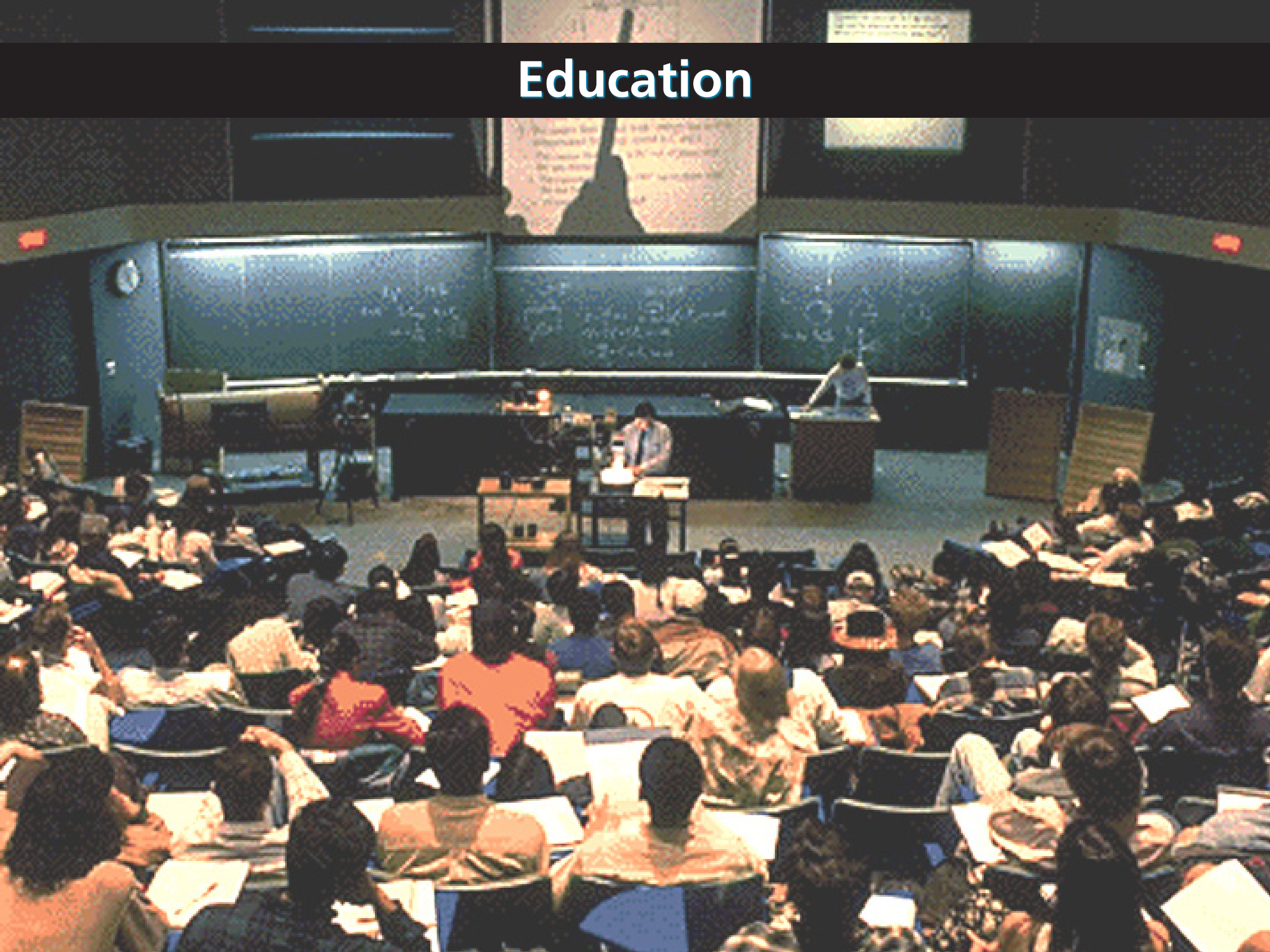
The Scientific Approach to Teaching: Using Data to Debunk Myths

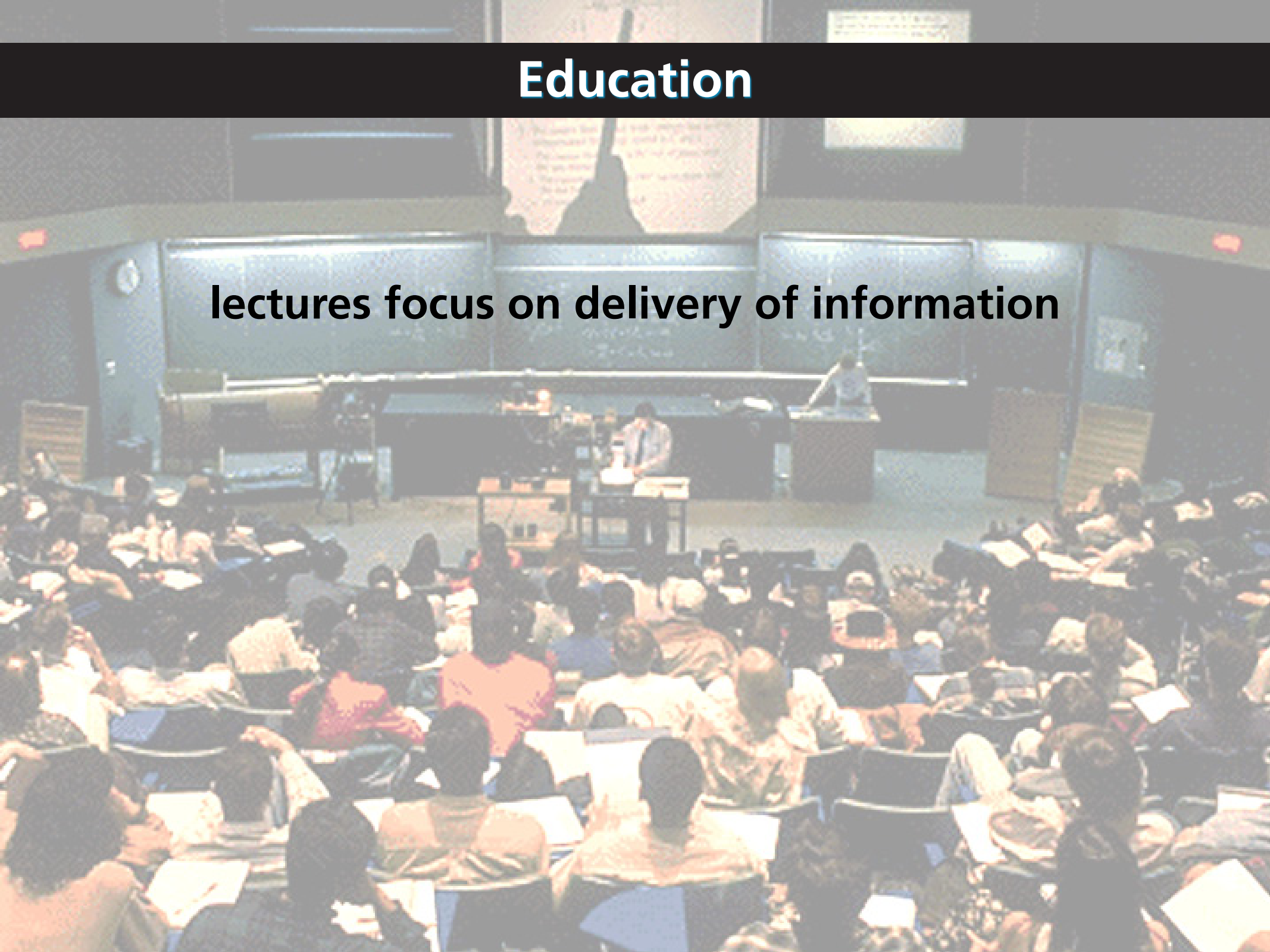
SALTISE
Dawson College
Montréal, QC, 21 May 2012

The Scientific Approach to Teaching: Using Data to Debunk Myths

Education

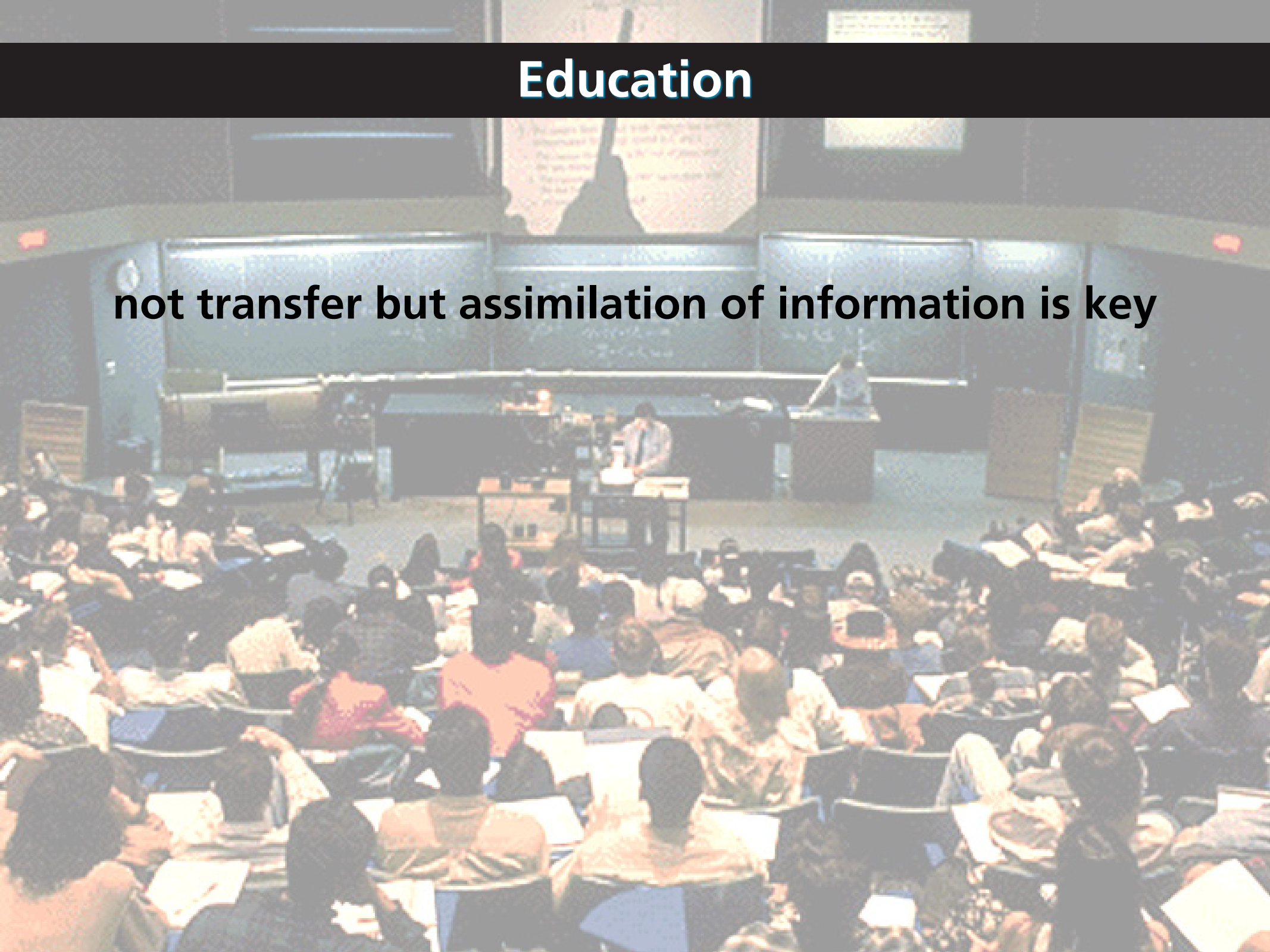


Education



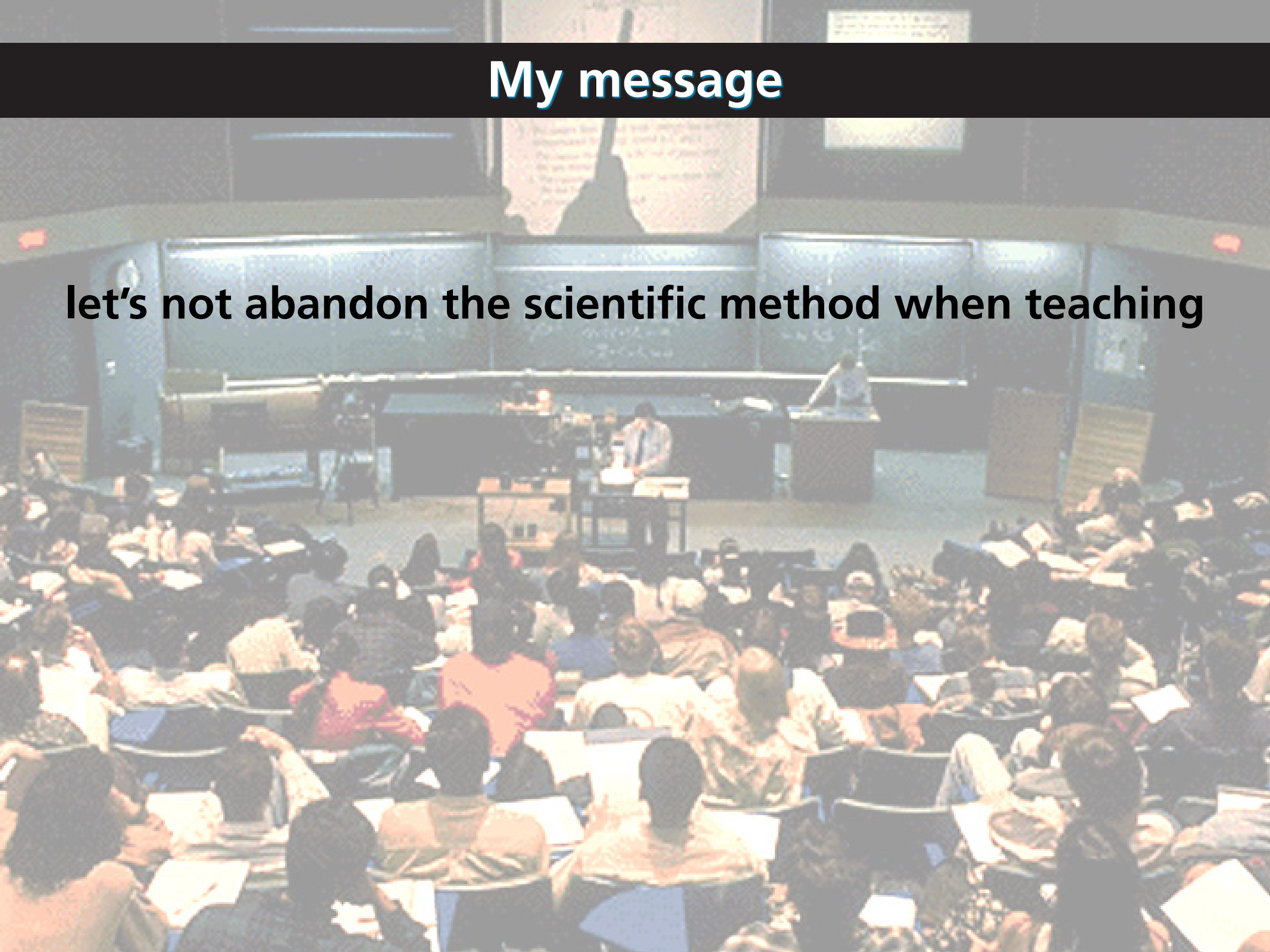
lectures focus on delivery of information

Education



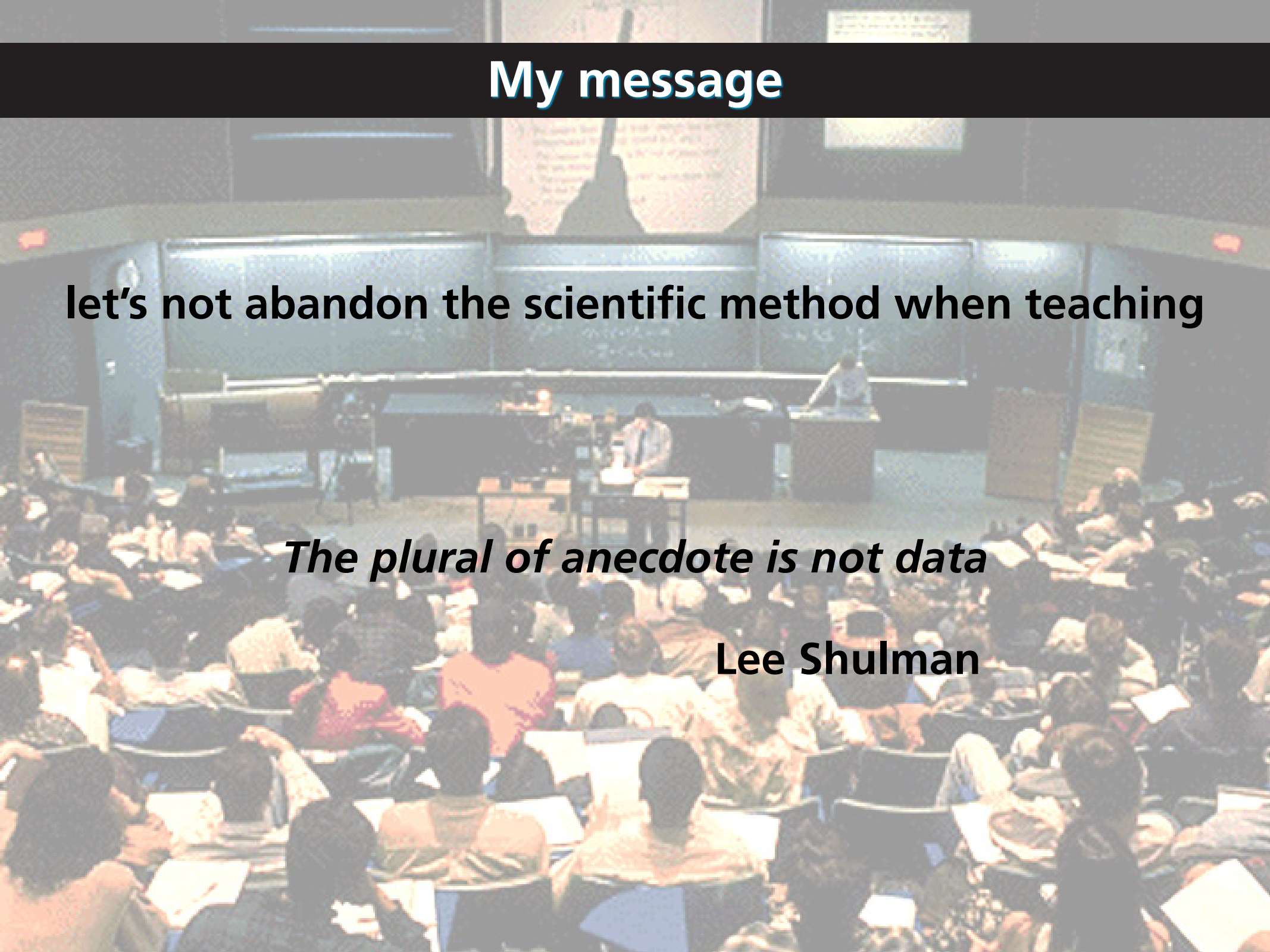
not transfer but assimilation of information is key

My message



let’s not abandon the scientific method when teaching

My message

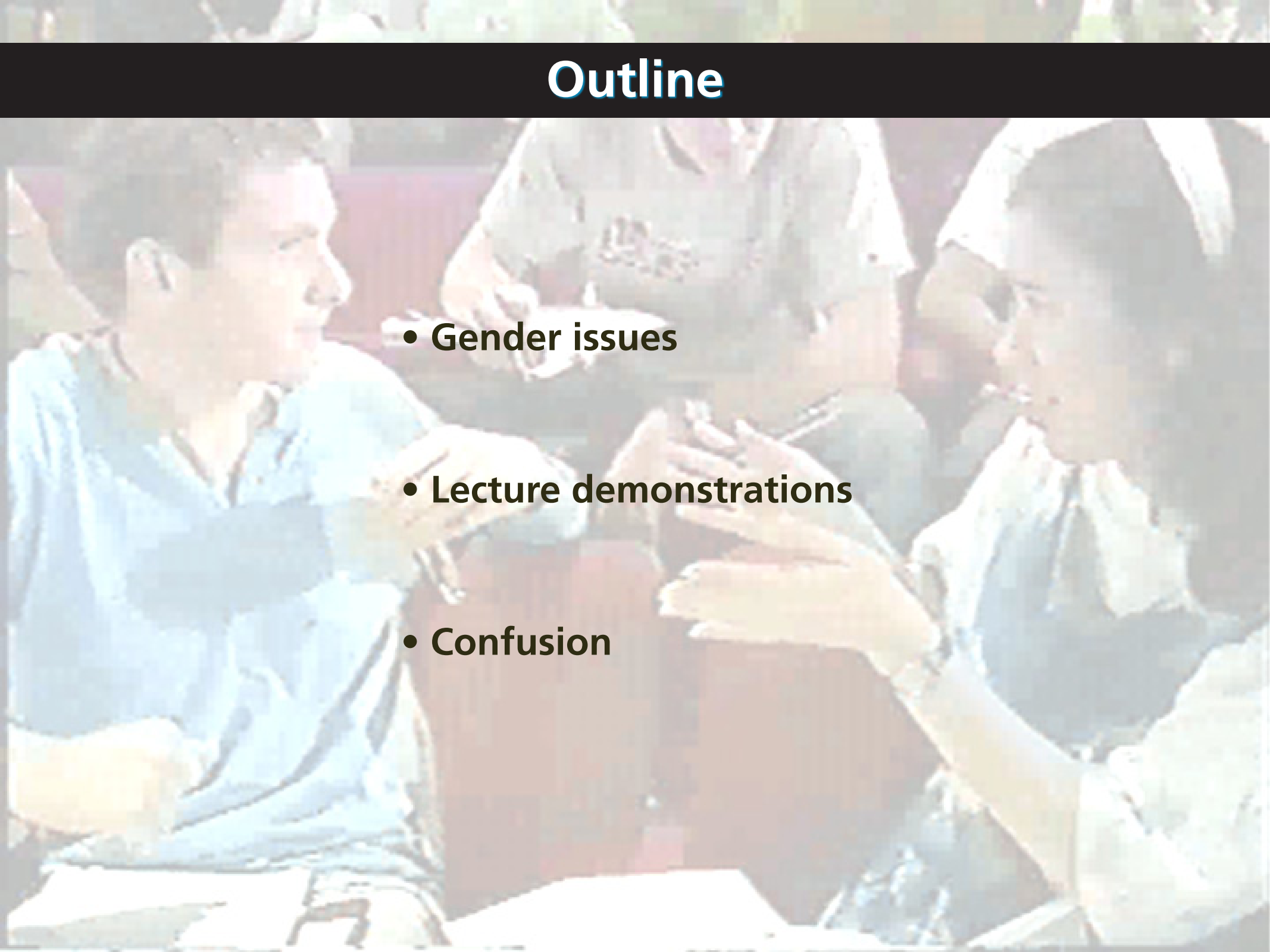


let's not abandon the scientific method when teaching

The plural of anecdote is not data

Lee Shulman

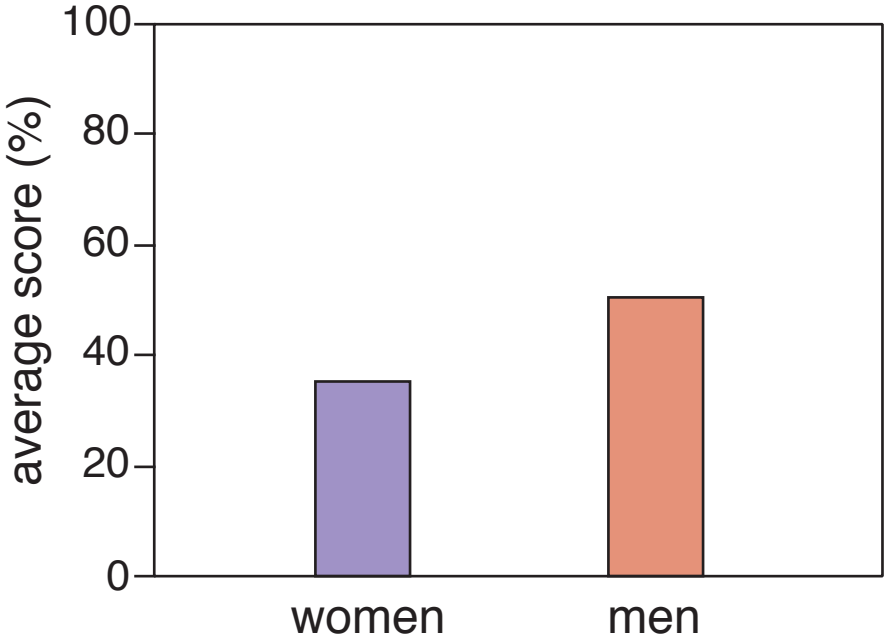
Outline



- Gender issues
- Lecture demonstrations
- Confusion

Gender issues

Force Concept Inventory postest scores



Gender issues

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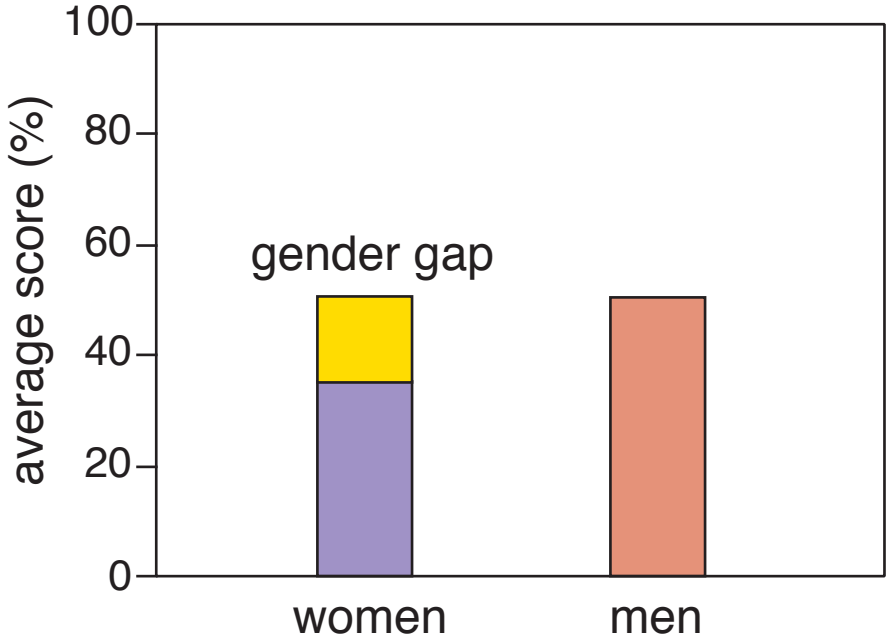

Gender issues

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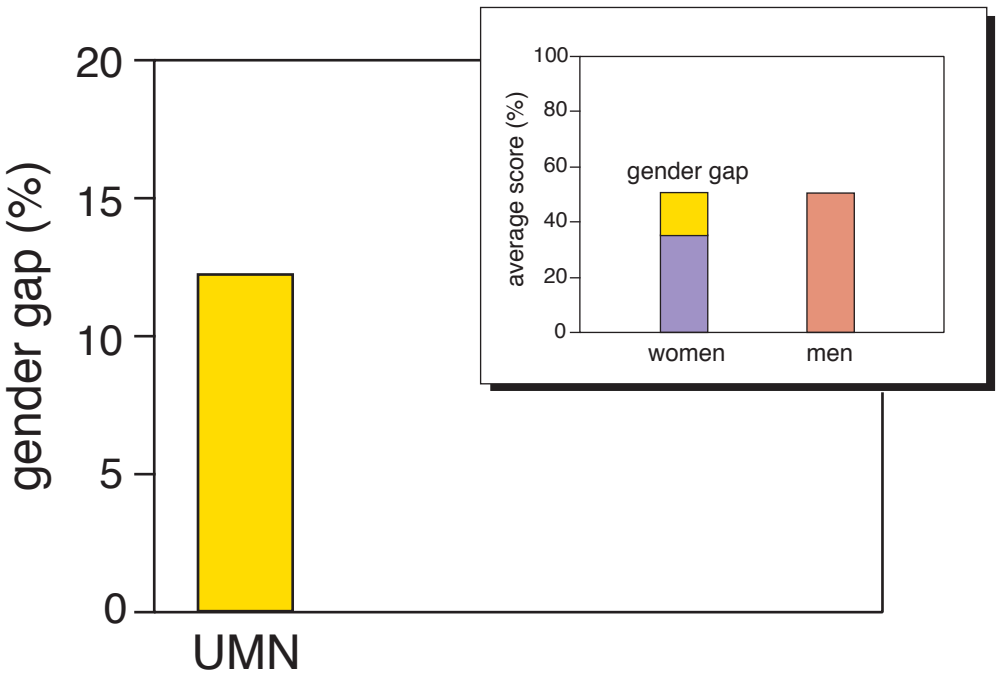

Gender issues

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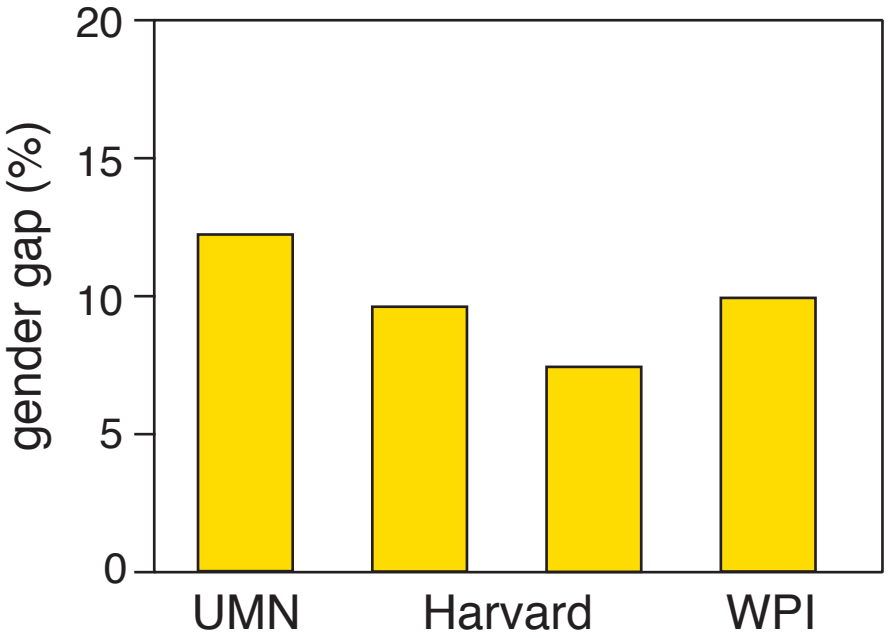
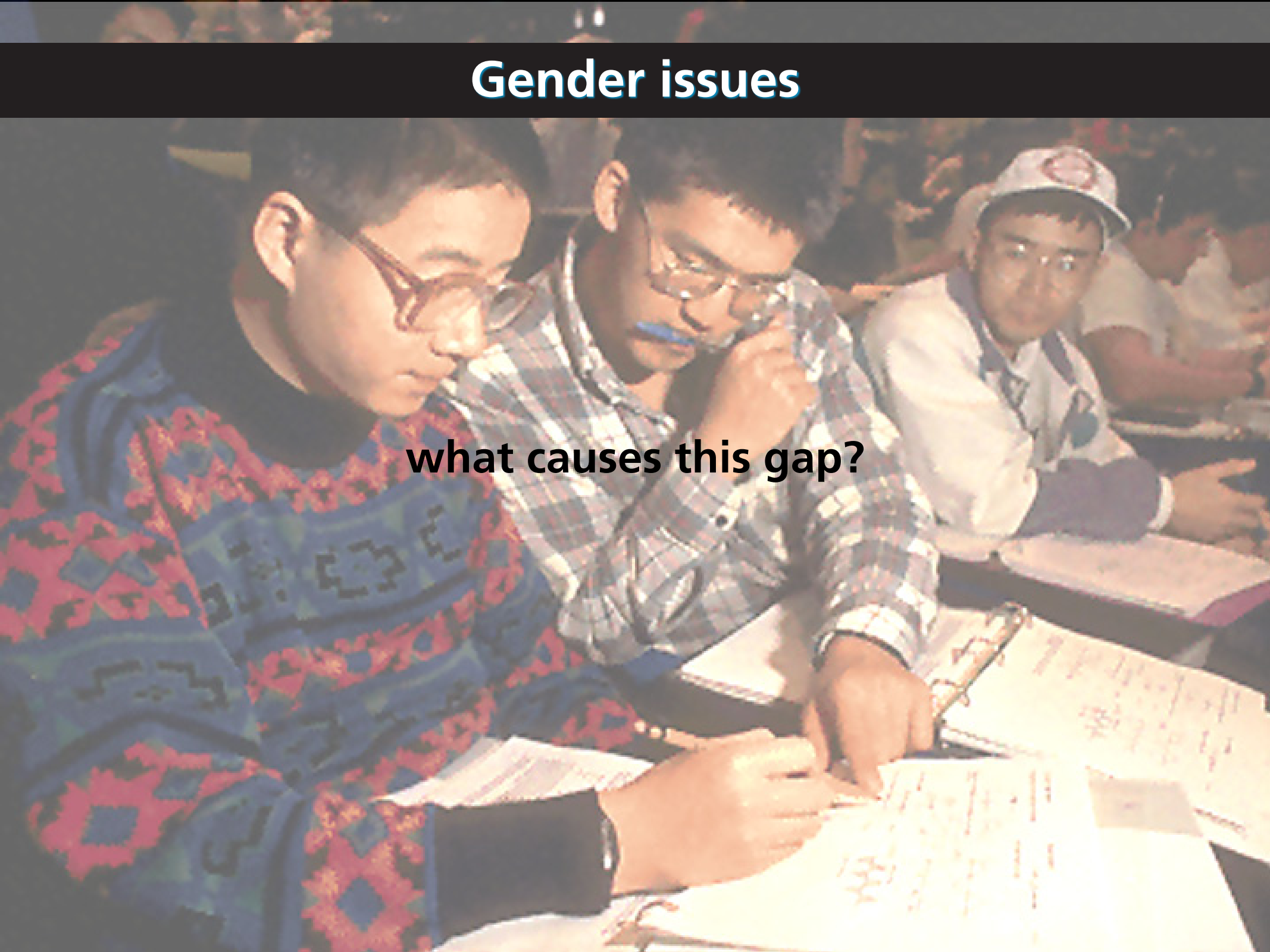


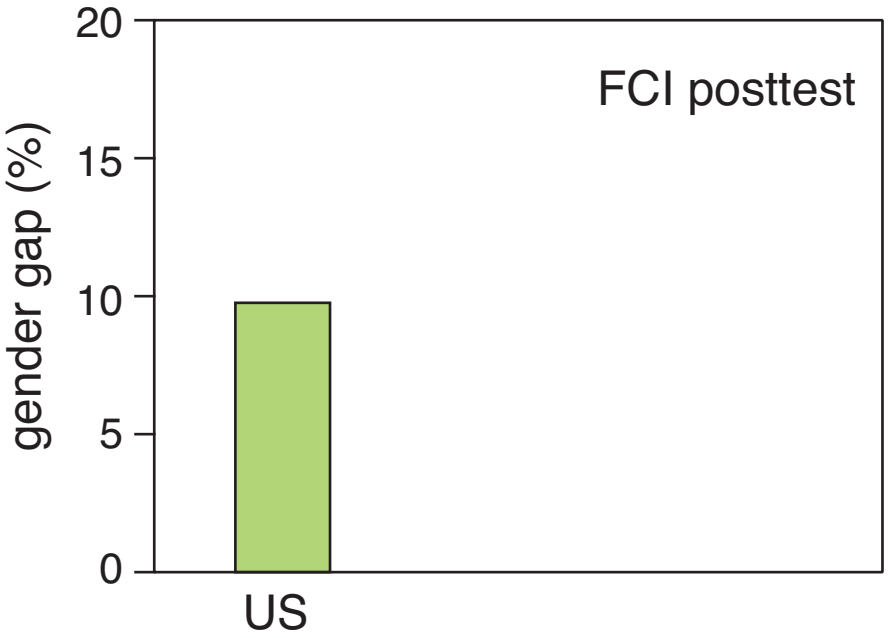
Gender issues



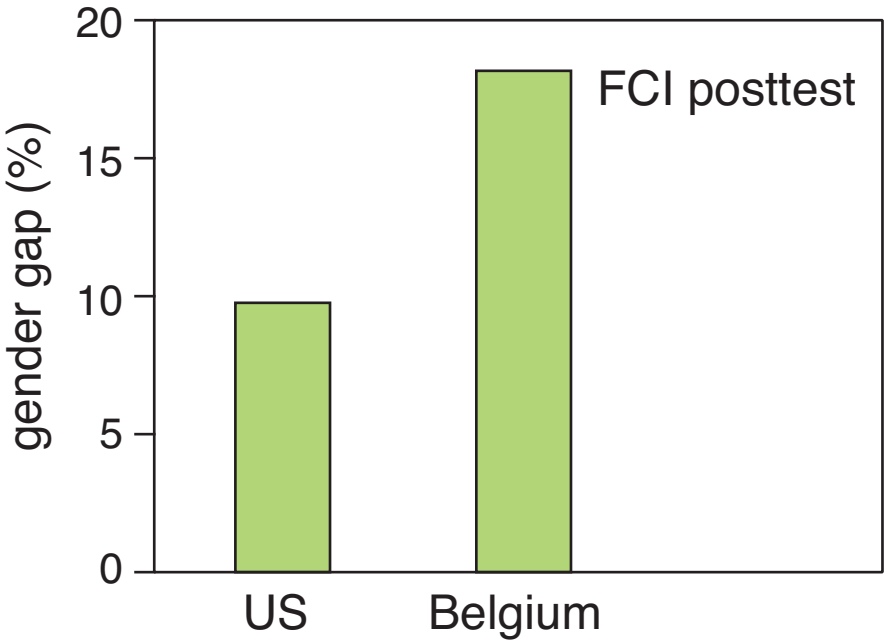
what causes this gap?

