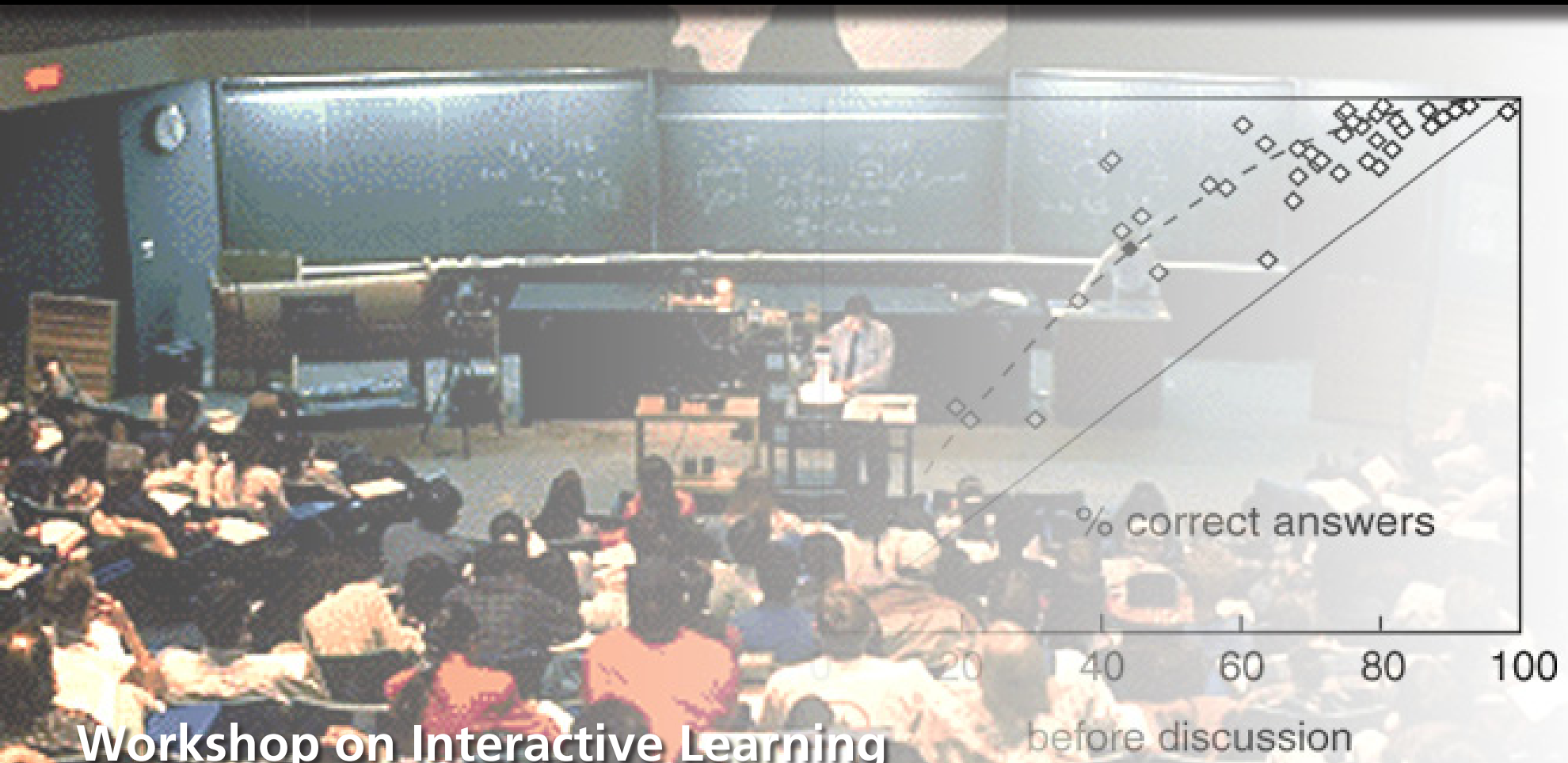
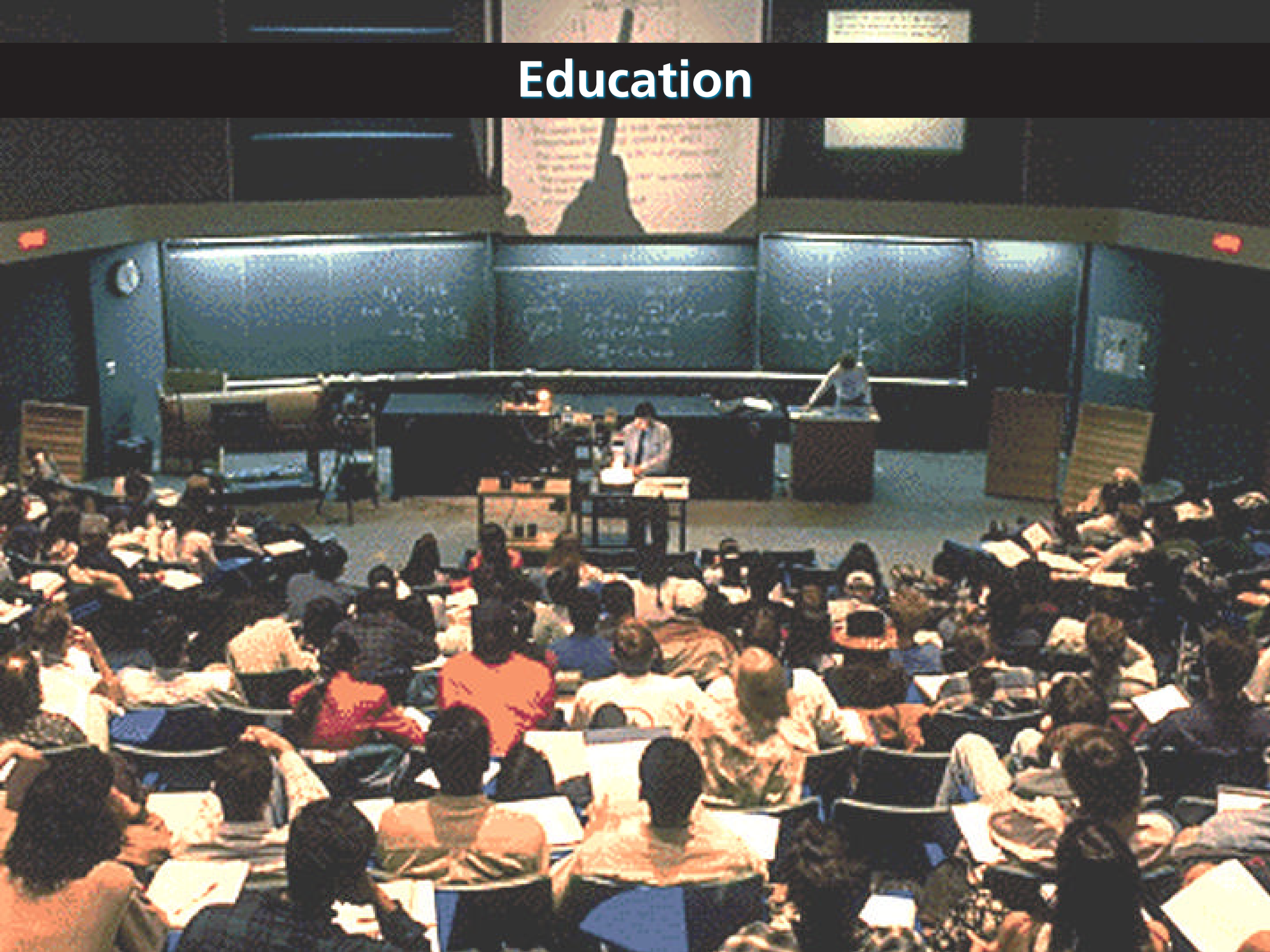
The scientific approach to teaching: research as a basis for course design

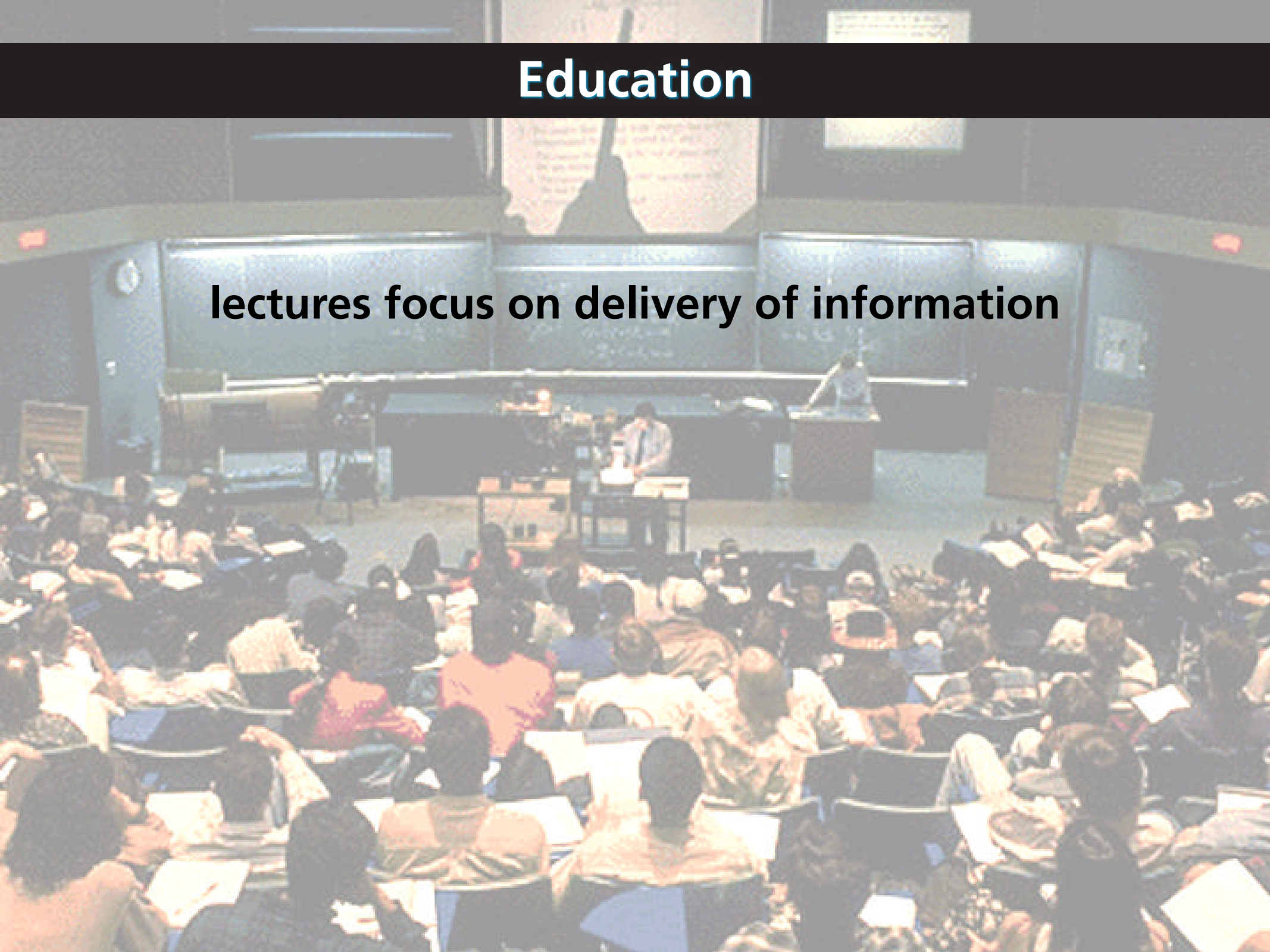


Workshop on Interactive Learning
in Undergraduate Physics
Australian National University
Canberra, Australia, 27 March 2009

Education

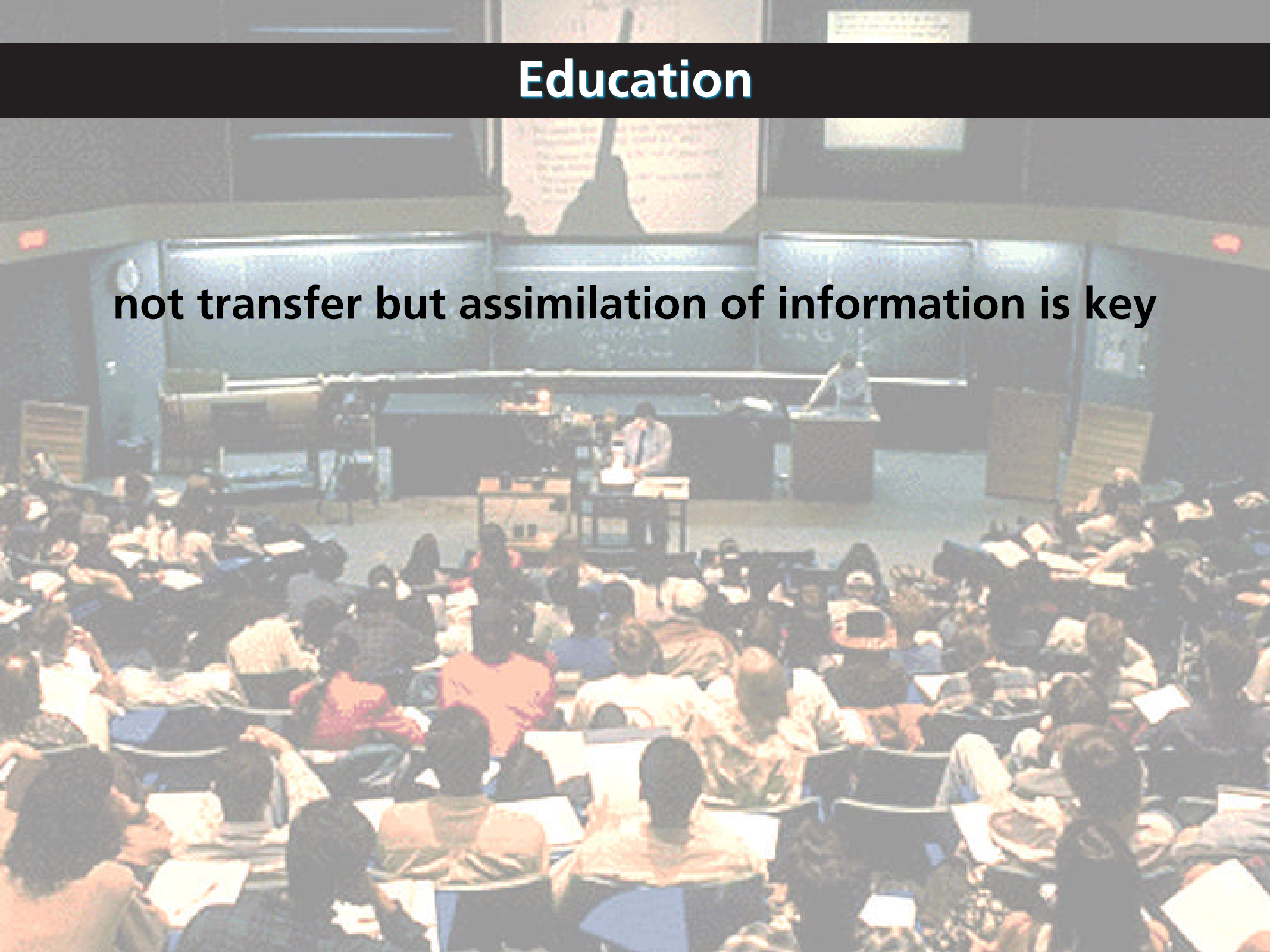


Education



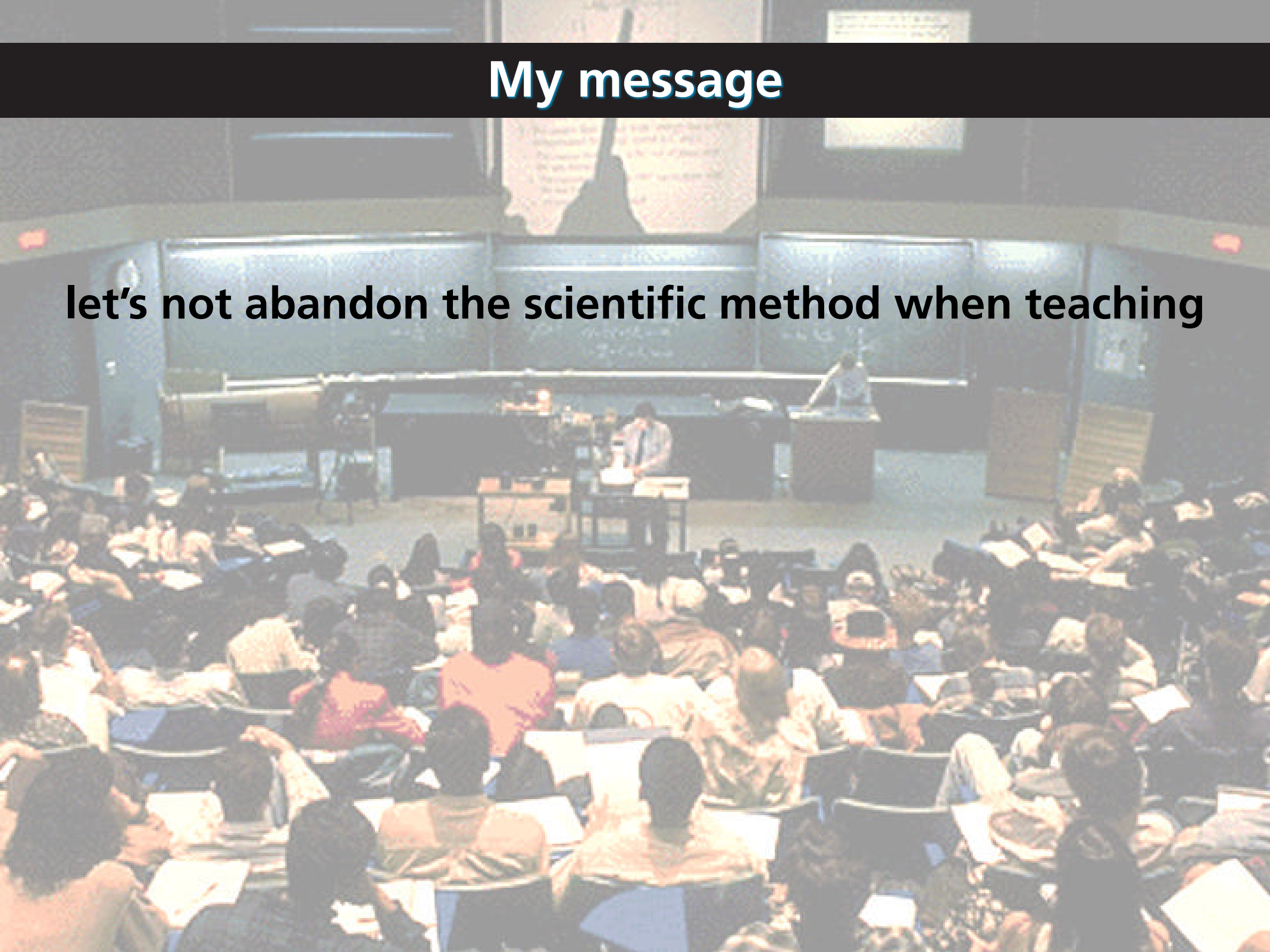
lectures focus on delivery of information

