Providing more equitable and effective physics education

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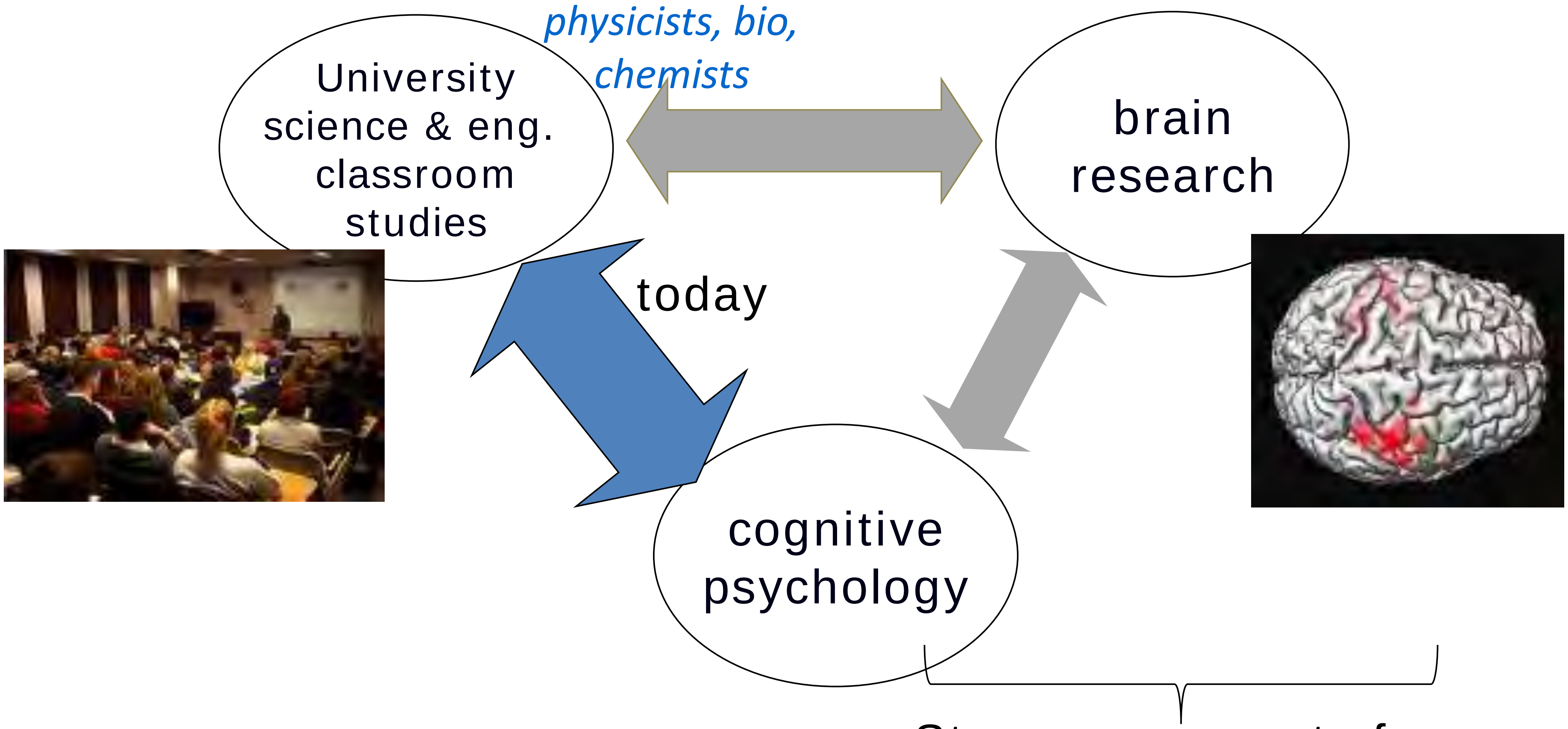
copies of slides to be available

*based on the research of many people, some from my science ed research group

Major advances past 1-2 decades

⇒ New insights on how to learn & teach complex thinking



Strong arguments for why apply to most fields

Rethinking how learning happens

old/current model

knowledge

soaks in, varies with brain

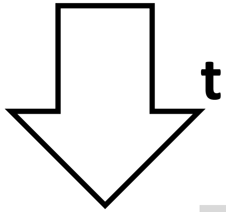
focus on:

- selecting best brains
- knowledge soup

new research-based view

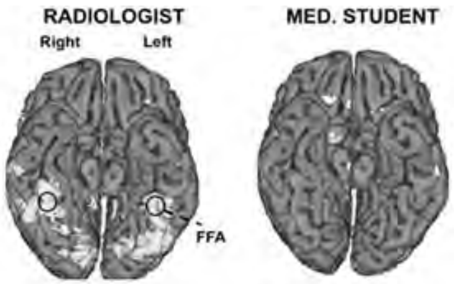
brain changeable

~ same



transformation

Change neurons by intense thinking.
Improved capabilities.



fMRI-- interpreting x-ray image

Brain research– learning is enhancing <u>relevant</u> neuron connections—
Like muscle development.
<u>Intensity</u> & <u>type</u> of exercise critical.

Researchers learning more effective ways to teach– brains develop new skills.

Conflicts with test-based system. Is no innate ability test that can measure & predict future success. Only measuring past educational opportunities not future capabilities.

Learning in large intro class*

Comparing the learning in class for two ~identical sections. 270 students each.
UBC 1st year university physics for engineers.

Control--standard lecture class– highly experienced Prof with good student ratings.
Experiment–- new physics Ph. D. trained in principles & methods of research-based teaching.

They agreed on:

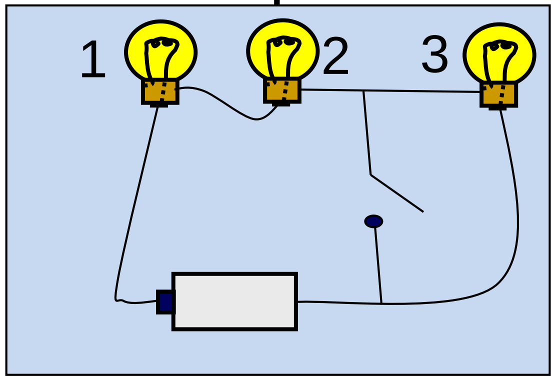
- Same material to cover *(Cover as much?)*
- Same class time (1 week)
- Same exam (jointly prepared)- start of next class

**Deslauriers, Schelew, Wieman, Sci. Mag. May 13, '11*

Experimental:

1. Short preclass reading assignment--Learn basic facts and terminology without wasting class time.

2. Class starts with question:



When switch is closed, bulb 2 will

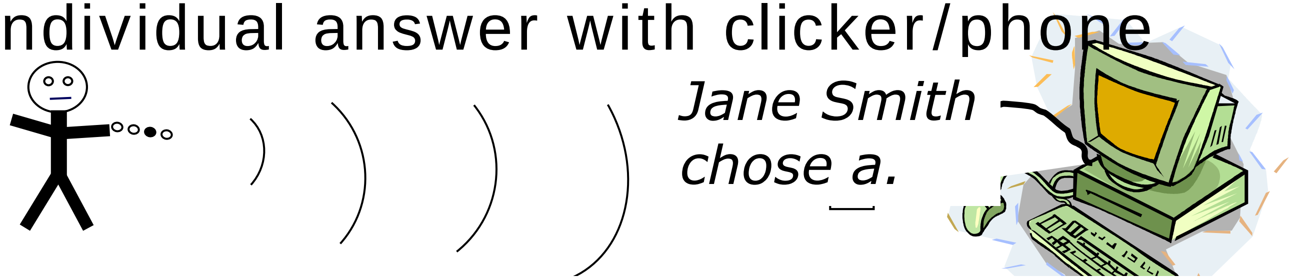
a. stay same brightness,

b. get brighter

c. get dimmer,

d. go out.

3. Individual answer with clicker/phone



4. Discuss with neighbors, revote. *("Peer instruction")*

<u>Instructor circulating and listening in on conversations</u>!

What aspects of student thinking like physicist, what not?