Gender issues

is it cultural?

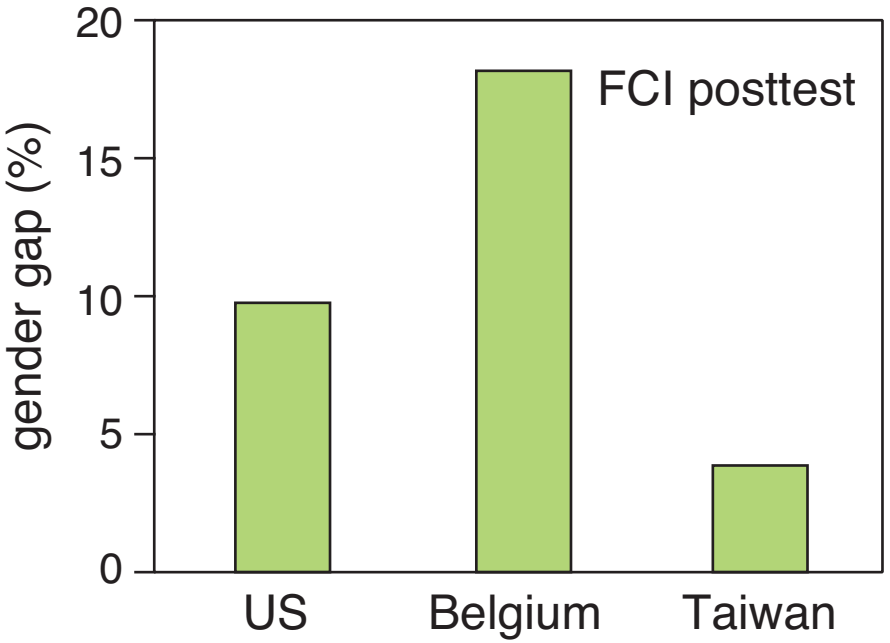


Gender issues



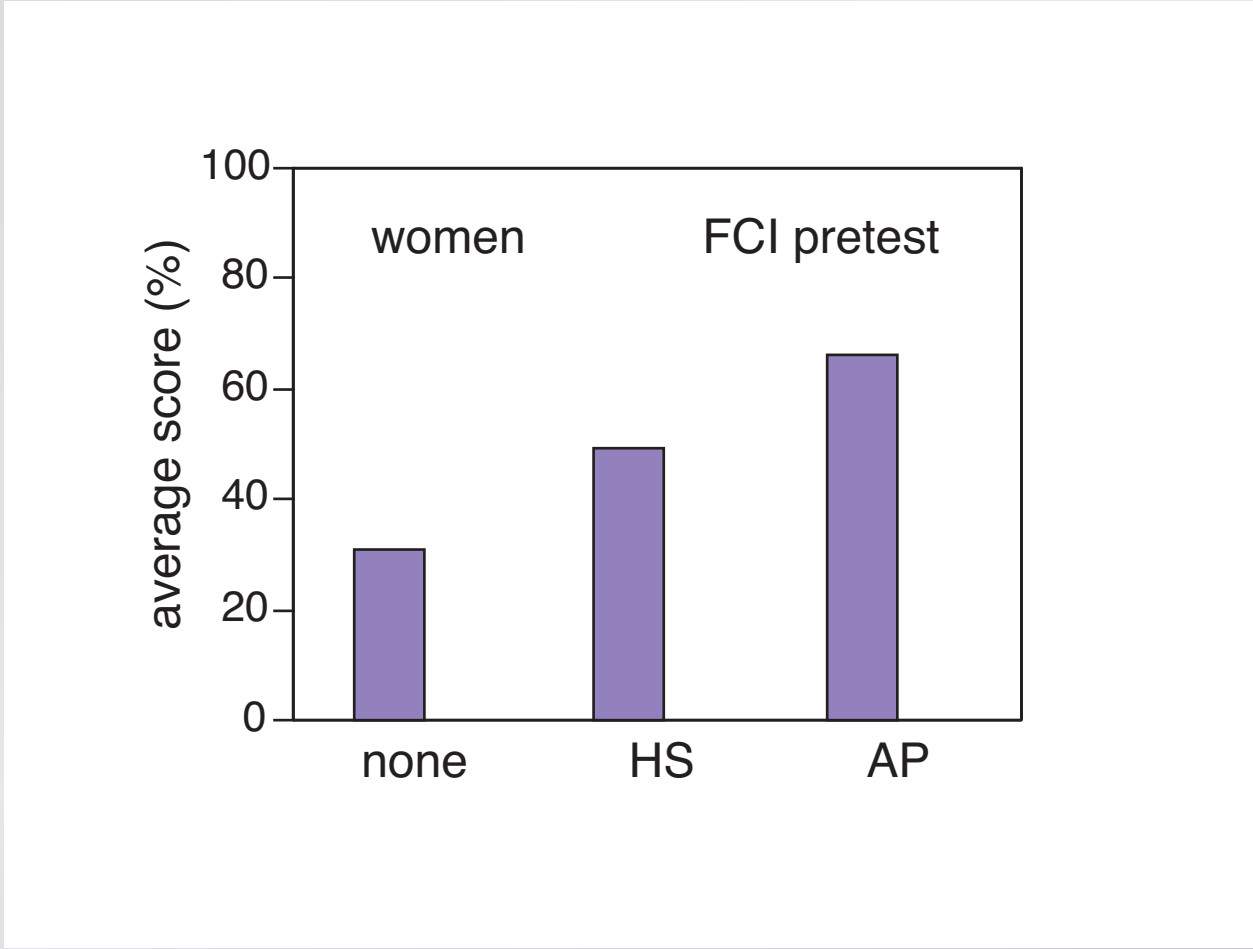
Gender issues

strong dependence on culture!



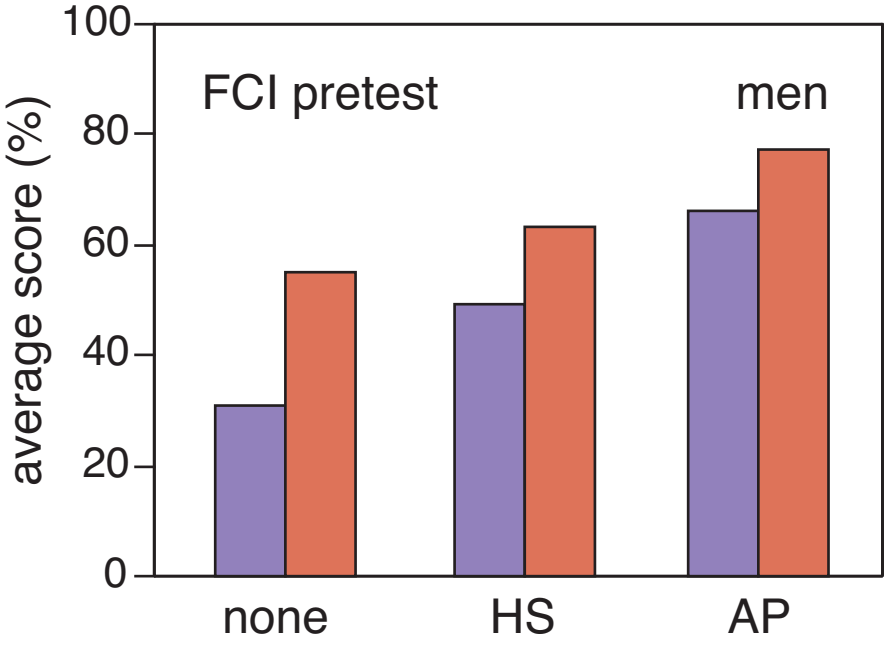
Gender issues

effect of precollege education



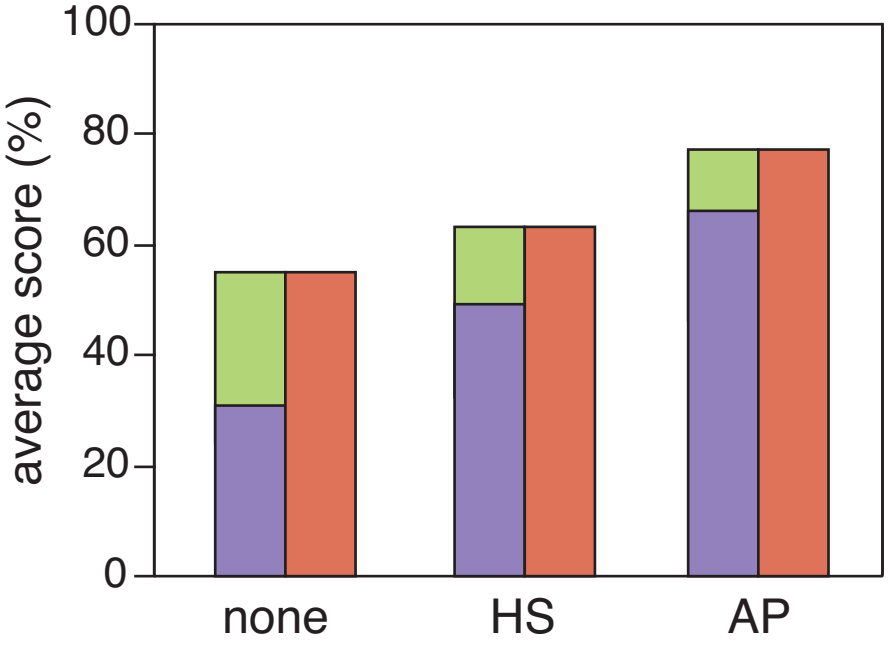
Gender issues

everyone gains…



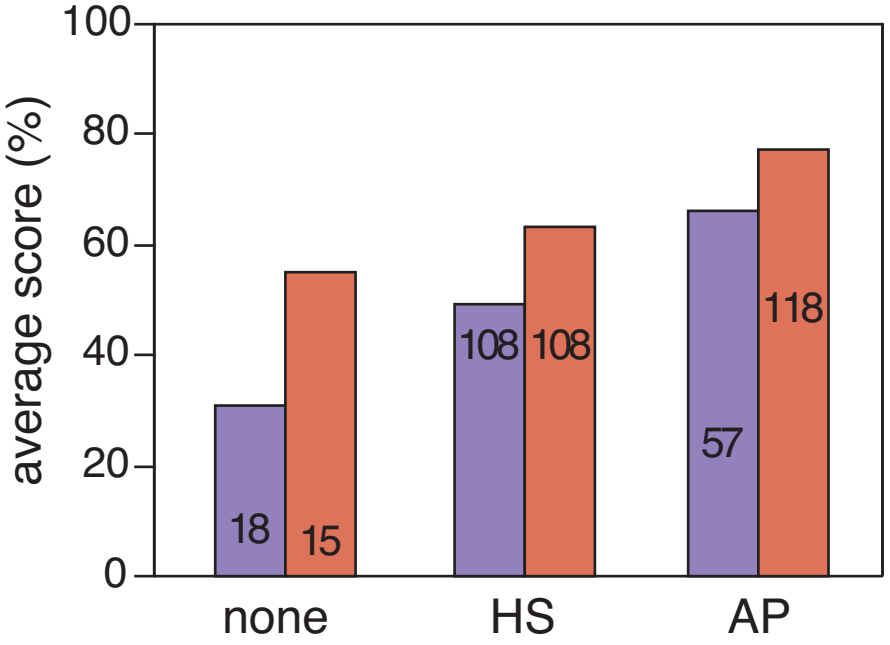
Gender issues

…but gap persists…



Gender issues

…and women underrepresented



Gender issues

Gender issues

increase collaboration and interactivity

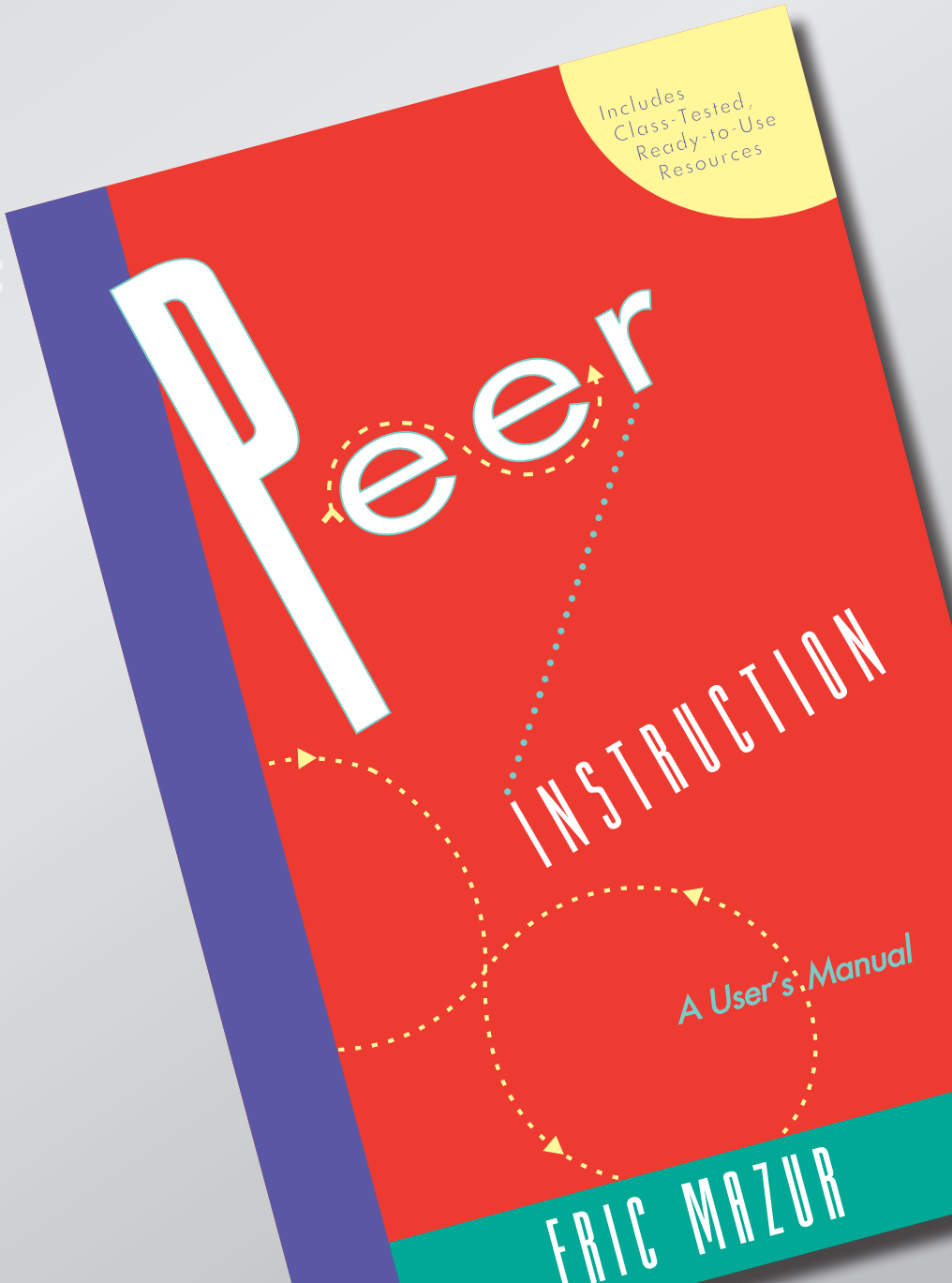
Gender issues

Compare three pedagogies:

T: traditional lectures

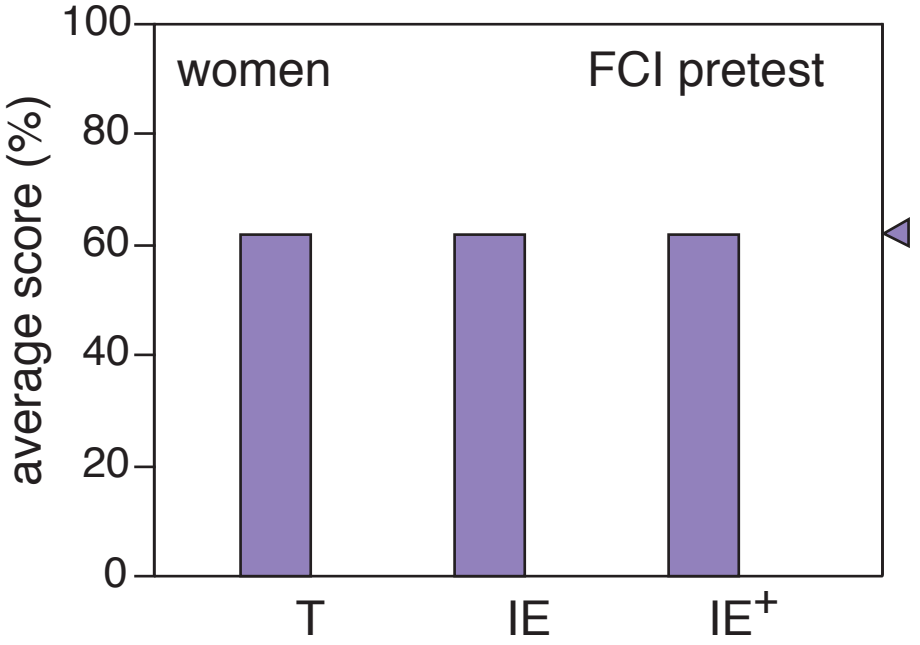
I: interactive lectures

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



Gender issues

does pedagogy help?



Gender issues

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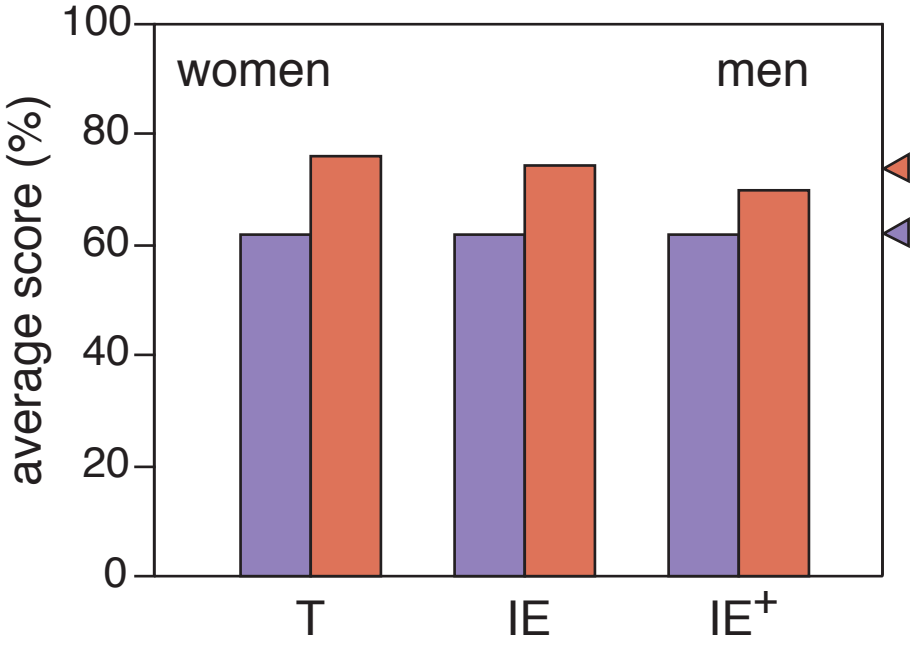

Gender issues

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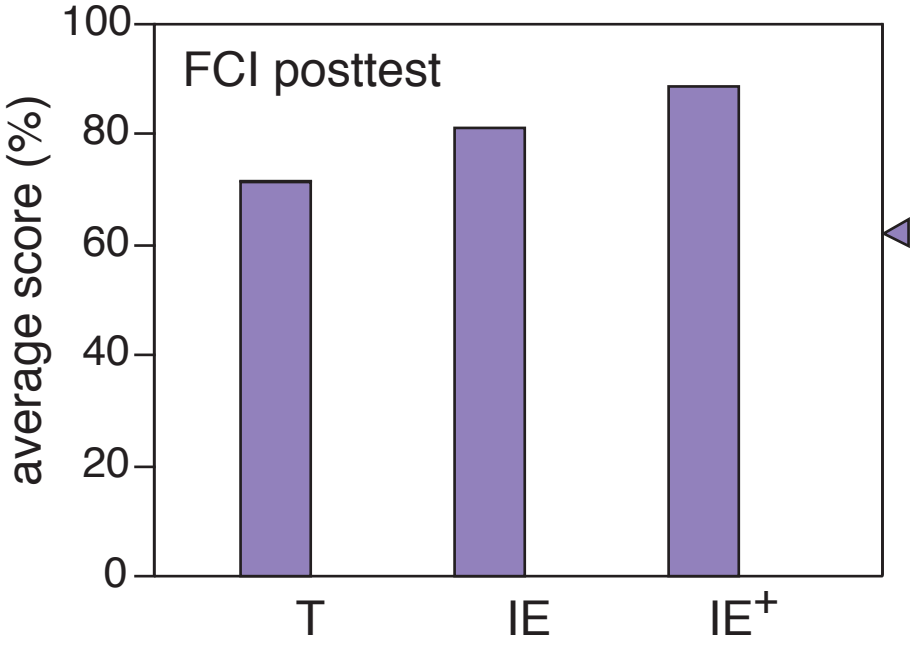
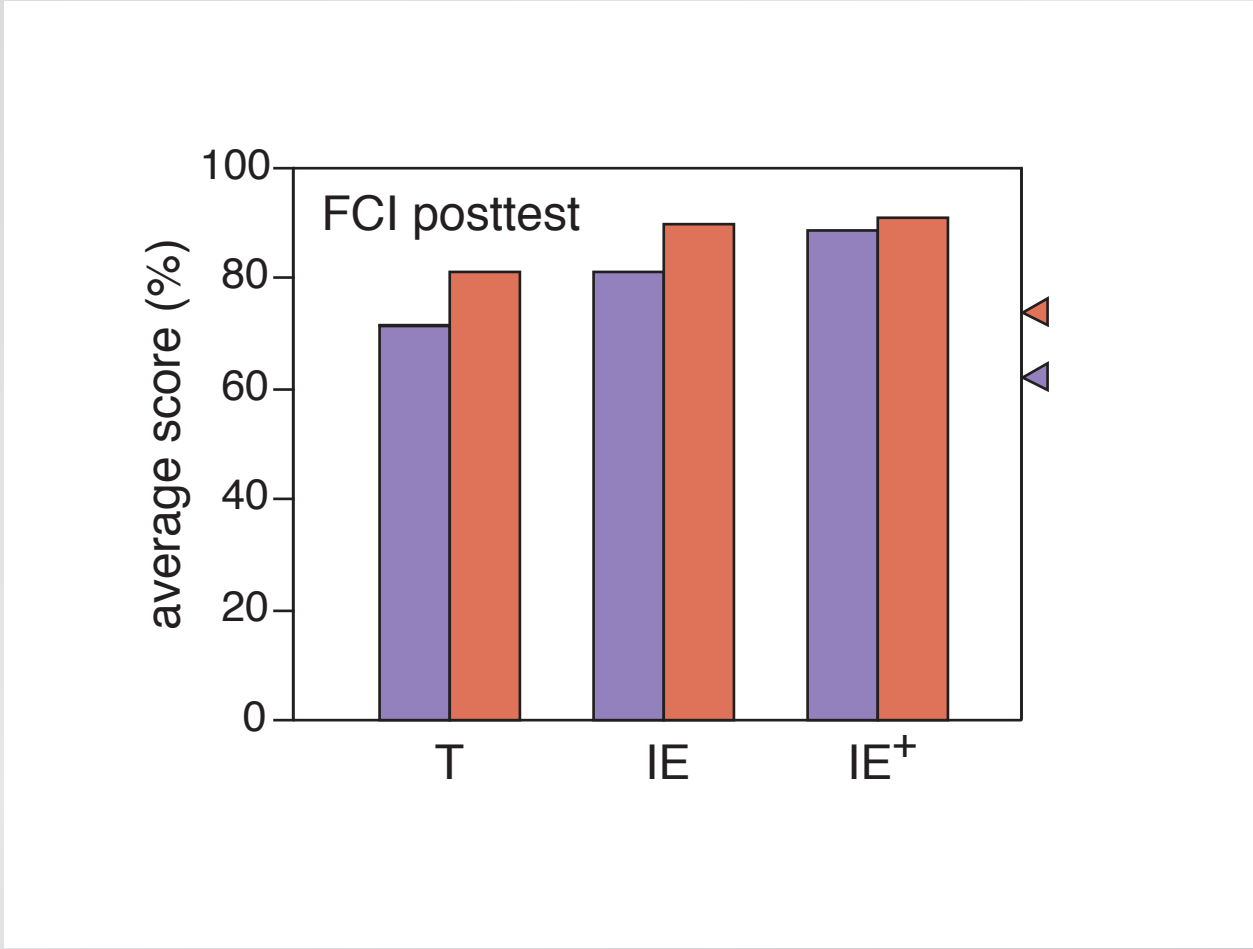


Gender issues

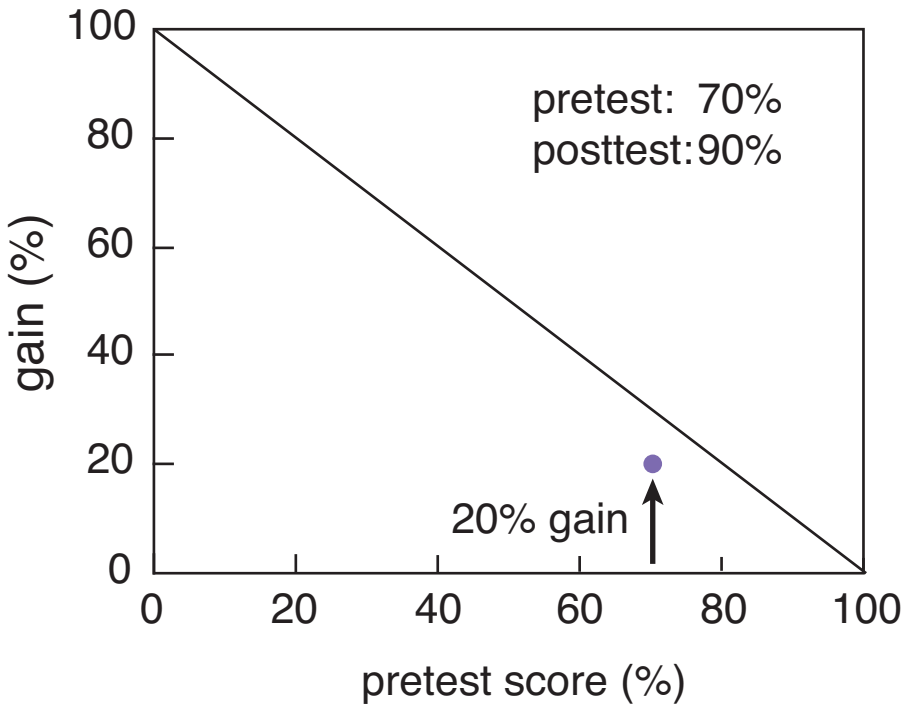
yes, pedagogy can eliminate gap!



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

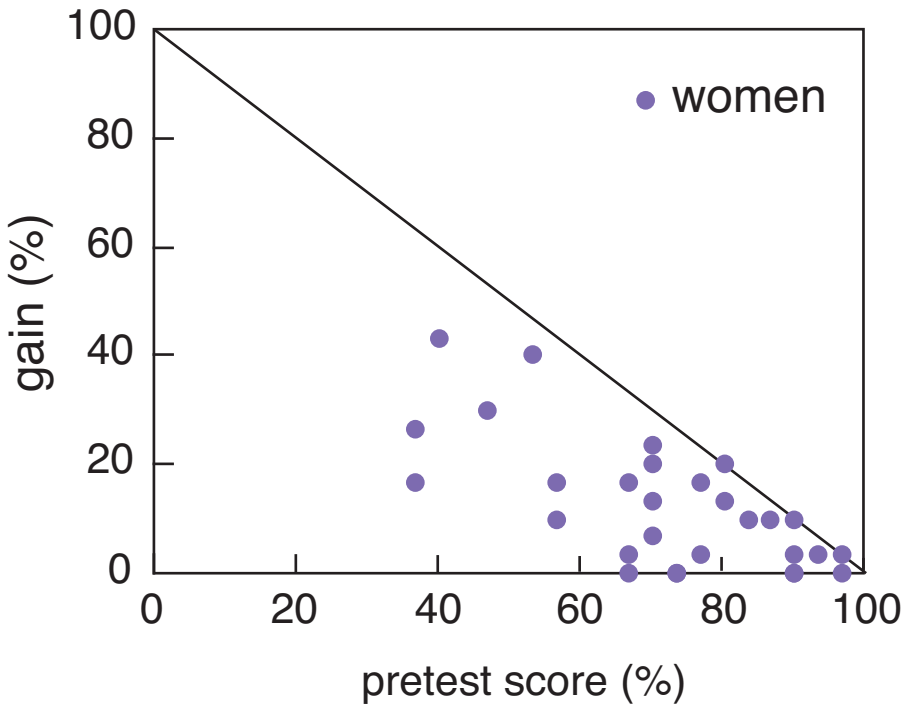
Gender issues

who are the low-gain students?