Education

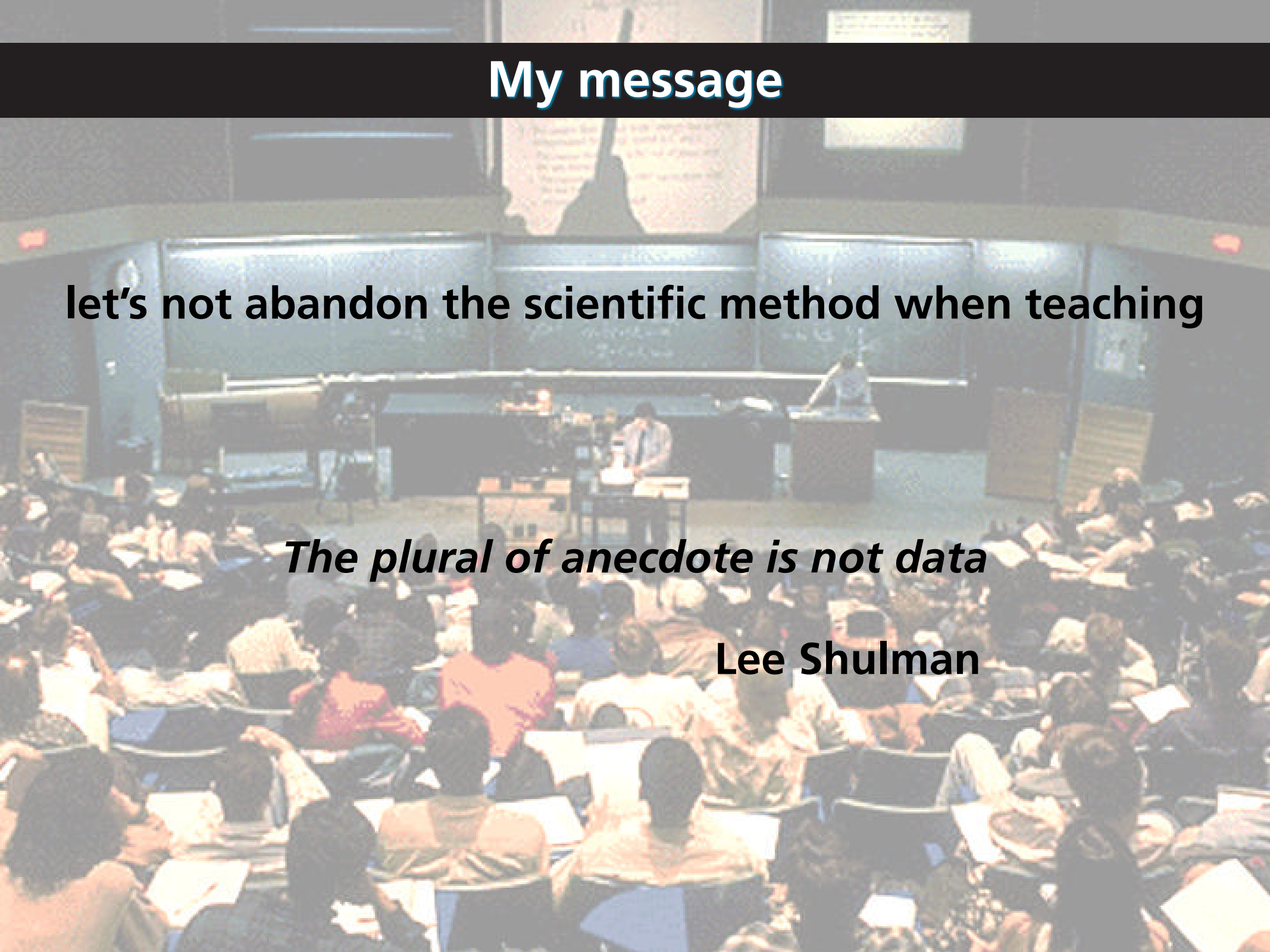


not transfer but assimilation of information is key

My message



let’s not abandon the scientific method when teaching



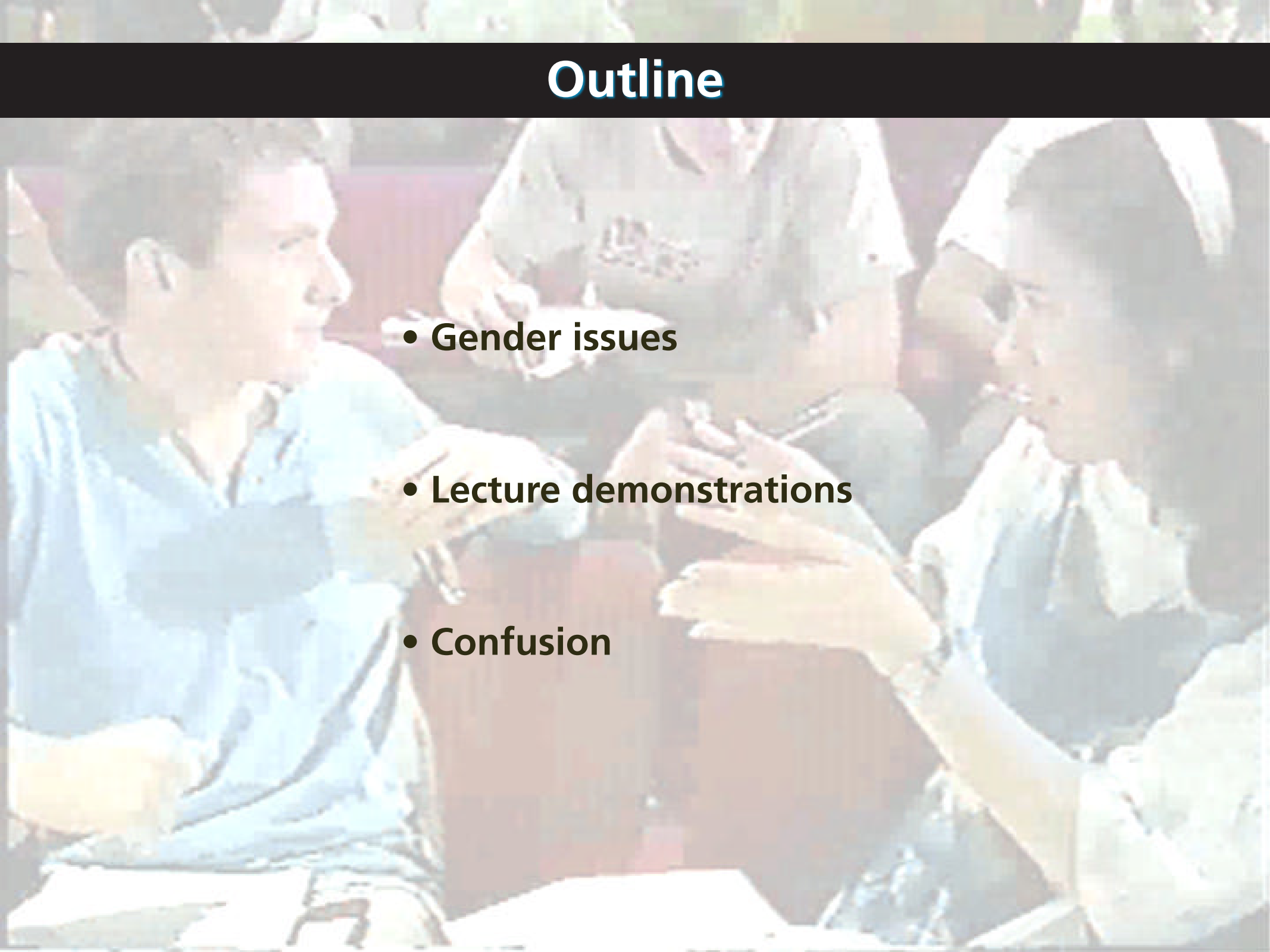
My message

let's not abandon the scientific method when teaching

The plural of anecdote is not data

Lee Shulman

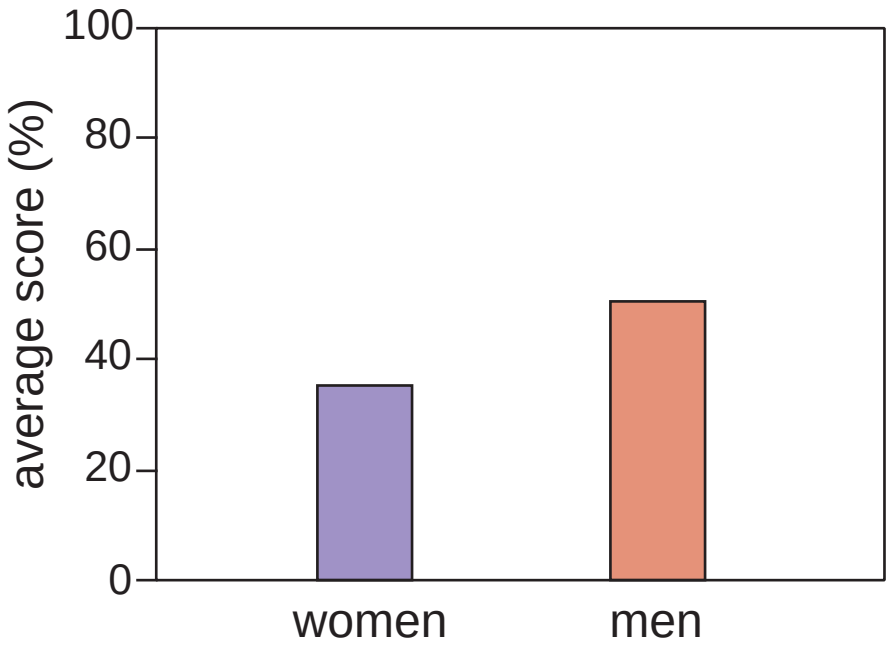
Outline



- Gender issues
- Lecture demonstrations
- Confusion

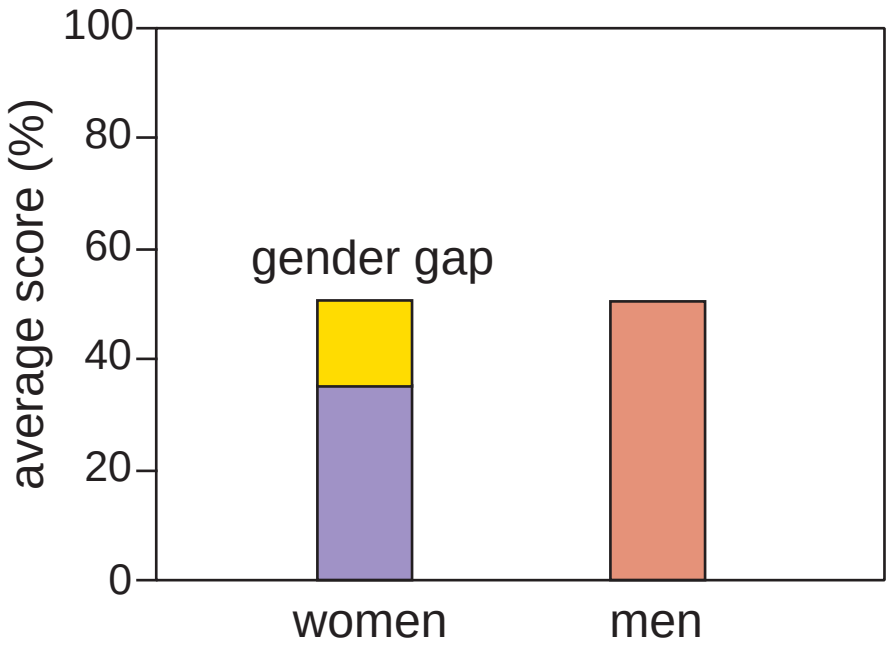
Gender issues

Force Concept Inventory postest scores



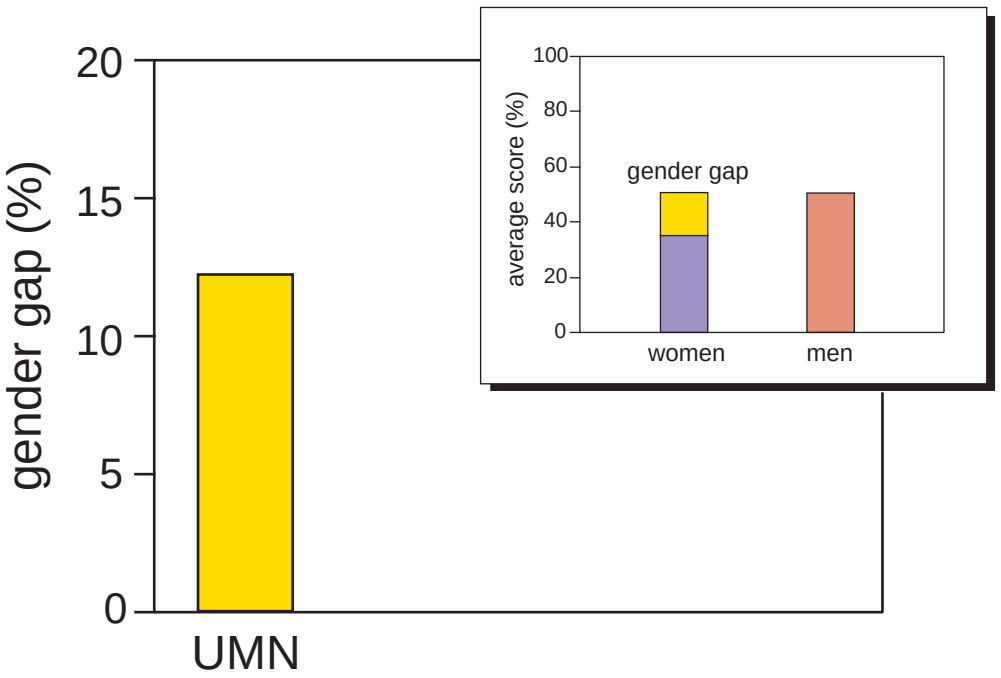