5. Demonstrate/show result

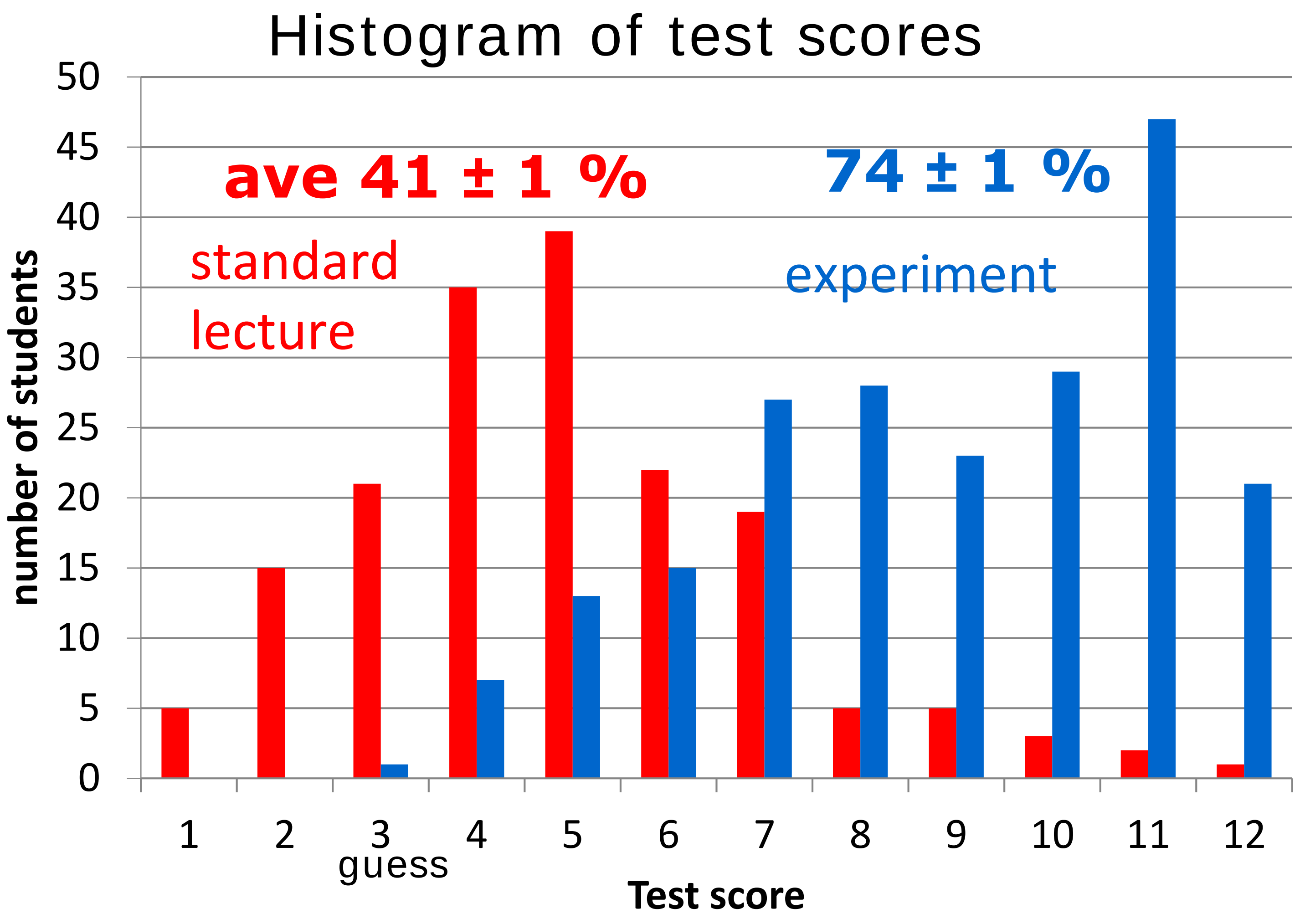
6. Instructor follow up summary– feedback on which models & which reasoning was correct, & **which incorrect and why**. Many student questions.

For more mathematical topics, students write out on worksheets.

Students practicing thinking like physicists--
(choosing, applying, testing conceptual models, critiquing reasoning...)