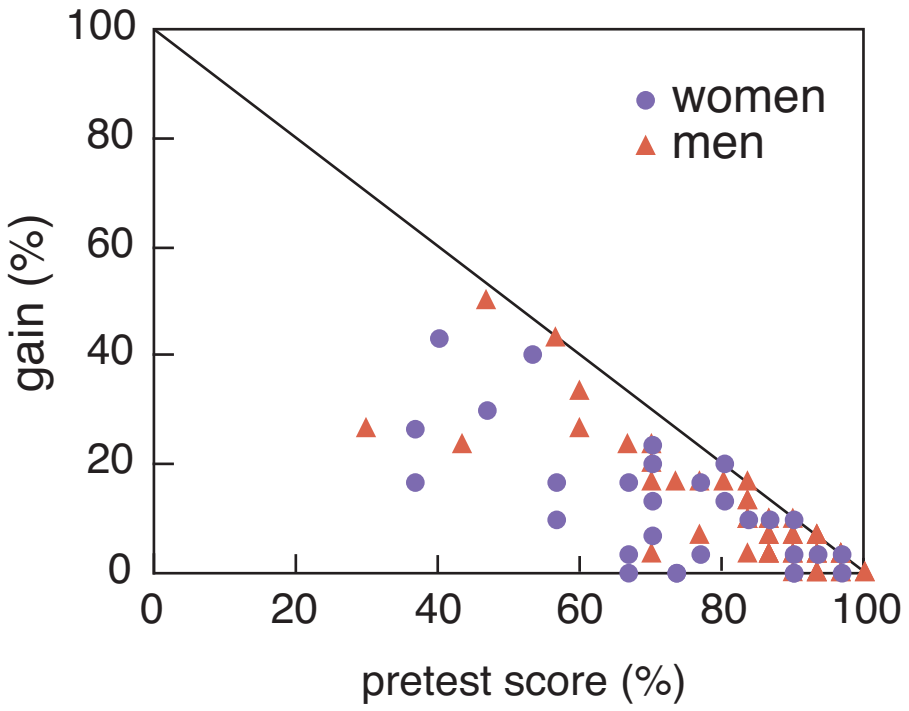
Gender issues

traditional class



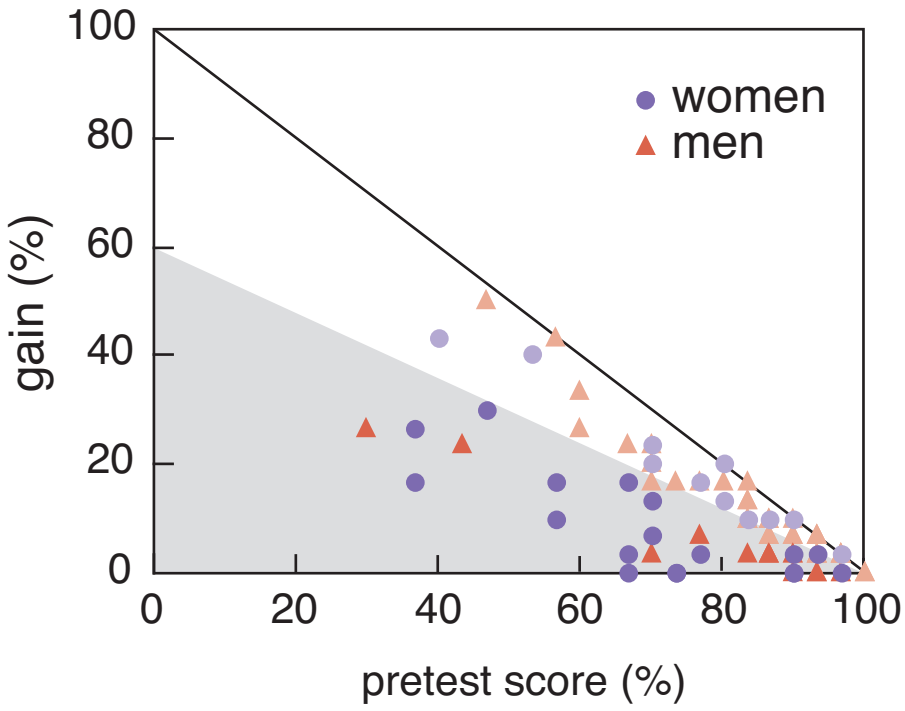
Gender issues

traditional class



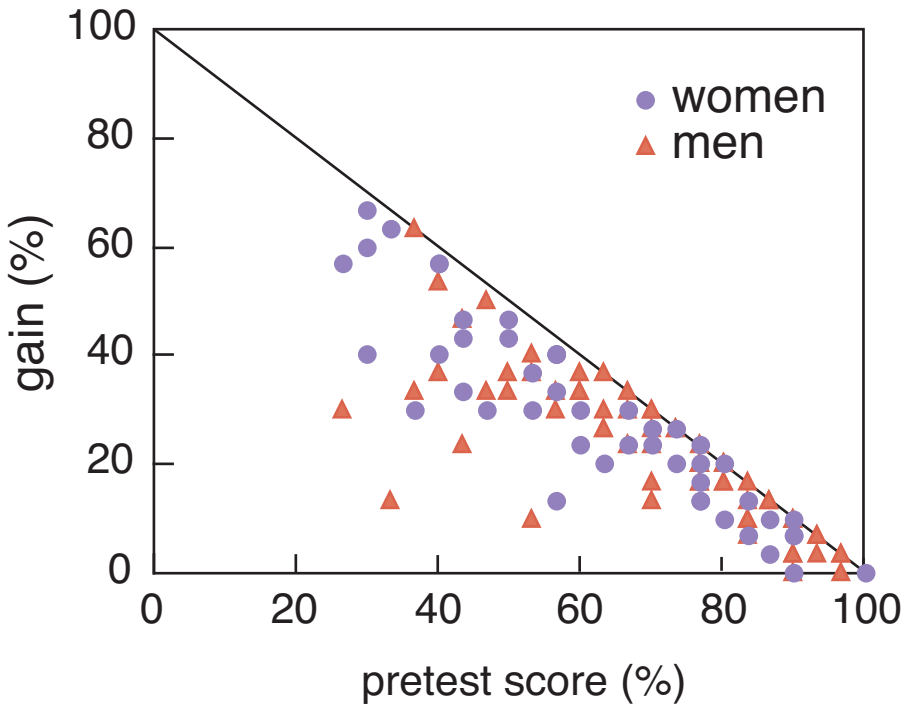
Gender issues

traditional class: gender imbalance



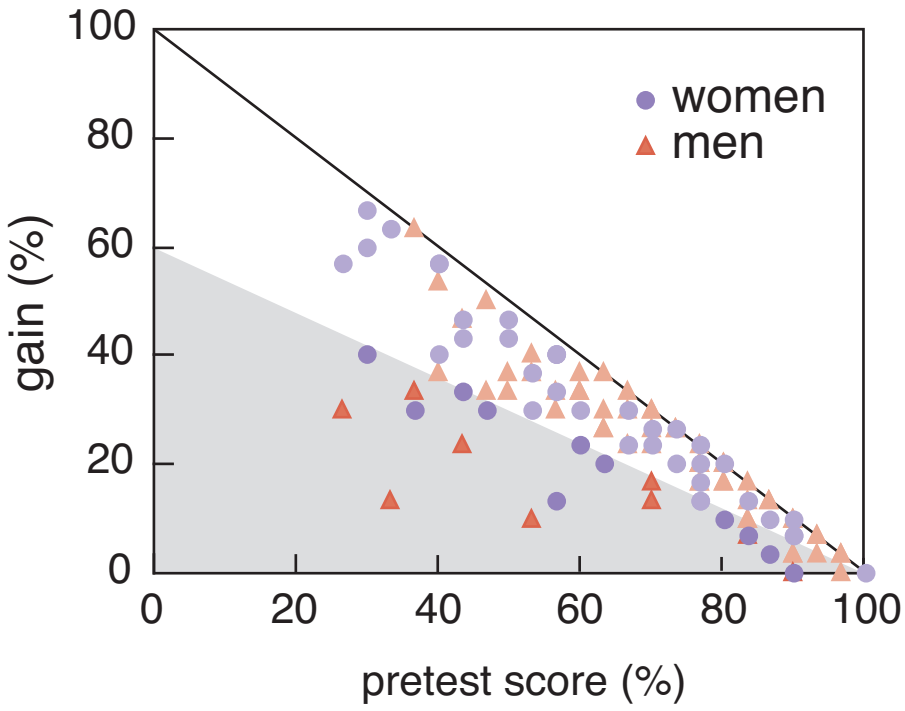
Gender issues

interactive class



Gender issues

interactive class: gender balance

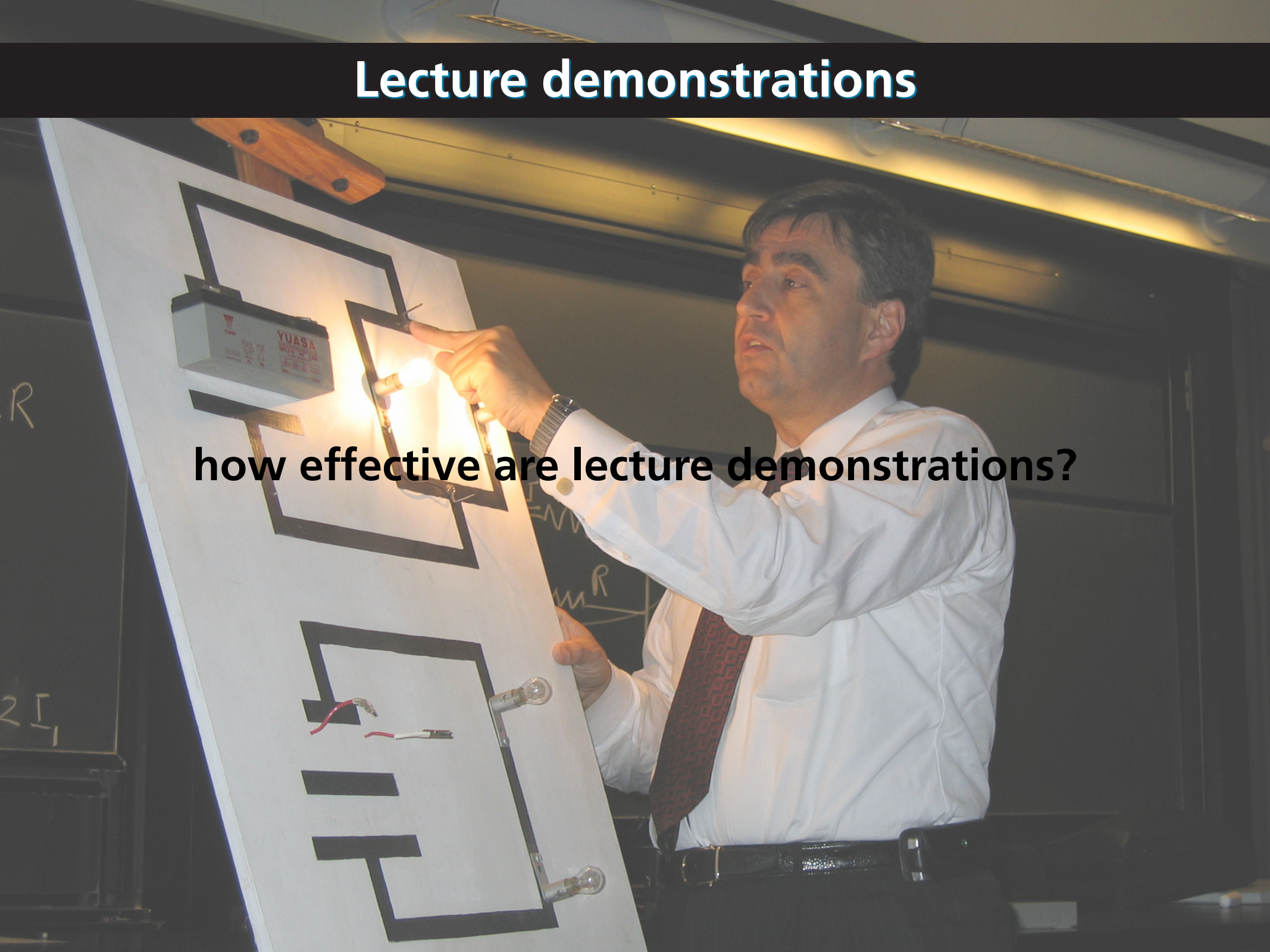


Gender issues

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.)

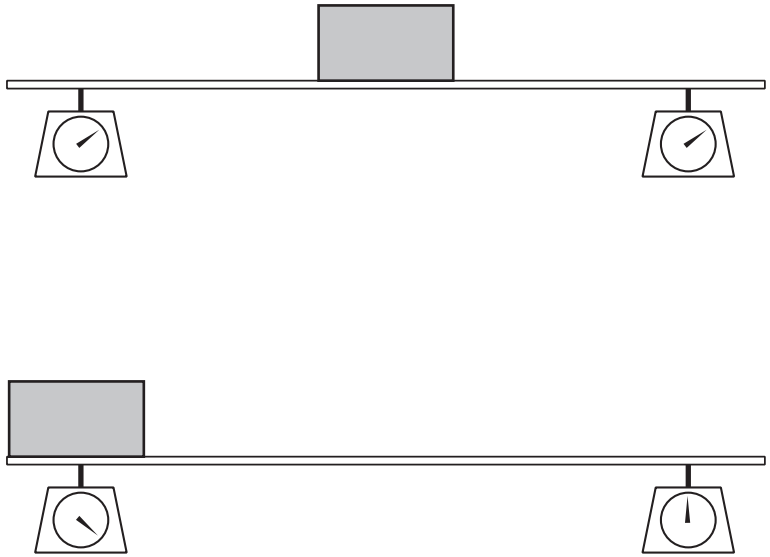
Lecture demonstrations

Follow up:

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

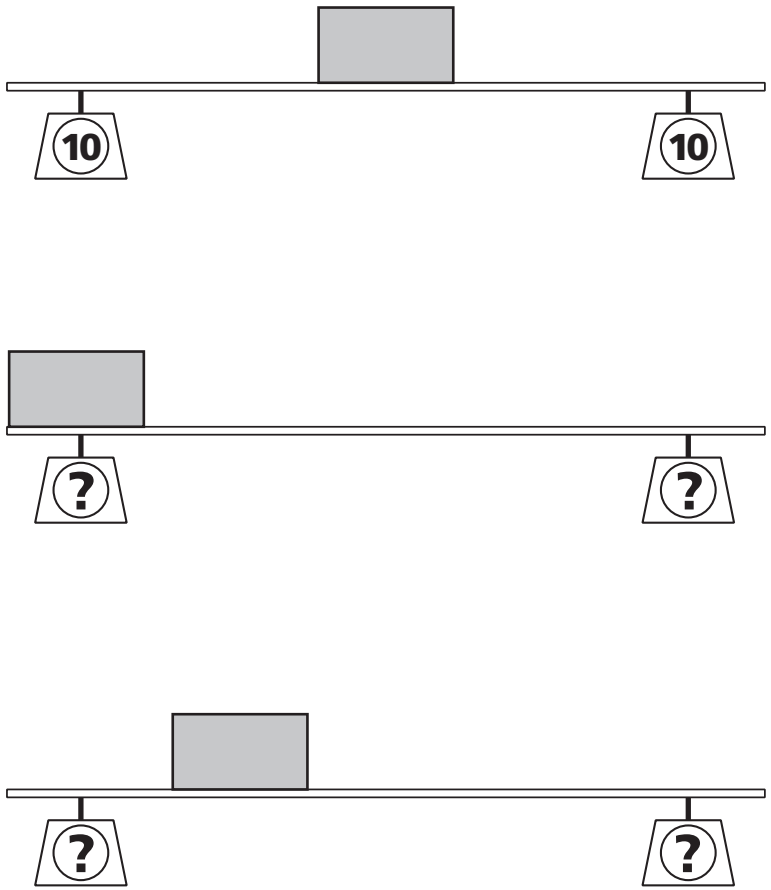
Lecture demonstrations

loaded beam demo



Lecture demonstrations

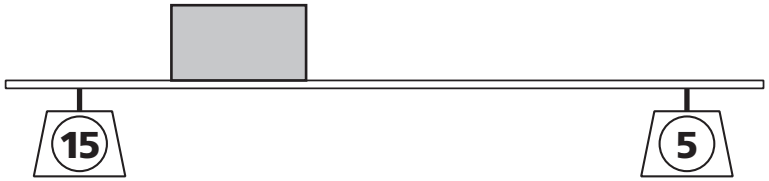
online test question



Lecture demonstrations

answers given

24% of students



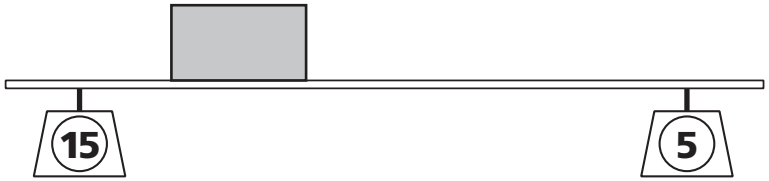
correct (mentions torque)

Lecture demonstrations

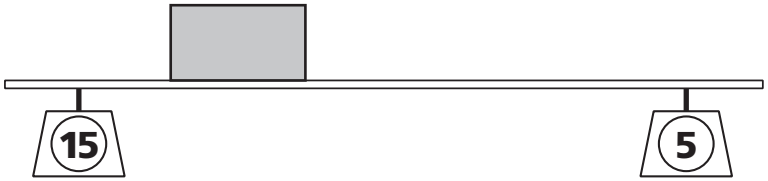
answers given

24% of students

38% of students



correct (mentions torque)



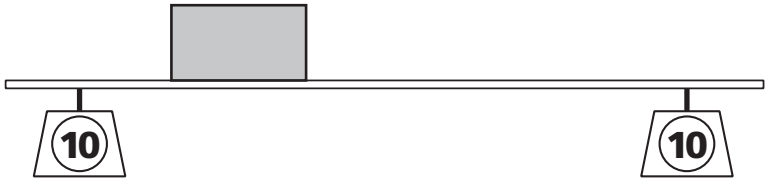
proportional reasoning

Lecture demonstrations

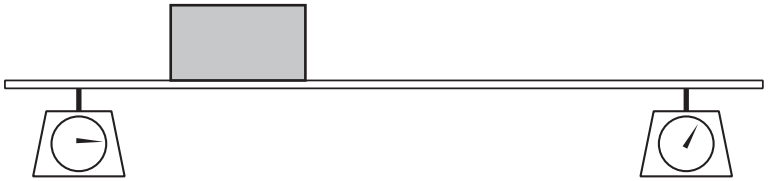
answers given

20% of students

10% of students



independent of position



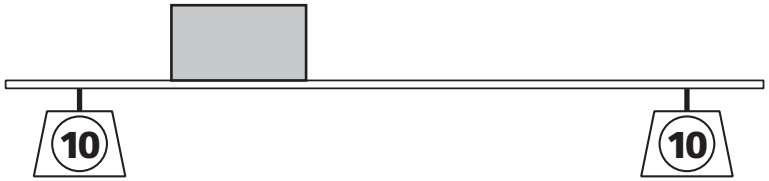
qualitative reasoning

Lecture demonstrations

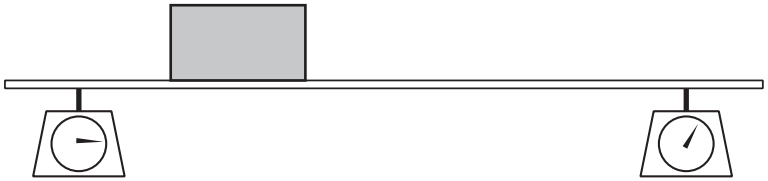
answers given

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%

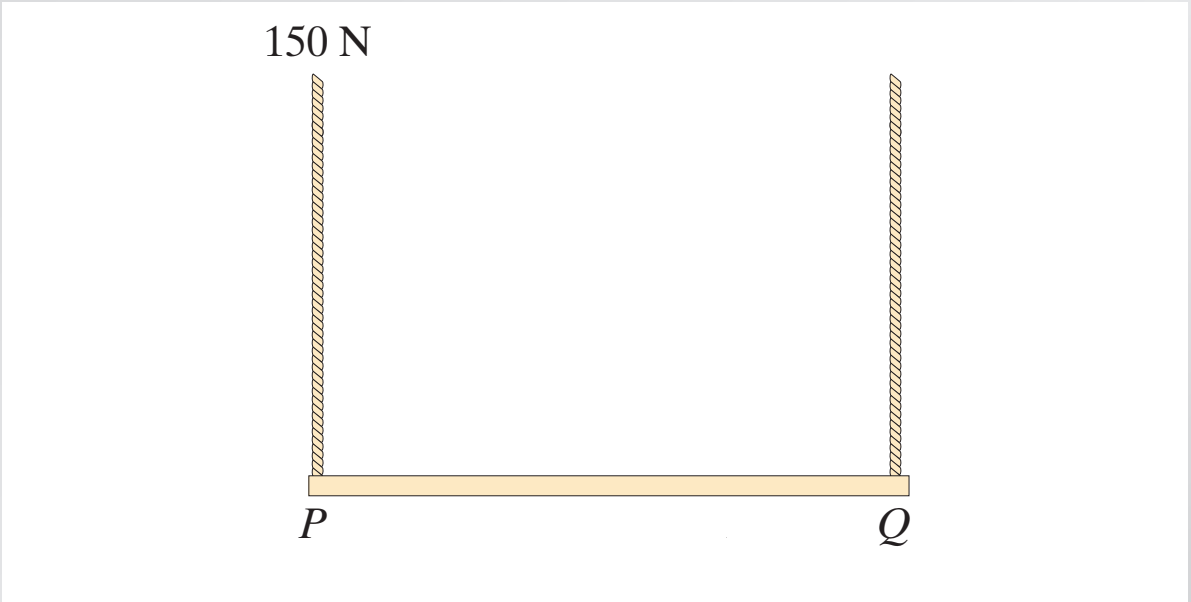
Lecture demonstrations

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

just presenting harmful?

Lecture demonstrations

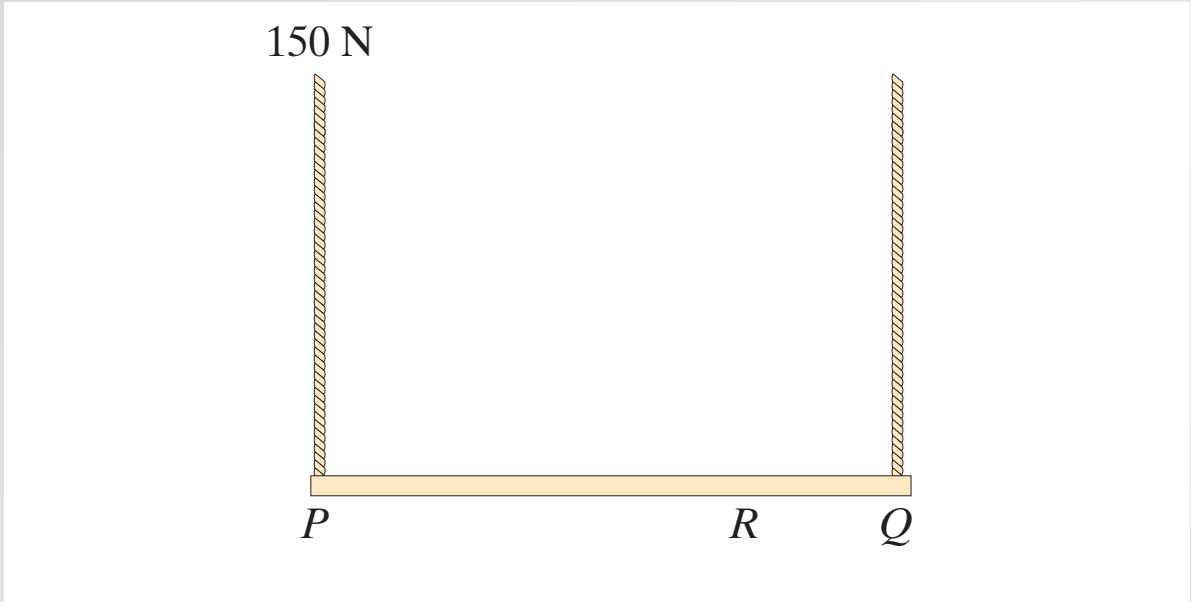
exam question



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

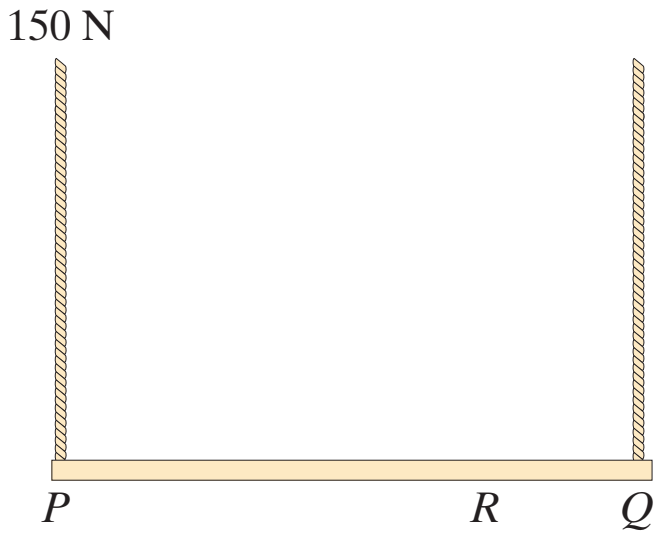
exam question

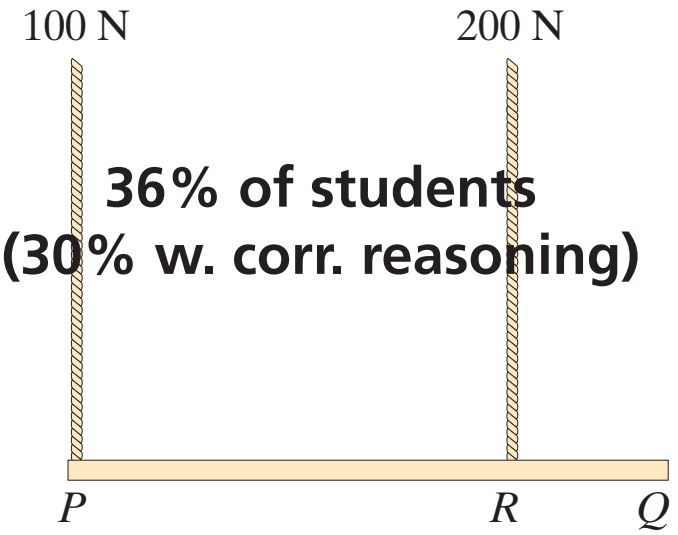


A uniform plank is supported by two ropes at points *P* and *Q*. The tension in the rope at *P* is 150 N. The point at which the other rope is attached to the plank is now moved to point *R* halfway between Q and the center of the plank. What are the tensions in the two ropes?

Lecture demonstrations

correct answer



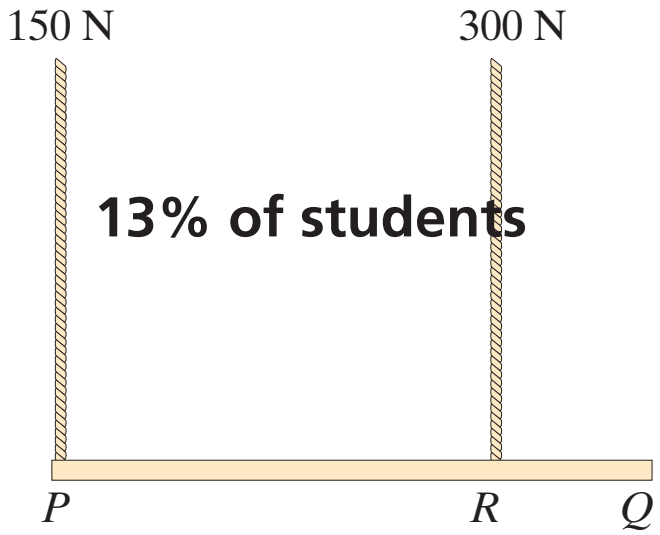


36% of students
(30% w. corr. reasoning)

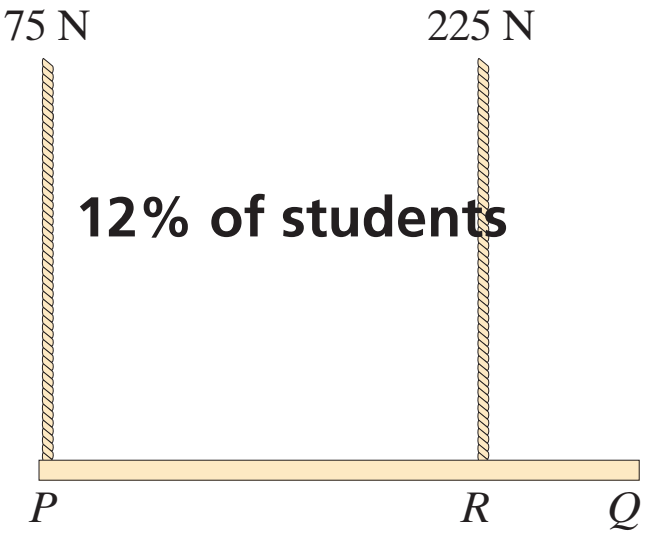
considerable improvement from online test