Gender issues

Force Concept Inventory postest scores



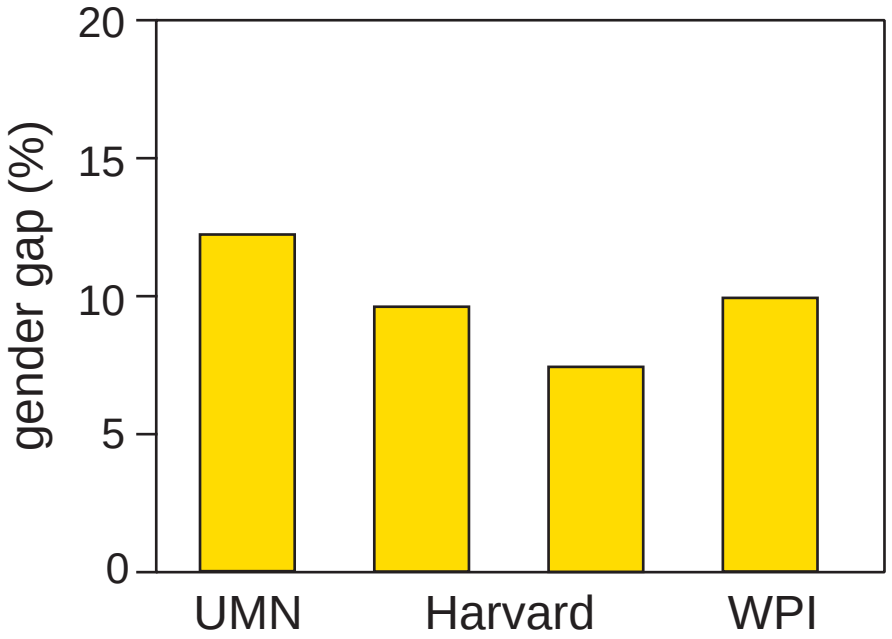
Gender issues

Force Concept Inventory postest scores

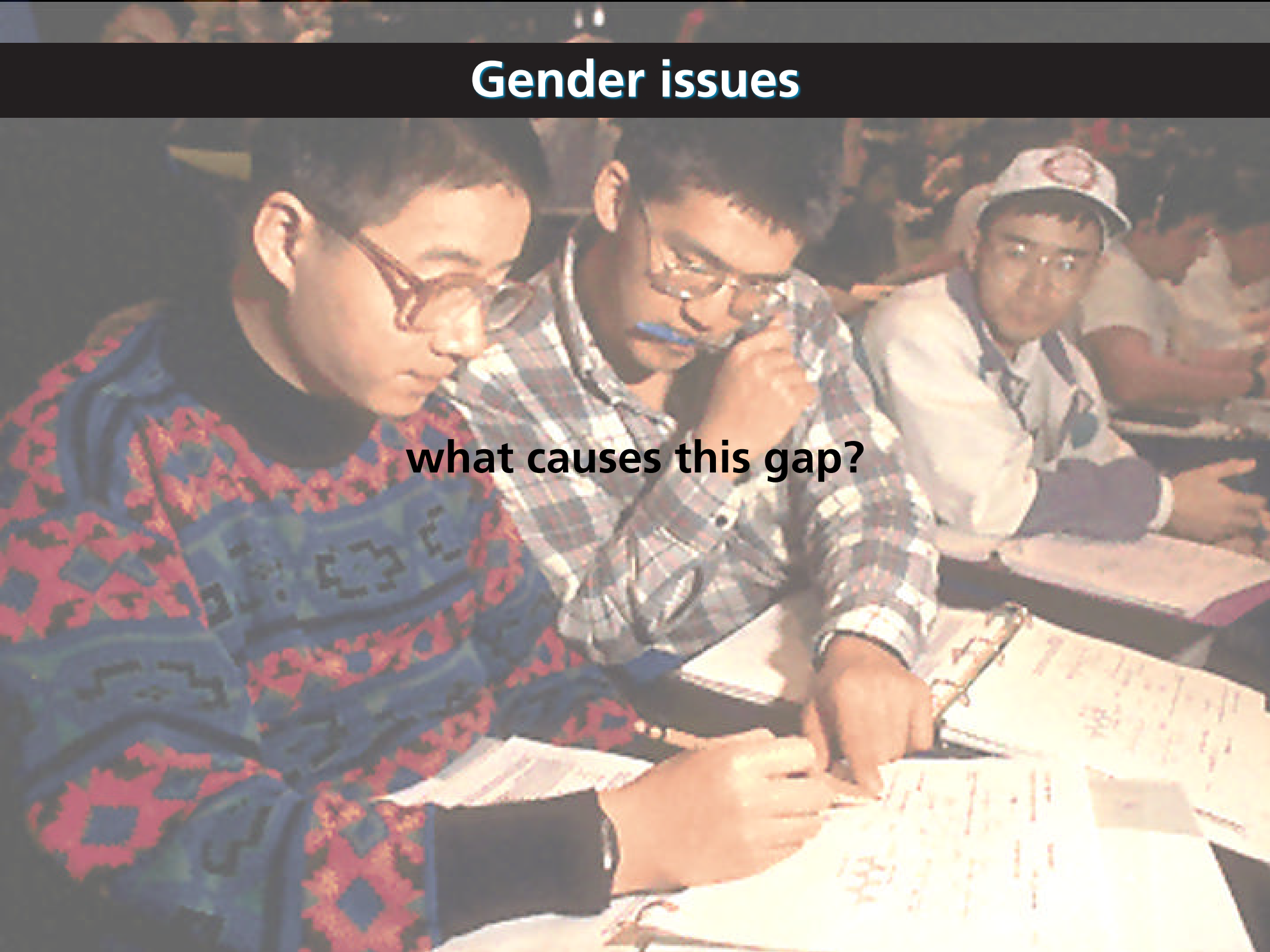


Gender issues

Force Concept Inventory postest scores



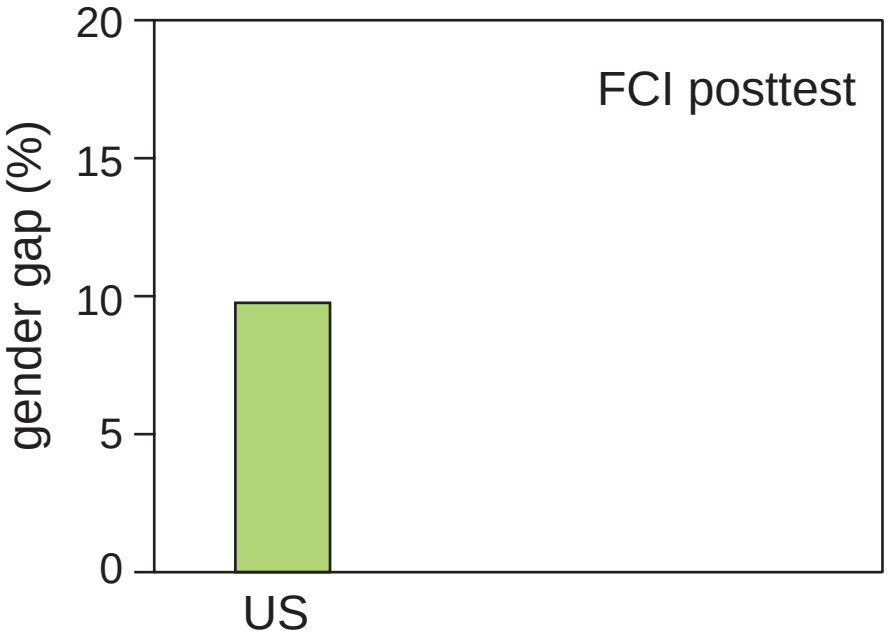
Gender issues



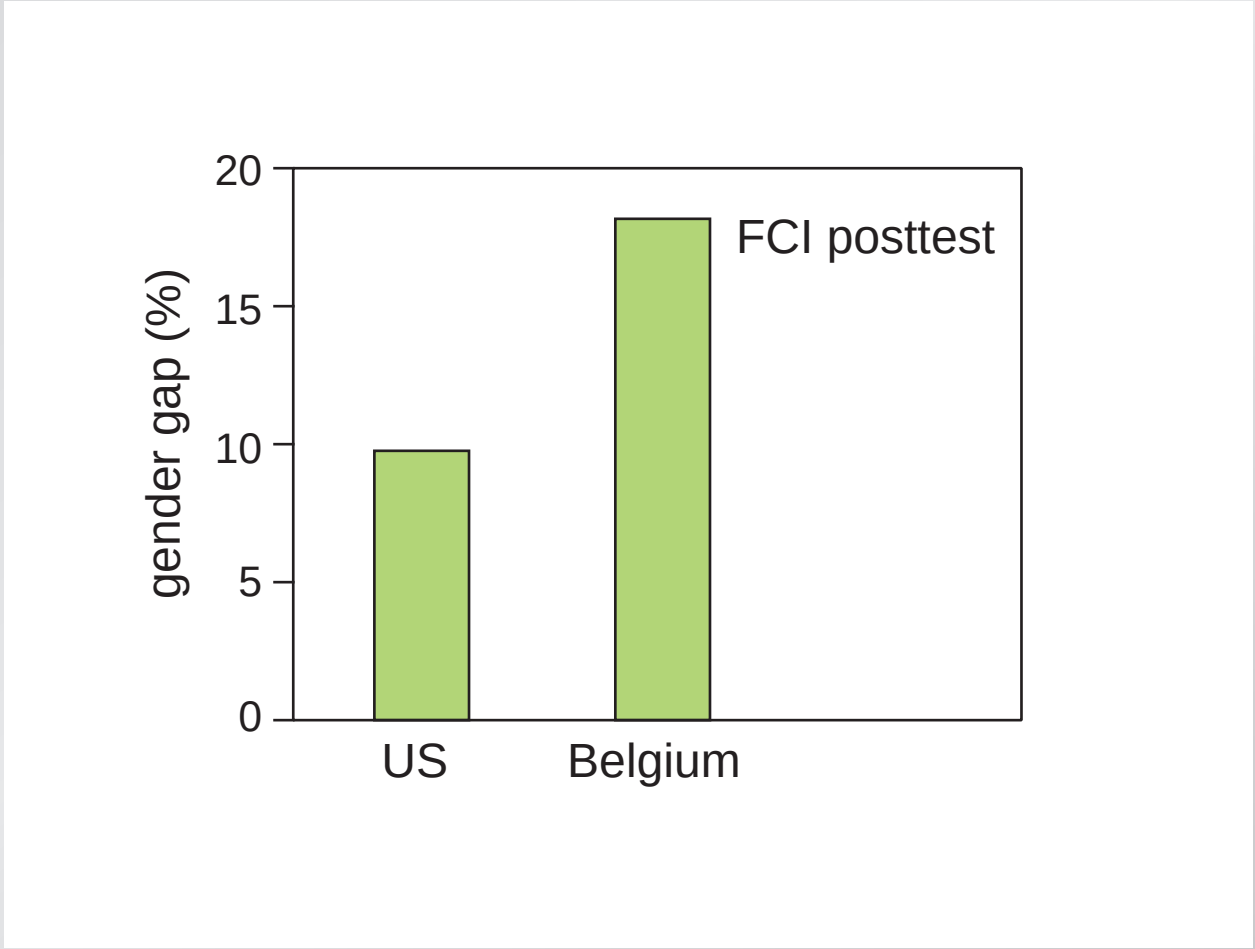
what causes this gap?

Gender issues

is it cultural?

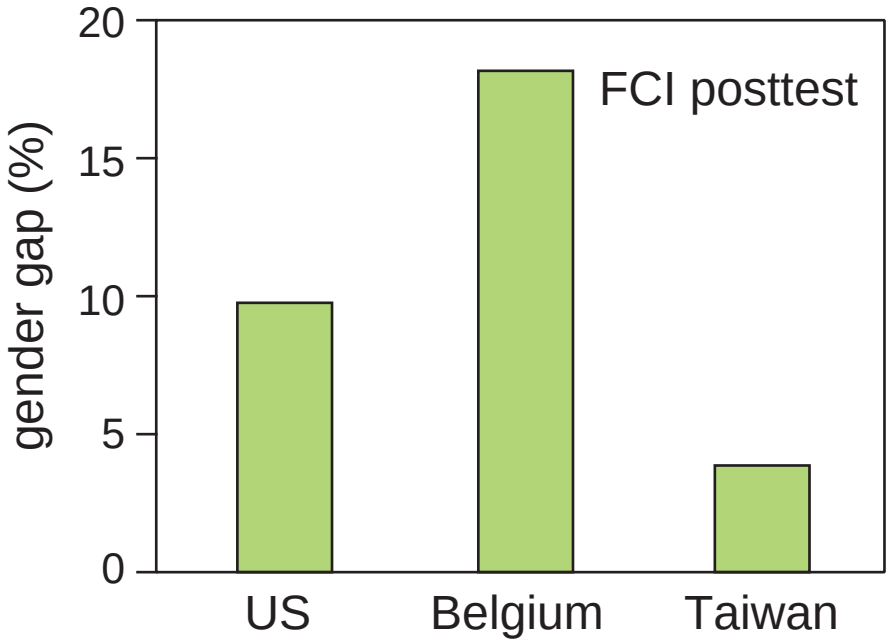


Gender issues



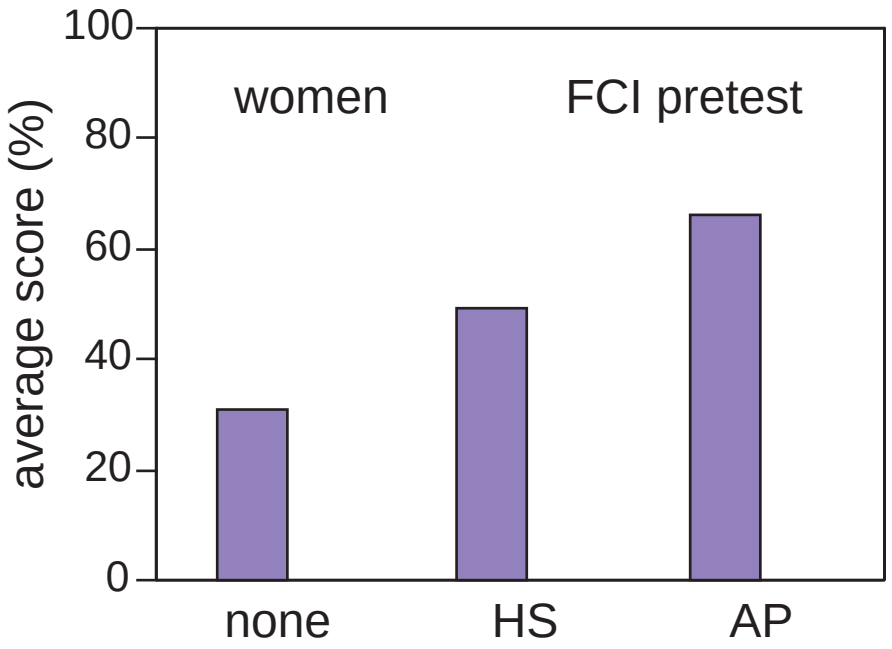
Gender issues

strong dependence on culture!



