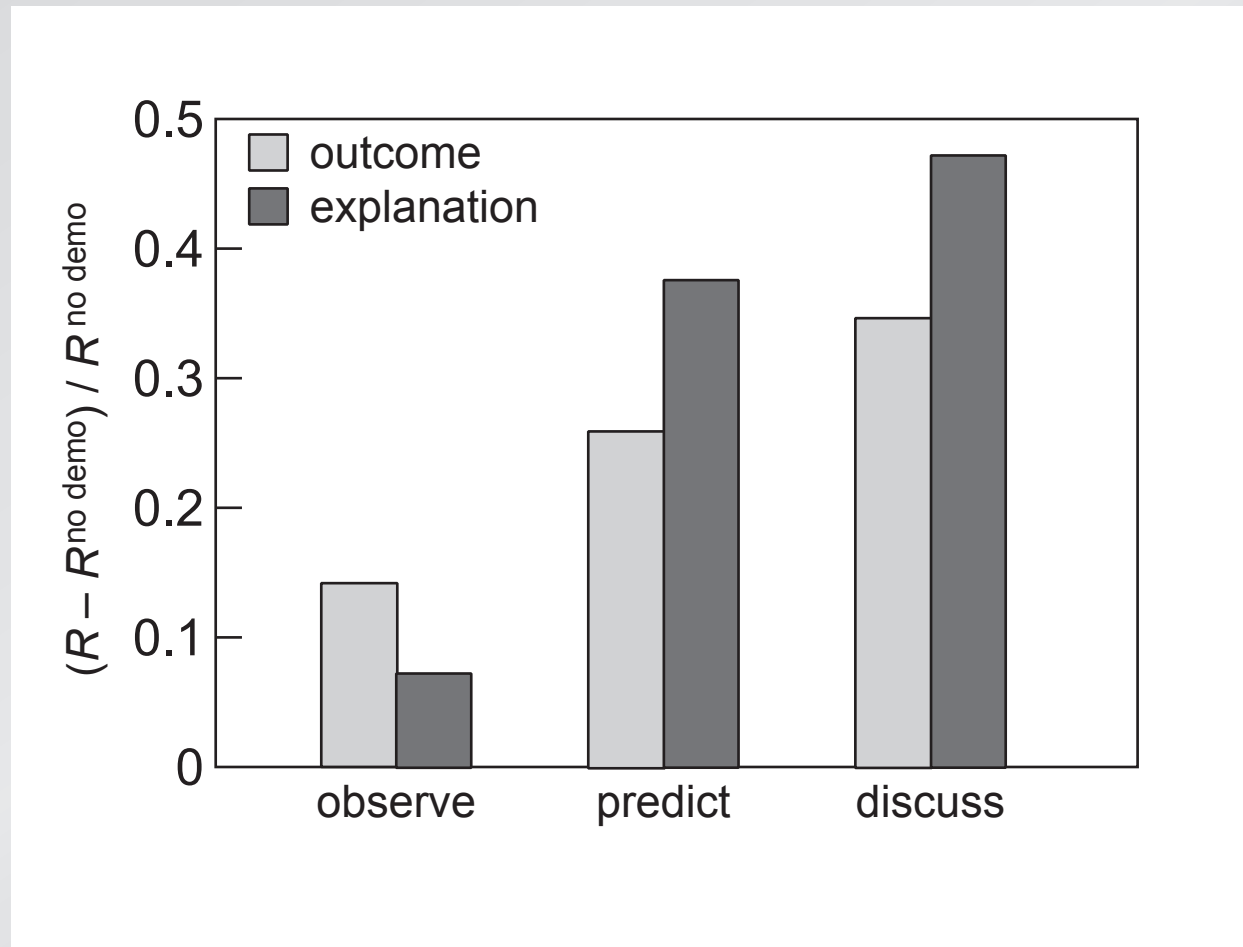
# Lecture demonstrations

improvement correlates with engagement



# Lecture demonstrations

improvement correlates with engagement





# Lecture demonstrations

**Points to keep in mind:**

- **demonstrations without engagement not very helpful**
- **results can be improved by having students predict outcome**

# Confusion



# Confusion

**instructors are praised for 'clear' lectures**

A photograph of a male professor in a plaid suit and red tie leaning over a desk to assist students in a lecture hall. The students are seated at green desks, and the professor is pointing at a document. The scene is dimly lit, and the overall tone is serious and focused.