Lecture demonstrations

incorrect answers



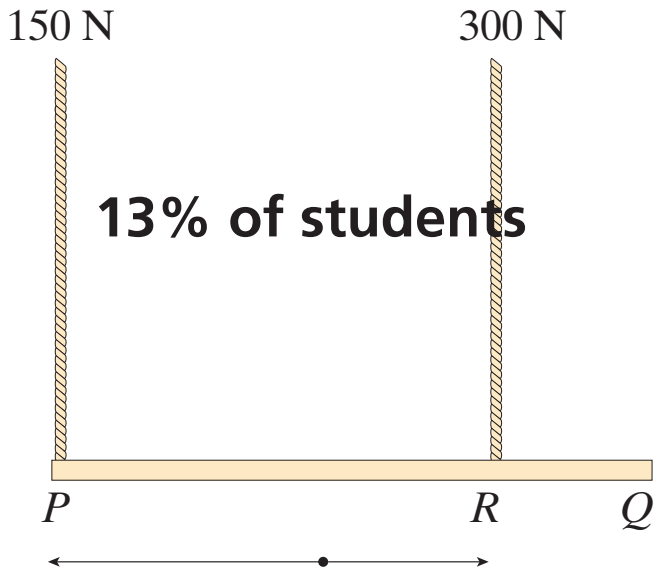
13% of students



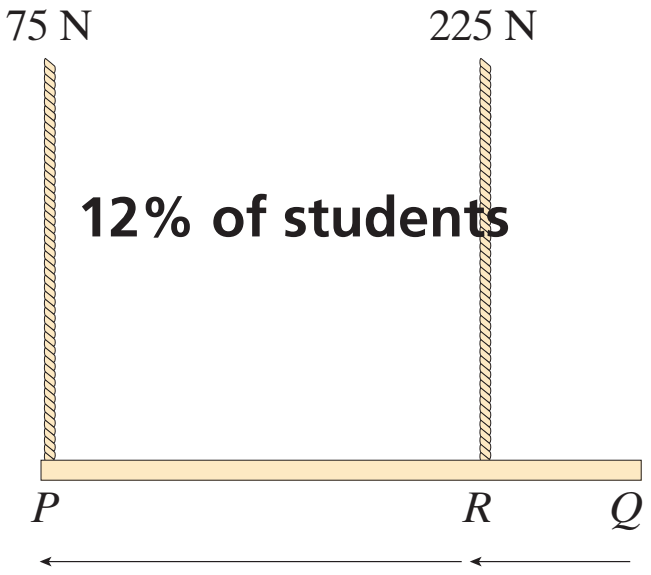
12% of students

Lecture demonstrations

incorrect answers



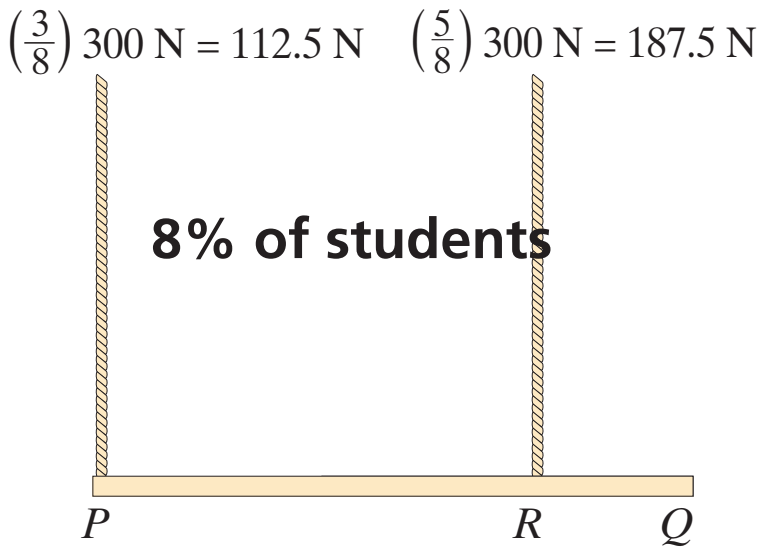
lever arm reduced by factor 2

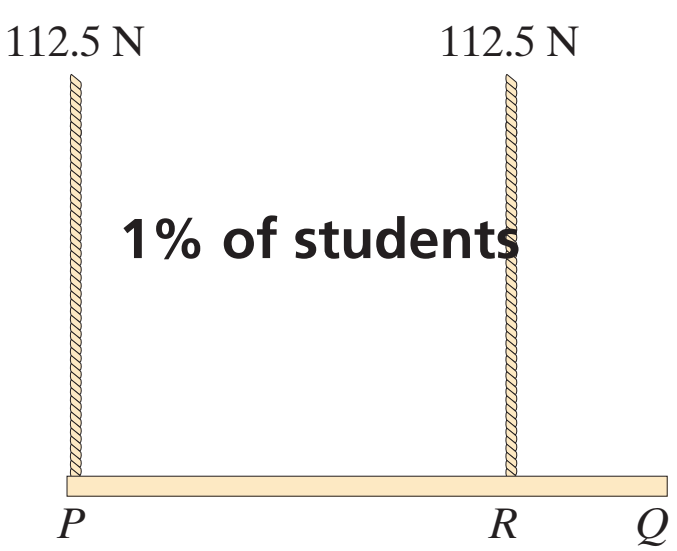


lever arms 1:3

Lecture demonstrations

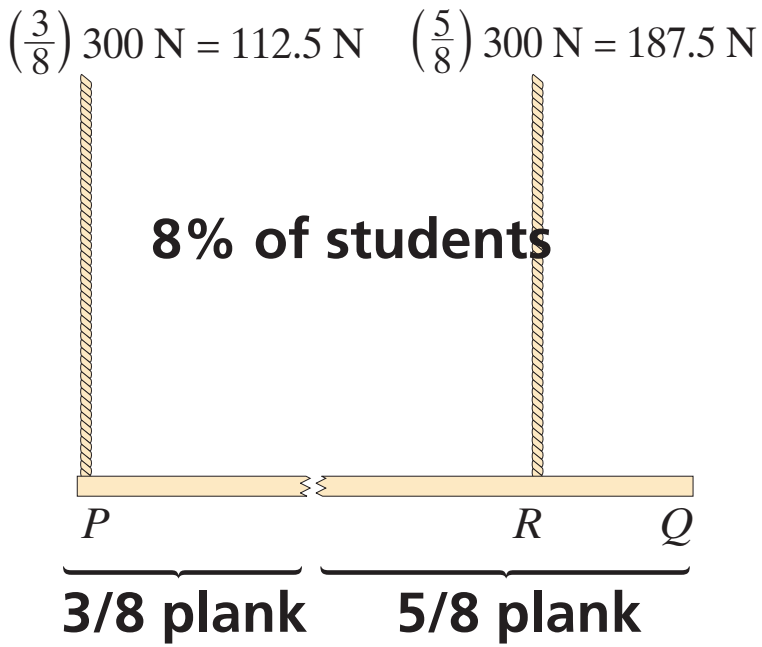
incorrect answers

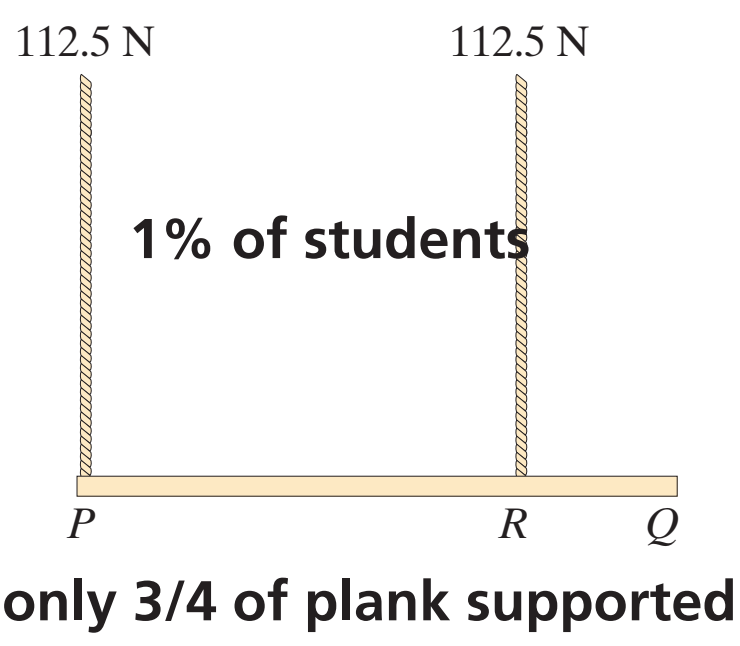




Lecture demonstrations

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%

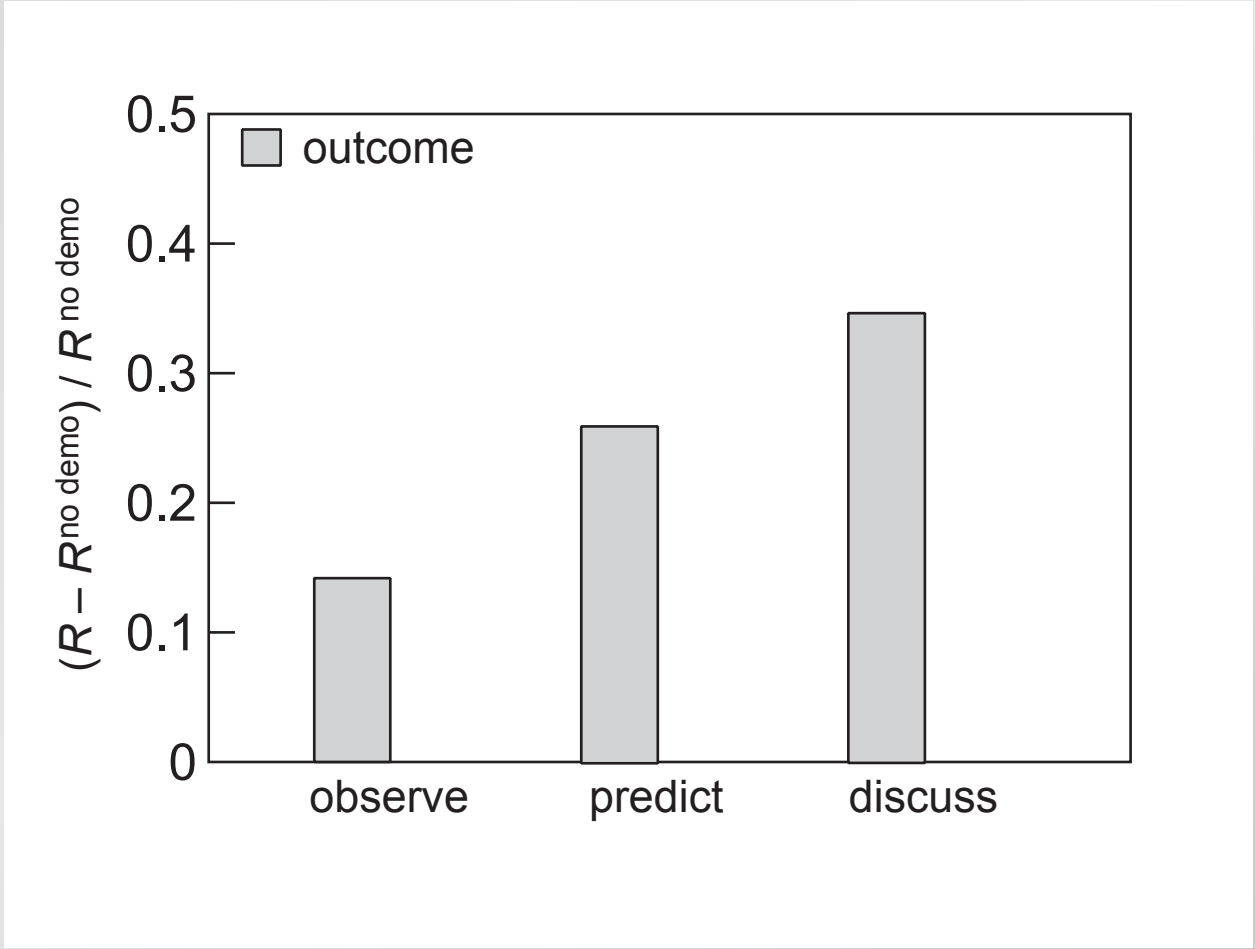
Lecture demonstrations

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

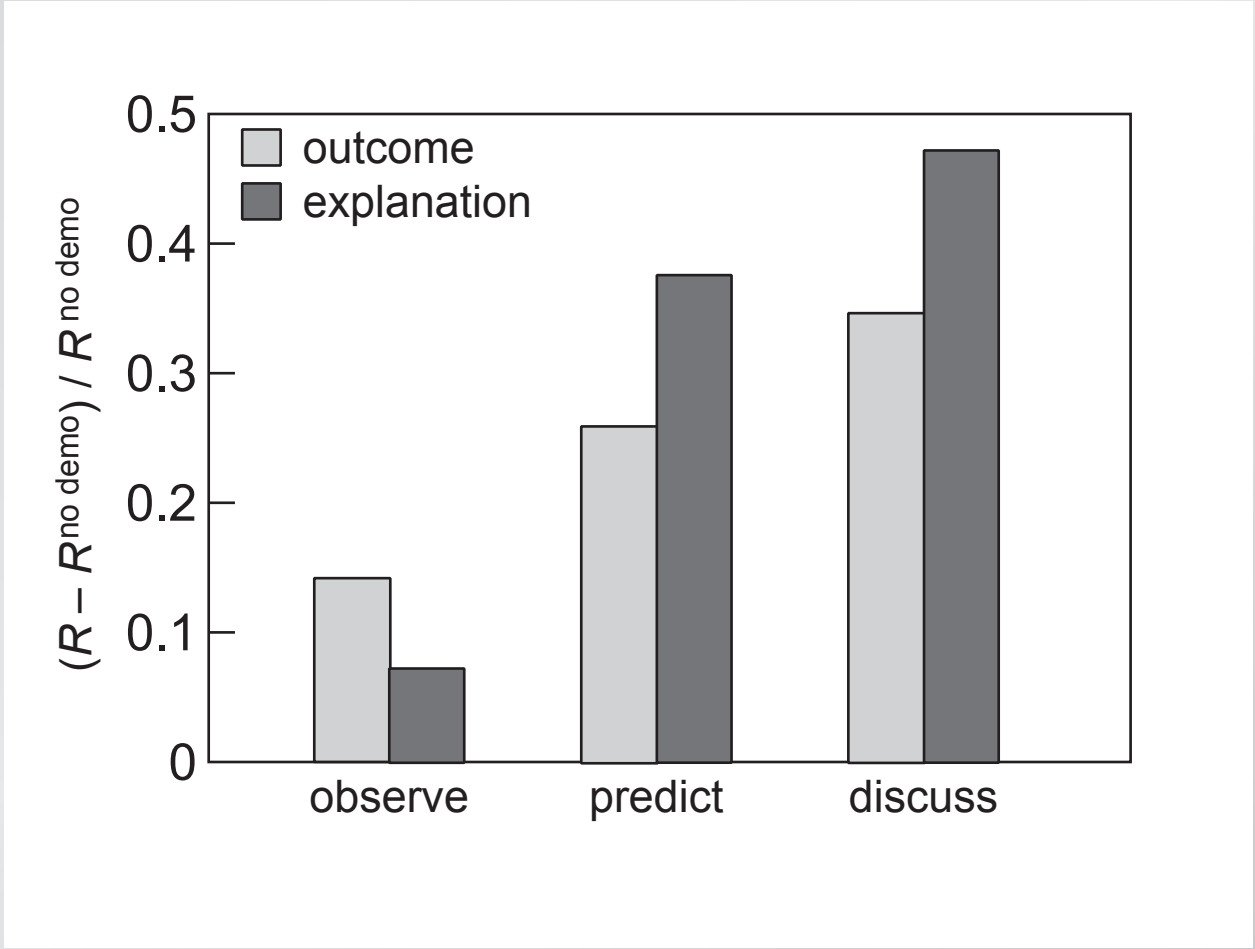
improvement correlates with engagement



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

Lecture demonstrations

improvement correlates with engagement



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

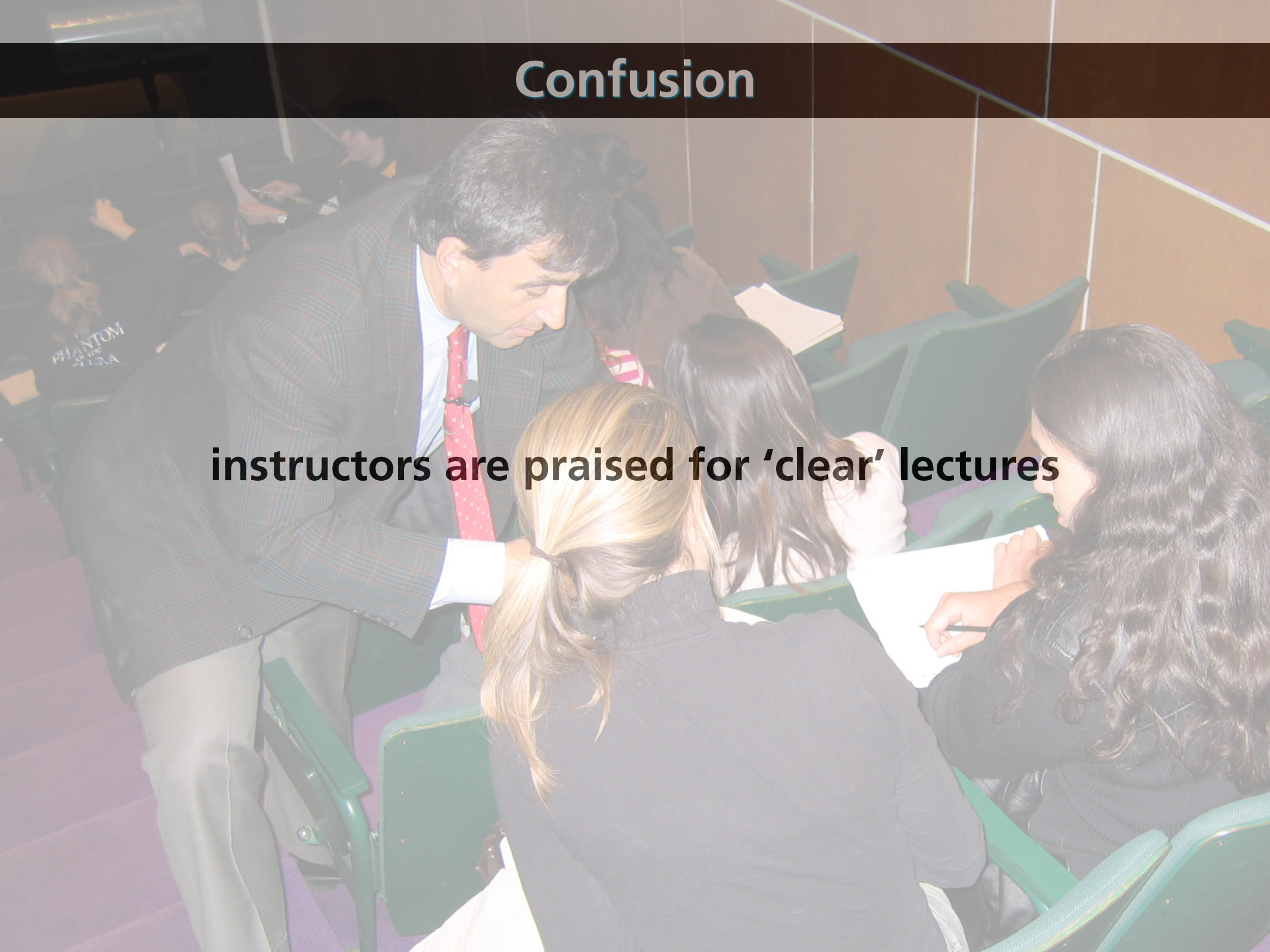
Lecture demonstrations

Points to keep in mind:

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

Confusion

Confusion

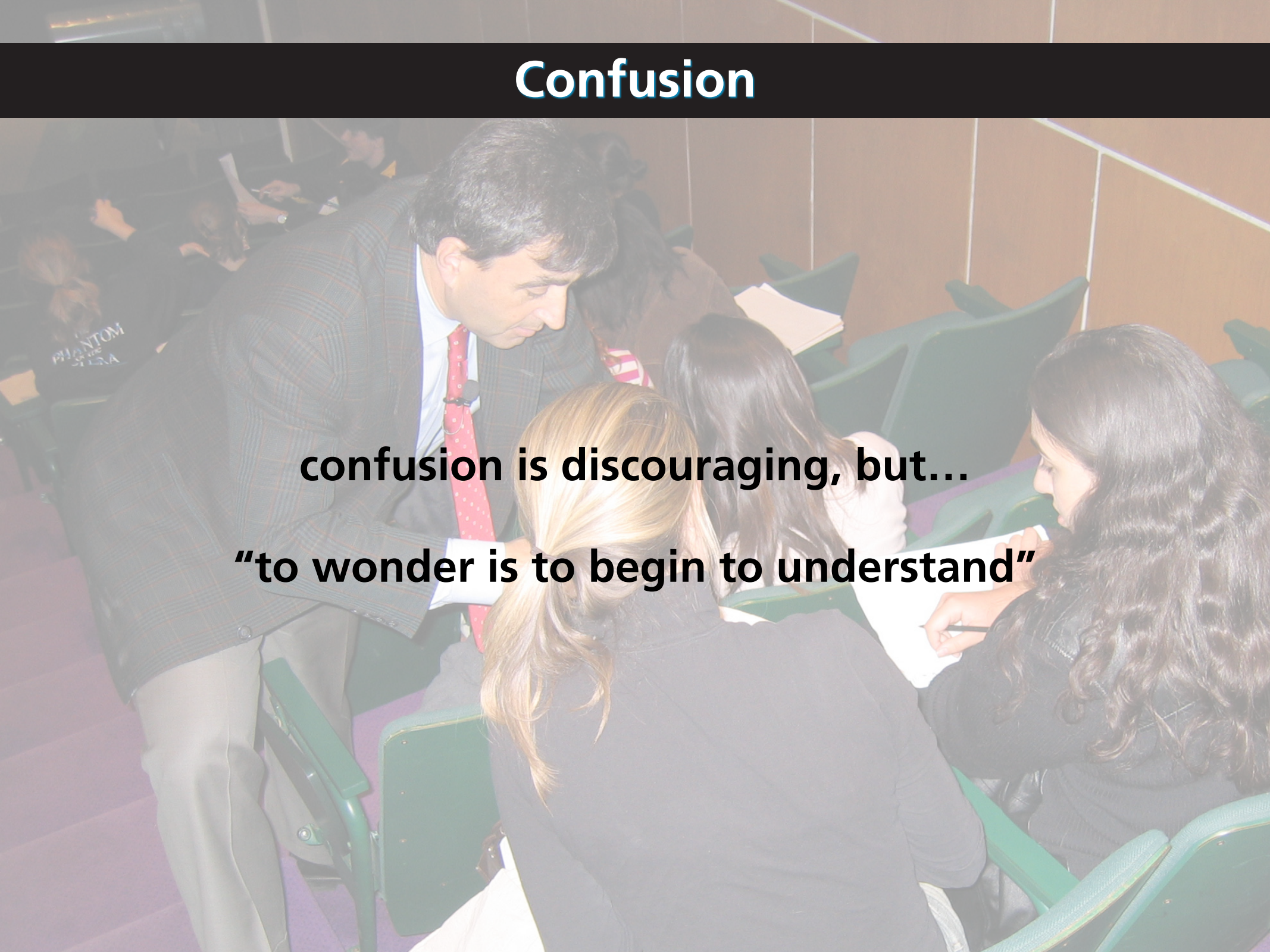


instructors are praised for ‘clear’ lectures

Confusion

confusion is discouraging, but…

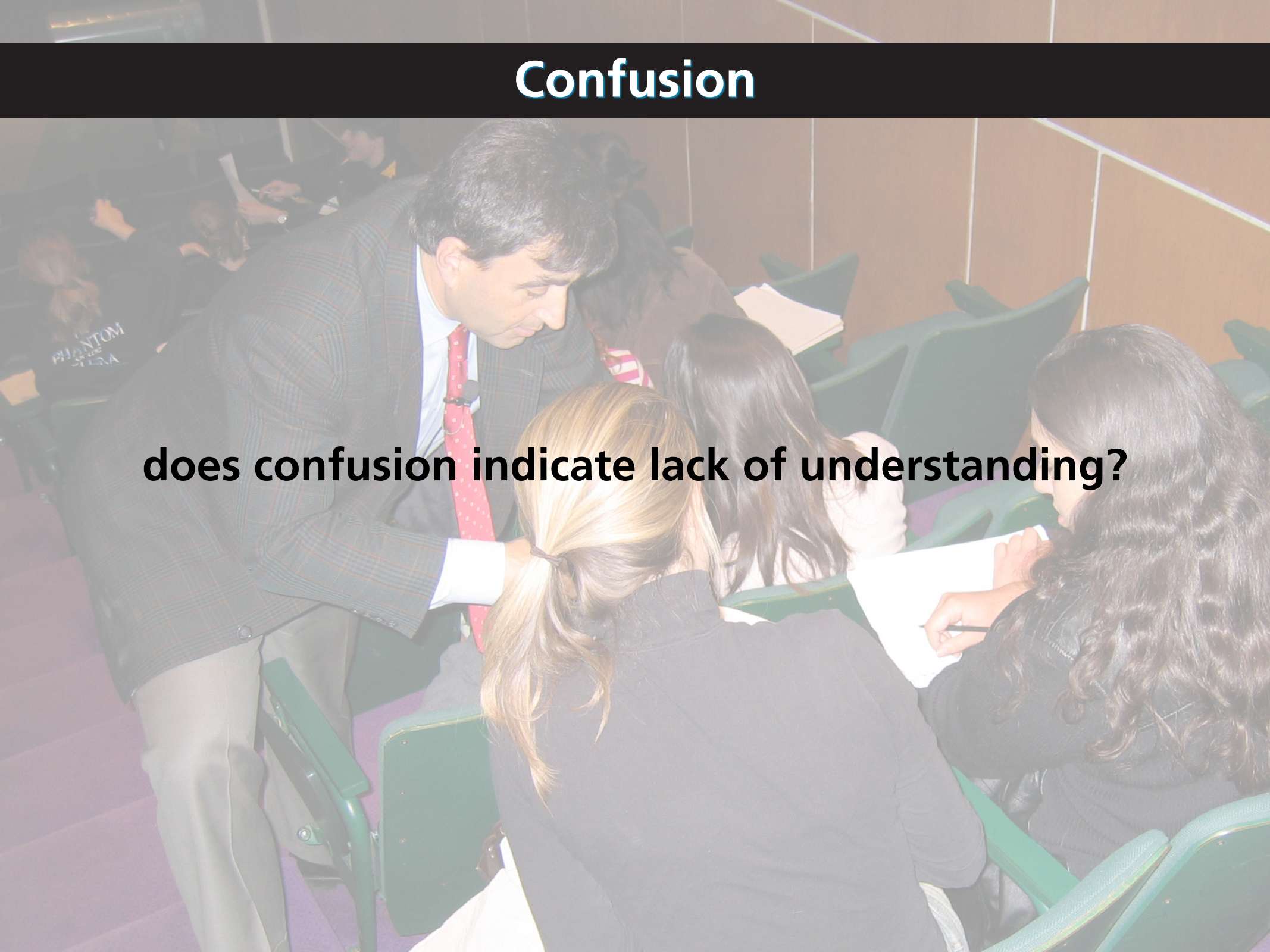
Confusion



confusion is discouraging, but…

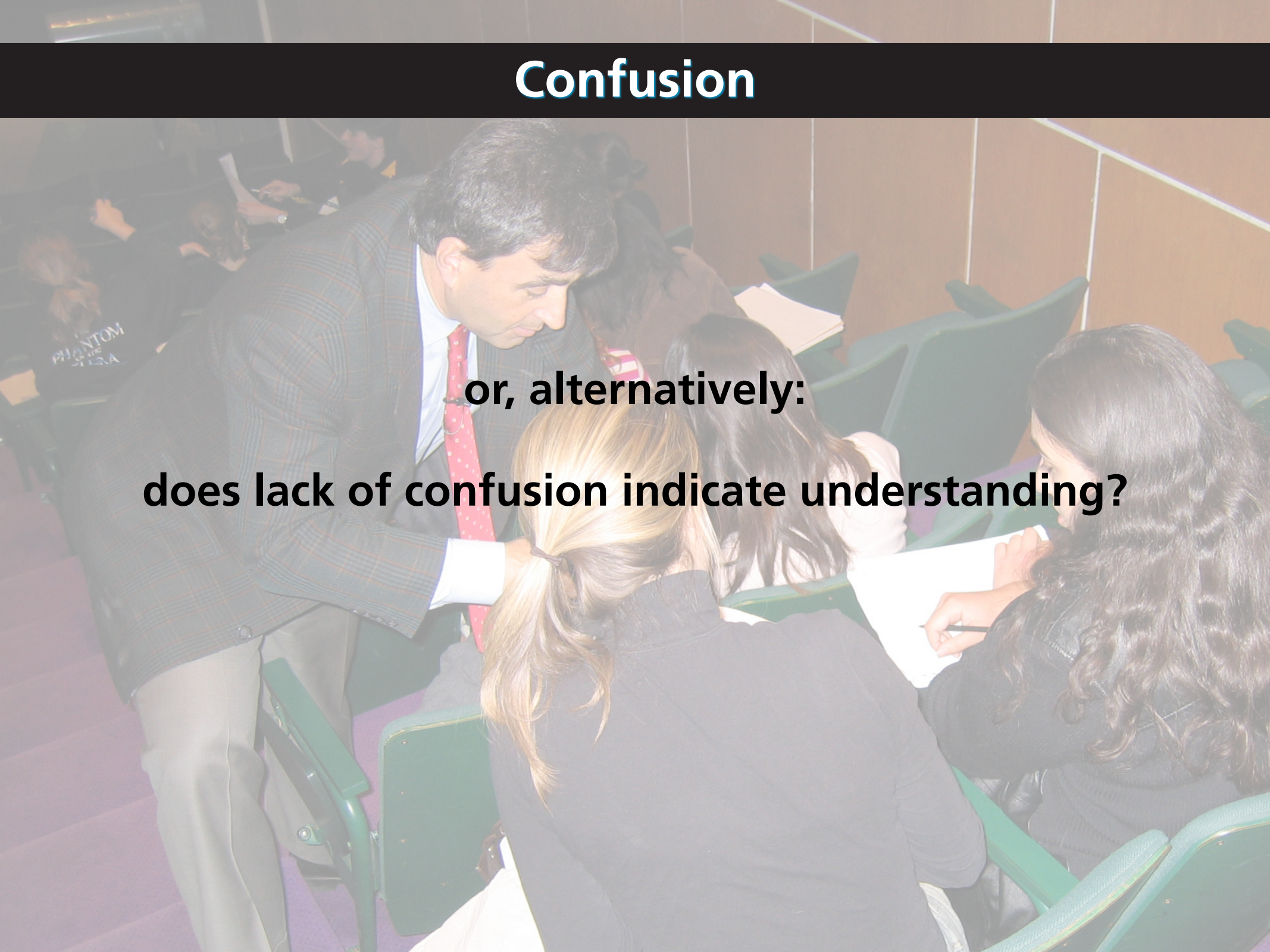
“to wonder is to begin to understand”

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:

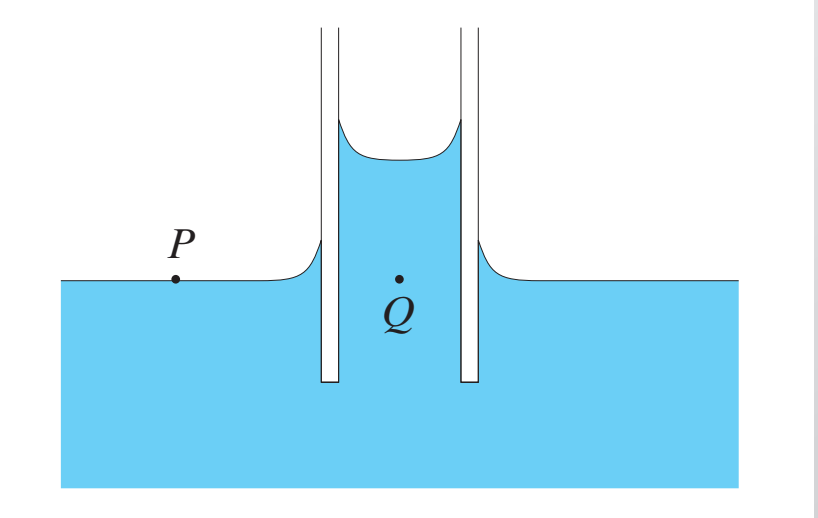
- **two questions on content (difficult!)**
- **one feedback question**

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?



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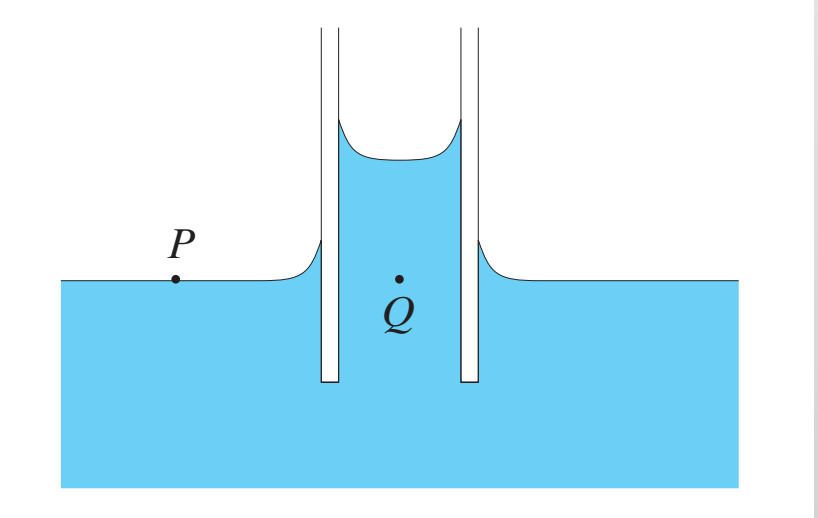

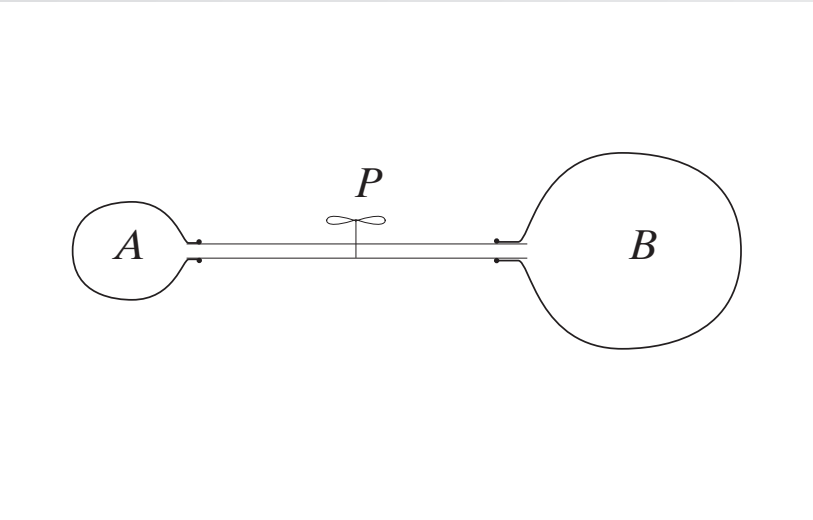

2. Two identical balloons are connected to a tube as shown below. Balloon *B* is inflated more than balloon *A*. Which way does the air flow when valve *P* is opened?

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

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WRONG

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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

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

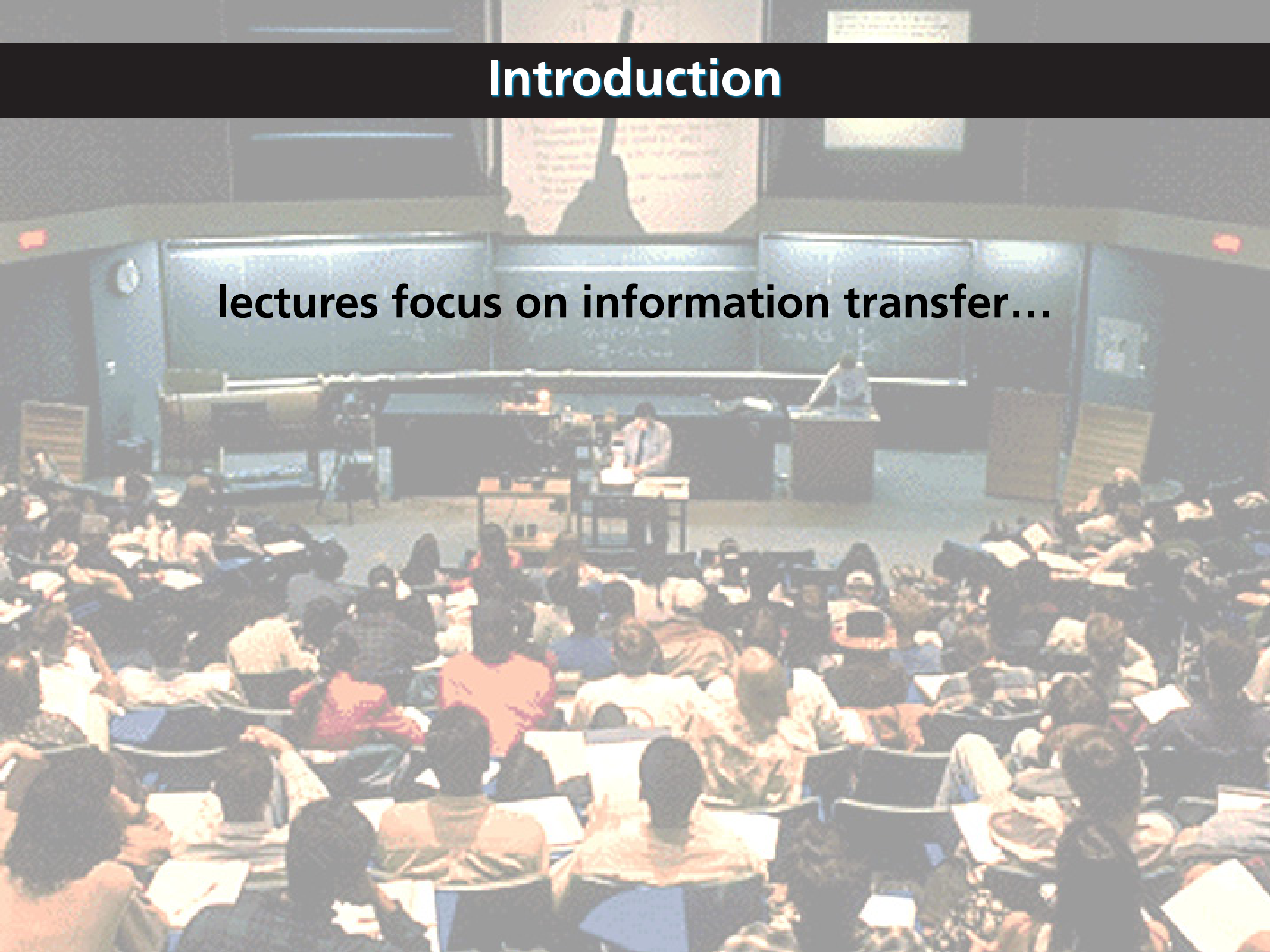
Conclusion

classroom data vital to improving education!