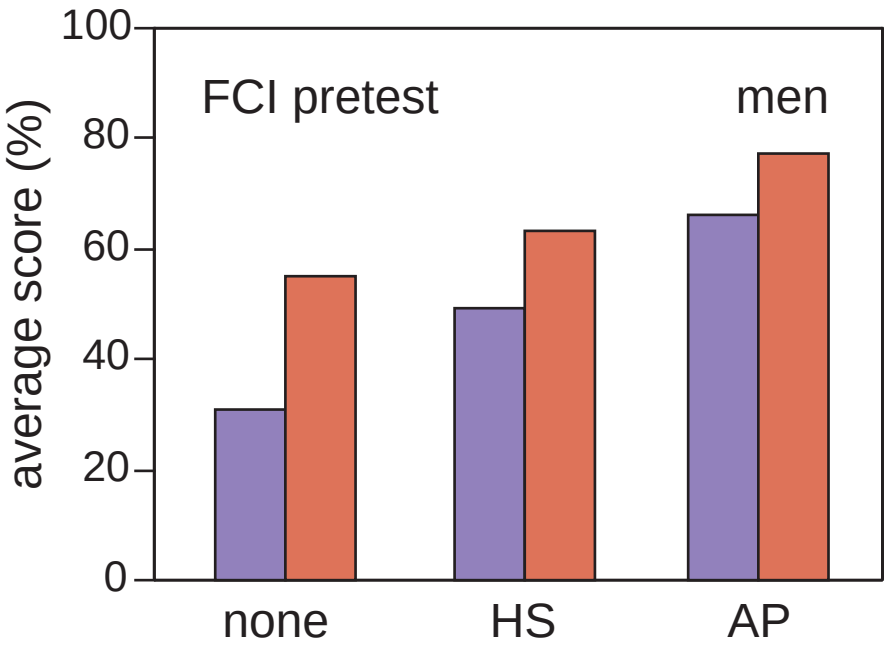
Gender issues

effect of precollege education



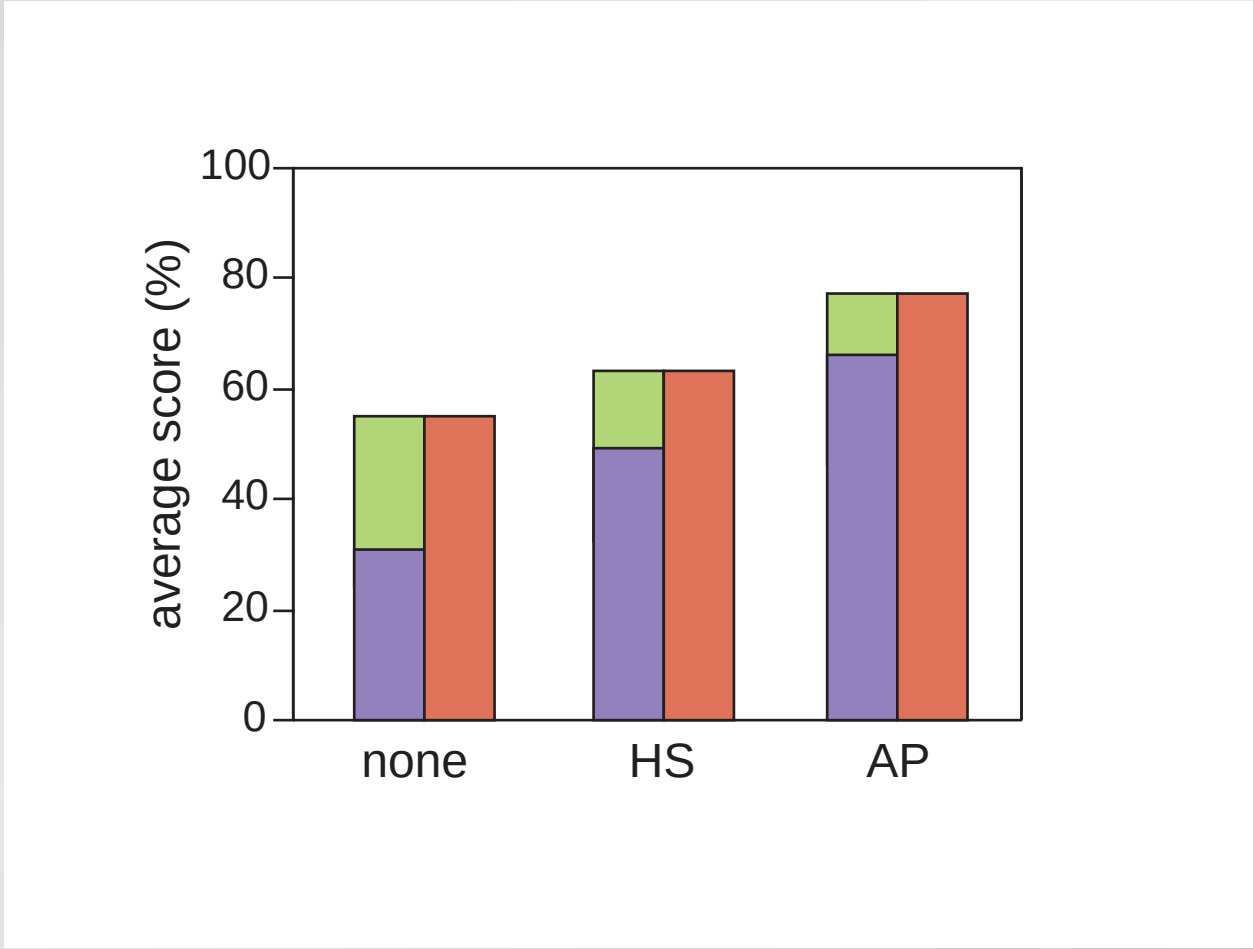
Gender issues

everyone gains…



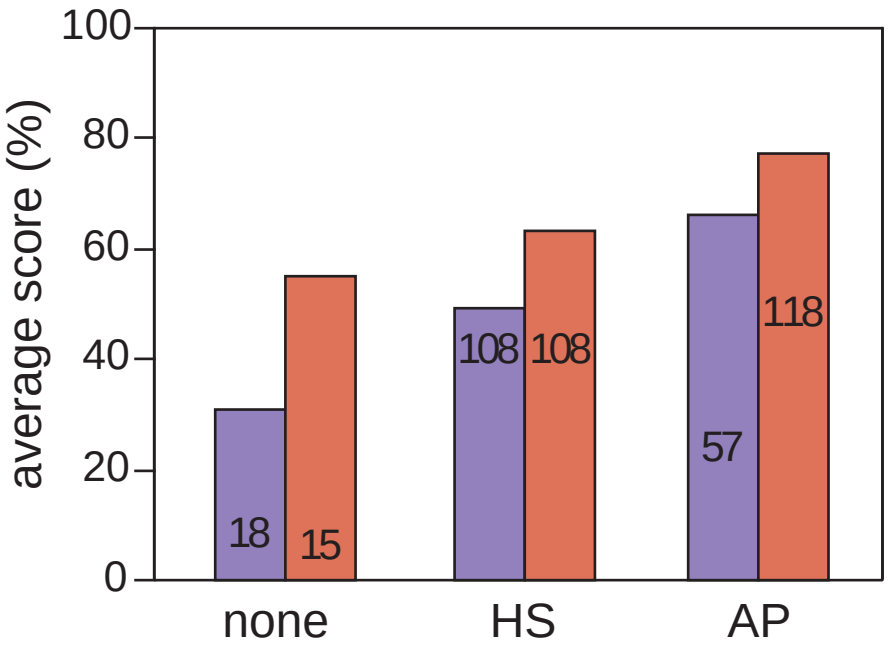
Gender issues

…but gap persists…



Gender issues

…and women underrepresented



Gender issues

Gender issues

increase collaboration and interactivity

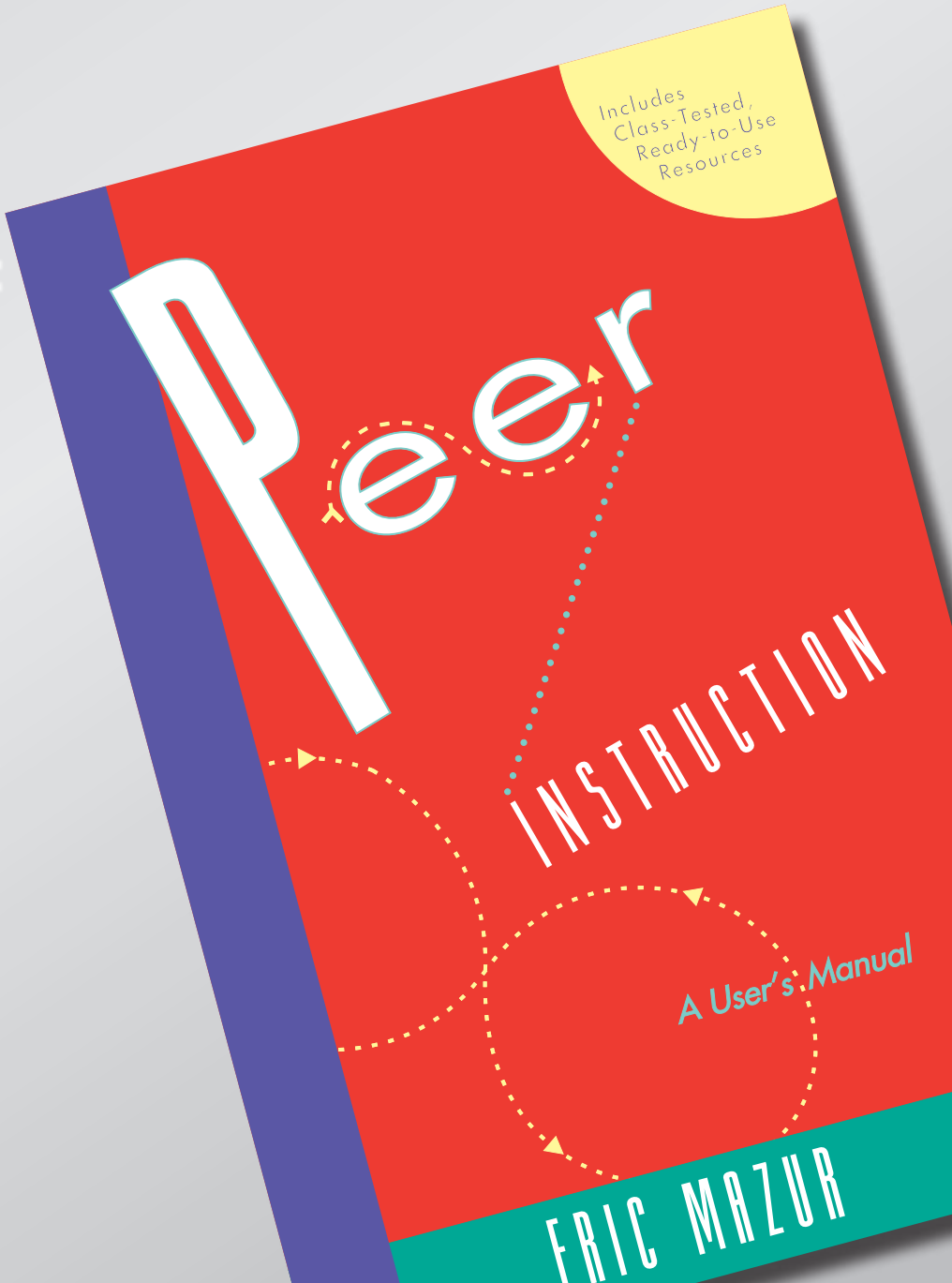
Gender issues

Compare three pedagogies:

T: traditional lectures

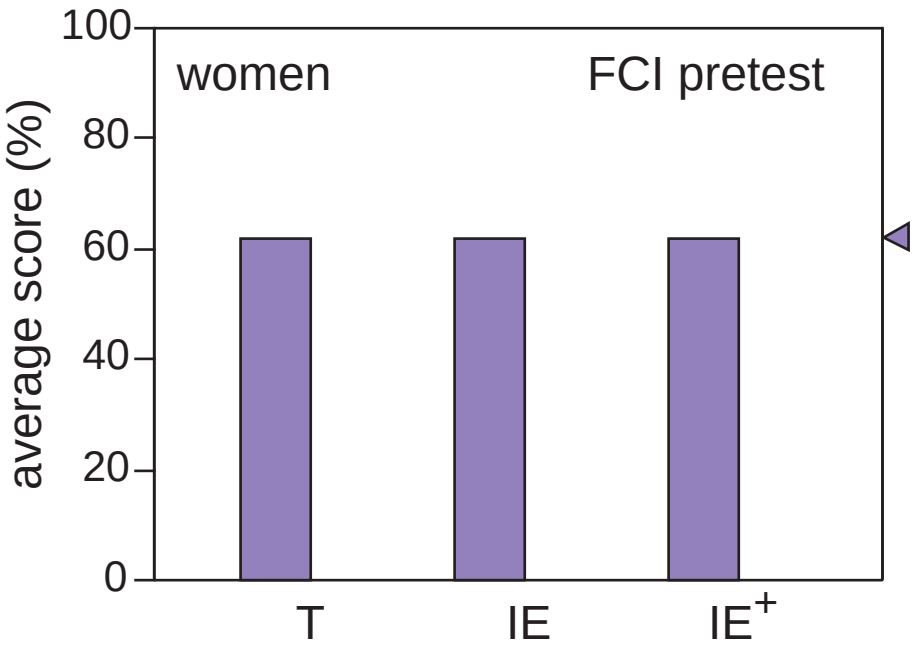
I: interactive lectures

I^{+}: interactive assignments, lectures, and tutorials



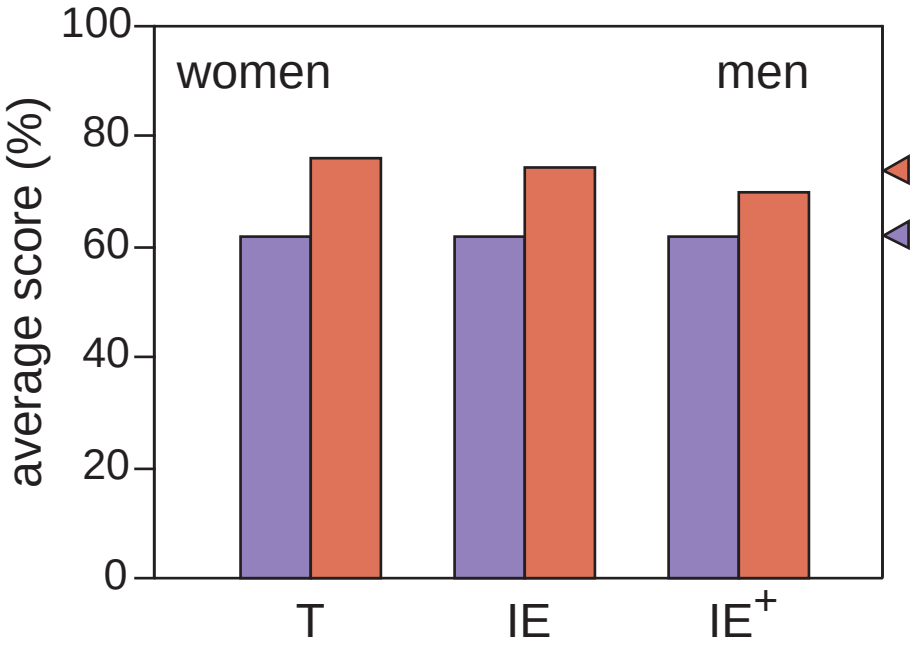
Gender issues

does pedagogy help?



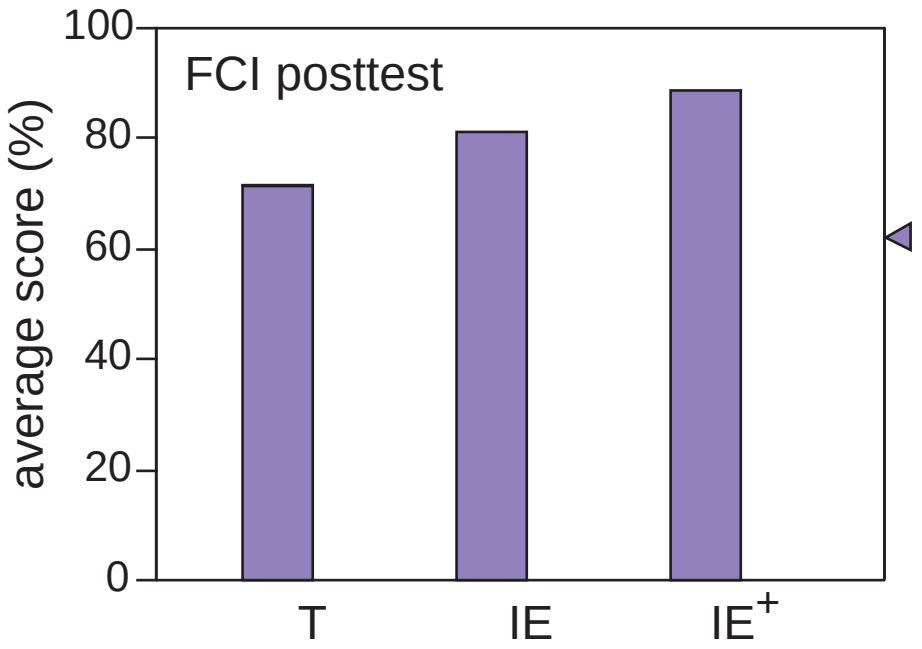
Gender issues

does pedagogy help?



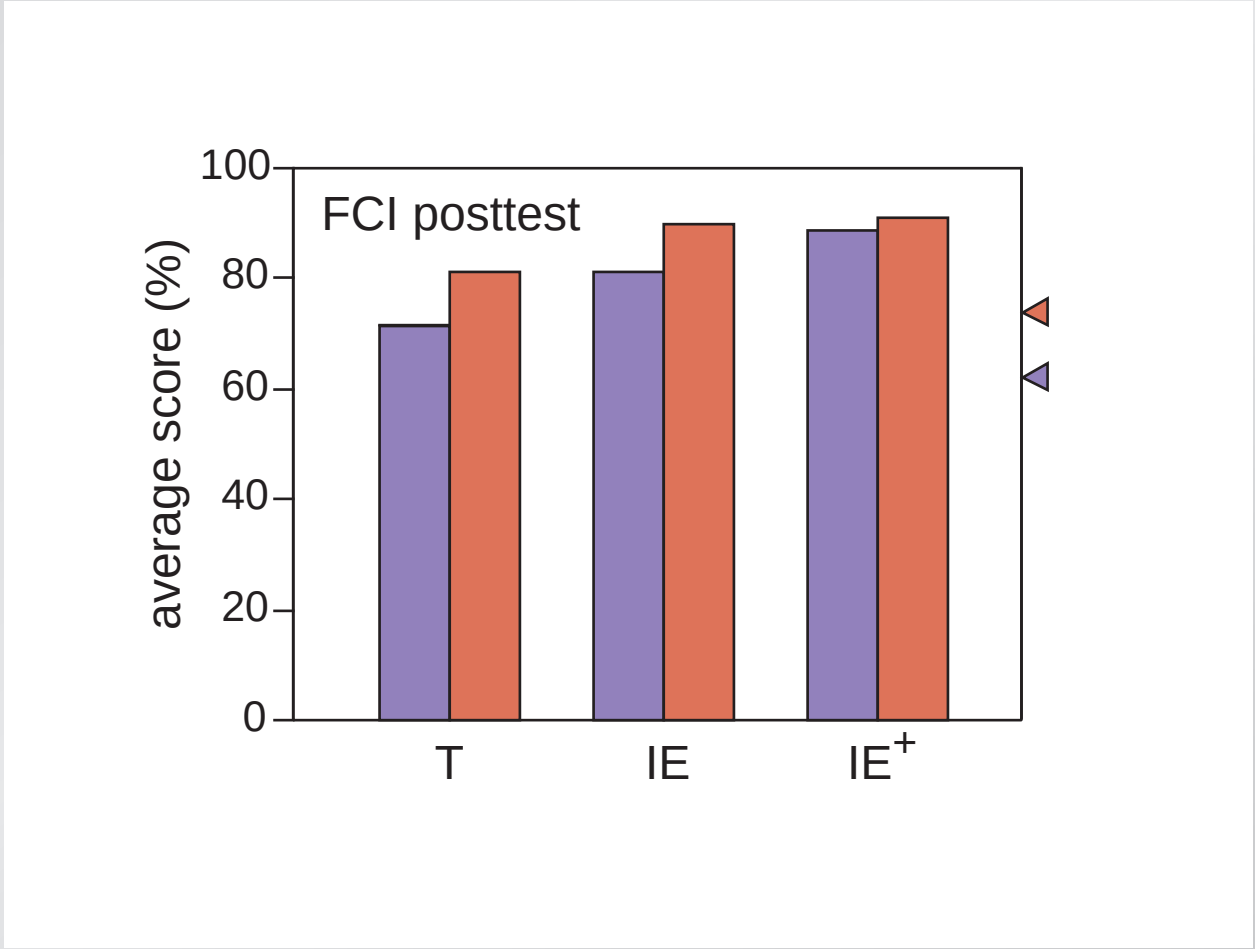
Gender issues

does pedagogy help?