# Confusion

**confusion is discouraging, but...**

A photograph of a man in a dark, patterned suit and a red tie with white polka dots leaning over a desk in a classroom. He is looking down at a book or paper held by a student. Several other students are seated at desks in the foreground and background, some looking towards the man. The classroom has green chairs and a wood-paneled wall. The text "PHANTOM" is visible on a student's shirt in the background.

# Confusion

A photograph of a man in a dark suit and red tie leaning over a desk to assist students in a classroom. The students are seated at green desks, and the man is looking down at a document on the desk. The background shows other students and a wooden wall.

**confusion is discouraging, but...  
“to wonder is to begin to understand”**

# Confusion

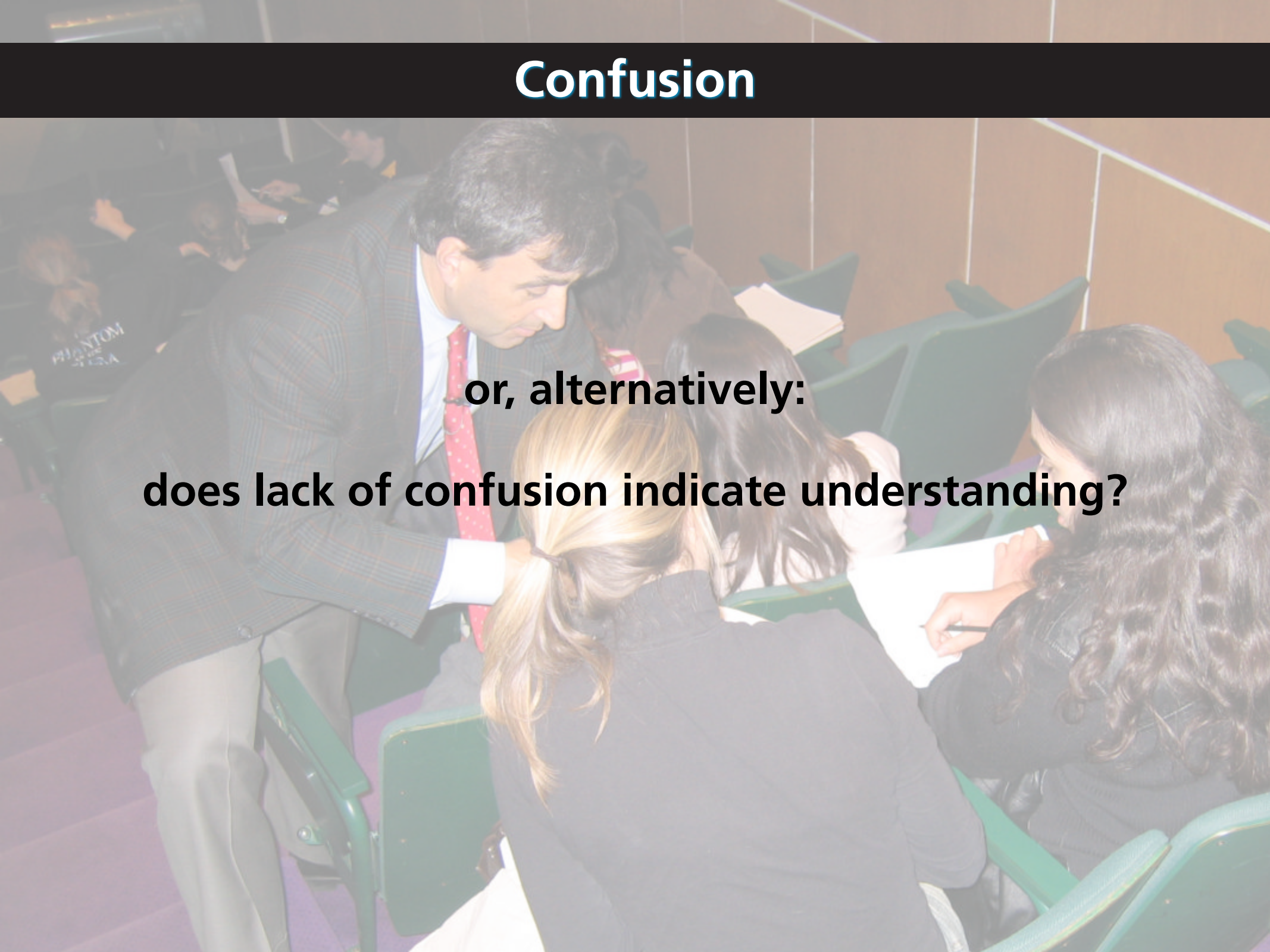
**does confusion indicate lack of understanding?**