The Scientific Approach to Teaching: Using Data to Debunk Myths

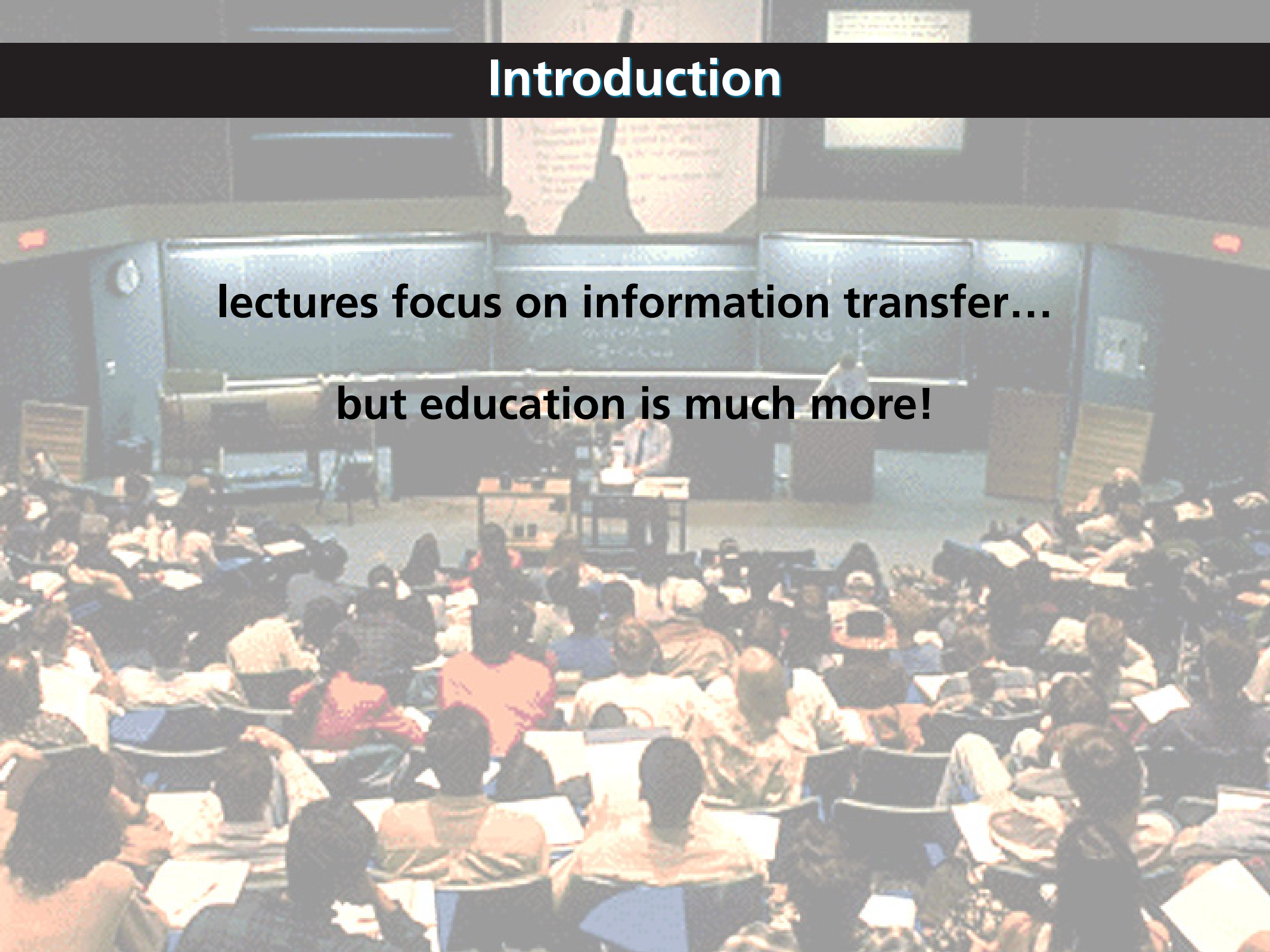
SALTISE
Dawson College
Montréal, QC, 21 May 2012

Introduction



lectures focus on information transfer…

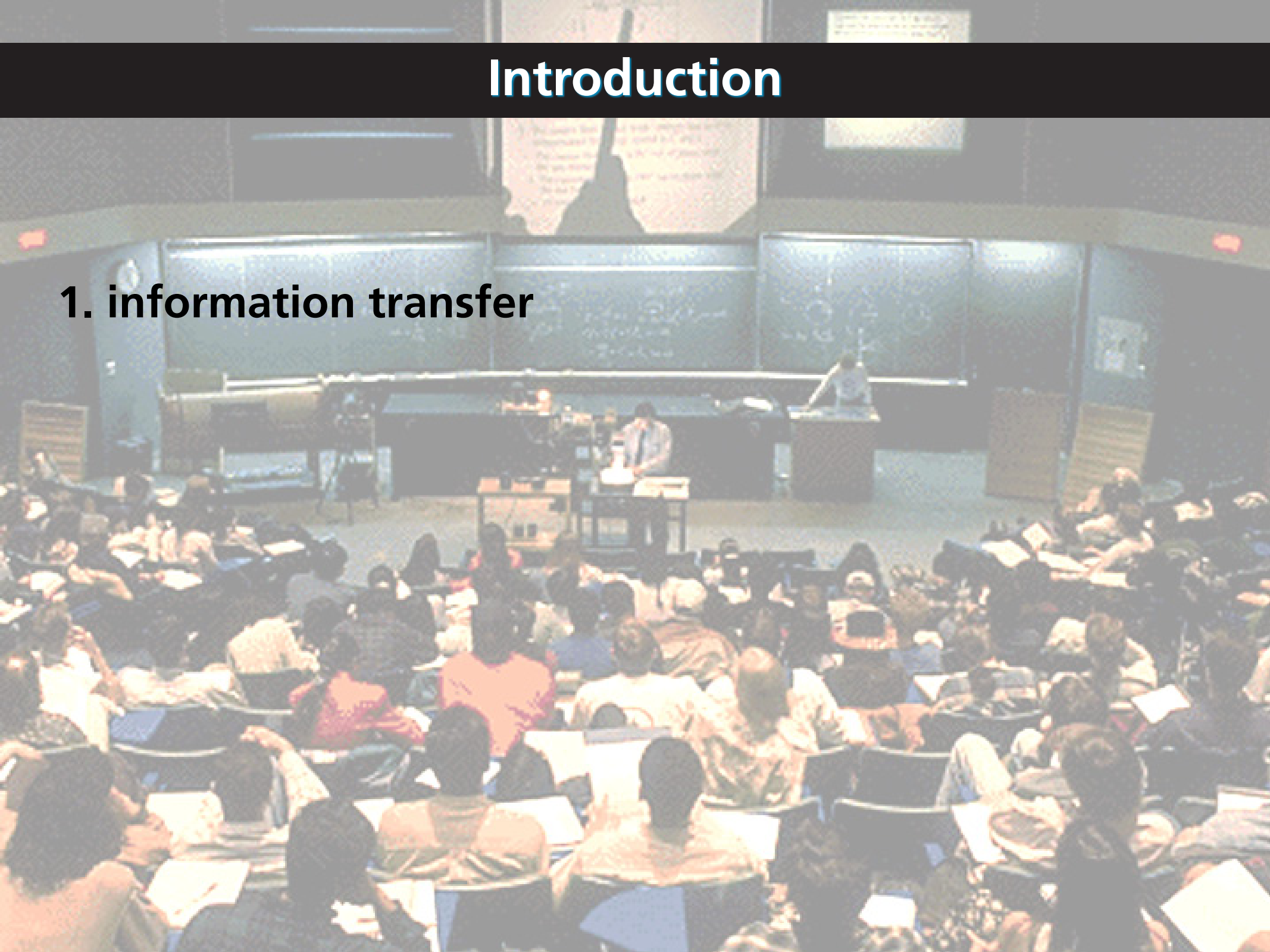
Introduction



lectures focus on information transfer…

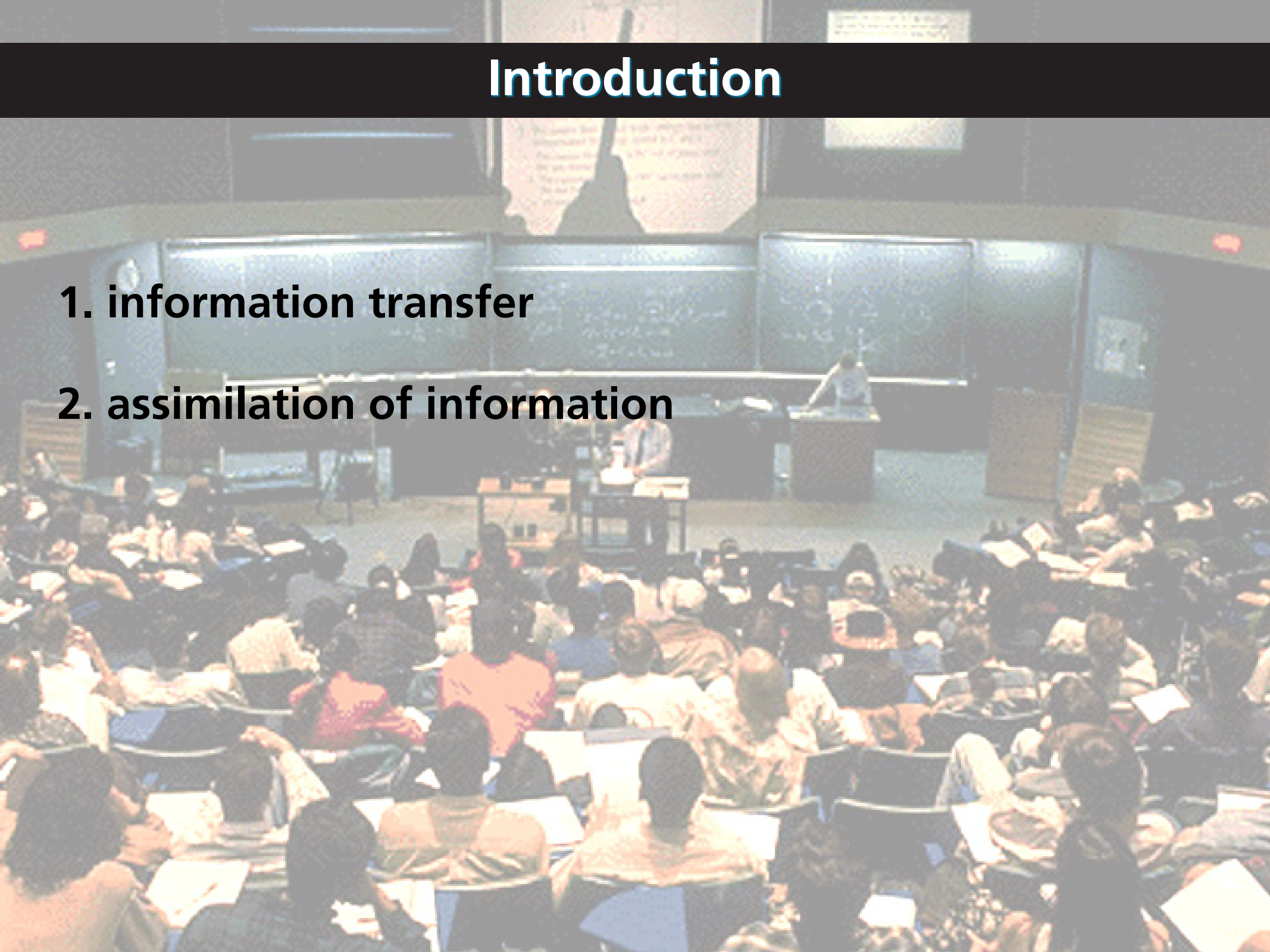
but education is much more!

Introduction



1. information transfer

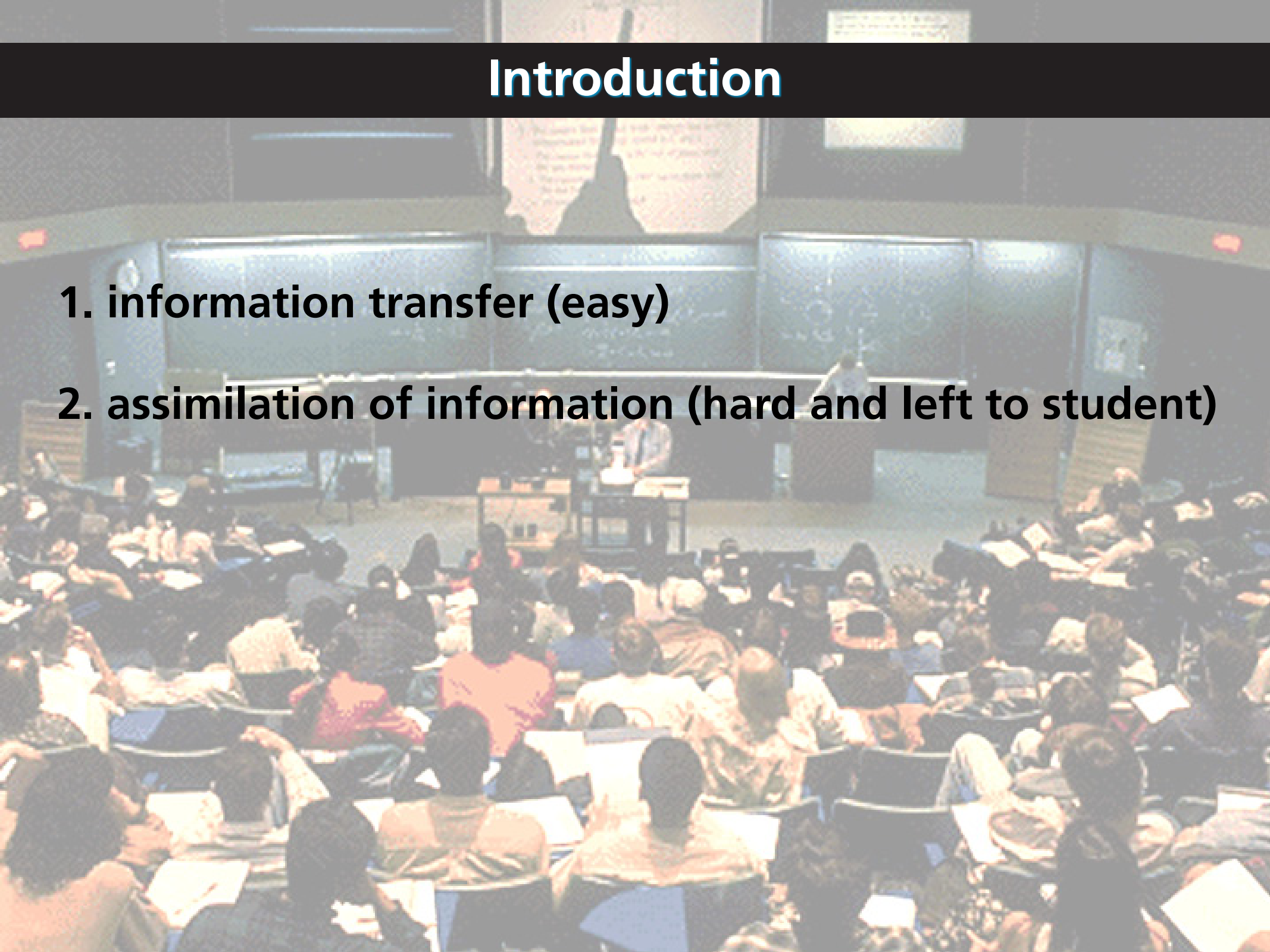
Introduction



1. information transfer

2. assimilation of information

Introduction



1. information transfer (easy)

2. assimilation of information (hard and left to student)

Introduction

Solution: move information transfer out of classroom!

Introduction

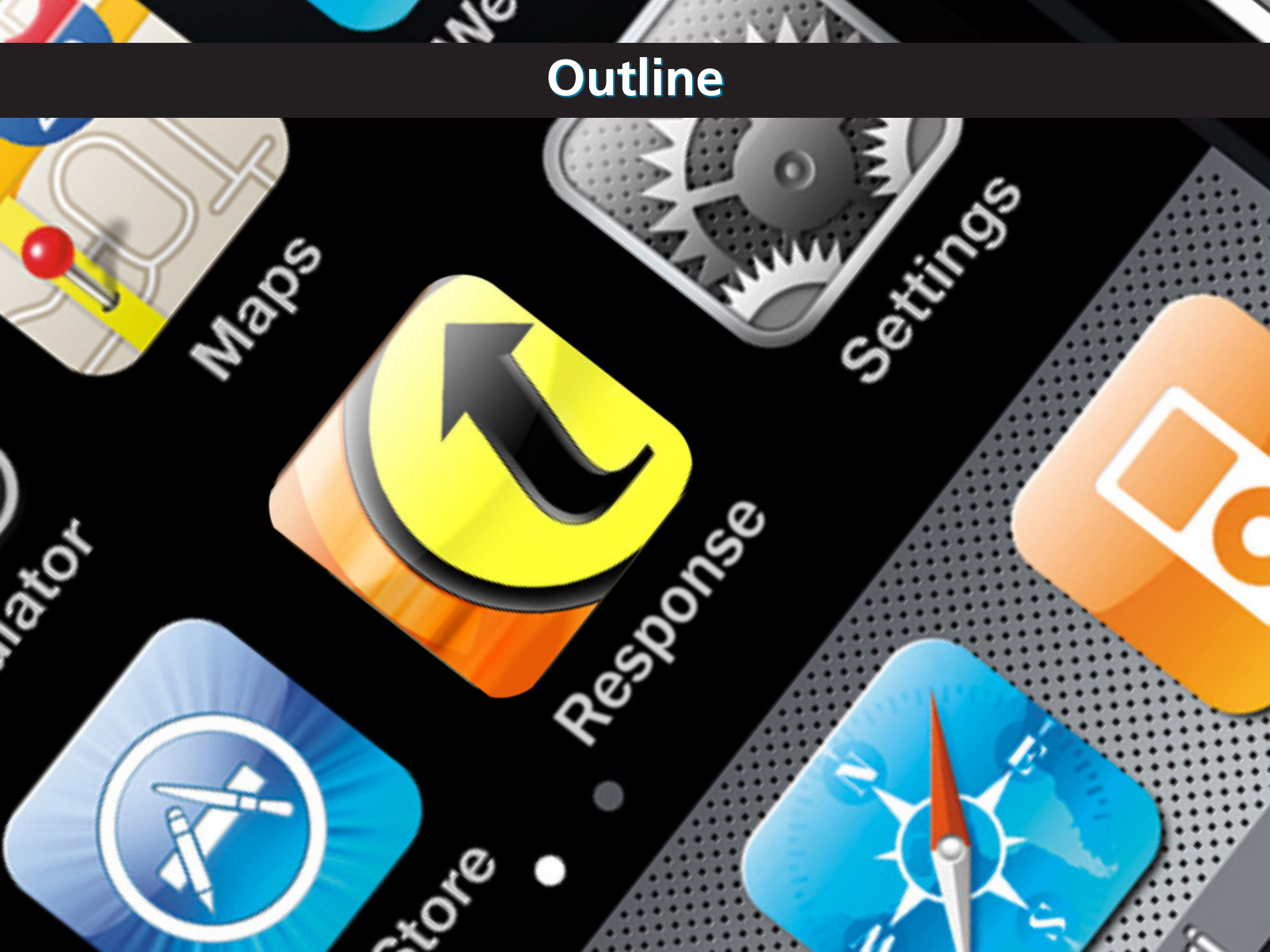
How to move information transfer out of classroom?

Introduction

How to move information transfer out of classroom?

Use JiTT (before class) and PI (in class)!

Outline



Outline

- PI & JiTT Overview
- Implementing PI & JiTT
- ConcepTests

PI & JiTT Overview

"How can I be sure that my students will prepare for class?"

PI & JiTT Overview

Students do not come to class prepared, because...

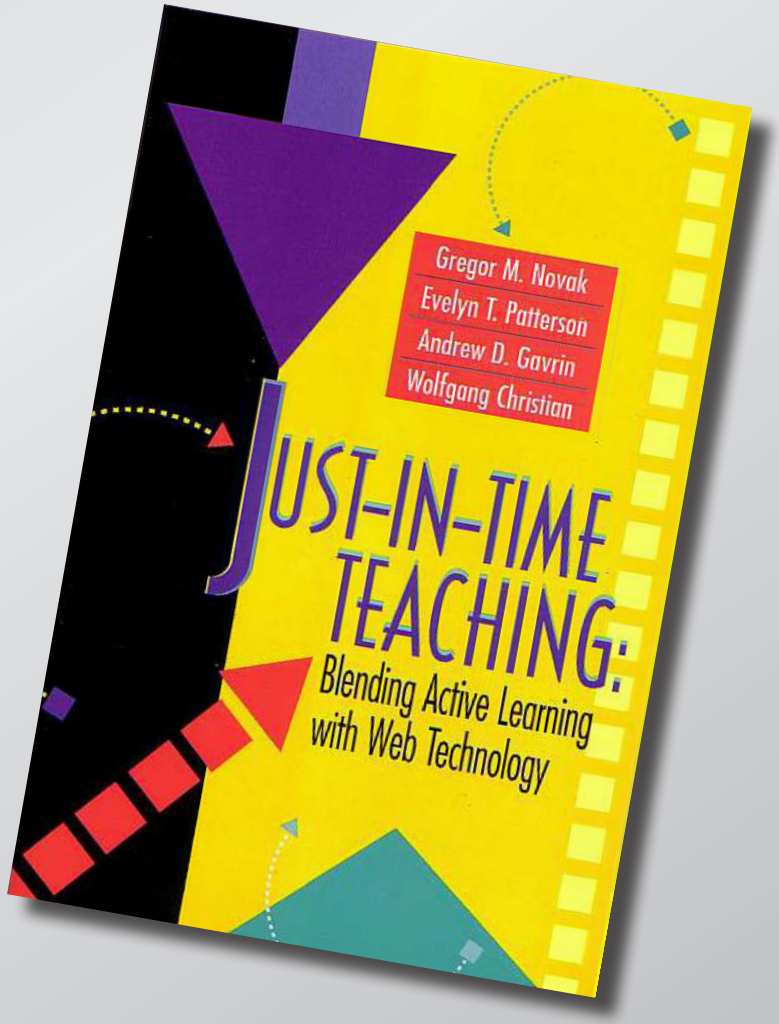
1. they don't have time.
2. they are not motivated to learn.
3. their instructors take away the incentive.
4. they do not have the requisite skills.
5. of some other reason.
6. They do come prepared in my class!

(select what you consider to be the main reason)

PI & JiTT Overview

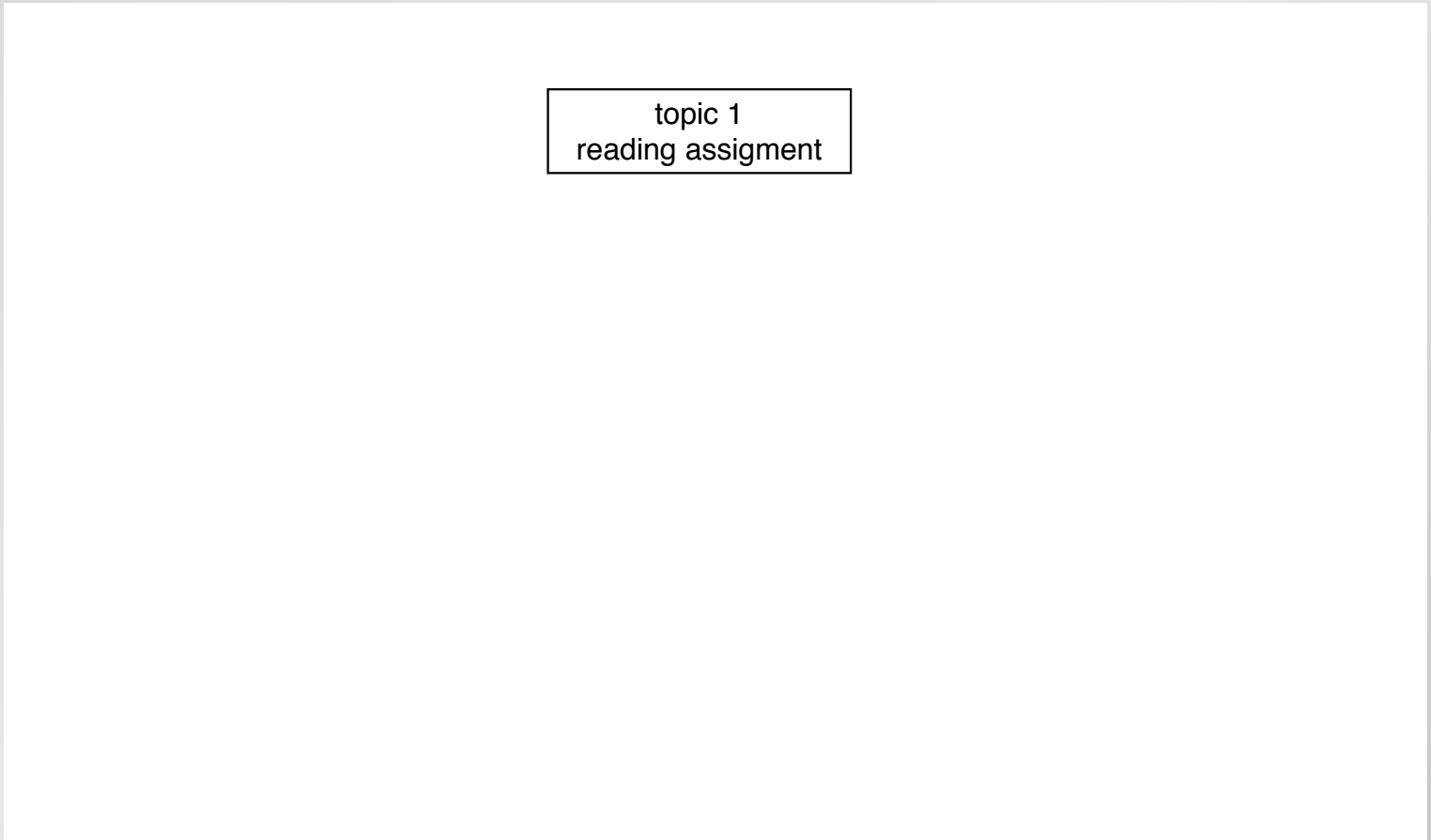
Just-in-time-Teaching (JiTT)

www.jitt.org



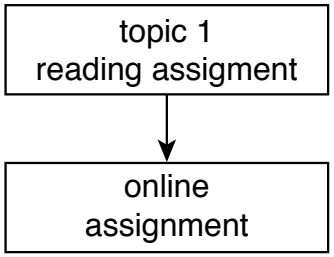
PI & JiTT Overview

JiTT workflow



PI & JiTT Overview

JiTT workflow



PI & JiTT Overview

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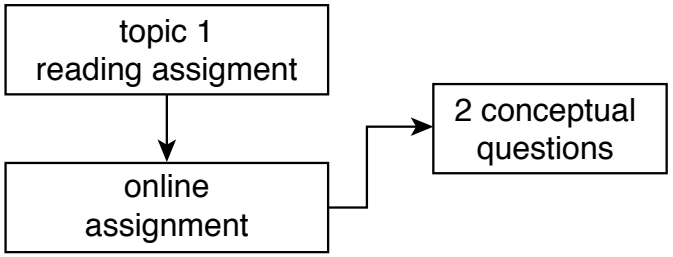
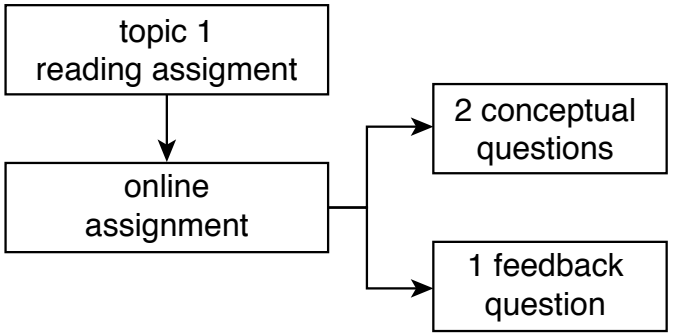


PI & JiTT Overview

JiTT workflow



PI & JiTT Overview

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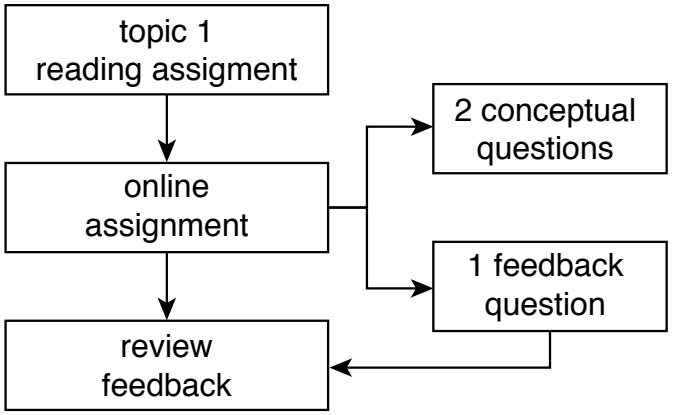

PI & JiTT Overview

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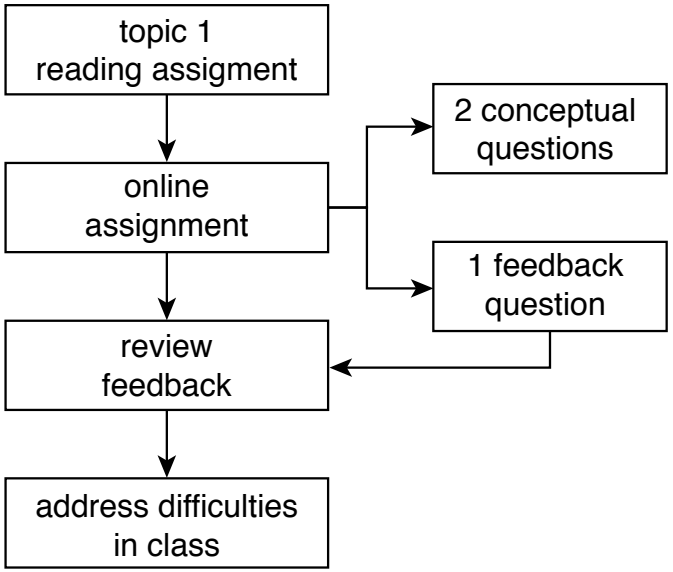
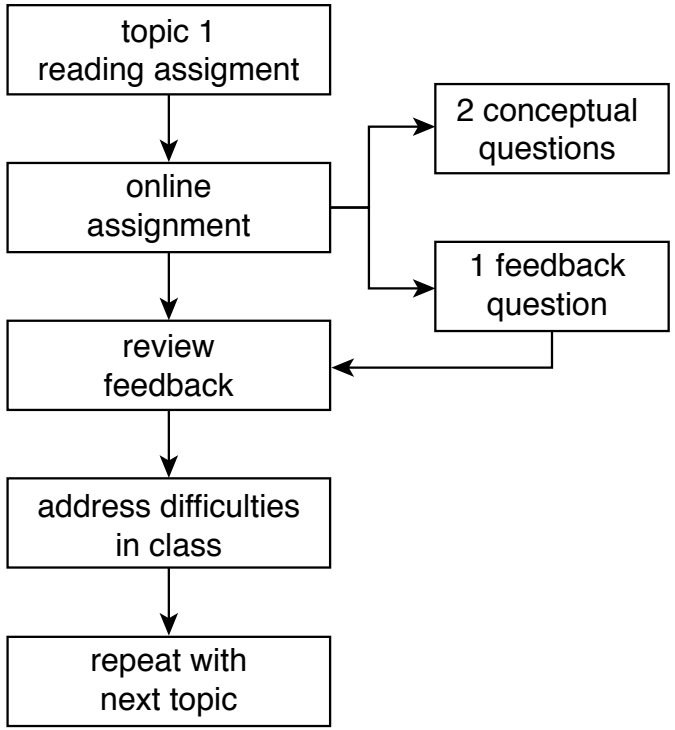


PI & JiTT Overview

JiTT workflow



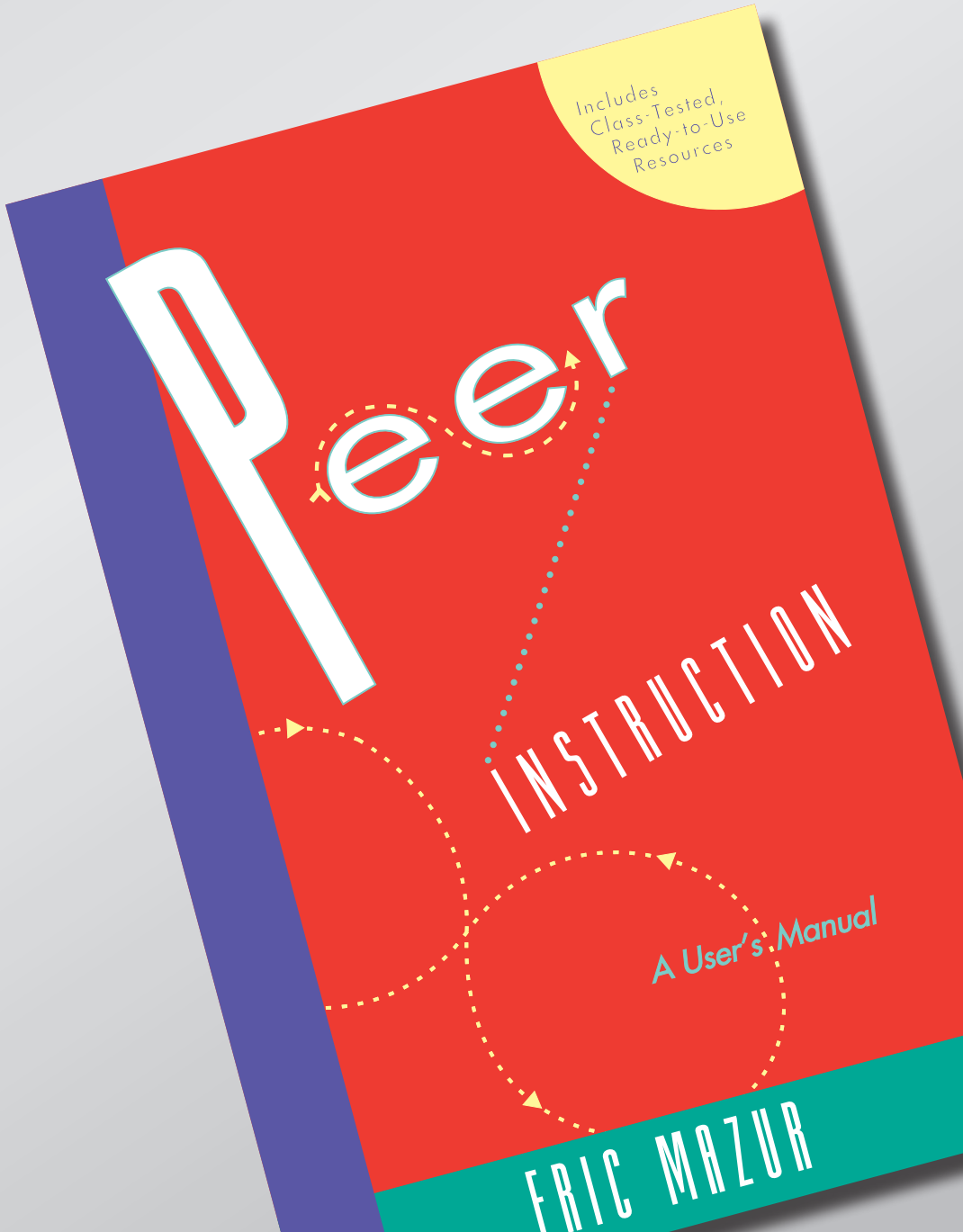
PI & JiTT Overview

JiTT:

- prepares you for class
- prepares students for class
- helps you address student difficulties

PI & JiTT Overview

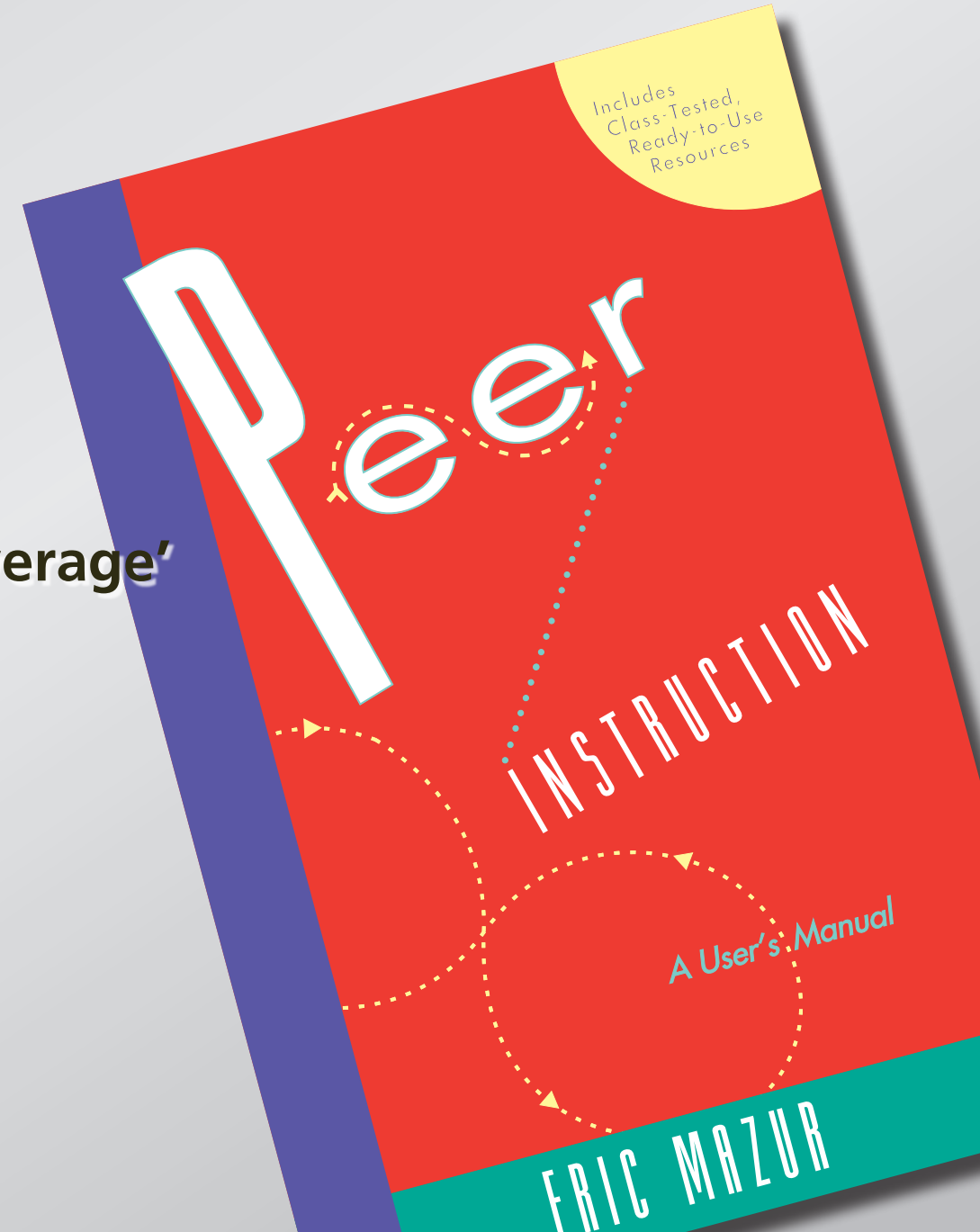
Peer Instruction (PI)



PI & JiTT Overview

Main features:

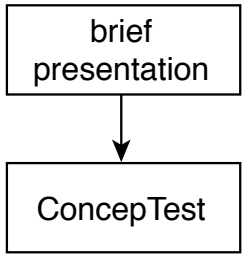
- **pre-class assignment**
- **in-class: depth, not 'coverage'**
- **ConcepTests**



PI & JiTT Overview

brief
presentation

PI & JiTT Overview



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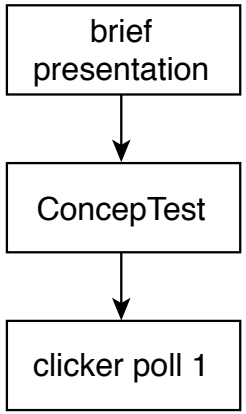