Gender issues

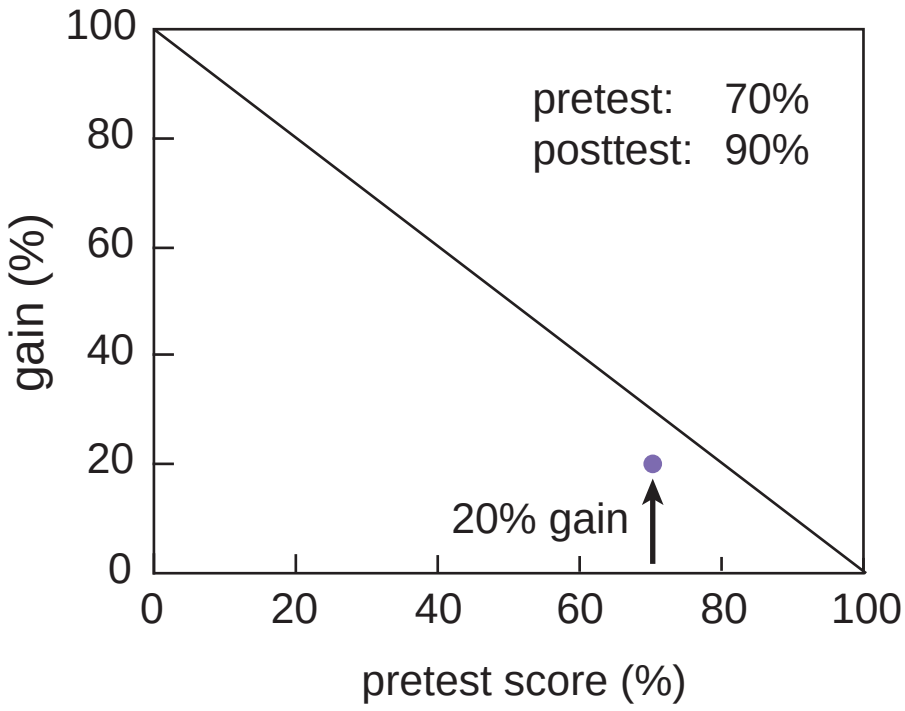
yes, pedagogy can eliminate gap!



Am. J. Phys. 74, 118 (2006)

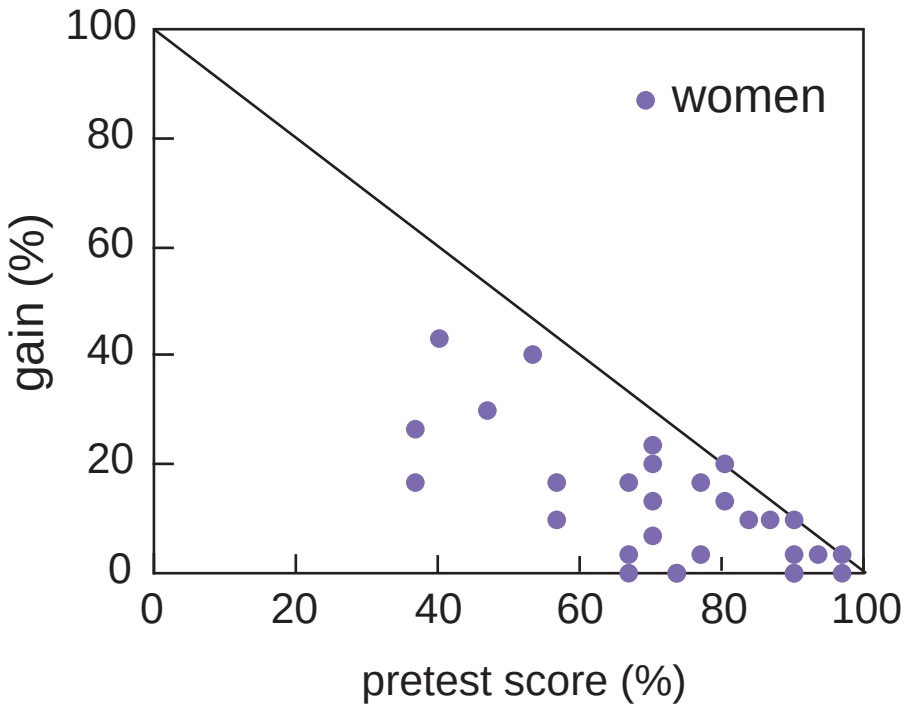
Gender issues

who are the low-gain students?



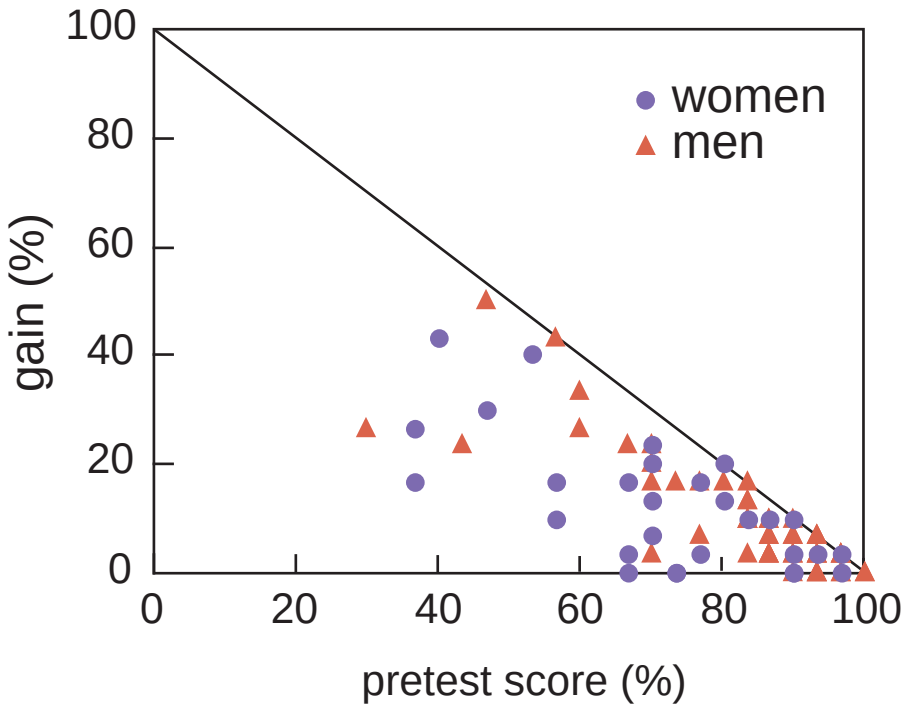
Gender issues

traditional class



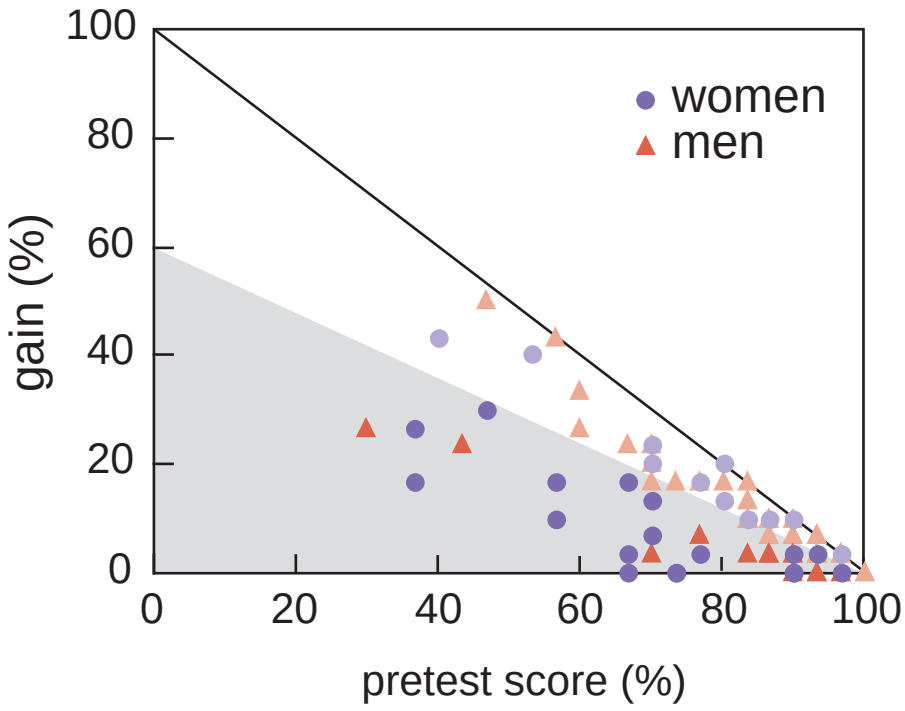
Gender issues

traditional class



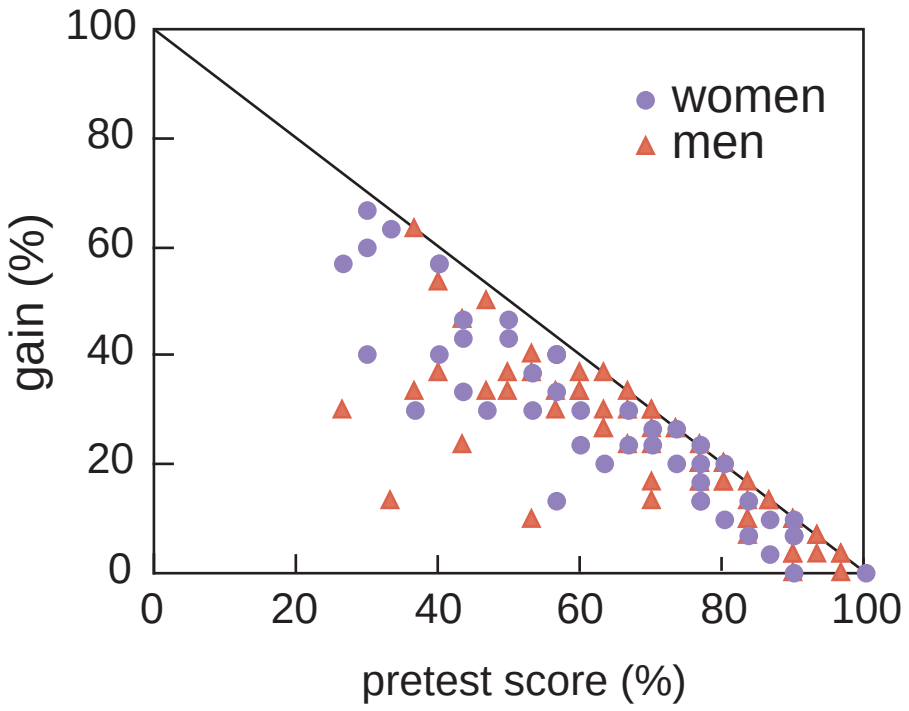
Gender issues

traditional class: gender imbalance



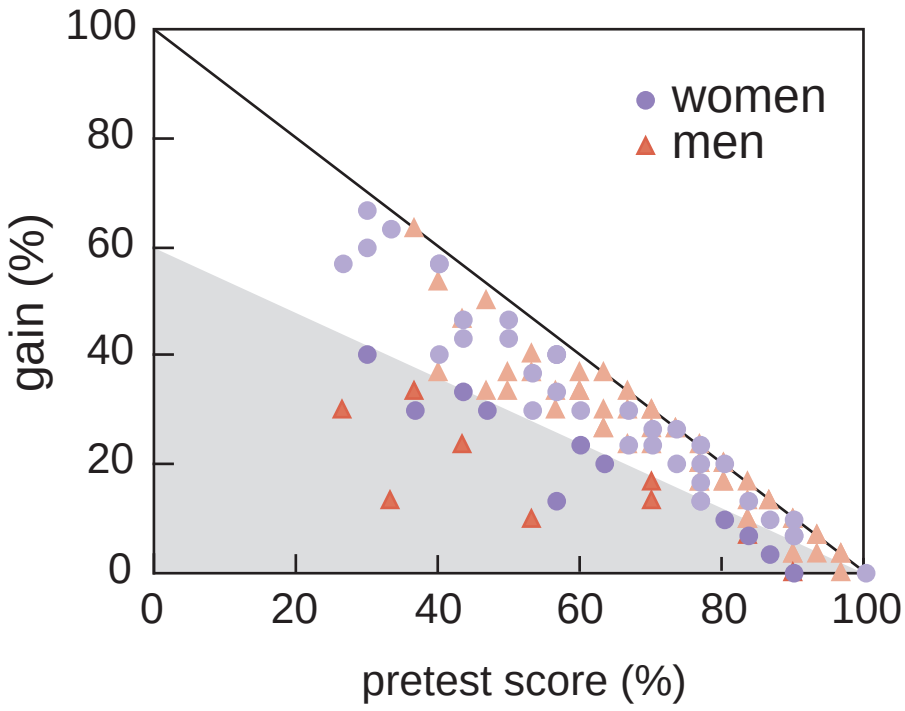
Gender issues

interactive class



Gender issues

interactive class: gender balance

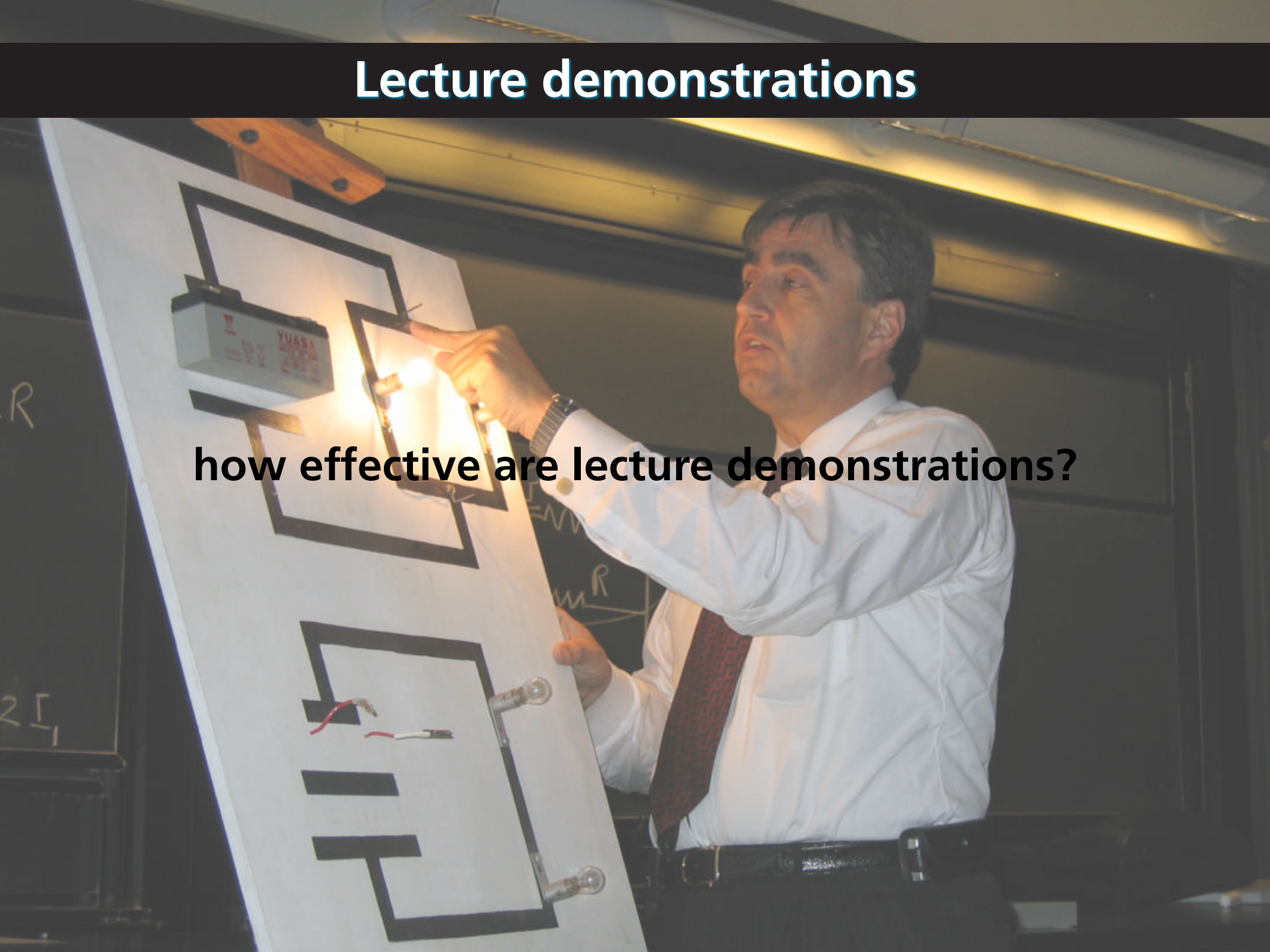


Gender issues

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.)