A photograph of a man in a dark suit and red tie leaning over a desk to assist students. The students are seated at green desks, and the man is pointing at a document on the desk. The background shows a classroom setting with other students and a wooden wall.

# Confusion

**or, alternatively:**

**does lack of confusion indicate understanding?**



# Confusion

**Web-based free-response reading assignment:**

- **two questions on content (difficult!)**
- **one feedback question**

*Novak et al., Just-in-Time Teaching: Blending active learning with web technology* (Prentice Hall, 1999).



# Confusion

**Web-based free-response reading assignment:**

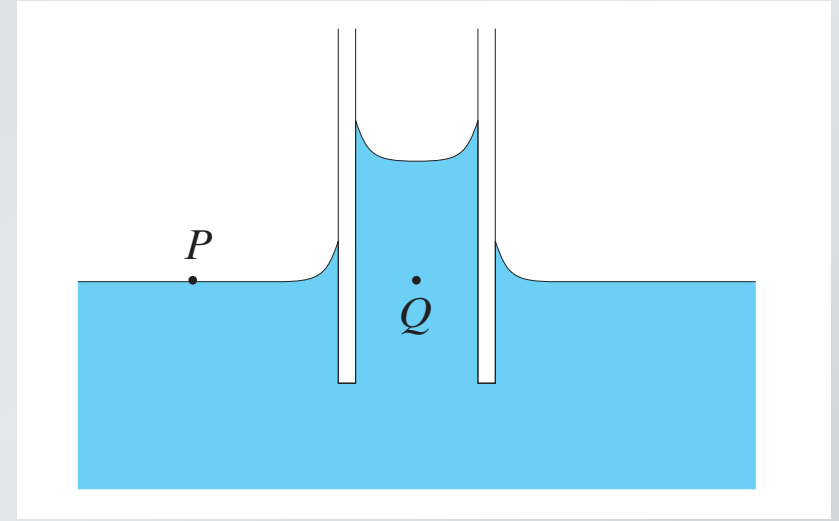
- **two questions on content (difficult!)**
- **one feedback question**

**analyze understanding and confusion**

*Novak et al., Just-in-Time Teaching: Blending active learning with web technology* (Prentice Hall, 1999).