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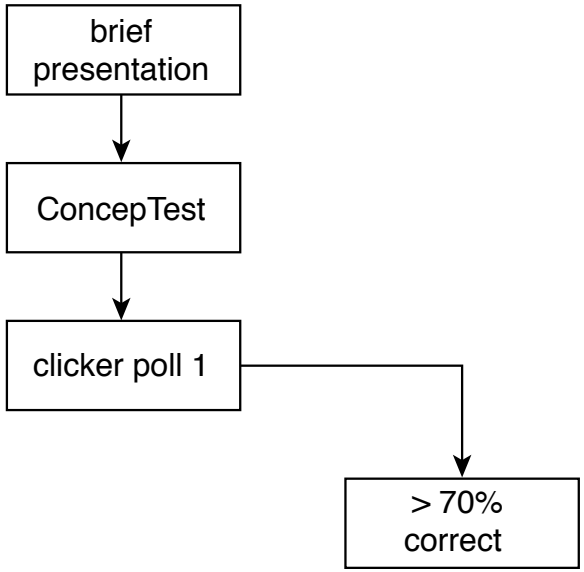

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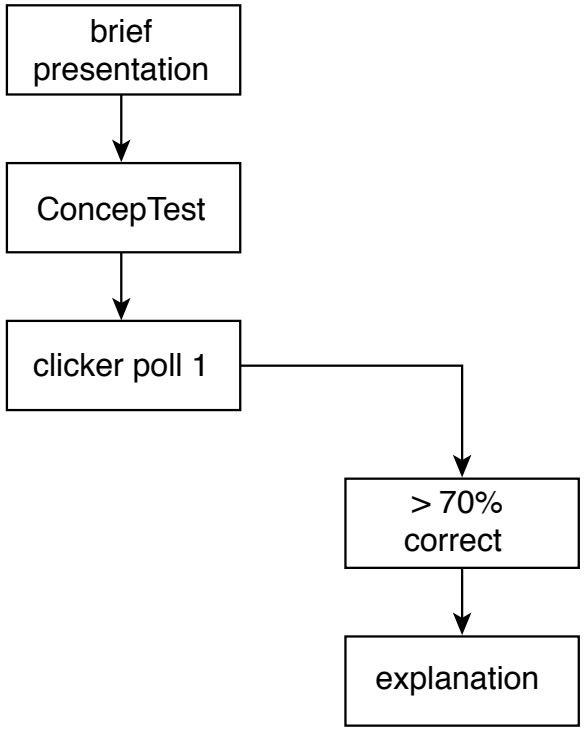

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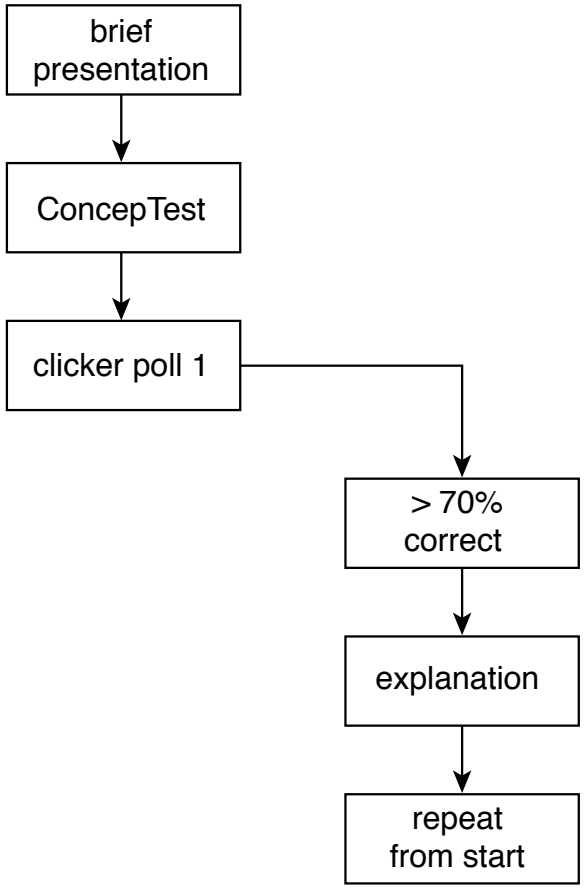

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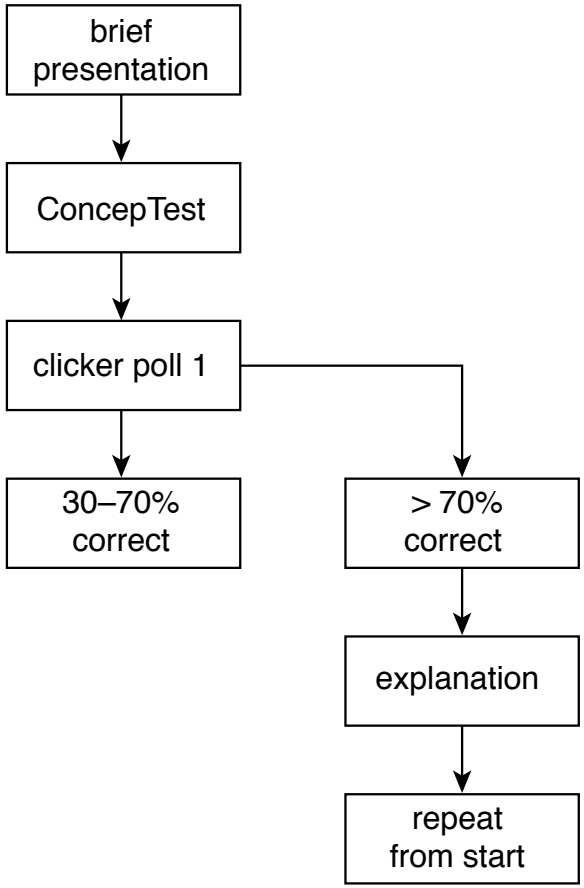

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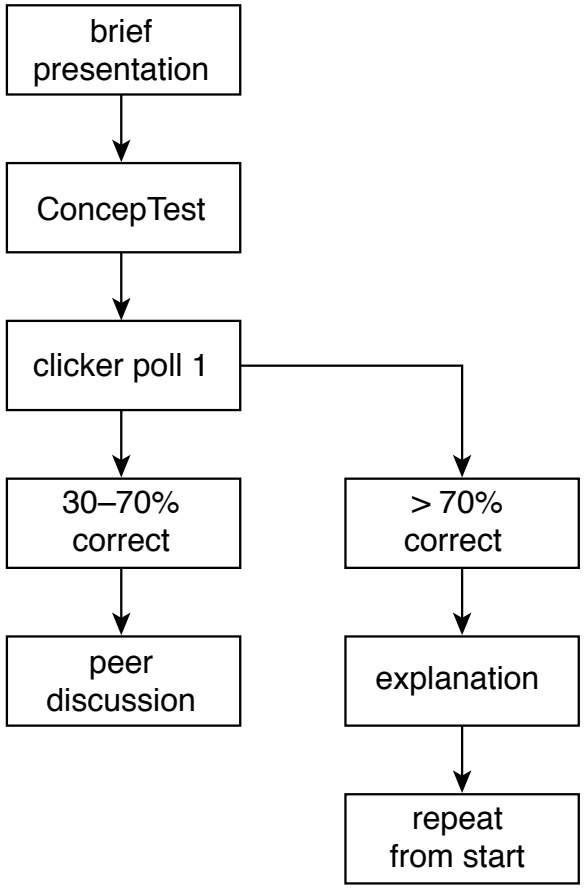

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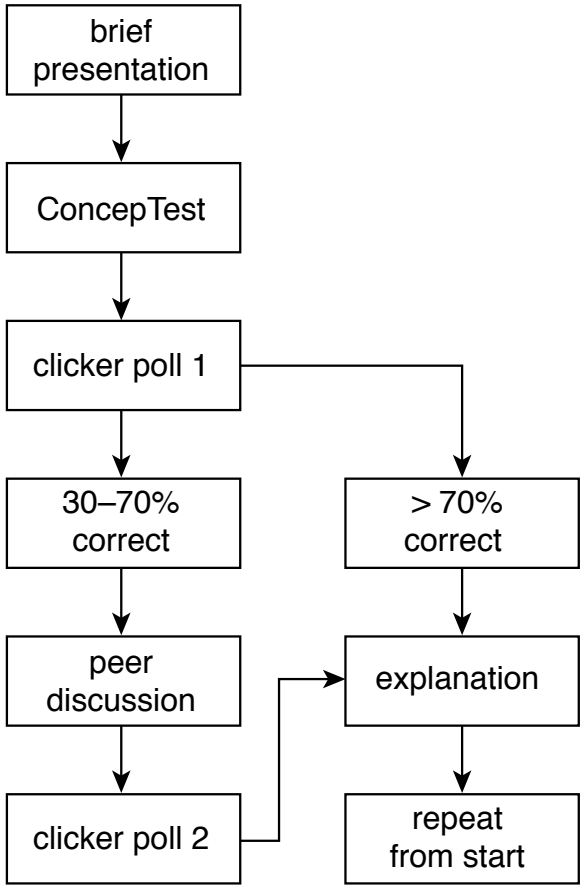

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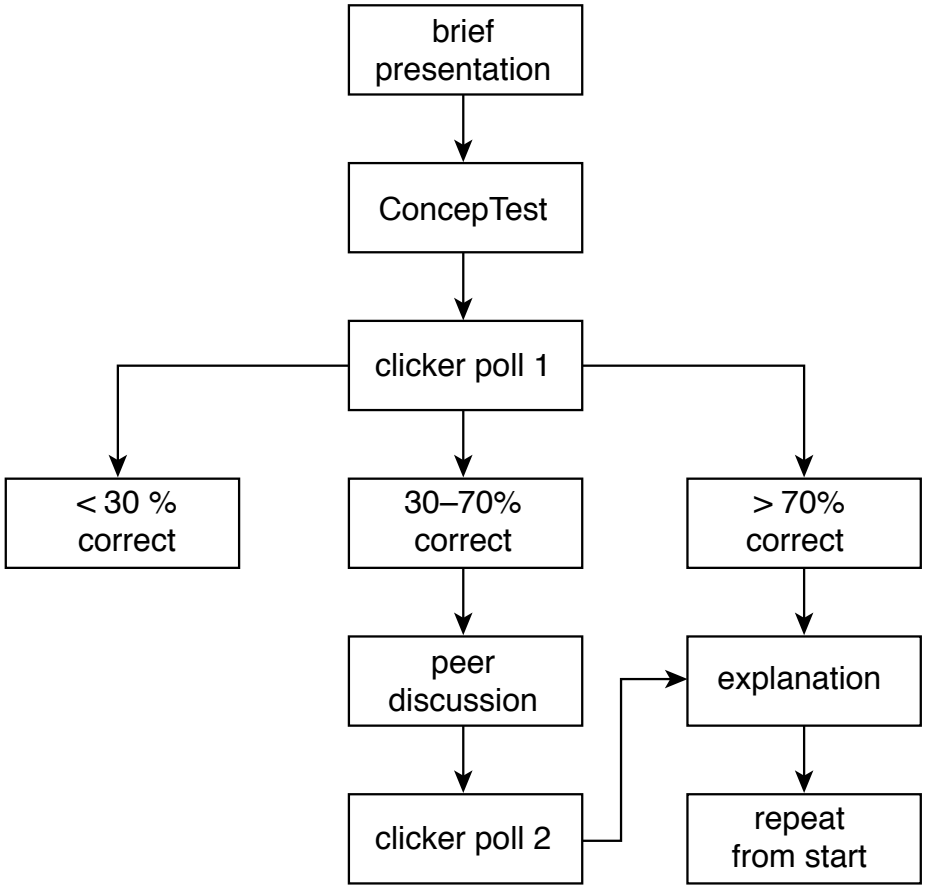

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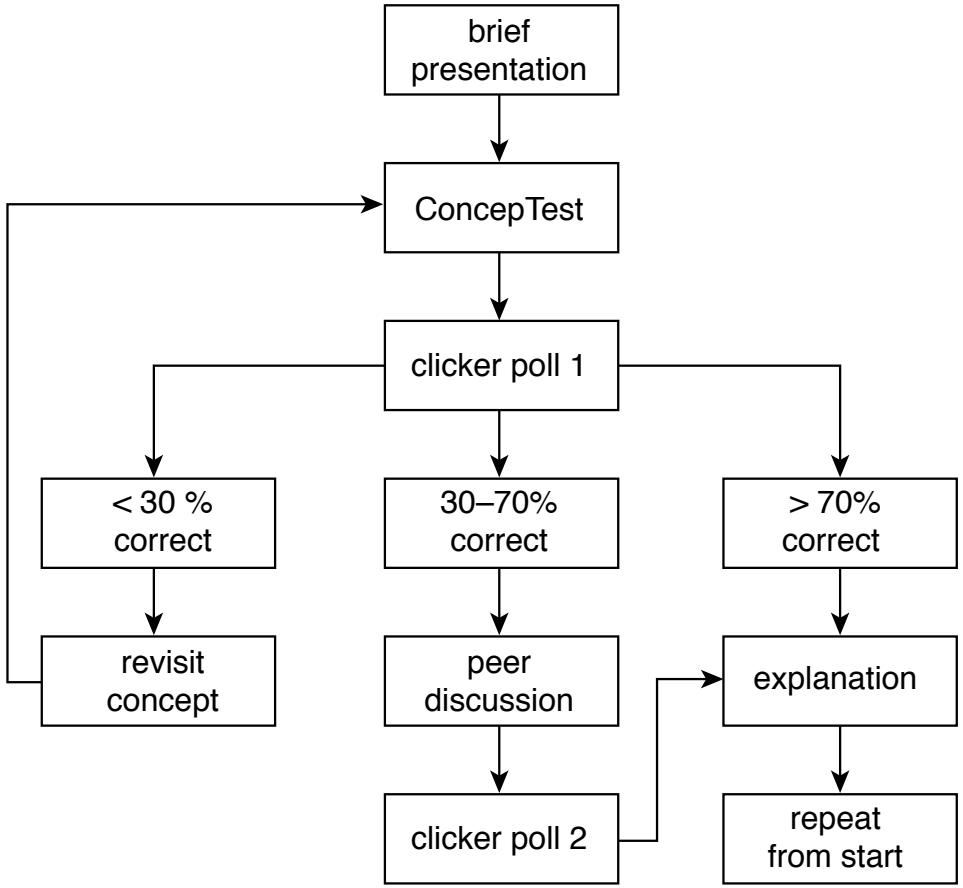

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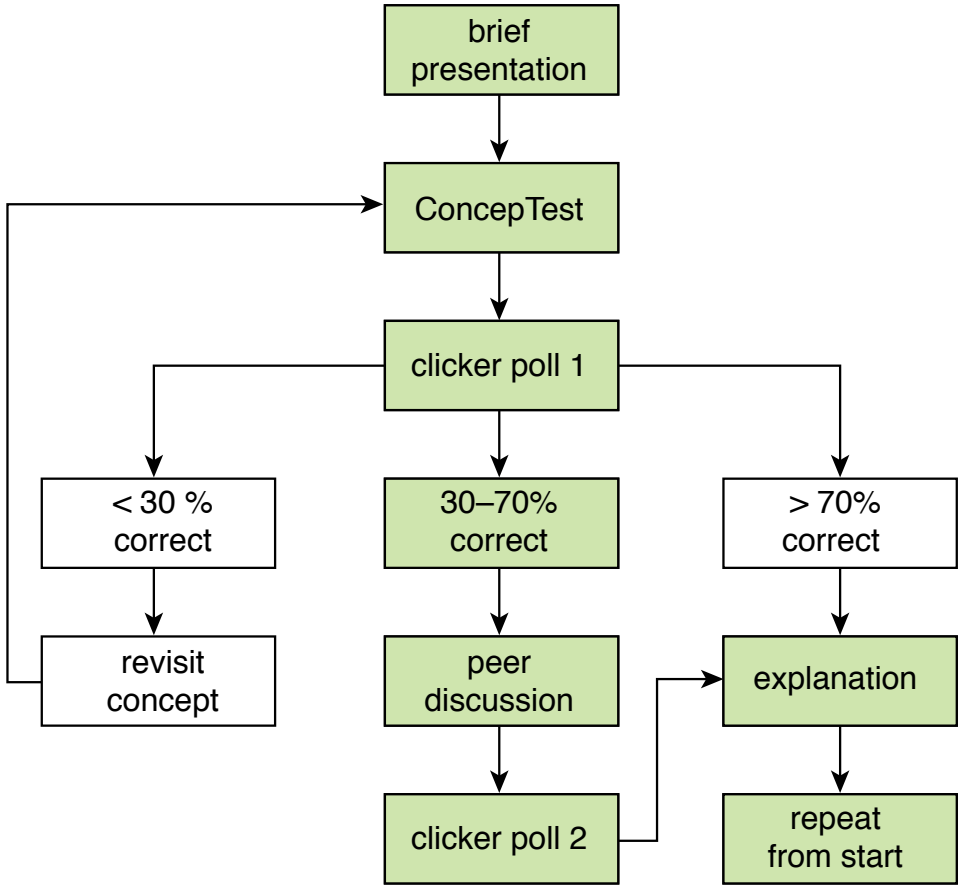


PI & JiTT Overview

PI:

- **helps students overcome difficulties**
- **encourages deep learning**
- **provides depth, not “coverage”**
- **helps you become aware of misconceptions**

Outline

- PI & JiTT Overview
- **Implementing PI & JiTT**
- ConcepTests

Implementing PI & JiTT

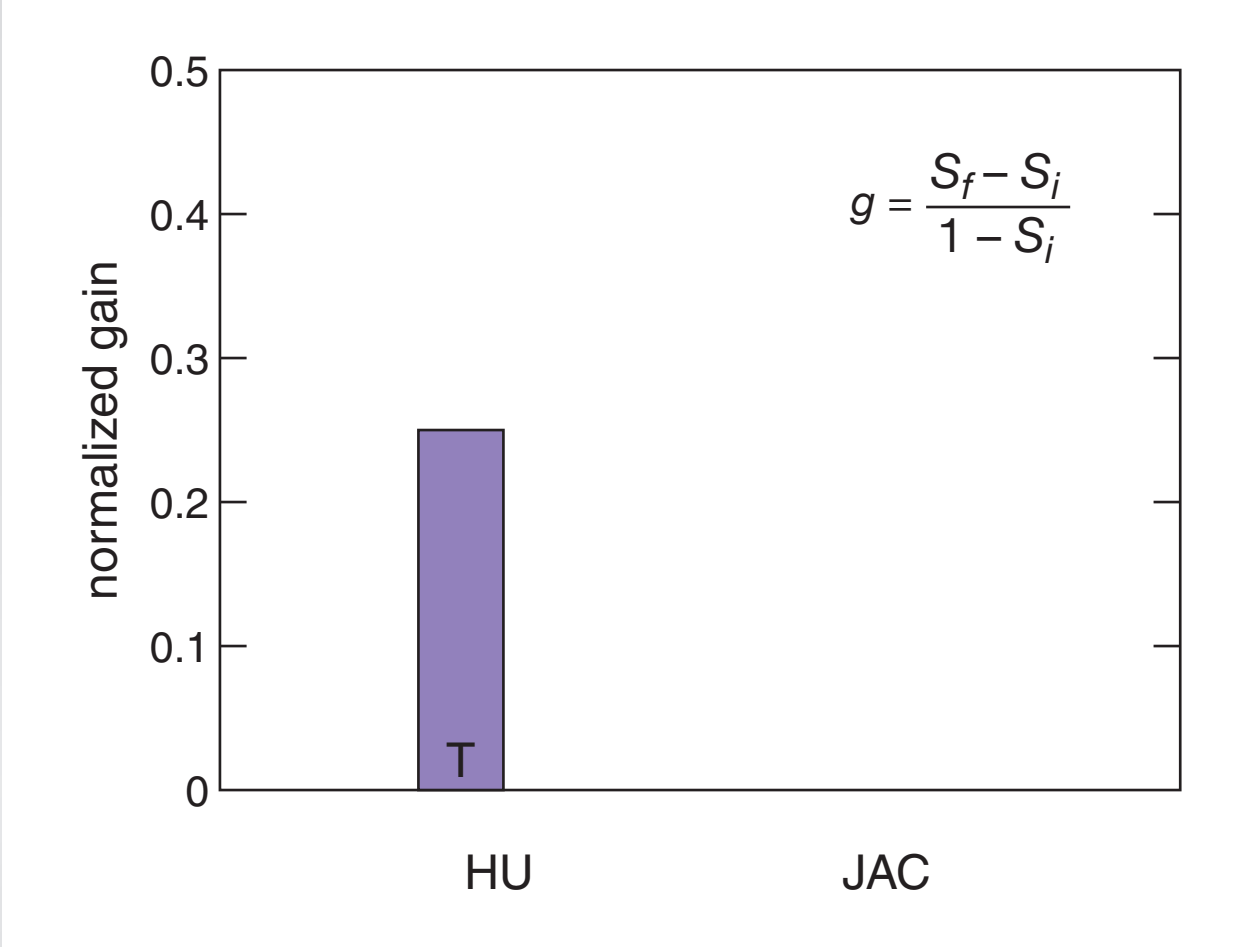
“Will it work at my institution?”

It works here…

…but will it work here?