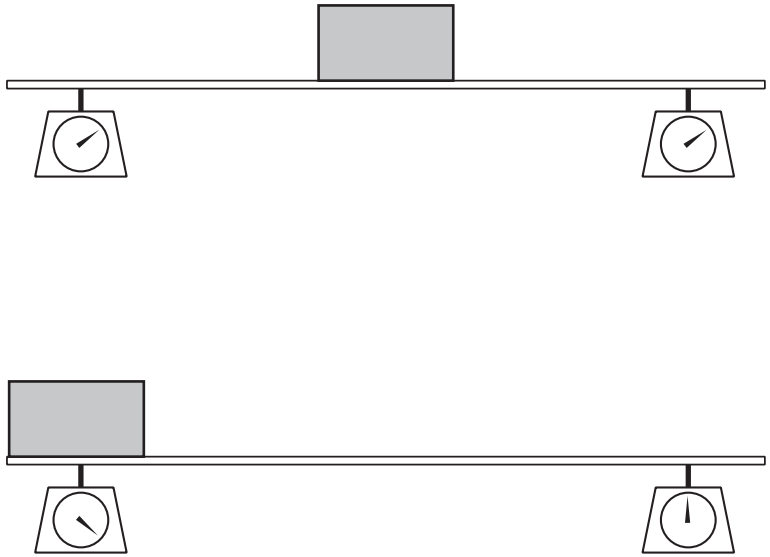
Lecture demonstrations

Follow up:

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

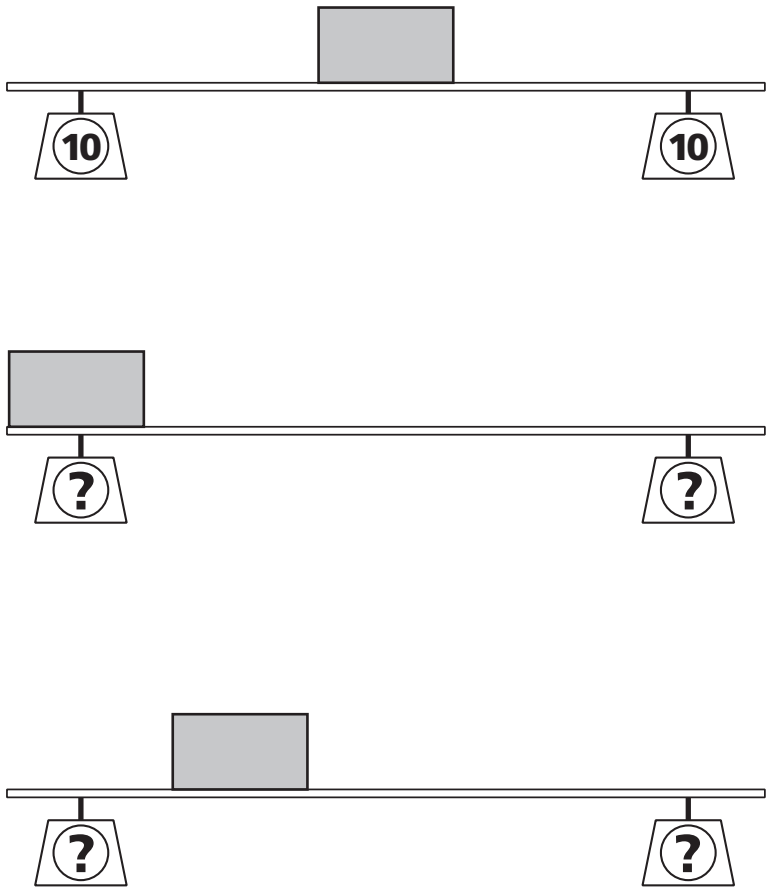
Lecture demonstrations

loaded beam demo



Lecture demonstrations

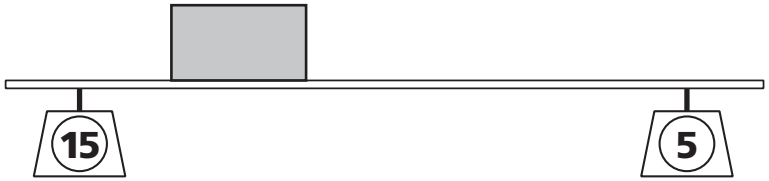
online test question



Lecture demonstrations

answers given

24% of students



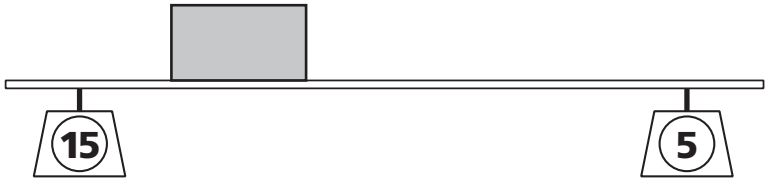
correct (mentions torque)

Lecture demonstrations

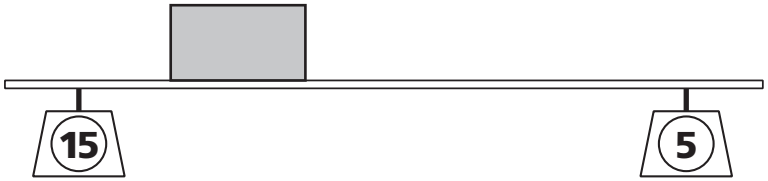
answers given

24% of students

38% of students



correct (mentions torque)



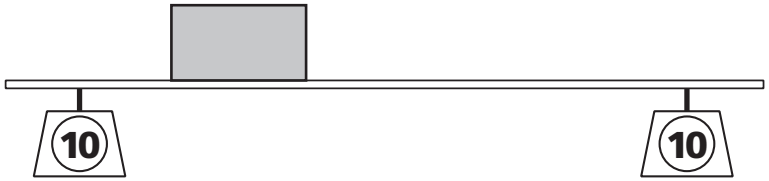
proportional reasoning

Lecture demonstrations

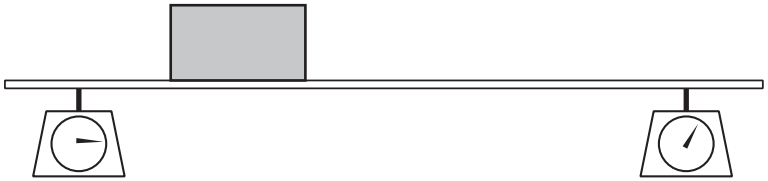
answers given

20% of students

10% of students



independent of position



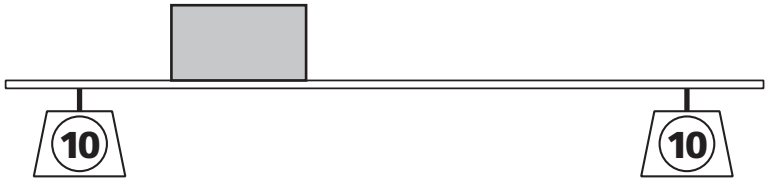
qualitative reasoning

Lecture demonstrations

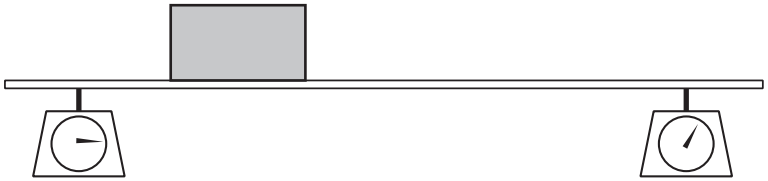
answers given

20% of students

10% of students



independent of position



qualitative reasoning

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

Lecture demonstrations

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

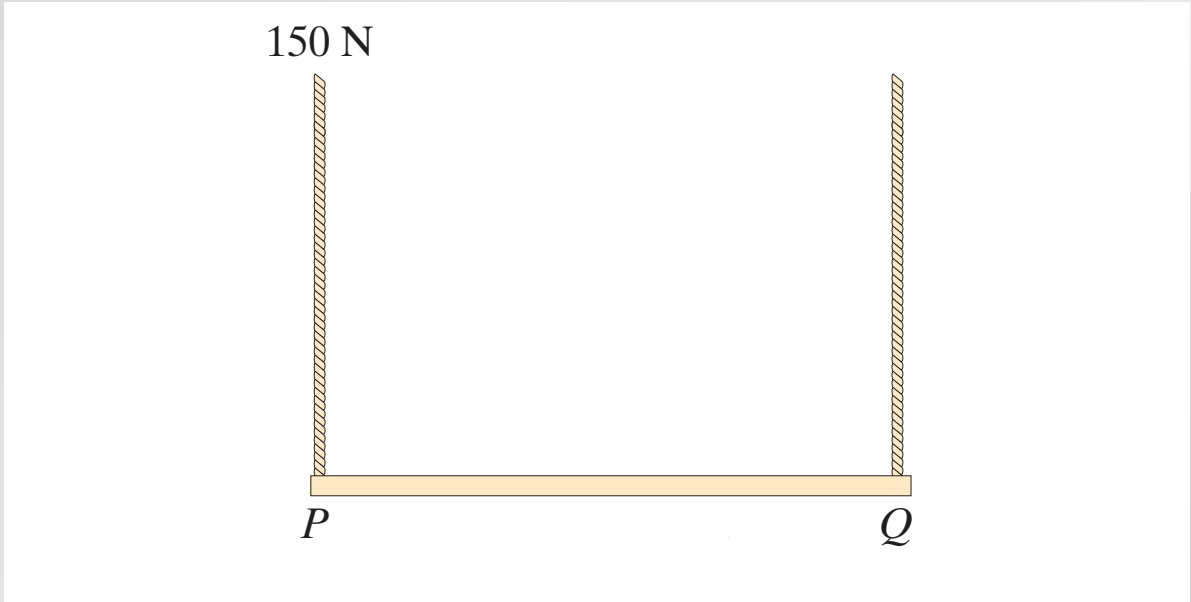
Lecture demonstrations

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

just presenting harmful?

Lecture demonstrations

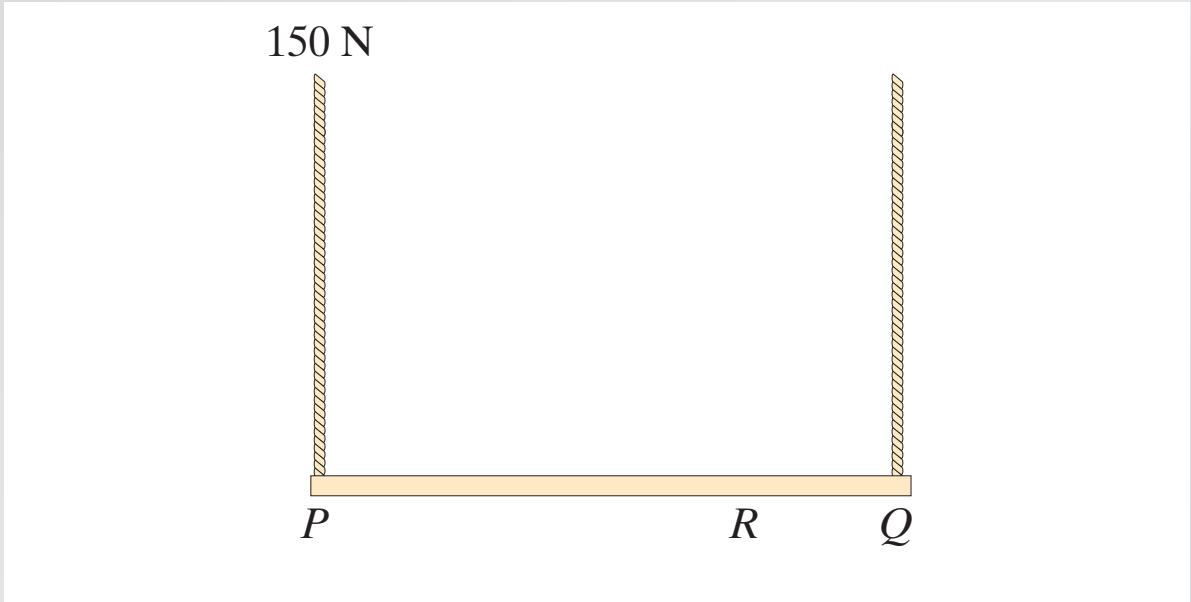
exam question



A uniform plank is supported by two ropes at points *P* and *Q*. The tension in the rope at *P* is 150 N.

Lecture demonstrations

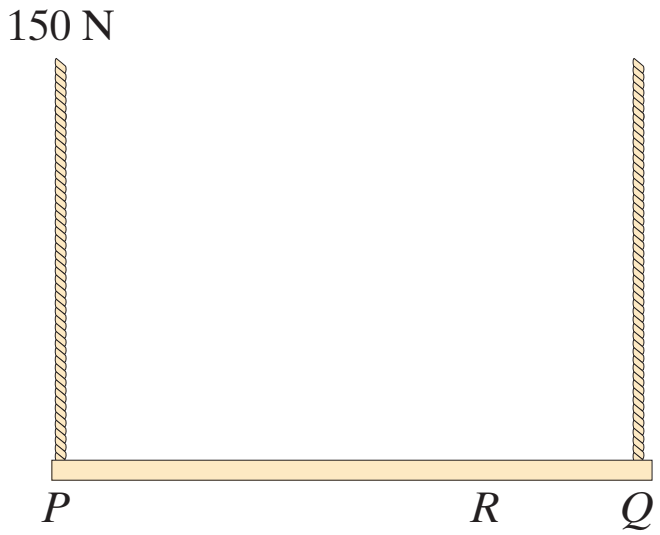
exam question

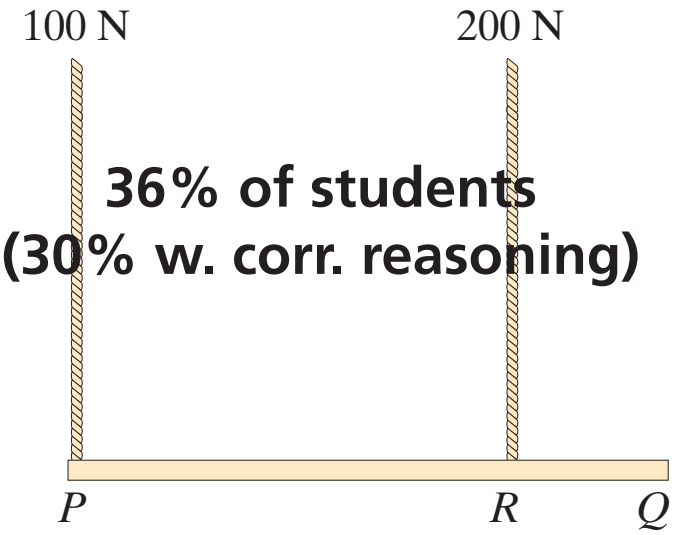


A uniform plank is supported by two ropes at points *P* and *Q*. The tension in the rope at *P* is 150 N. The point at which the other rope is attached to the plank is now moved to point *R* halfway between Q and the center of the plank. What are the tensions in the two ropes?

Lecture demonstrations

correct answer



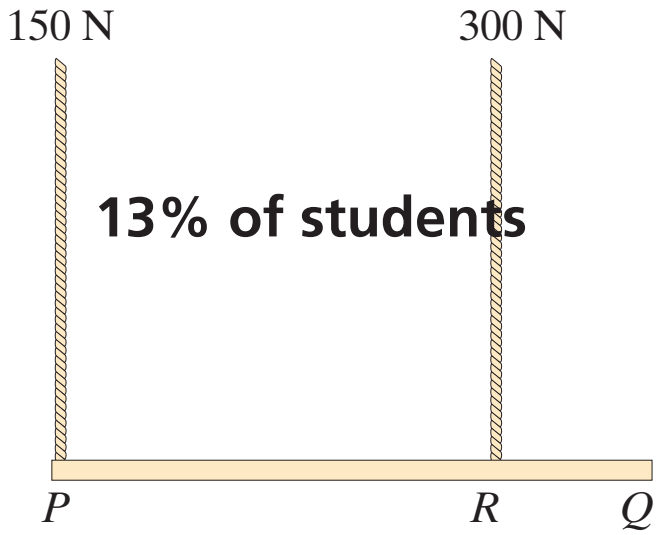


36% of students
(30% w. corr. reasoning)

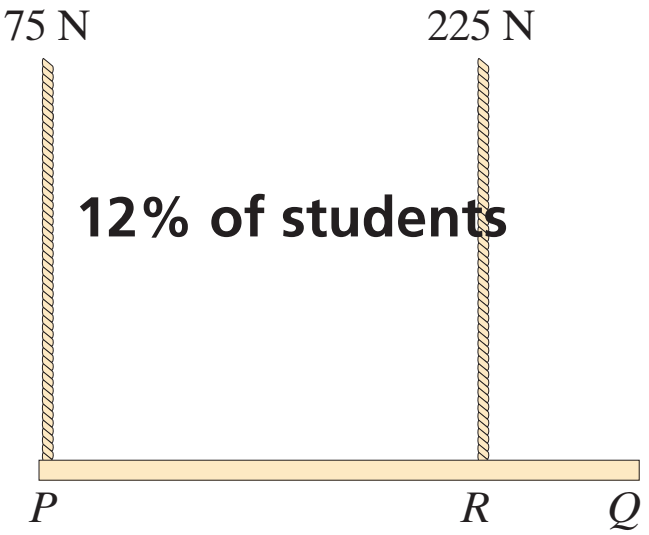
considerable improvement from online test