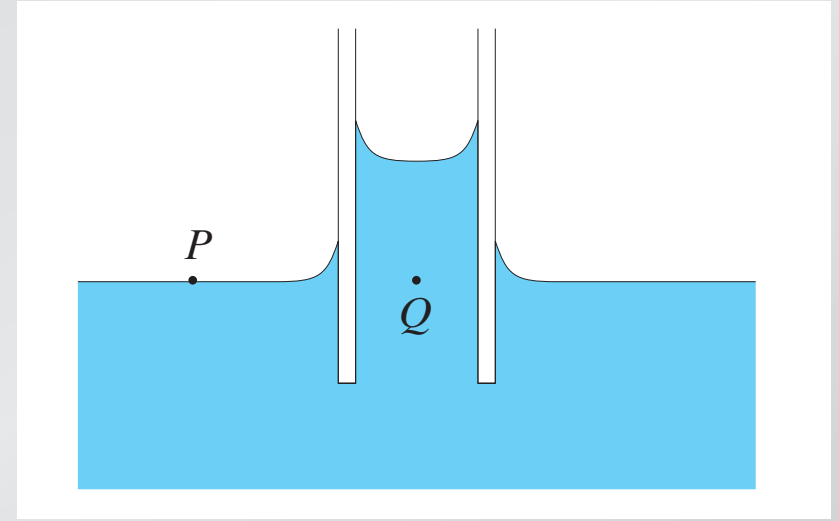
# Confusion

1. 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?

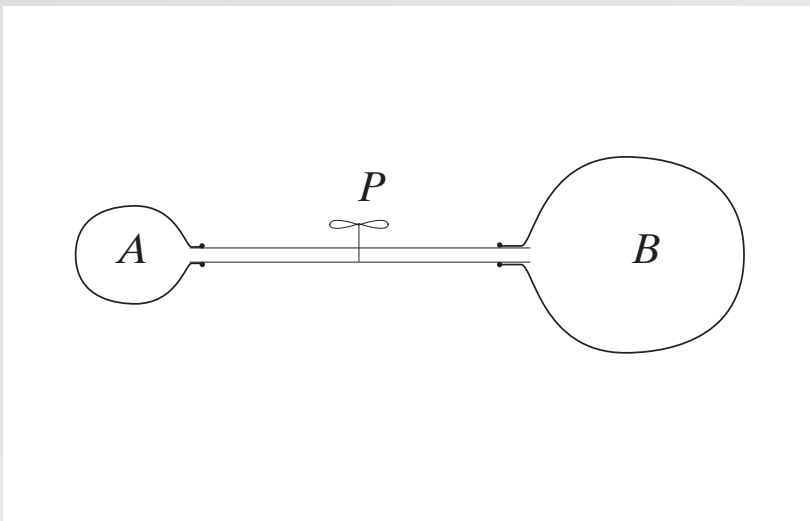


# Confusion

1. 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?



2. 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?



# Confusion

**3. Please tell us briefly what points of the reading you found most difficult or confusing. If you did not find any part of it difficult or confusing, please tell us what parts you found most interesting.**

# Confusion

## sample answer

- 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.**

# Confusion

sample answer

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.

# Confusion

sample answer

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# Confusion

sample answer

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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.



# Confusion

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.

# Confusion

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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# Confusion

## Analysis

### Coding of responses:

- Q1 and Q2: correct or incorrect
- Q3: confusion expressed on topic of Q1/Q2

**Correlate confusion with correctness**

# Confusion

traditional textbook on Laplace's law and capillarity

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

# Confusion

traditional textbook on Laplace's law and capillarity

---

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

---

---

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

---

# Confusion

**“Confused” students twice as likely correct!**



# Confusion

using research-based text

---

<b>torque</b>	<b>correct</b>	<b>incorrect</b>
<b>confused</b>	<b>45%</b>	<b>55%</b>
<b>not confused</b>	<b>43%</b>	<b>57%</b>

---

# Confusion

using research-based text

---

<b>torque</b>	<b>correct</b>	<b>incorrect</b>
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---

**text compels students to think while reading**

# Confusion

**More confusion among students who understand!  
(especially when students are not pushed to think)**

# Confusion

## Confusion...

- **doesn't correlate with understanding**
- **is not (necessarily) the result of poor teaching**
- **is part of the learning process**

# Conclusion

**classroom data vital to improving education!**

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