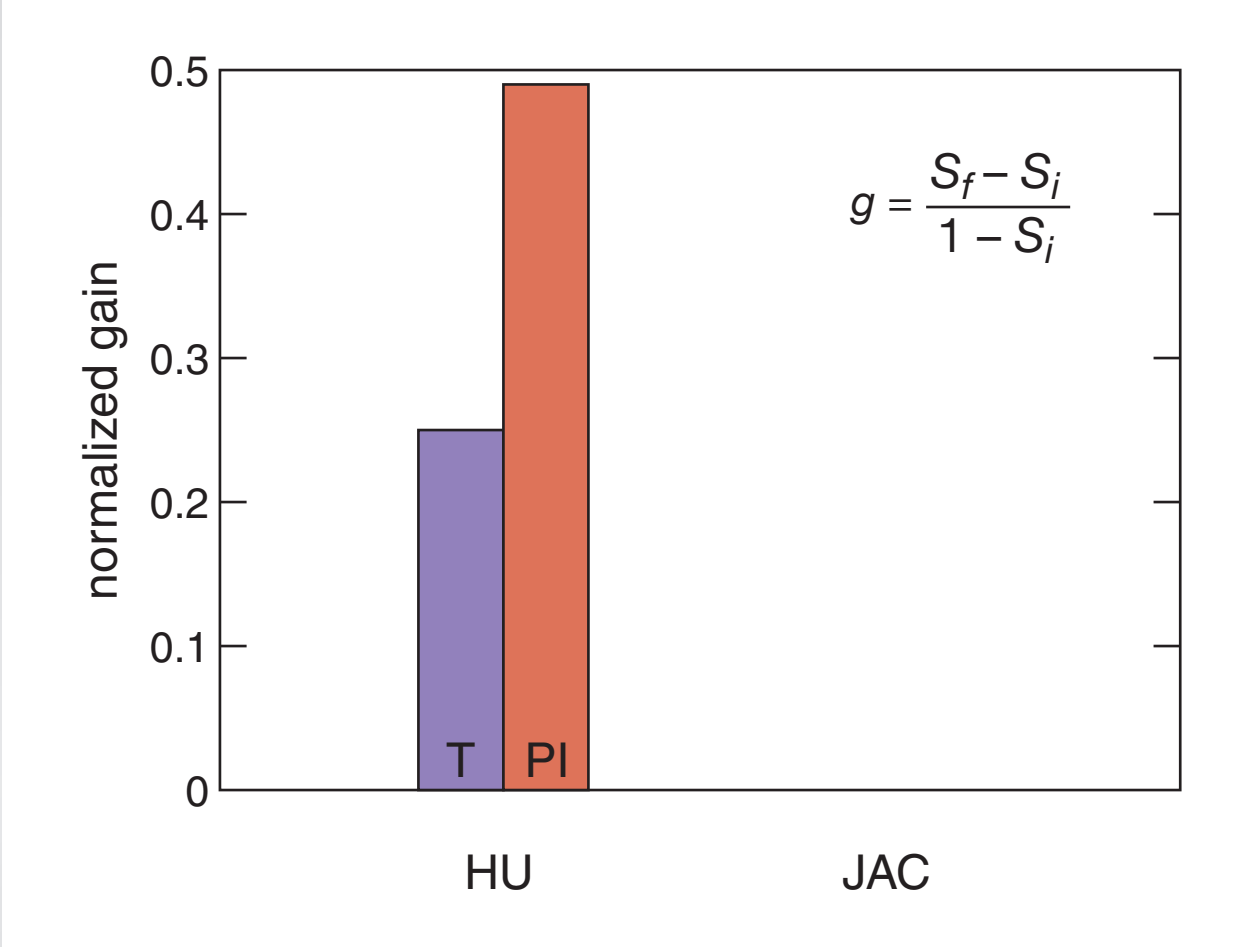
Implementing PI & JiTT

FCI normalized gain



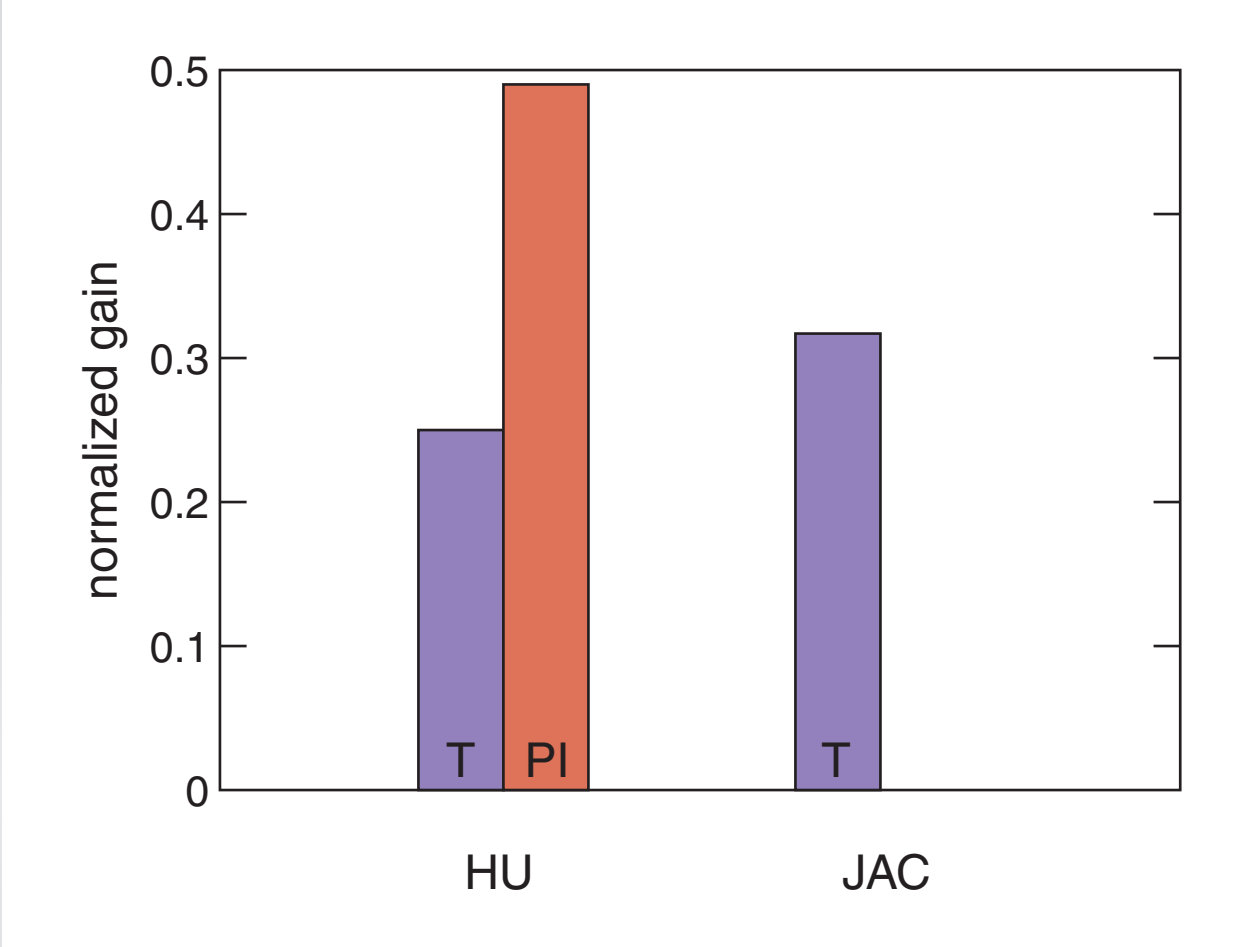
Implementing PI & JiTT

FCI normalized gain



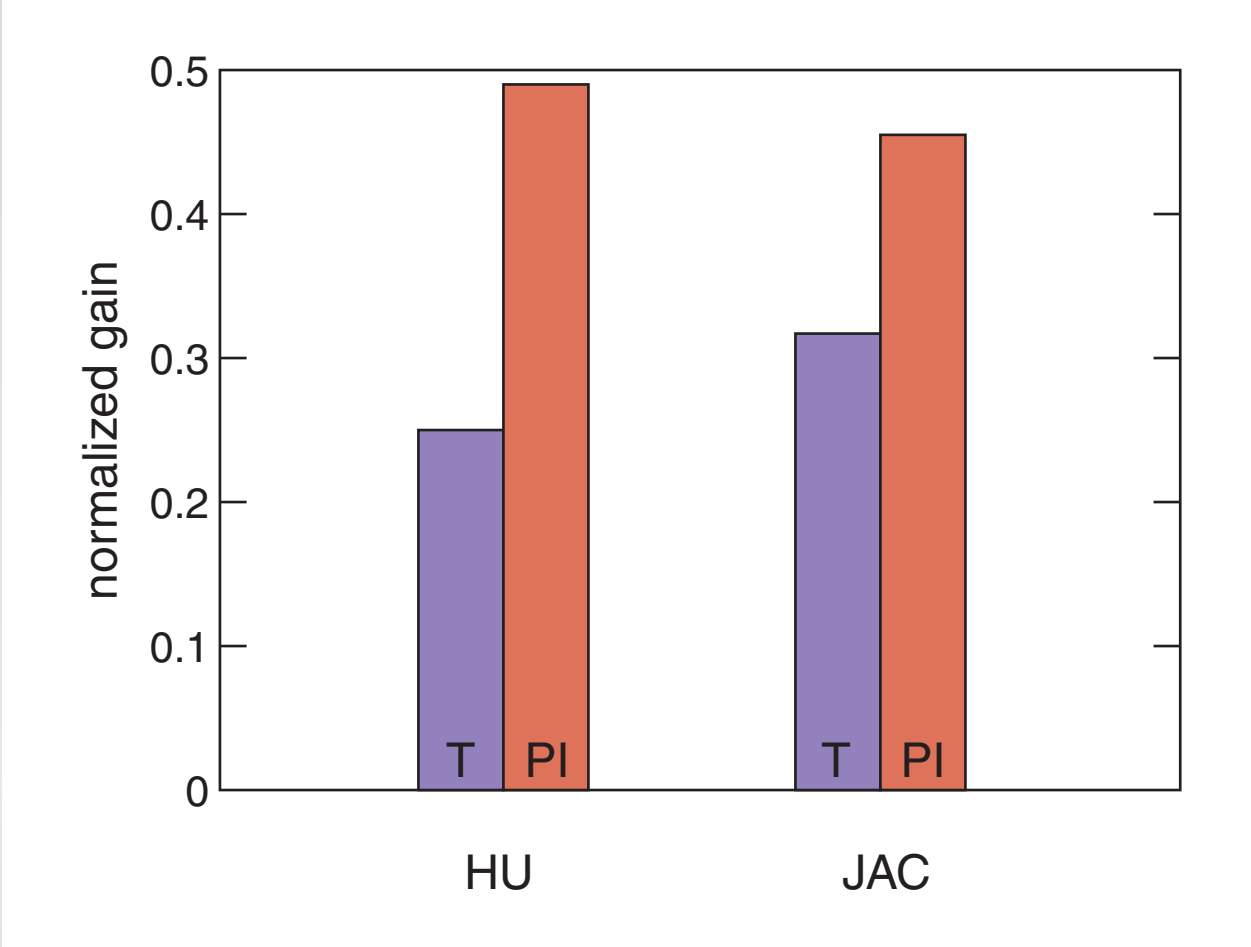
Implementing PI & JiTT

FCI normalized gain



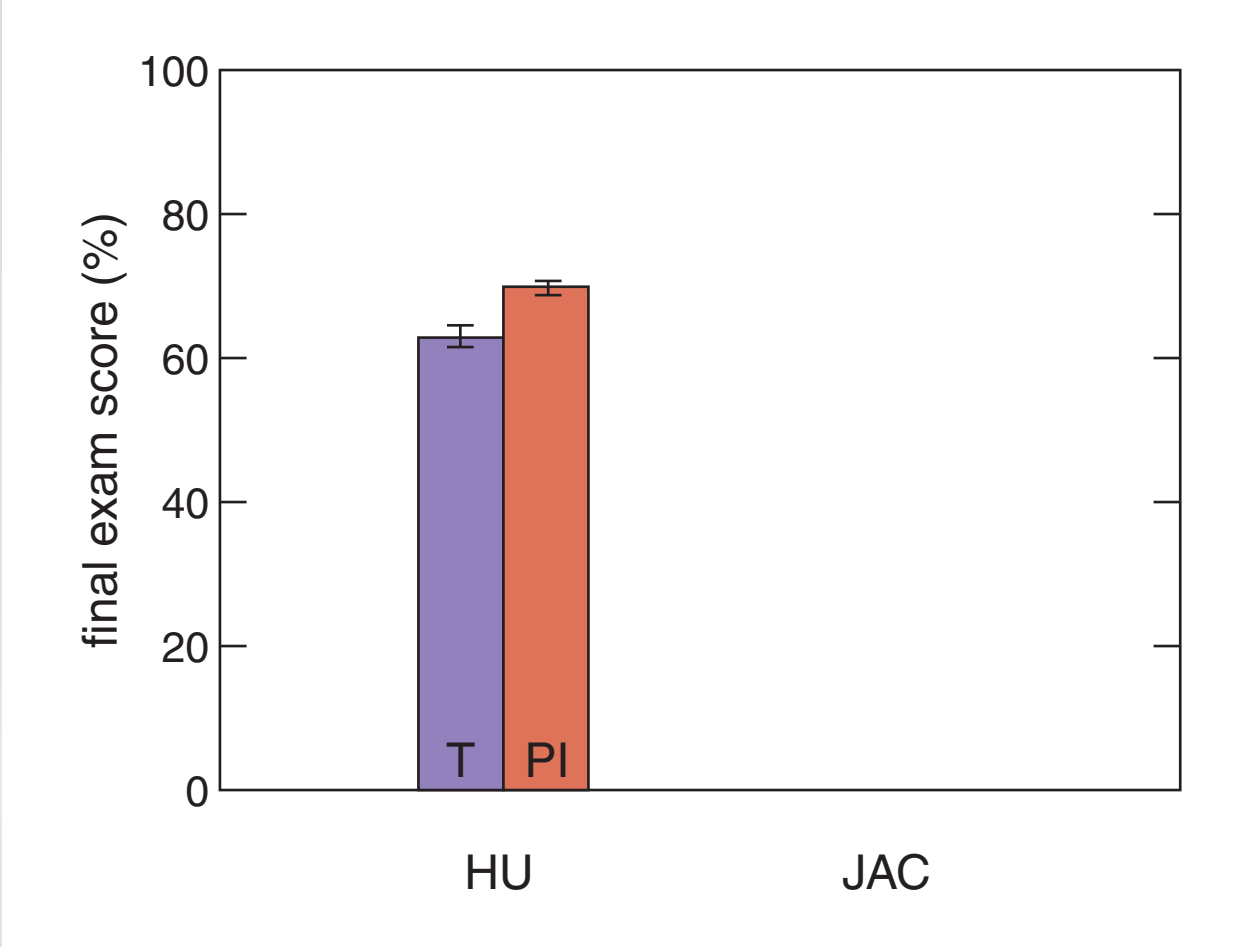
Implementing PI & JiTT

FCI normalized gain



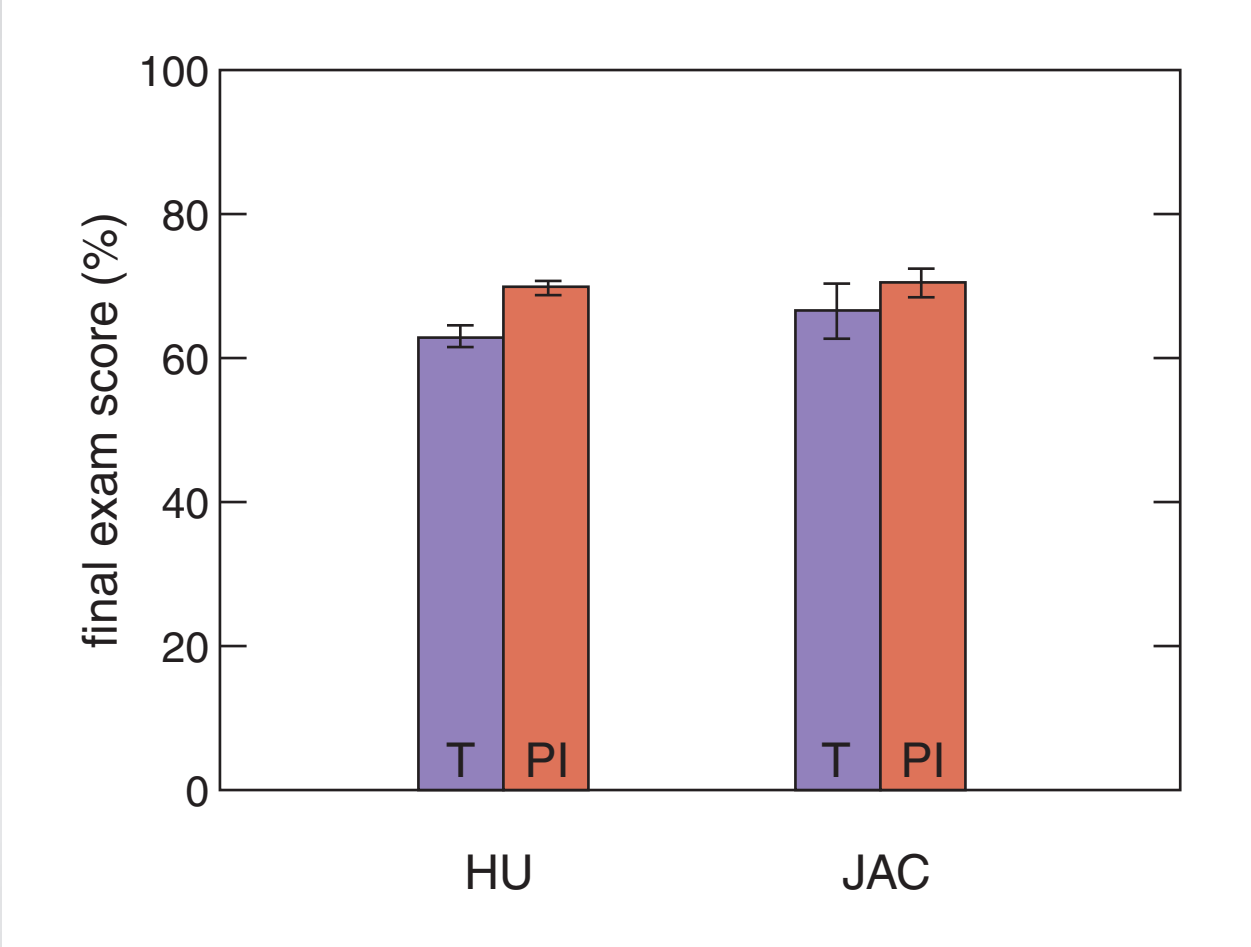
Implementing PI & JiTT

exam performance



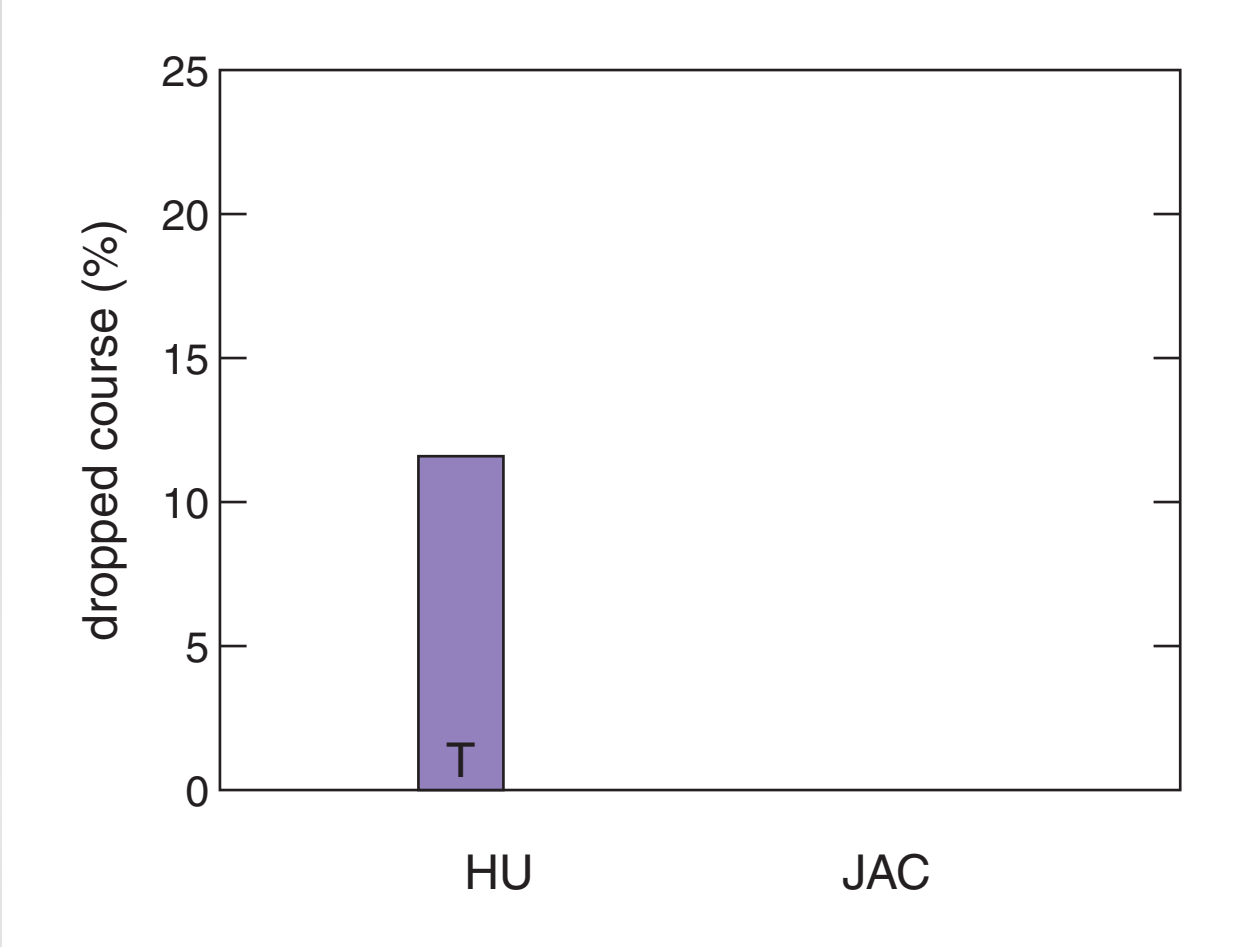
Implementing PI & JiTT

exam performance



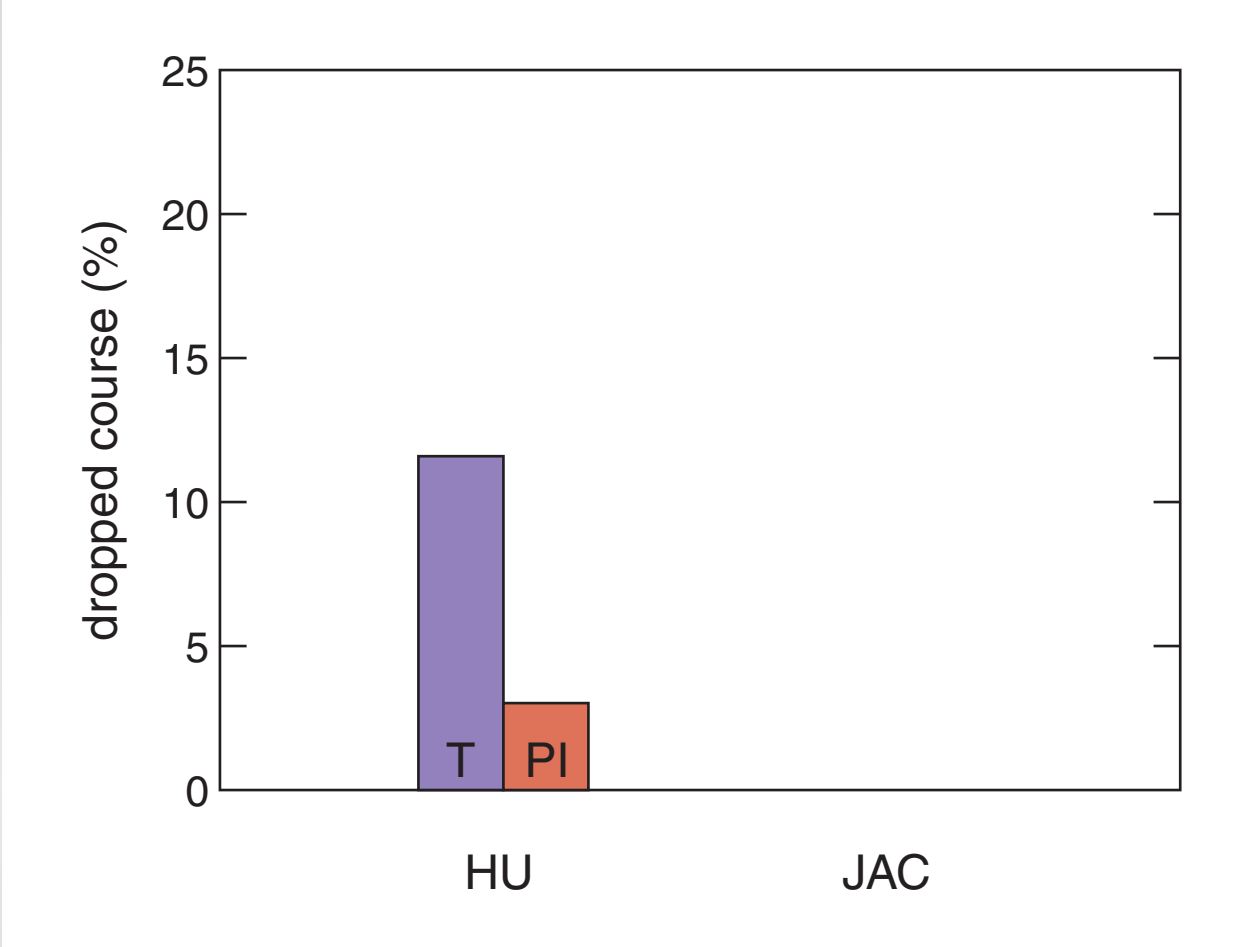
Implementing PI & JiTT

student retention



Implementing PI & JiTT

student retention



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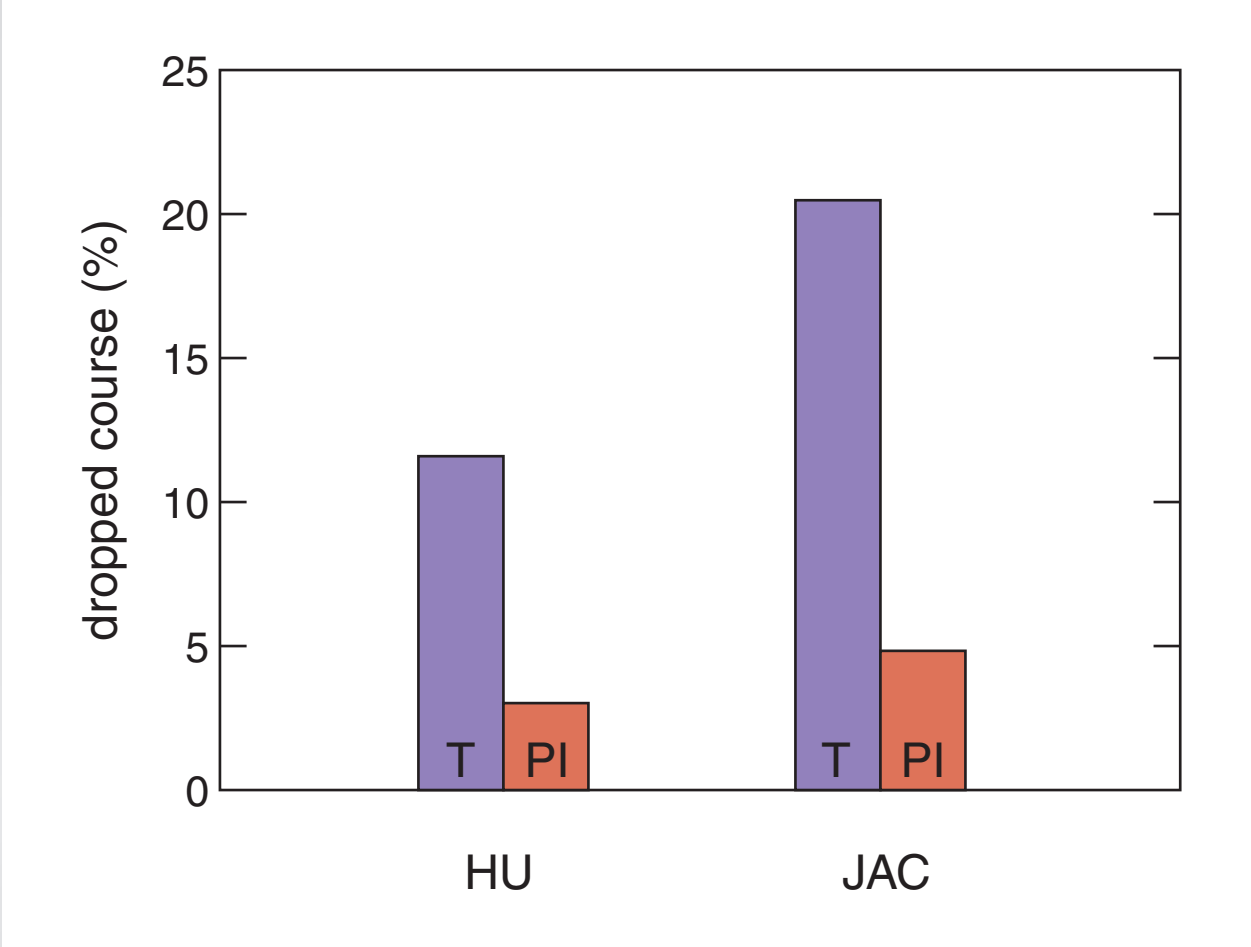
student retention



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similar learning gains in different environments

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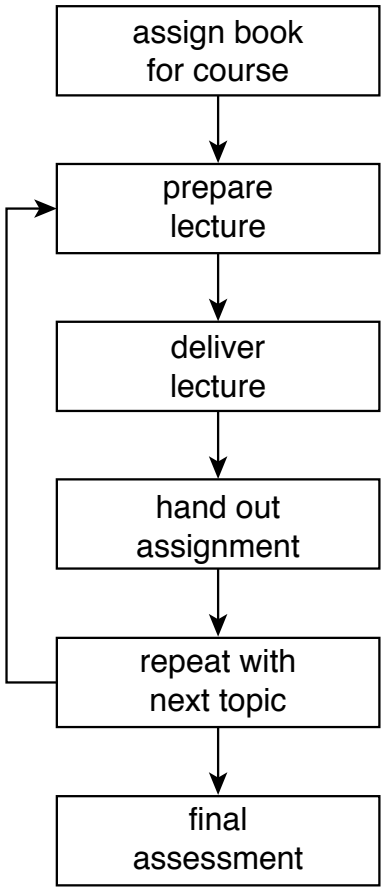
"How is preparing a PI class different from preparing a lecture-based class?"

Implementing PI & JiTT

preparing for a lecture-based class



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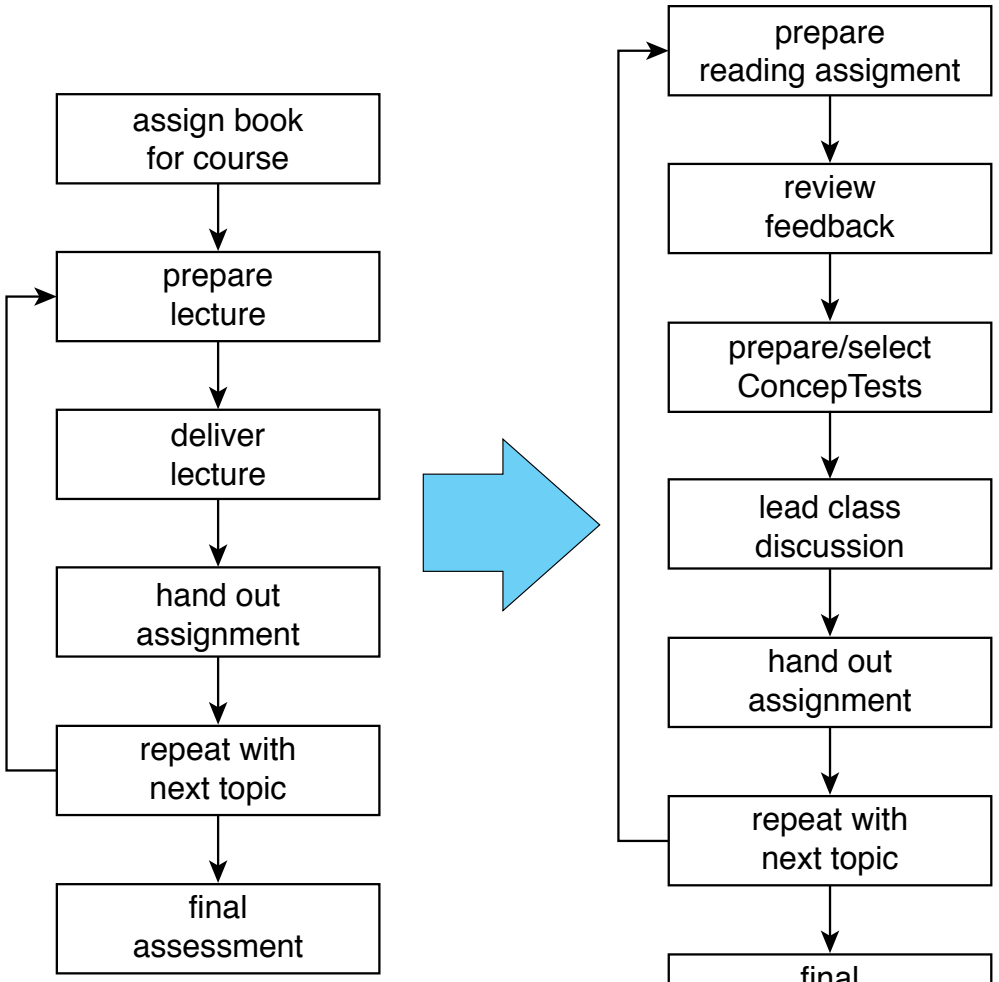
transitioning: where does the effort go?



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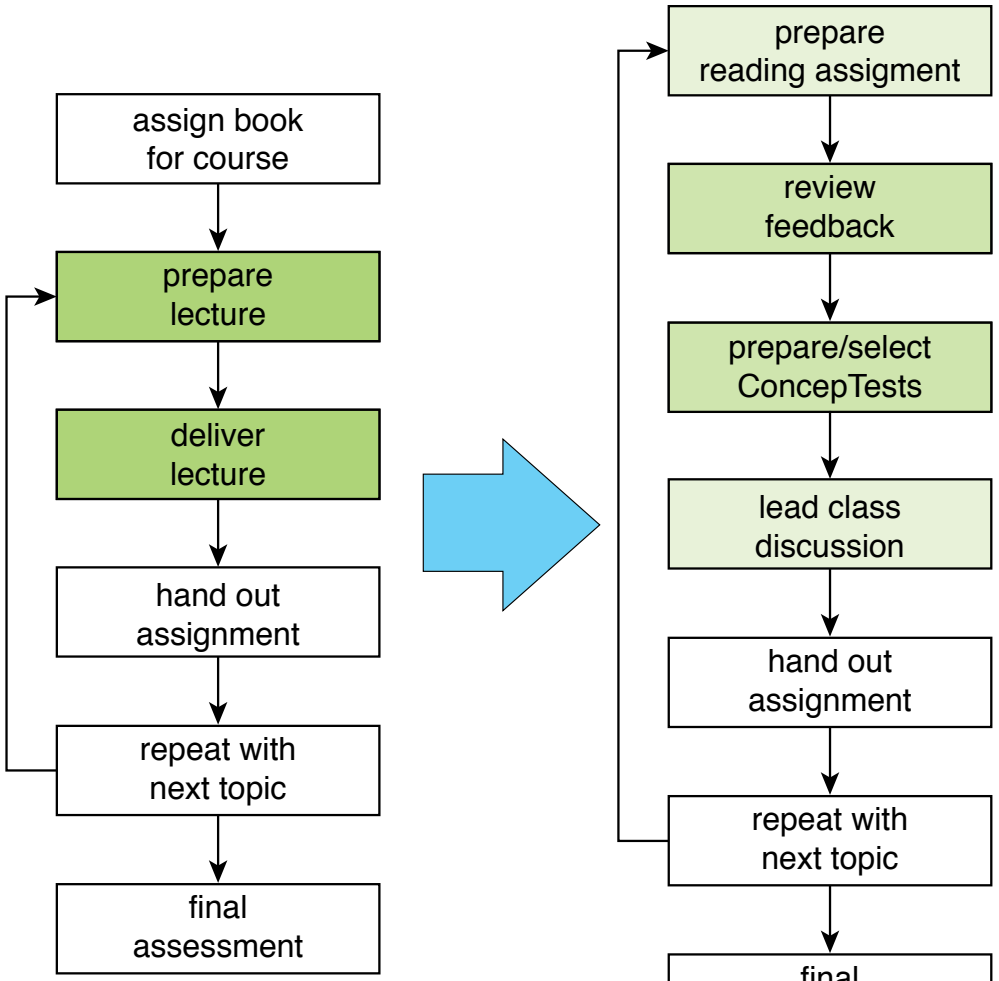
transitioning: where does the effort go?



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New activities:

1. **Reading assignment**
2. **ConcepTests**

Implementing PI & JiTT

“How do I cover everything using this method?”

Implementing PI & JiTT

	traditional	PI
in-class coverage	complete	partial

Implementing PI & JiTT

	traditional	PI
in-class coverage	complete	partial
out-of-class coverage	?	complete

Implementing PI & JiTT

	traditional	PI
in-class coverage	complete	partial
out-of-class coverage	?	complete
material learned	little	substantial

Implementing PI & JiTT

	traditional	PI
in-class coverage	complete	partial
out-of-class coverage	?	complete
material learned	little	substantial

what good is coverage if little is retained?

Outline

- PI & JiTT Overview
- Implementing PI & JiTT
- ConcepTests

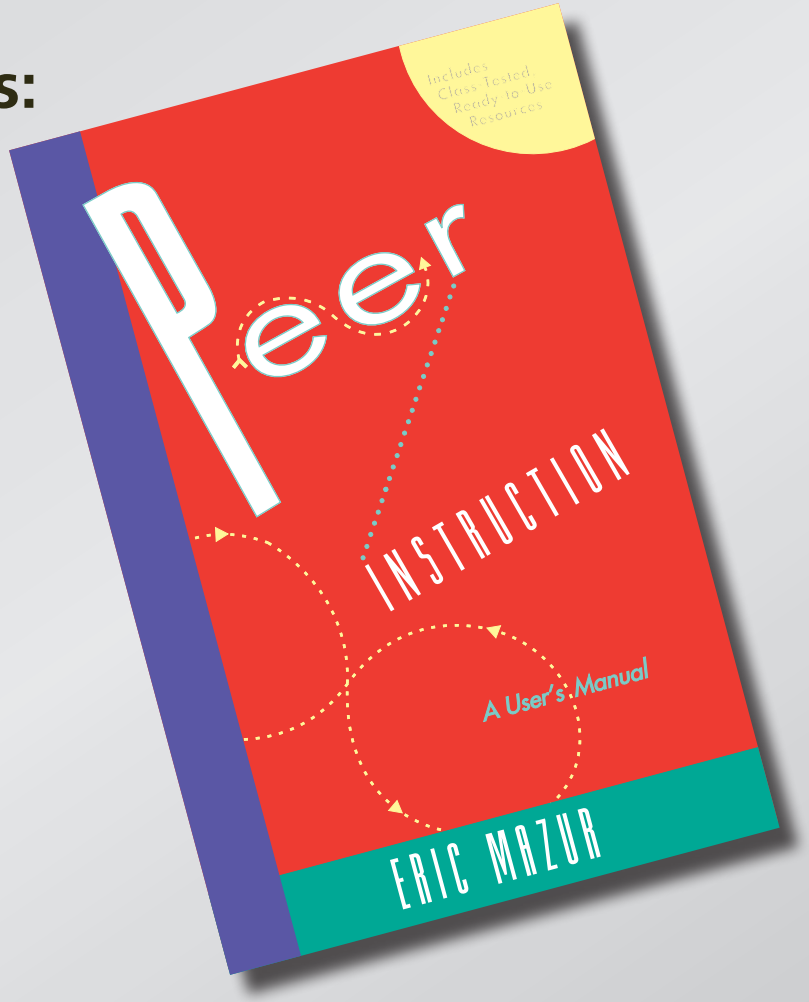
ConcepTests

“Where can I get examples of good questions?”

ConcepTests

Books with ConcepTests:

- **Physics (Prentice Hall)**



ConcepTests

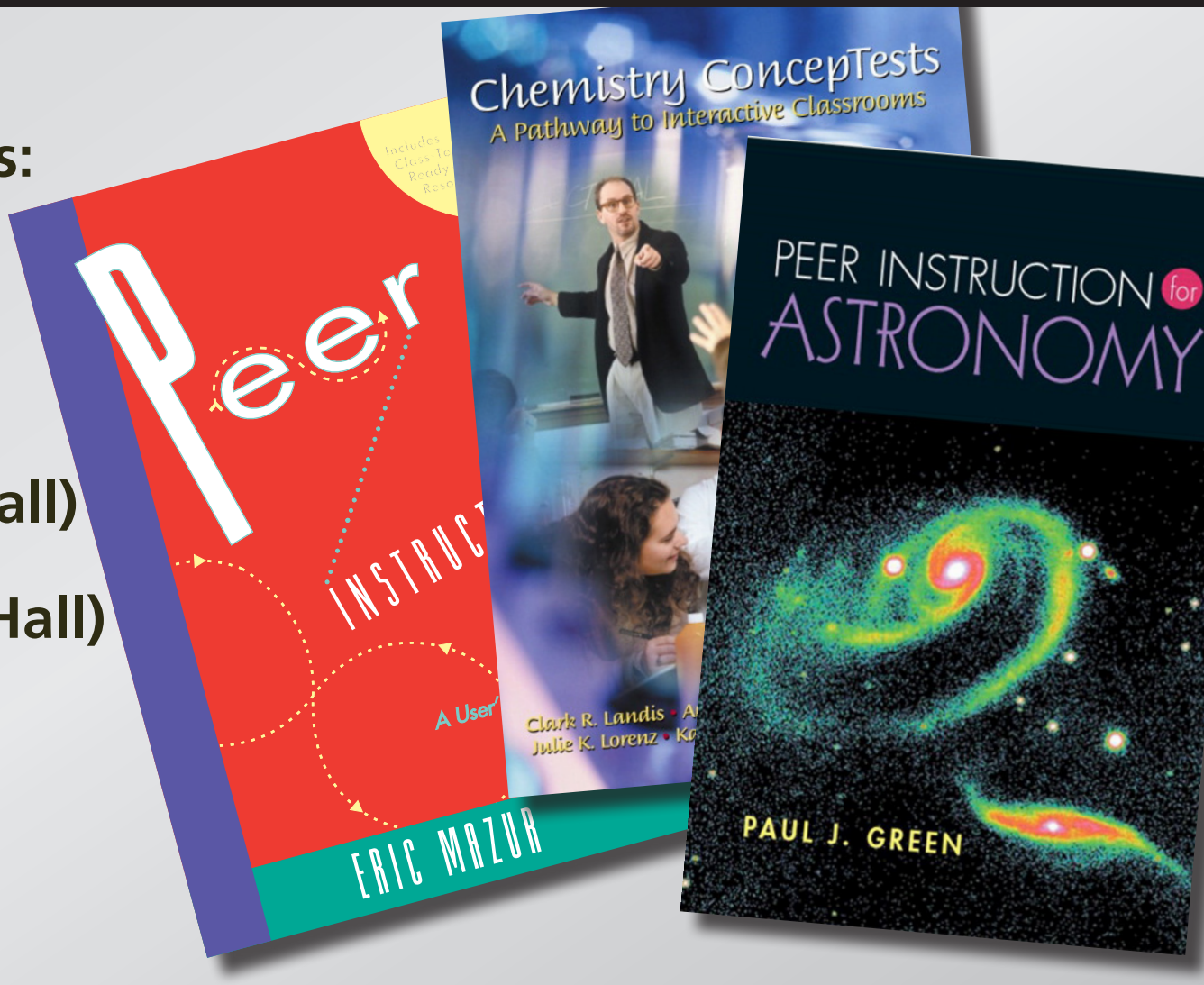
Books with ConcepTests:

- Physics (Prentice Hall)
- Chemistry (Prentice Hall)

ConcepTests

Books with ConcepTests:

- Physics (Prentice Hall)
- Chemistry (Prentice Hall)
- Astronomy (Prentice Hall)



ConcepTests

Books with ConcepTests:

- Physics (Prentice Hall)
- Chemistry (Prentice Hall)
- Astronomy (Prentice Hall)
- Calculus (Wiley)

ConcepTests

… or try searching Google:

<subject> “Peer Instruction”

<subject> ConcepTest

<subject> “Concept Test”

<subject> clickers

ConcepTests

Good conceptual questions (ConcepTests):

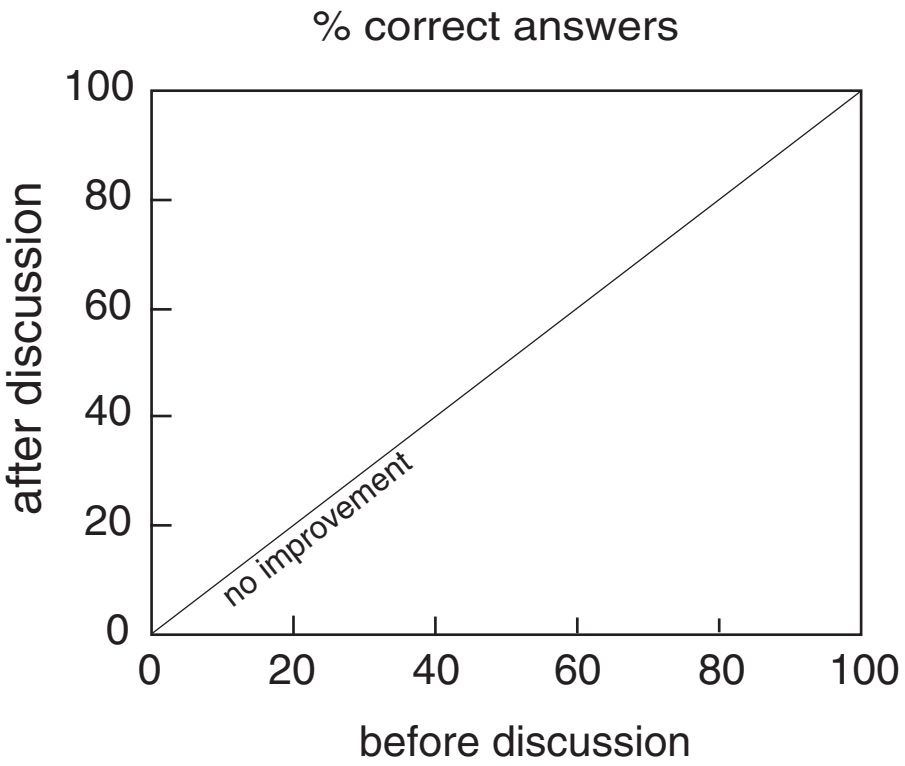
- are based on common student difficulties
- focus on single concept
- require more than “plug and chug” or recall
- are clear and concise
- are of manageable difficulty

ConcepTests

“How can I promote active/fruitful discussions?”