Lecture demonstrations

incorrect answers



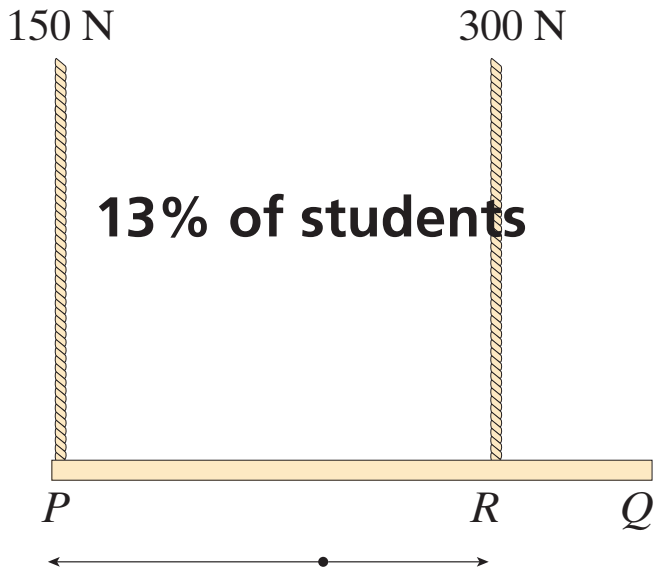
13% of students



12% of students

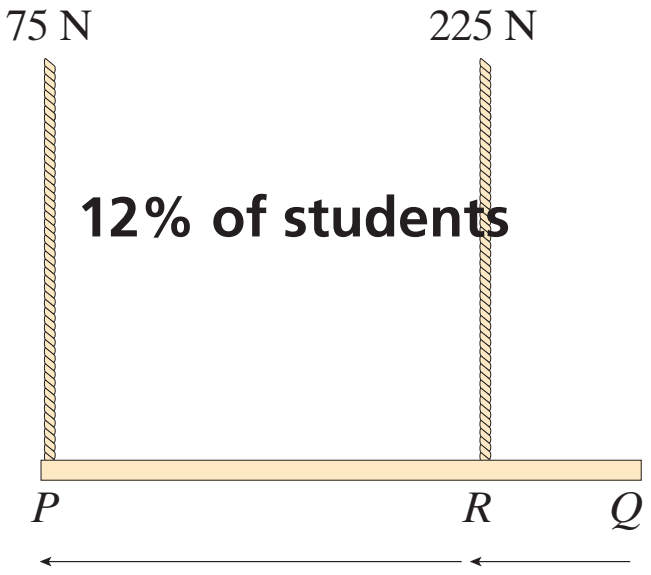
Lecture demonstrations

incorrect answers



13% of students

lever arm reduced by factor 2

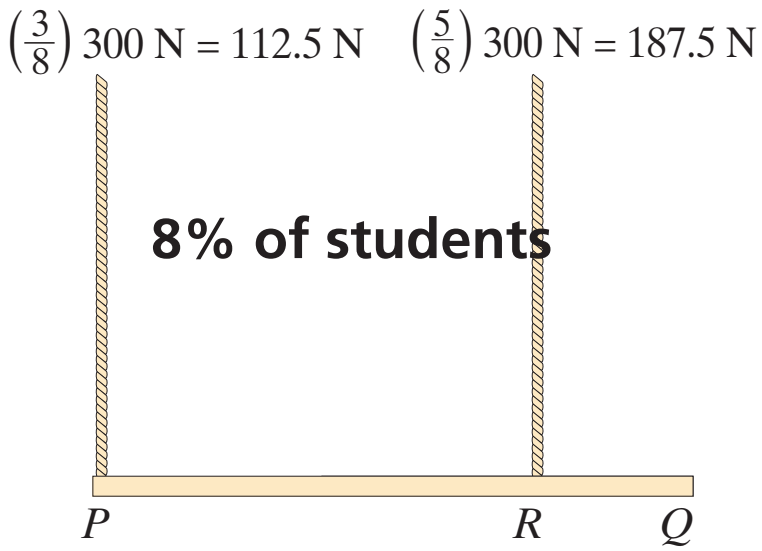


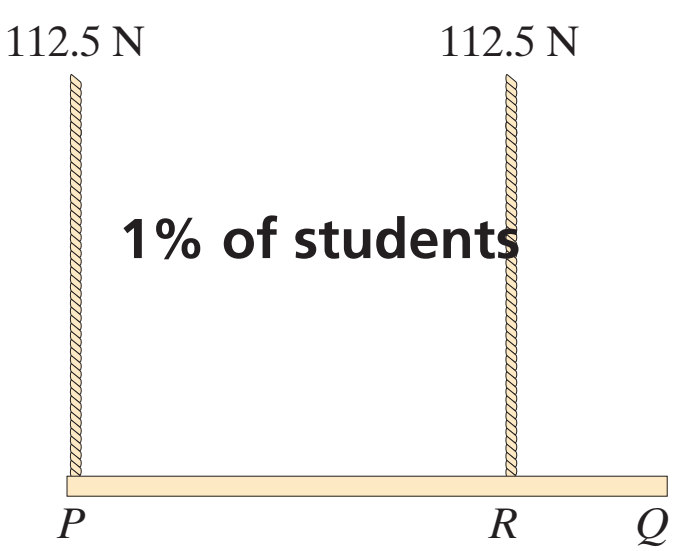
12% of students

lever arms 1:3

Lecture demonstrations

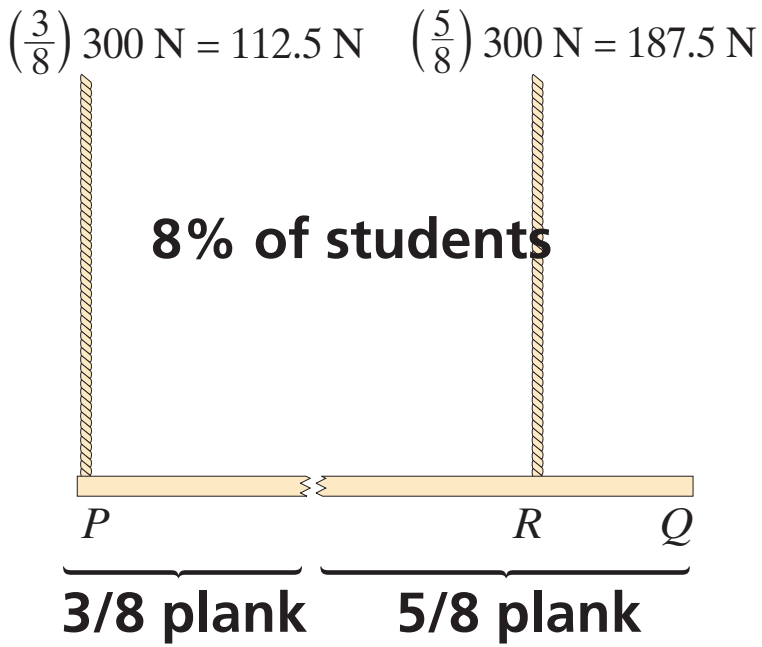
incorrect answers

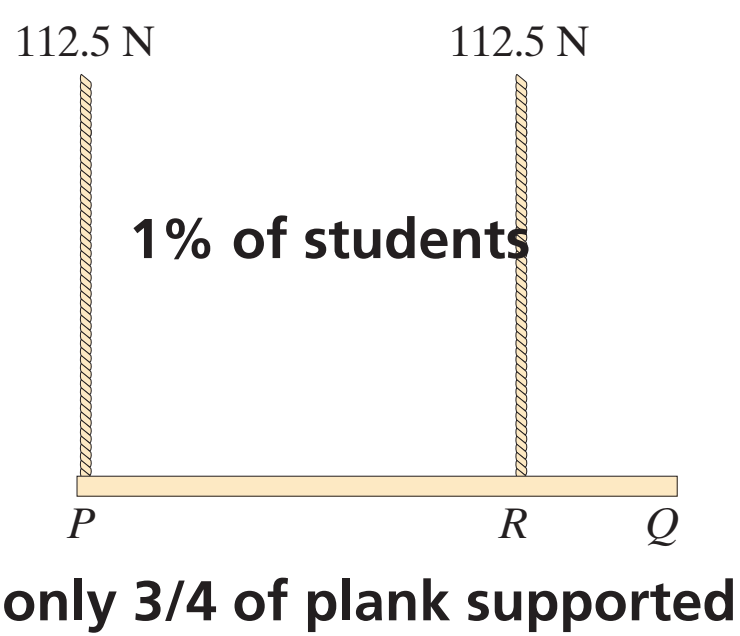




Lecture demonstrations

incorrect answers





who would have thought??

Lecture demonstrations

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

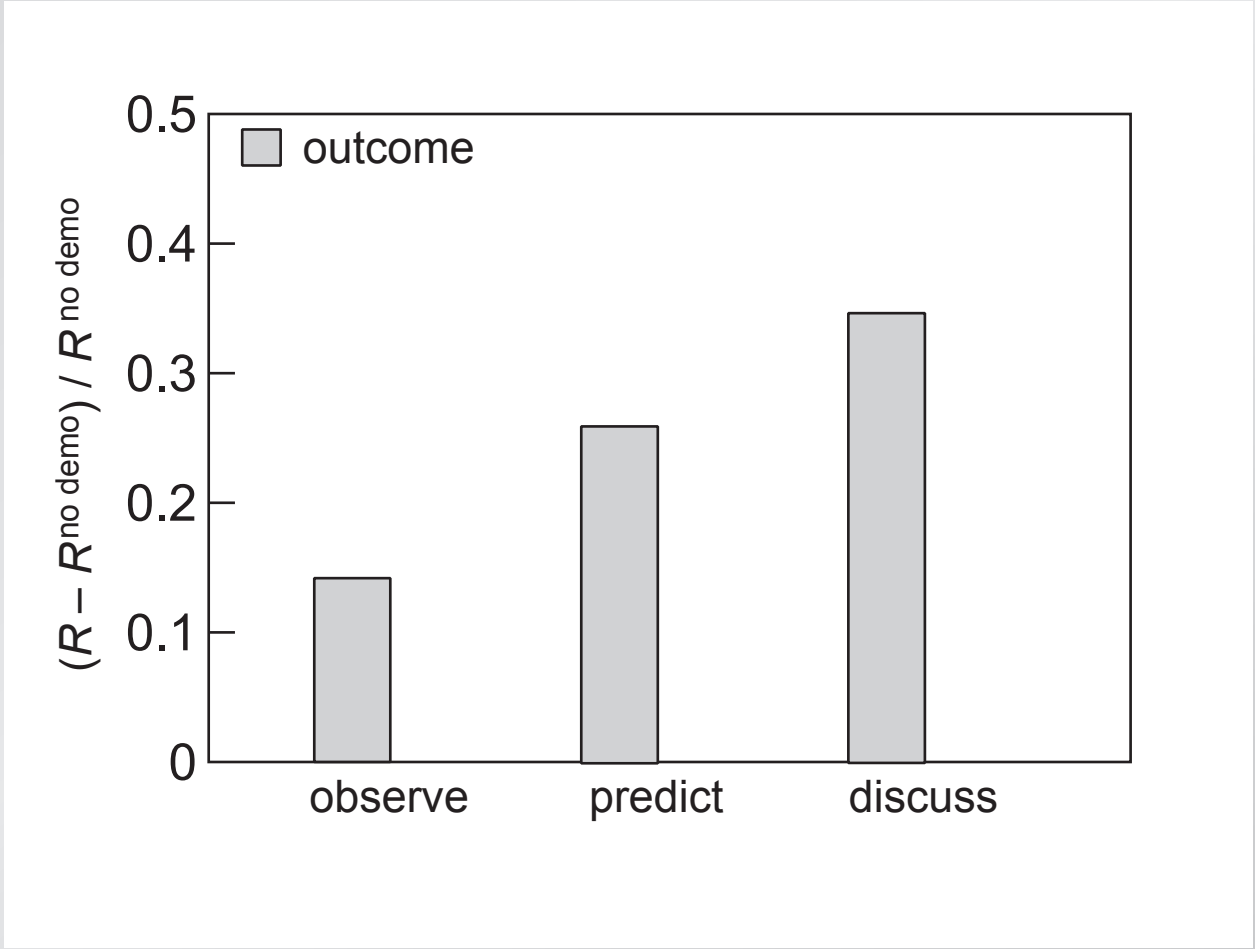
Lecture demonstrations

aggregate results for seven demonstrations

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

Lecture demonstrations

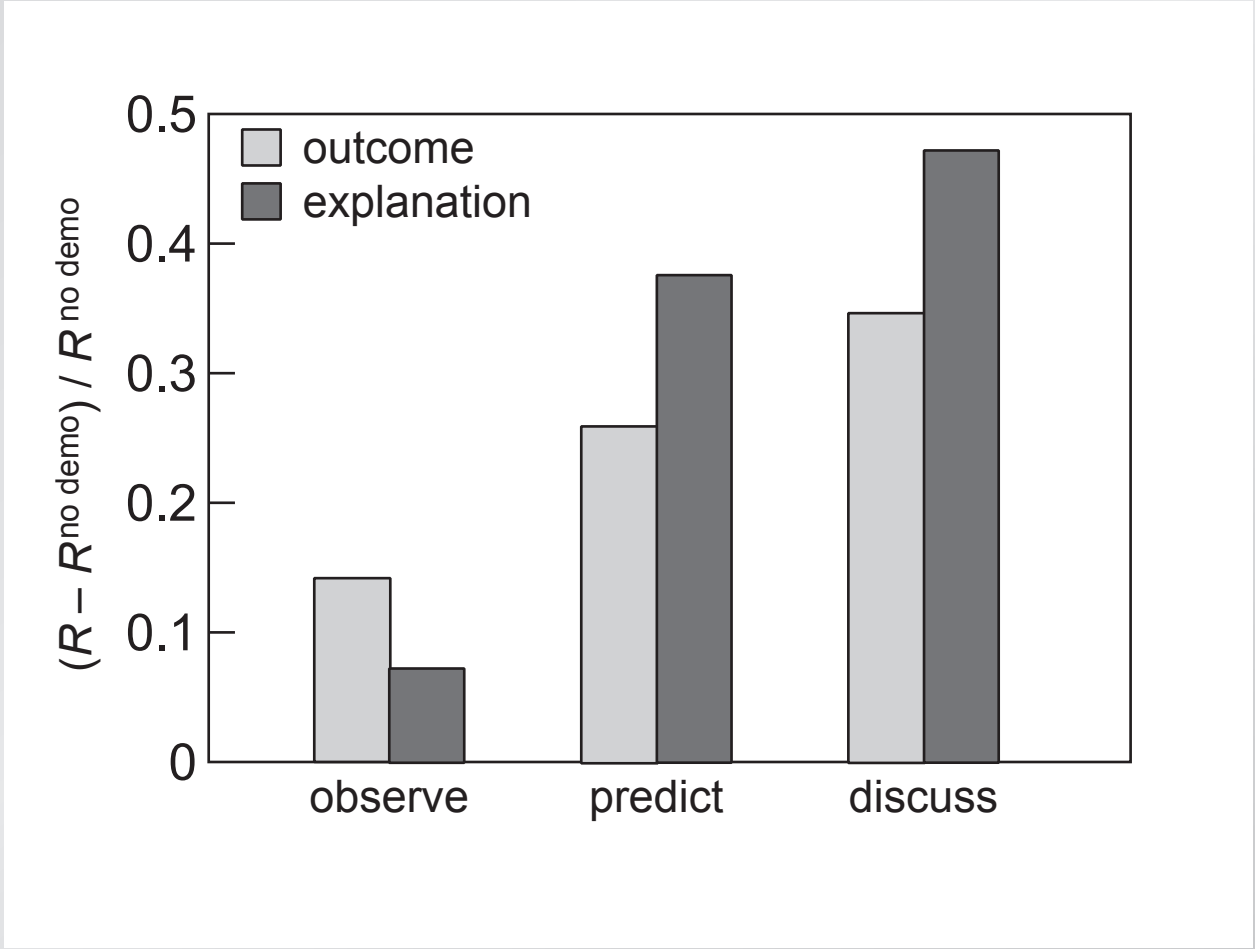
improvement correlates with engagement



Am. J. Phys. 72, 835 (2004)

Lecture demonstrations

improvement correlates with engagement



Am. J. Phys. 72, 835 (2004)

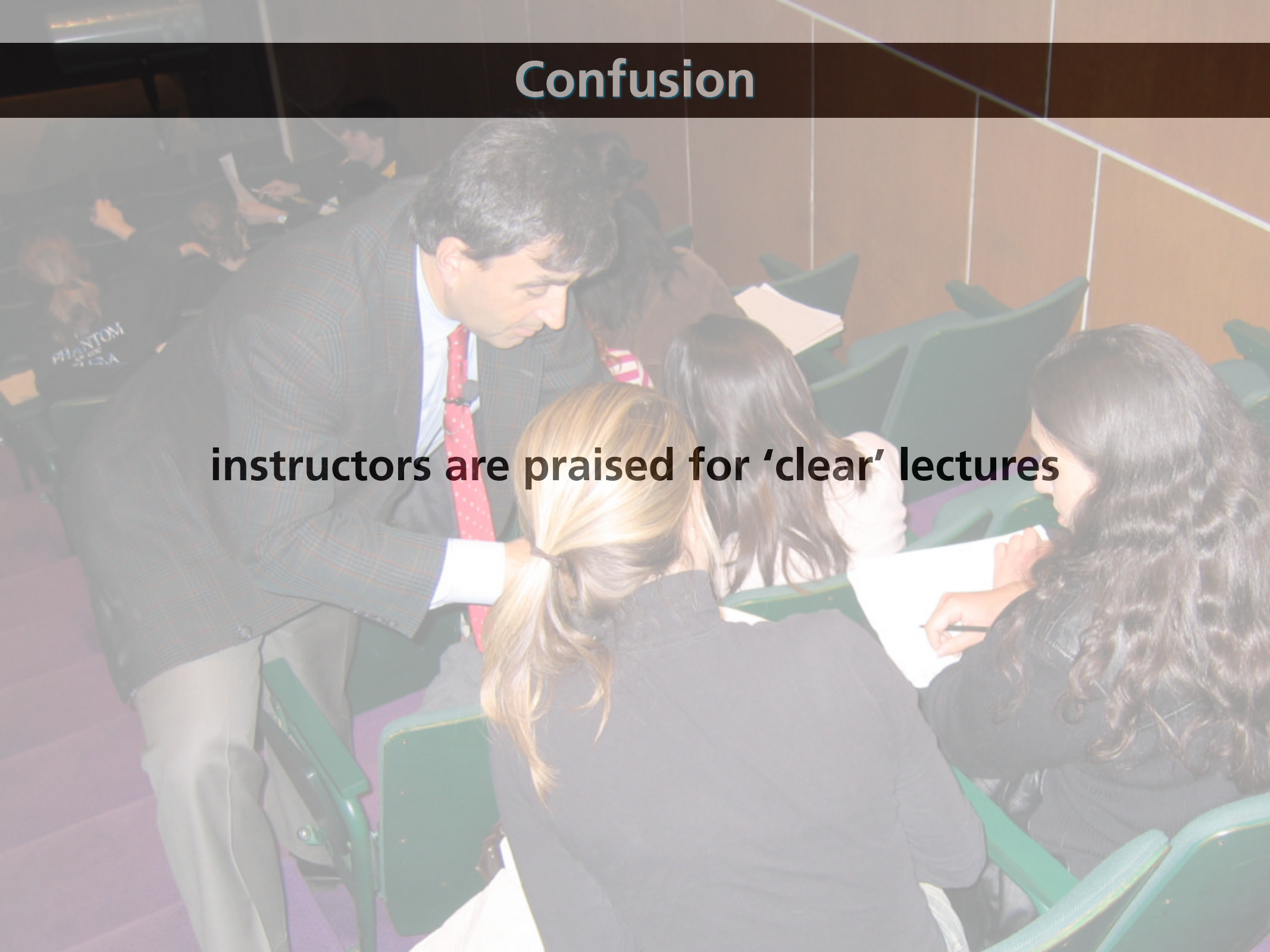
Lecture demonstrations

Points to keep in mind:

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

Confusion

Confusion

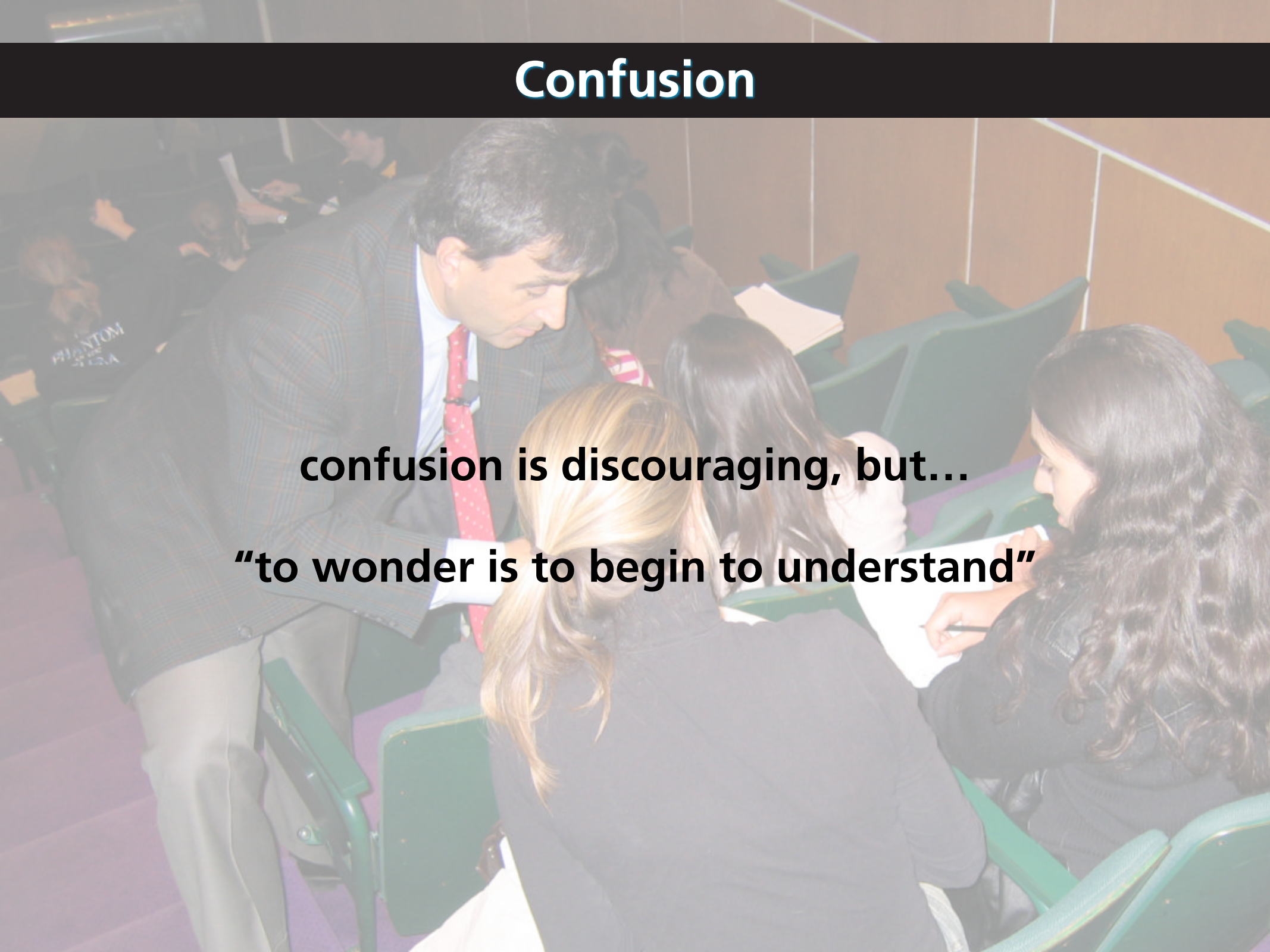


instructors are praised for ‘clear’ lectures

Confusion

confusion is discouraging, but…

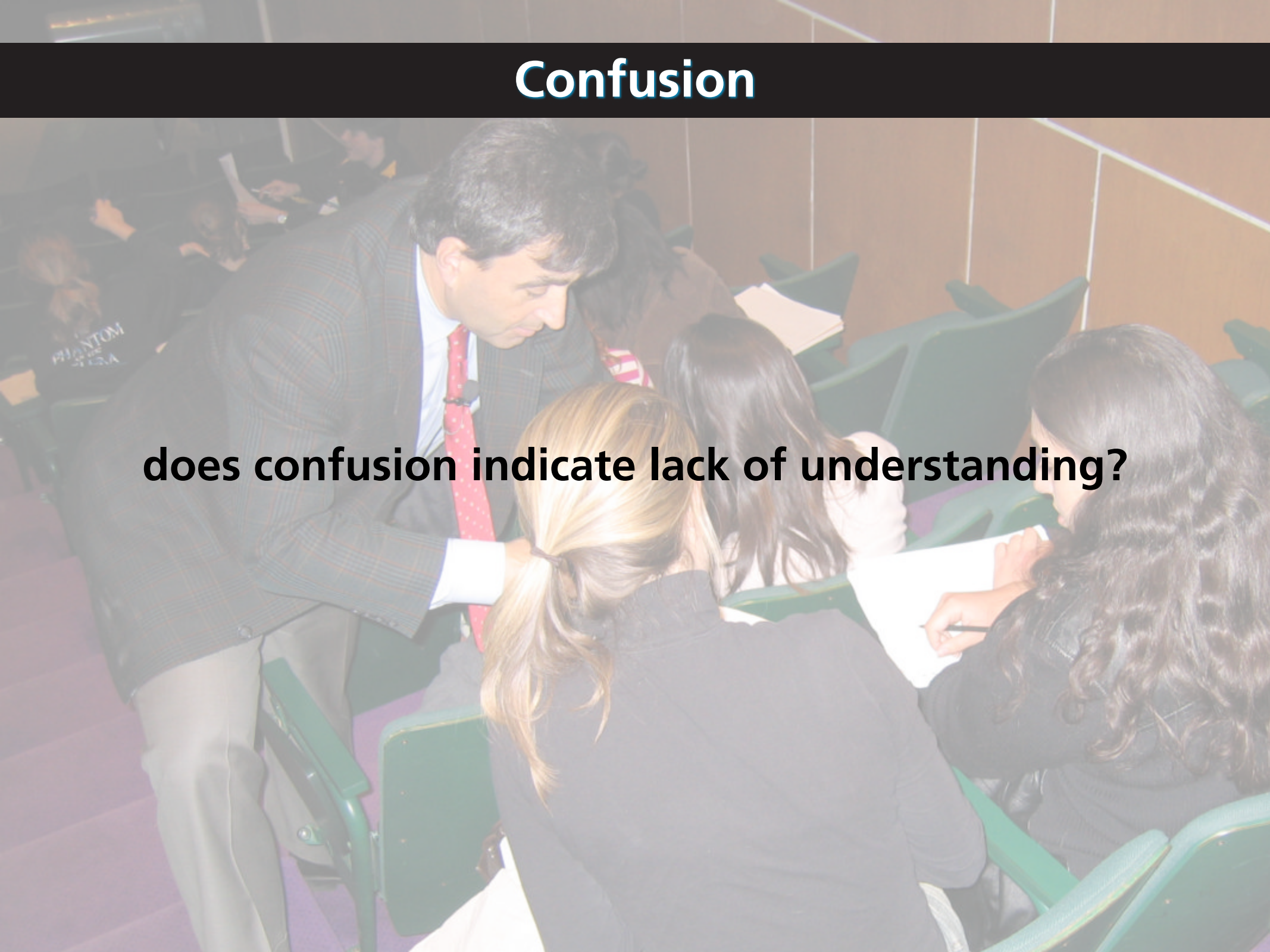
Confusion



confusion is discouraging, but…

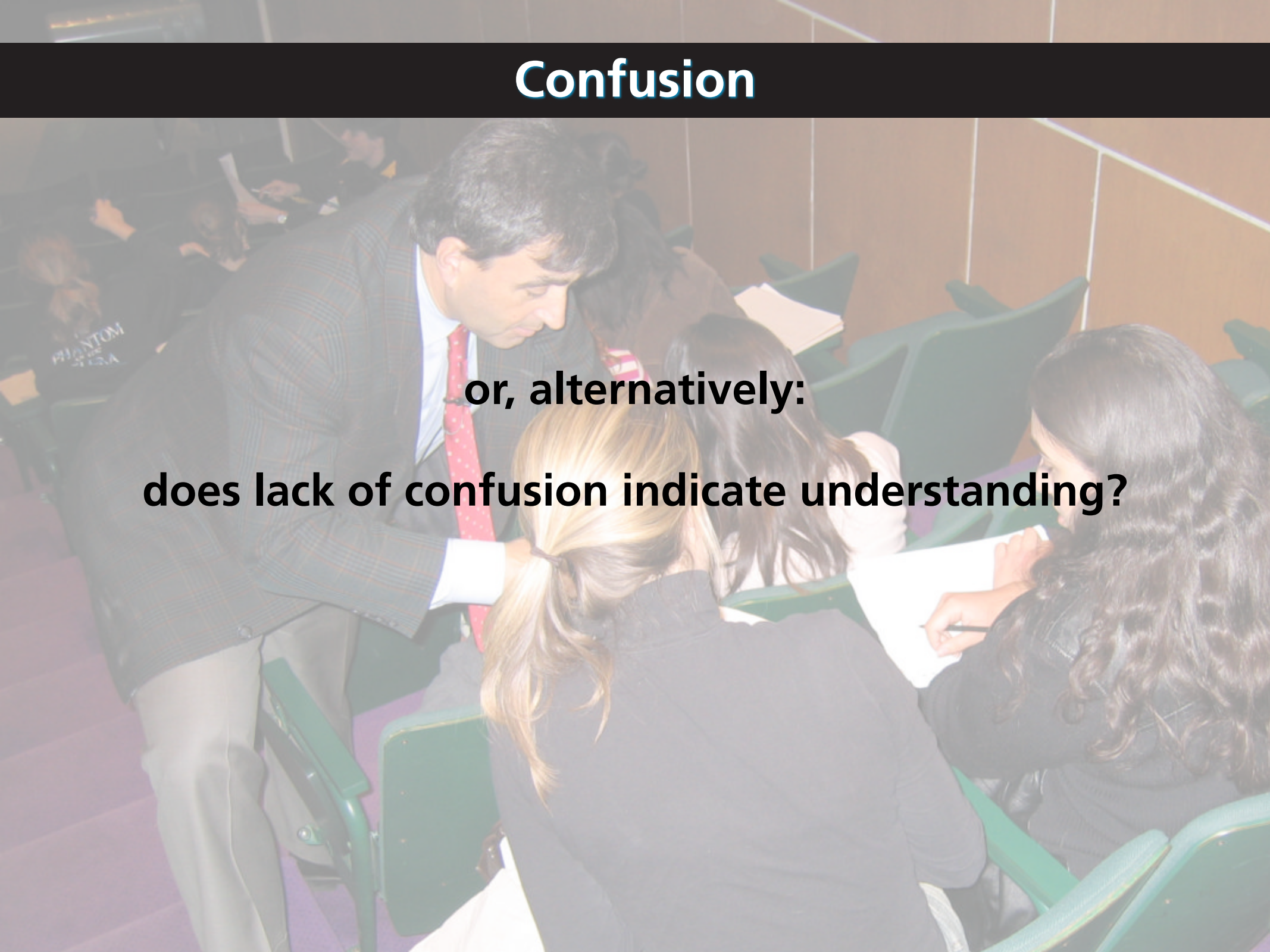
“to wonder is to begin to understand”

Confusion



does confusion indicate lack of understanding?

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:

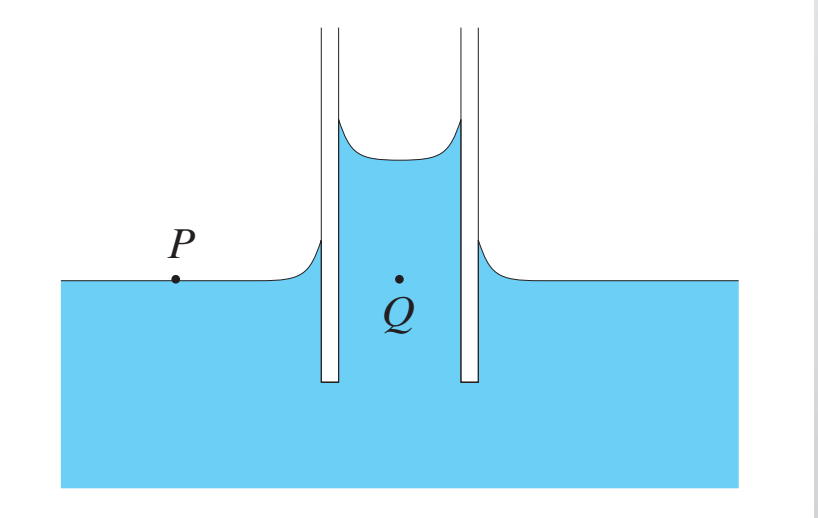
- **two questions on content (difficult!)**
- **one feedback question**

analyze understanding and confusion

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

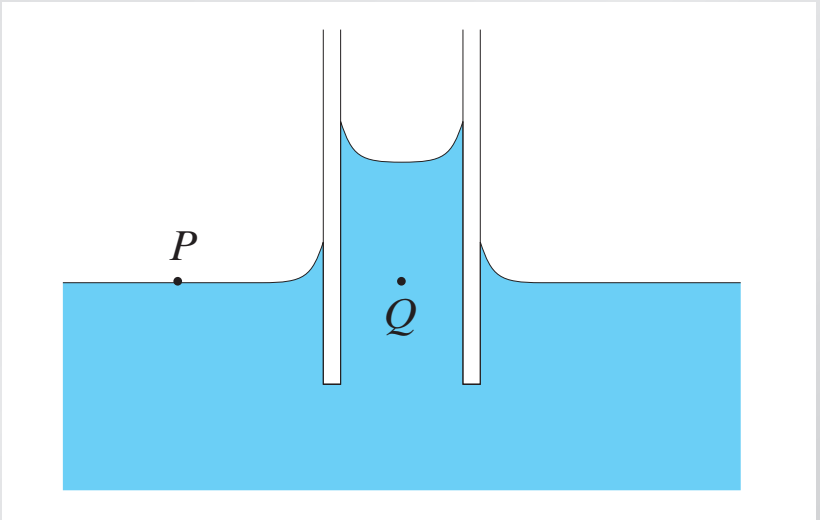
Confusion

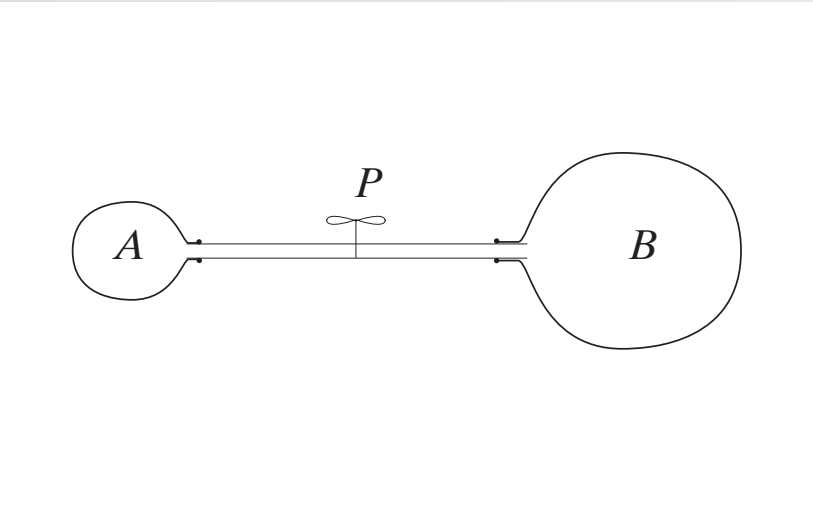
1. Consider the capillary rise of a liquid in a glass tube. How does the pressure at point *P* at the surface of the liquid compare to the pressure at point *Q* at equal height?



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.

WRONG

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.

WRONG

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.

WRONG

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.

WRONG

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.

WRONG

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.

YES!

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.

YES!

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.

YES!

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.

YES!

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.

YES!

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

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

torque	correct	incorrect
confused	45%	55%
not confused	43%	57%

Confusion

using research-based text

torque	correct	incorrect
confused	45%	55%
not confused	43%	57%

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!

Acknowledgments:

Catherine Crouch
Mercedes Lorenzo
Paul Callan
Adam Fagen
Jessica Watkins
Emily Fair Oster

Pat and Ken Heller (UMN)
Laura McCullough (UMN)
Steve Pierson (WPI)
Tom Keil (WPI)

Funding:

National Science Foundation

for a copy of this presentation:

http://mazur-www.harvard.edu