ConcepTests

ConcepTest data



ConcepTests

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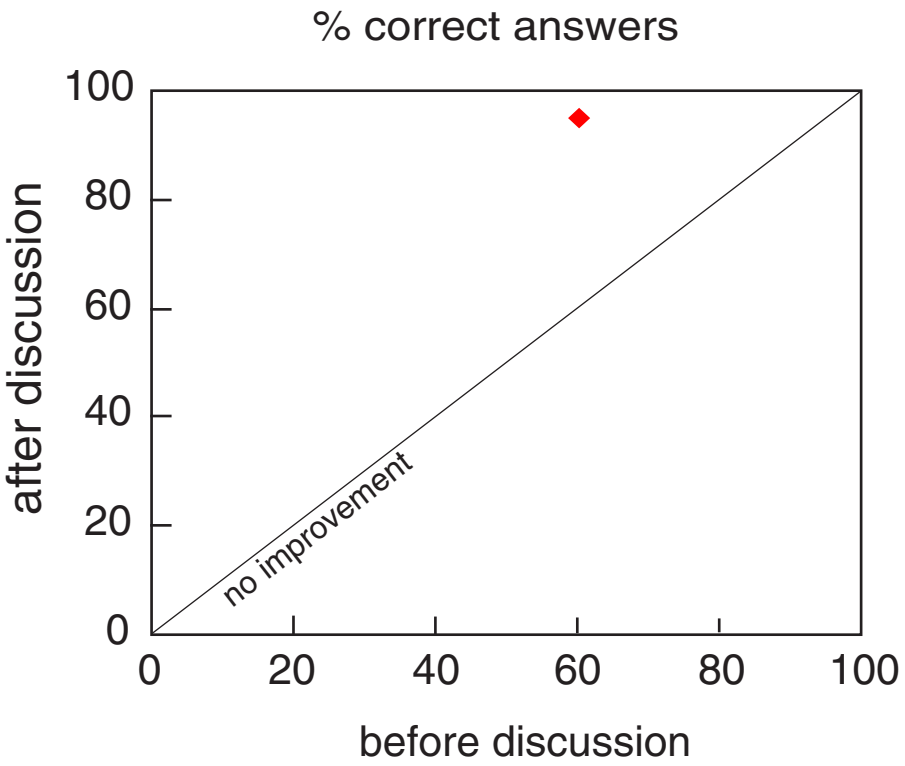

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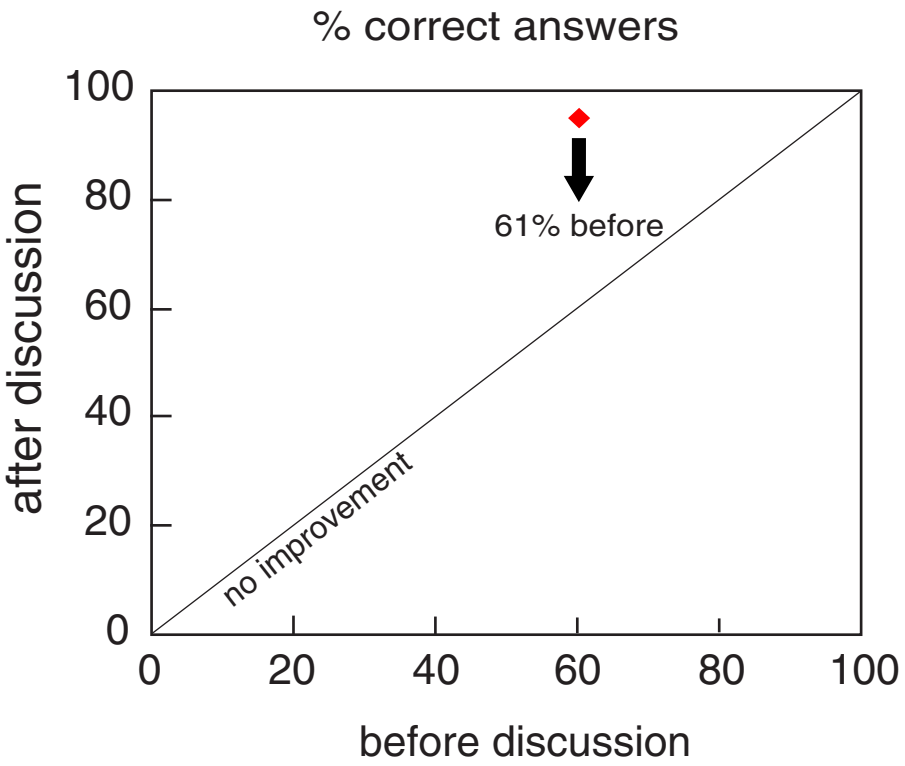

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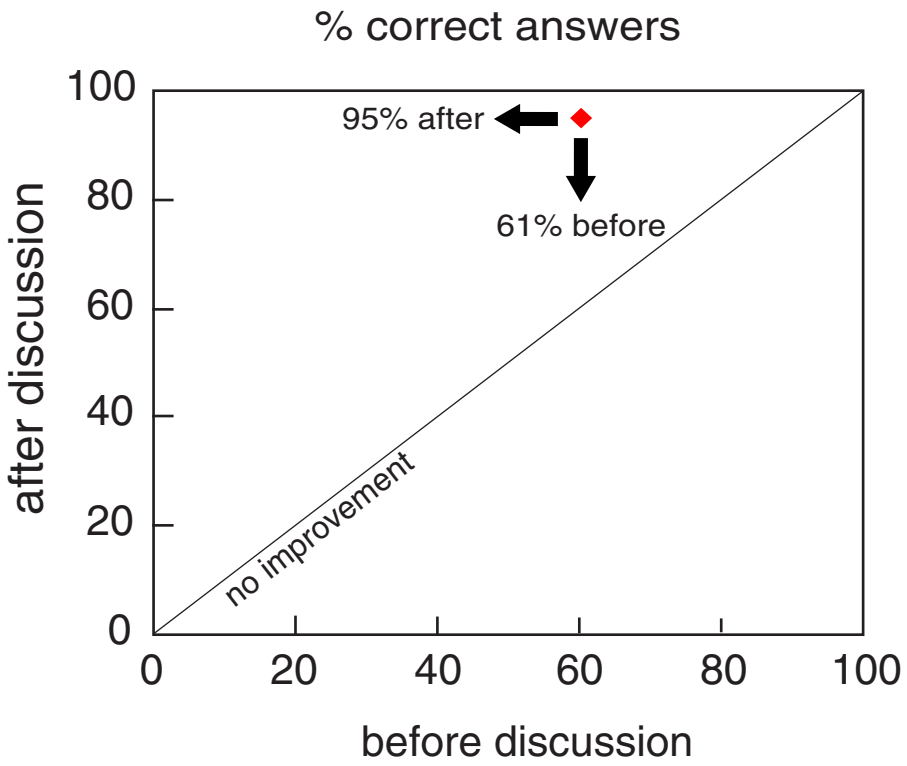

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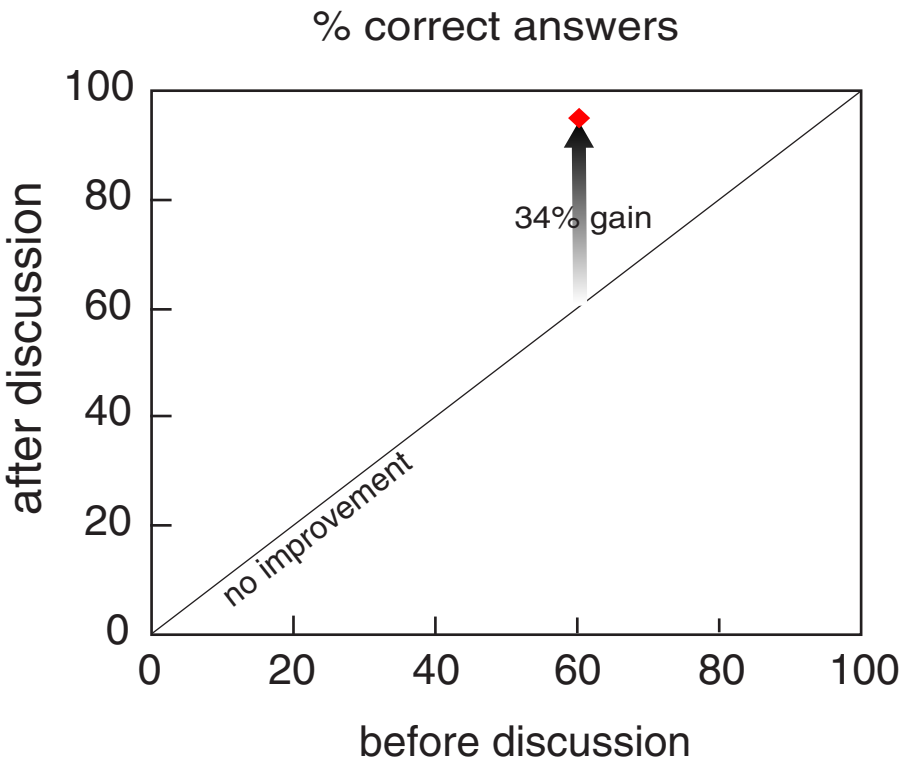

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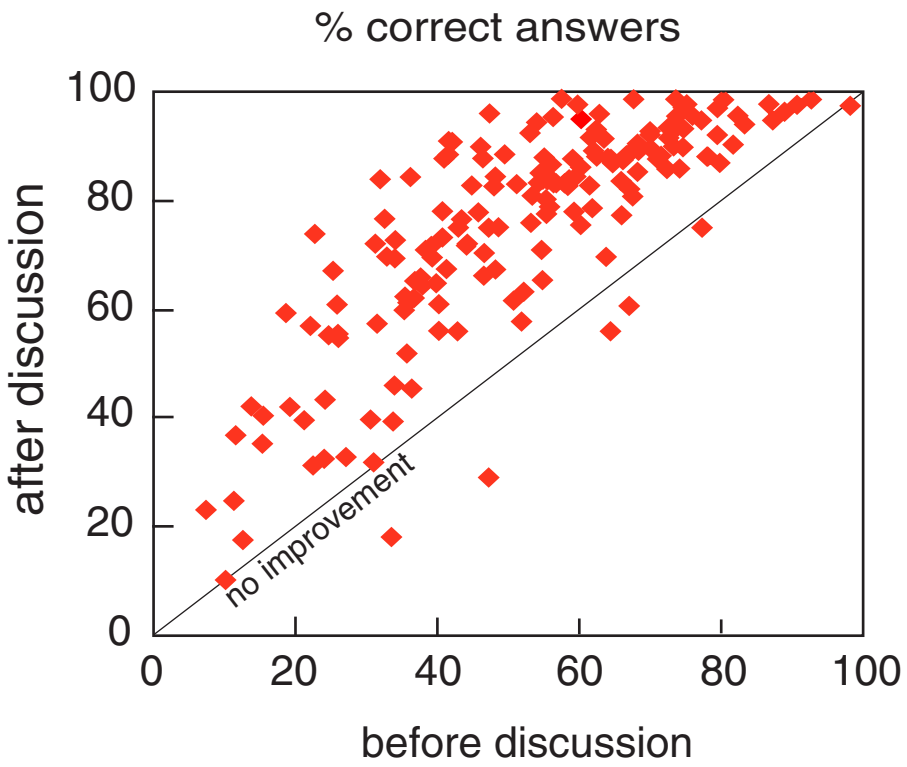

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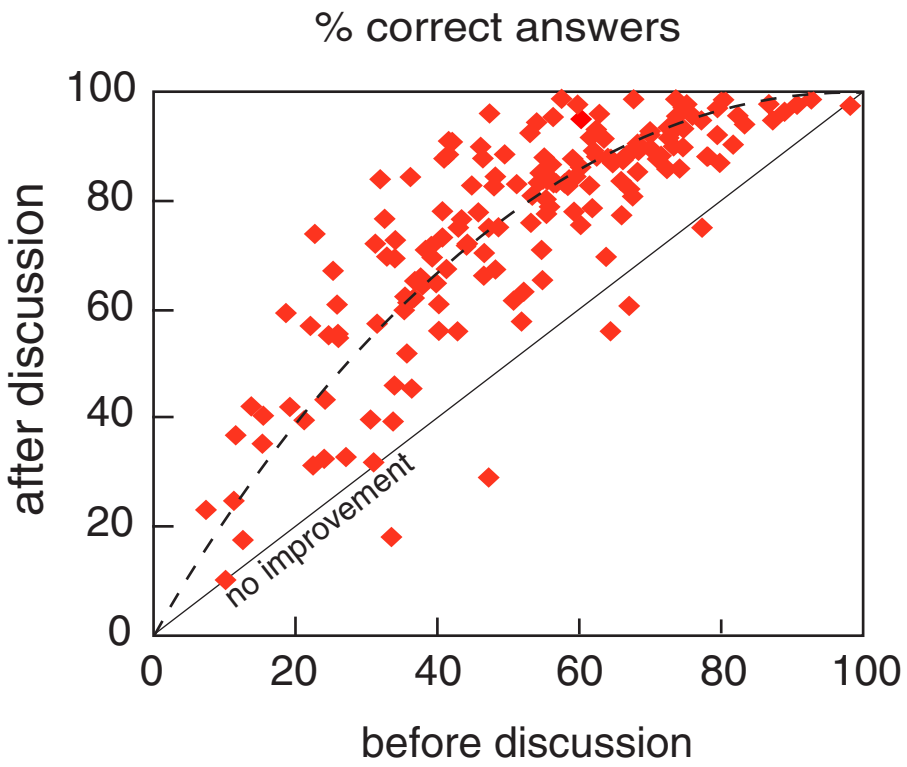

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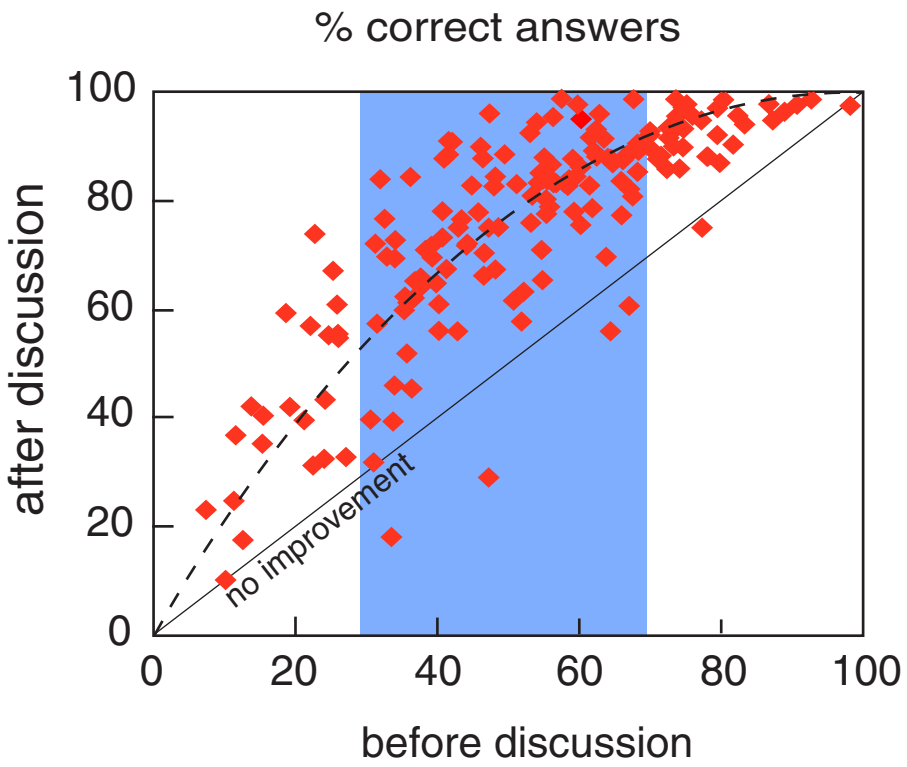
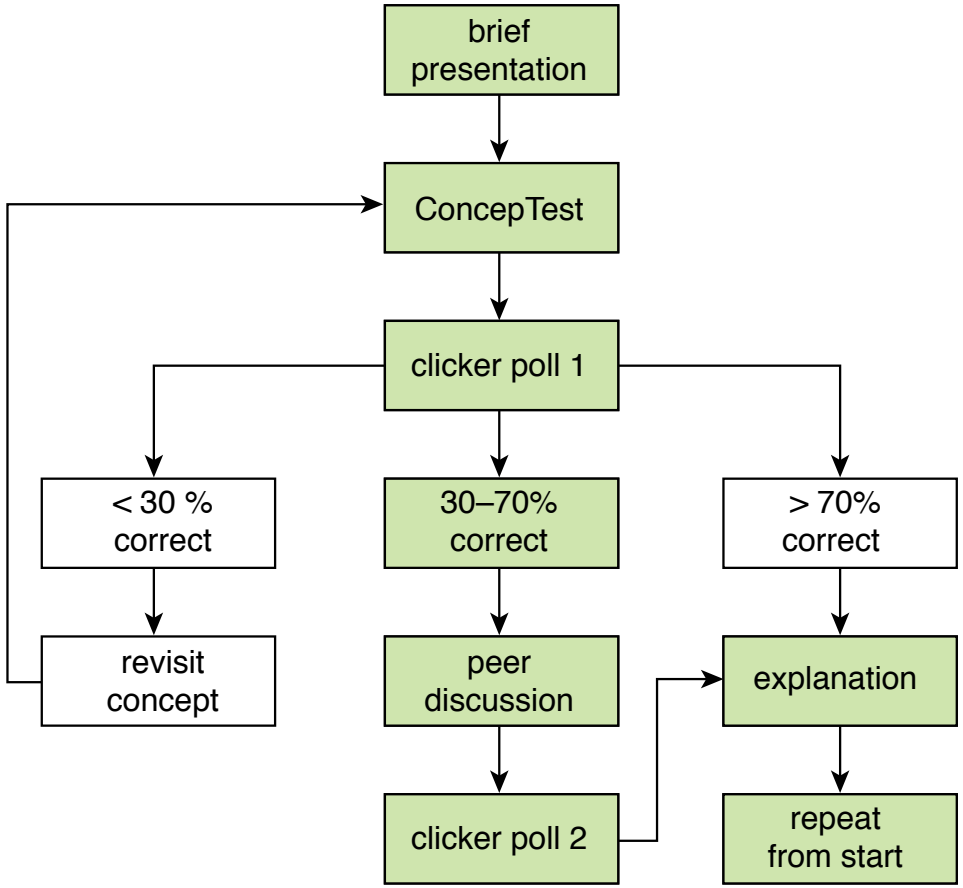


ConcepTests



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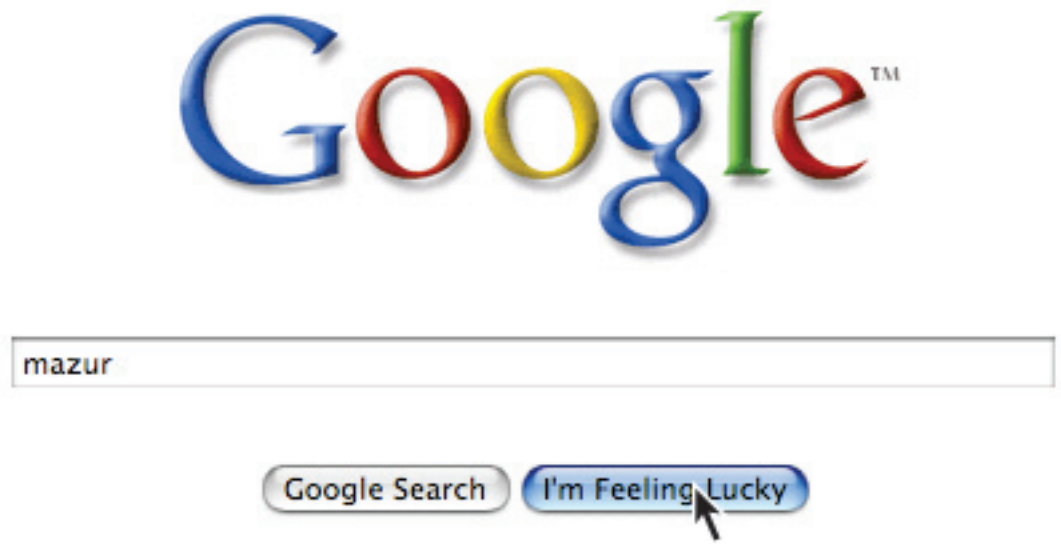
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Implementing PI & JiTT

“What constitutes a good problem?”

Implementing PI & JiTT

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. 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.

Implementing PI & JiTT

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. 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.

How long do you have to wait before someone frees up a space?

Implementing PI & JiTT

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. 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.

How long do you have to wait before someone frees up a space?

Requires:

Assumptions
Developing a model
Applying that model

Implementing PI & JiTT

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. 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. On average people shop for 2 hours.

How long do you have to wait before someone frees up a space?

Implementing PI & JiTT

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Implementing PI & JiTT

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Assuming people leave at regularly-spaced intervals, how long do you have to wait before someone frees up a space?

Implementing PI & JiTT

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. 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. On average people shop for 2 hours.

Assuming people leave at regularly-spaced intervals, how long do you have to wait before someone frees up a space?

Requires:

Applying a (new) model

Implementing PI & JiTT

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 2 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.

How long do you have to wait before someone frees up a space?

Implementing PI & JiTT

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 2 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.

How long do you have to wait before someone frees up a space?

$$t_{wait} = \frac{T_{shop}}{N_{spaces}}$$

Implementing PI & JiTT

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 2 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.

How long do you have to wait before someone frees up a space?

Requires:

Using a calculator

$$t_{wait} = \frac{T_{shop}}{N_{spaces}}$$

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Need to test meaningful skills!

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Some additional ideas:

- Open book/computer exam
- Collaborative exam
- Multidimensional testing

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"How do I deal with students who resist this new approach to studying?"

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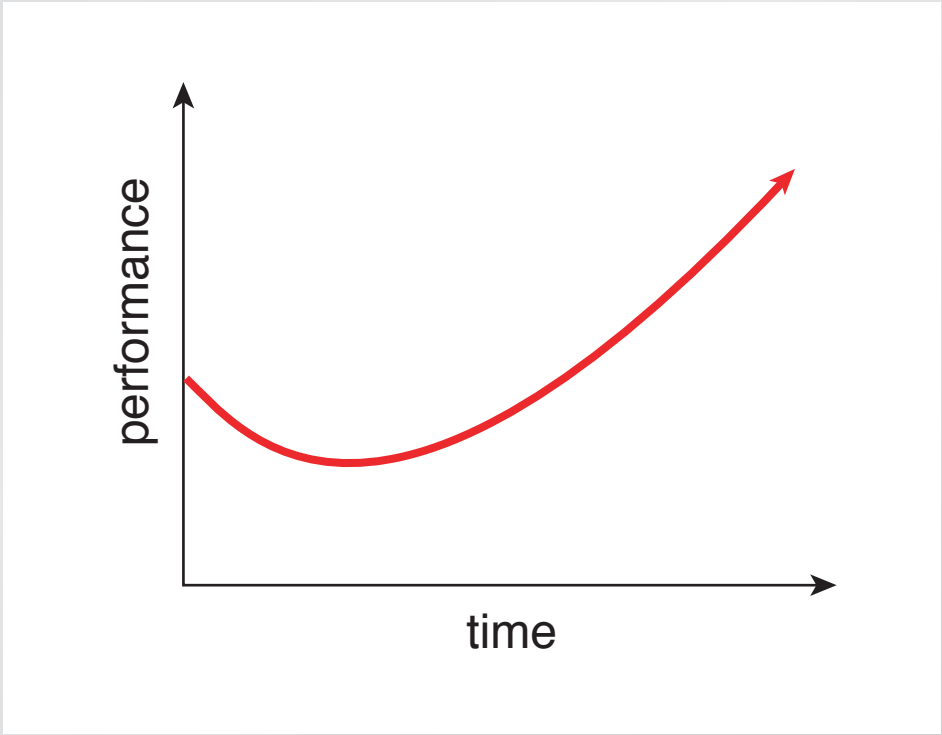
After changing, things might get *worse* before they get better!



Implementing PI & JiTT

Written on Wednesday Feb 16, two weeks into the course:

> Subject: concerns
>
> Professor Mazur,
>
> Here are a few concerns. I speak for many of my classmates.
>
> 1) You are giving us WAY to much work. After spending multiple hours on the problem set, and not being able to figure out many of the questions, I now see that we have an additional 6 or 7 pages or homework in the workbook. I just spent 4 hours on the lab, and I am not confident on almost half of the questions. This is more work than I have had all semester in all of my other classes combined.
>
> 2) If you are going to give us this much work, I would suggest re-structuring the lectures. I find the readings very difficult to understand. I am not a bad student (I got a solid A in physics 1a), but it is very difficult to internalize the readings. You should spend most of the lecture going over, point by point, the readings in their entirety. While the PRS clickers are fun, they do not help me understand the complex material.
>
> I am extremely flustered by the incredibly large amount of work, and my inability to understand it, and I am strongly considering dropping the course.

Implementing PI & JiTT

Written on Monday May 23, just after the final exam:

> Subject: Thanks!
>
> Professor Mazur,
>
> First of all I want to thank you for a great semester. You are an excellent professor, and it is clear that you truly care about each and every student.
>
> The exam went well today. I'm not sure to what extent you will curve the final grades (if at all), but it looks like I may be right around the cutoff point between an A and an A-. I studied as hard as I could and I'm keeping my fingers crossed about the A, but no matter what happens with my grade you should know that you are one of the best professors that I have ever had at Harvard.
>
> Thanks again!

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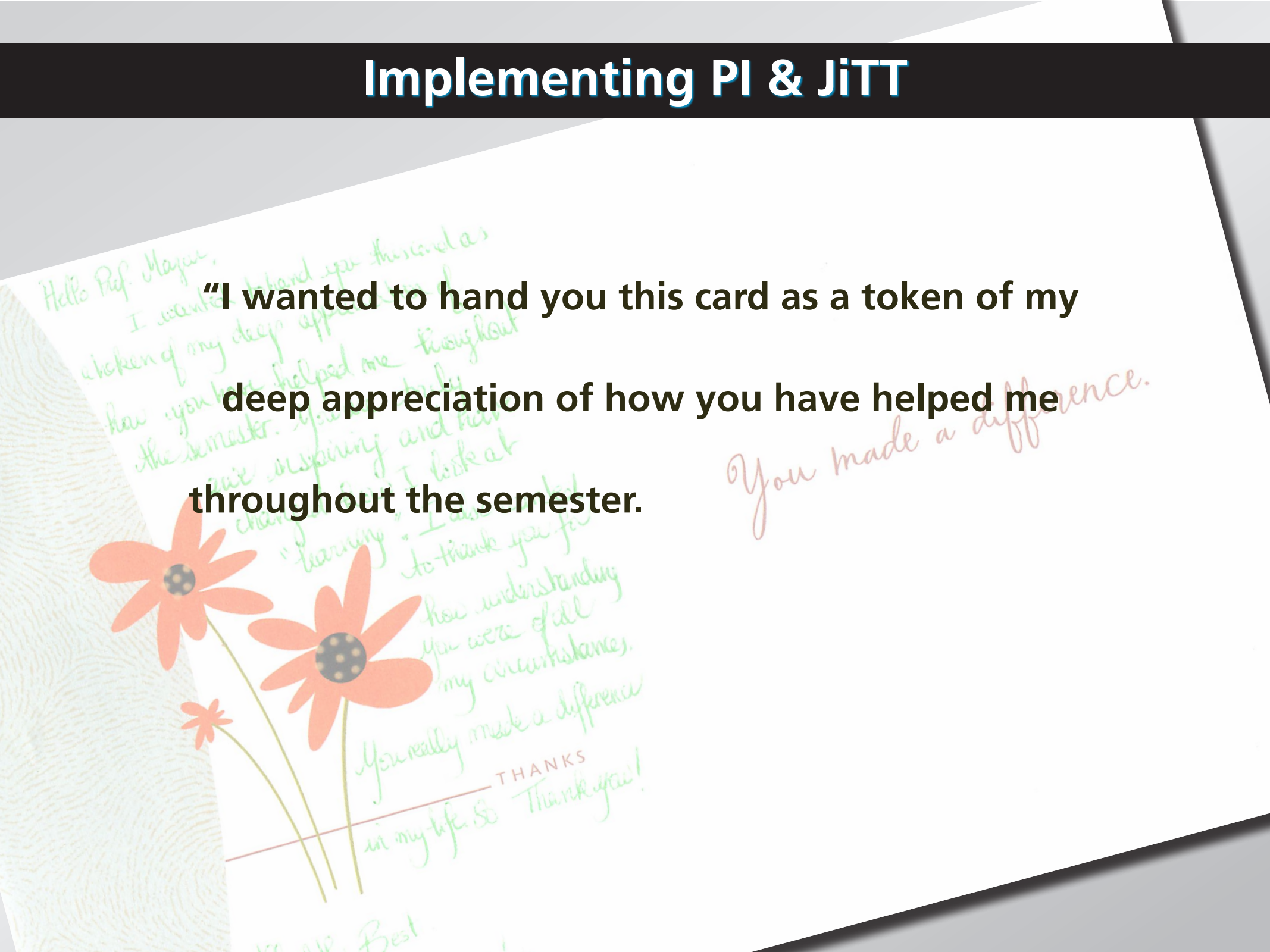

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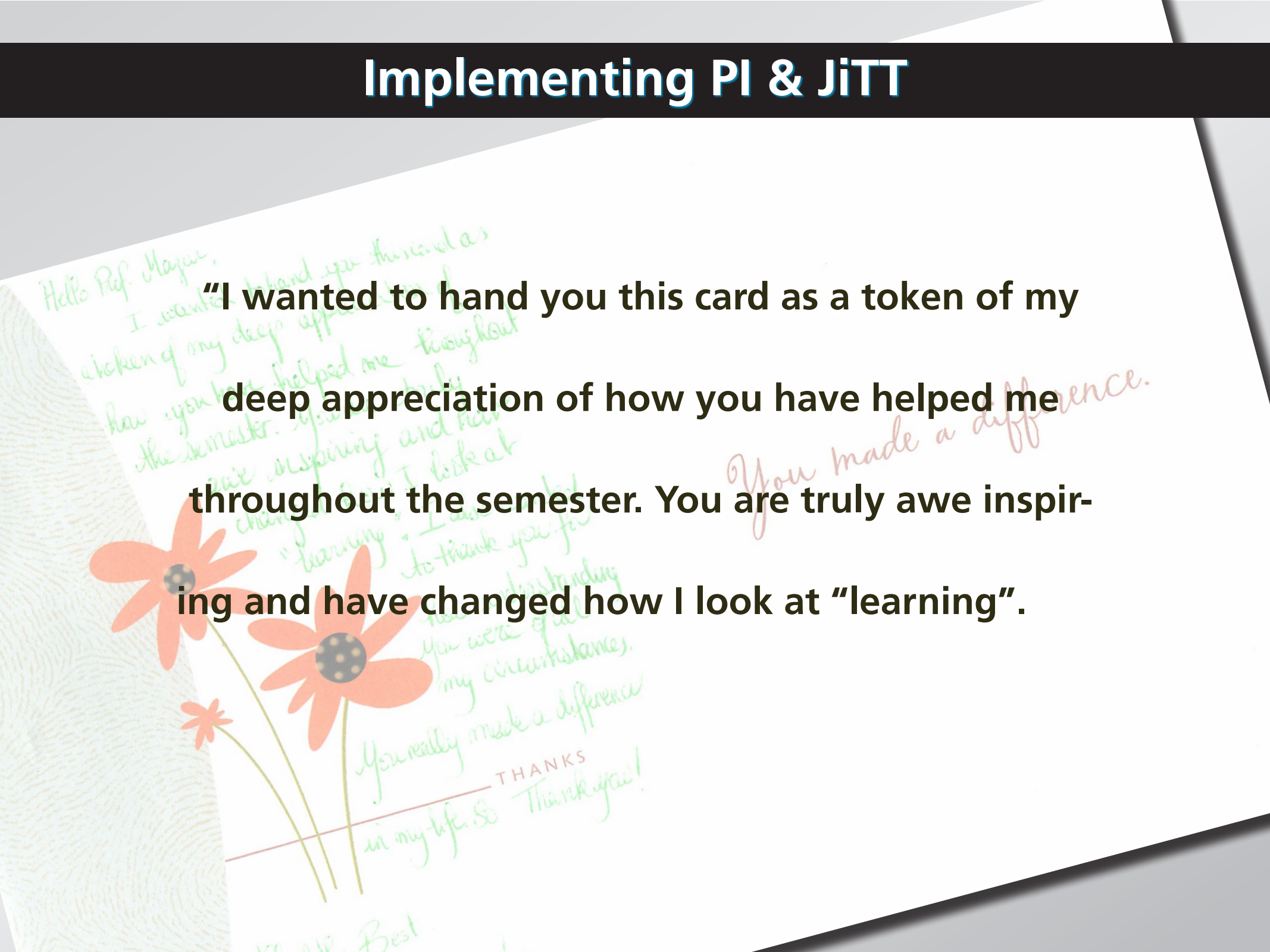

"I wanted to hand you this card as a token of my deep appreciation of how you have helped me throughout the semester. You are truly awe inspiring and have changed how I look at "learning".

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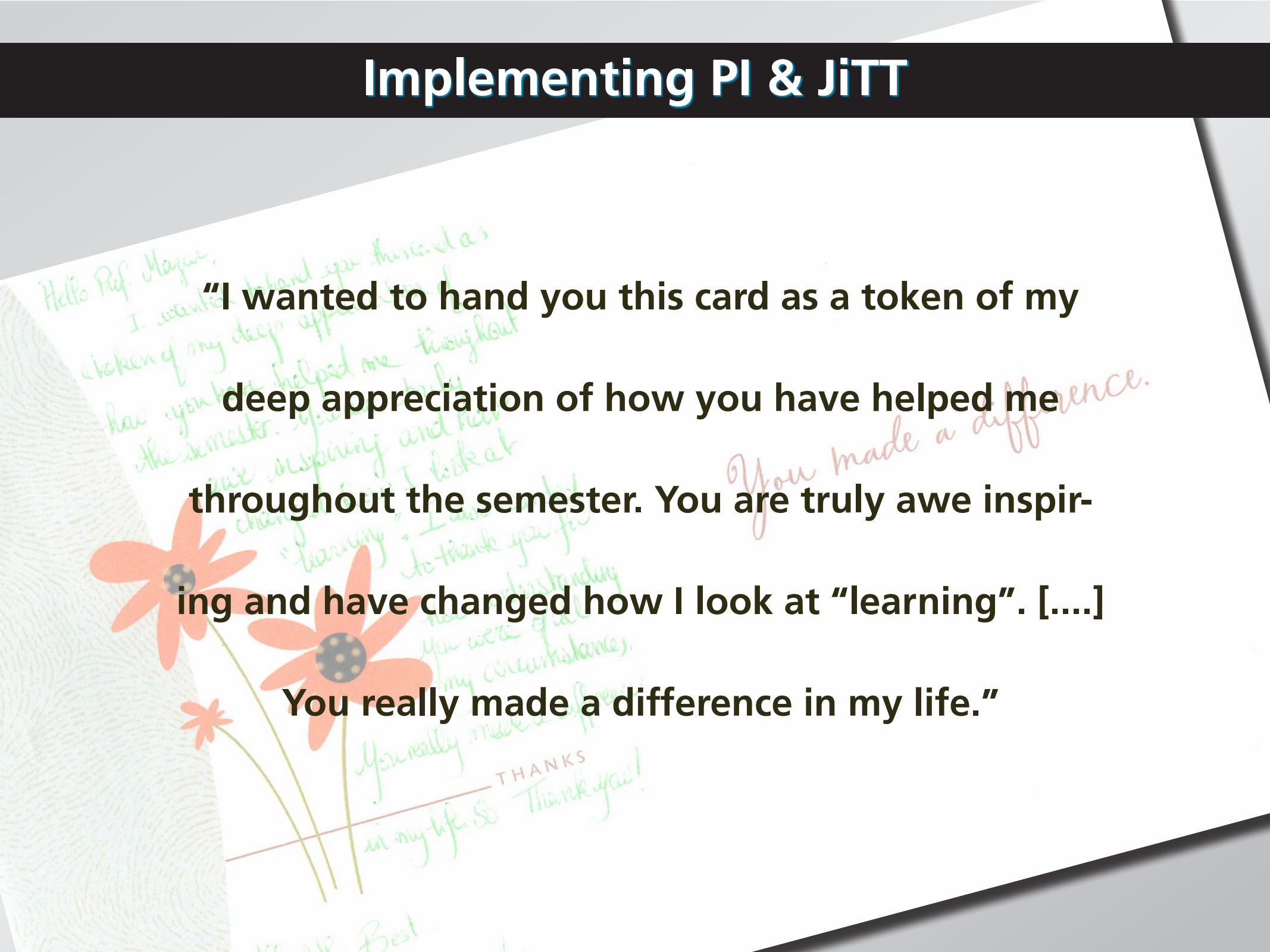

"I wanted to hand you this card as a token of my deep appreciation of how you have helped me throughout the semester. You are truly awe inspiring and have changed how I look at "learning". [....] You really made a difference in my life."

Implementing PI & JiTT

and don’t forget…

Implementing PI & JiTT

and don’t forget…

PI leads to better learning and retention!