Feedback—other students, informed instructor, demo

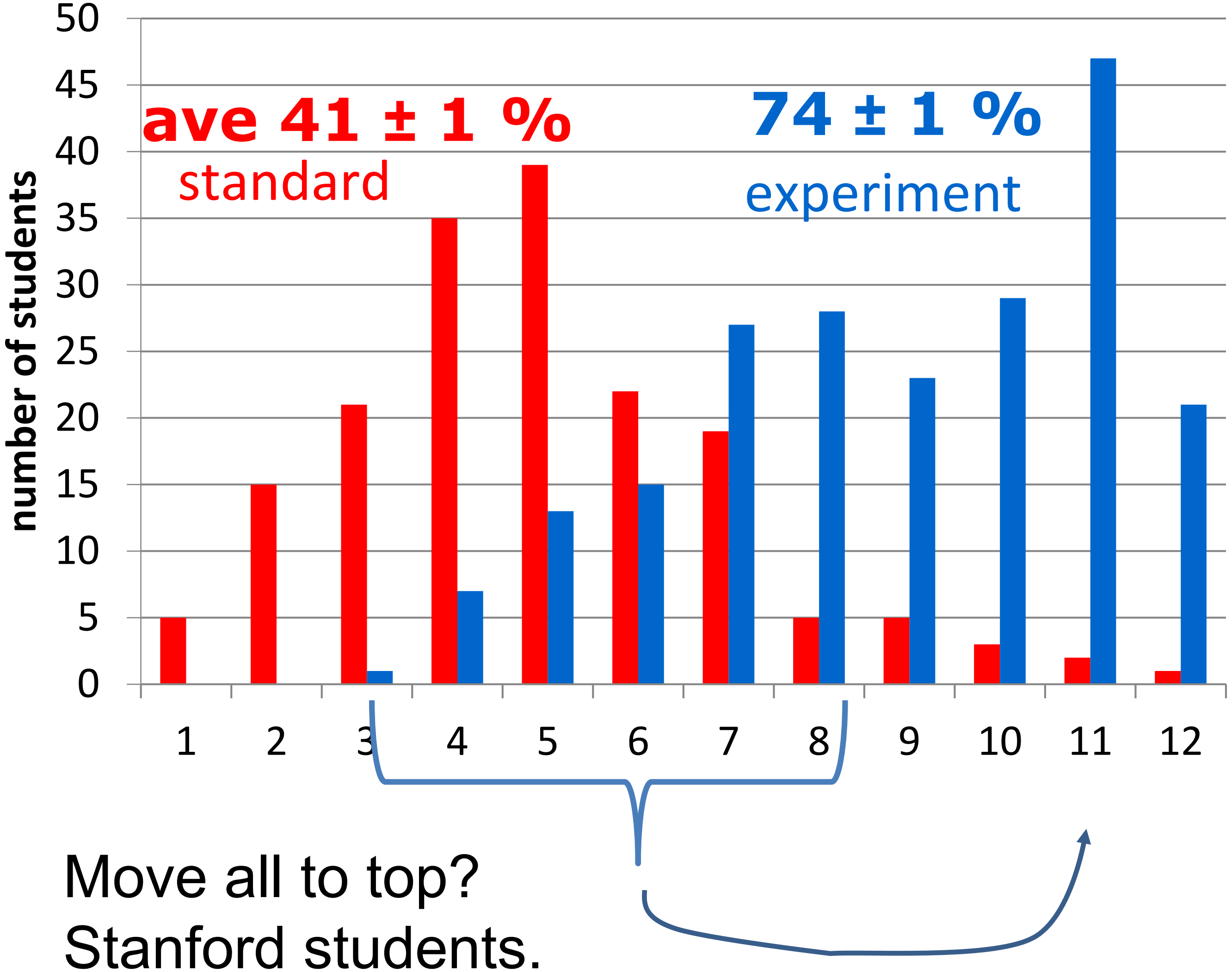
Identical surprise quiz given in both sections



Learning from lecture tiny.
Clear improvement for <u>entire</u> student population.

Deslauriers, Schelew, Wieman, Sci. Mag. May 13, '11

But how to compress distribution?



Move all to top?
Stanford students.

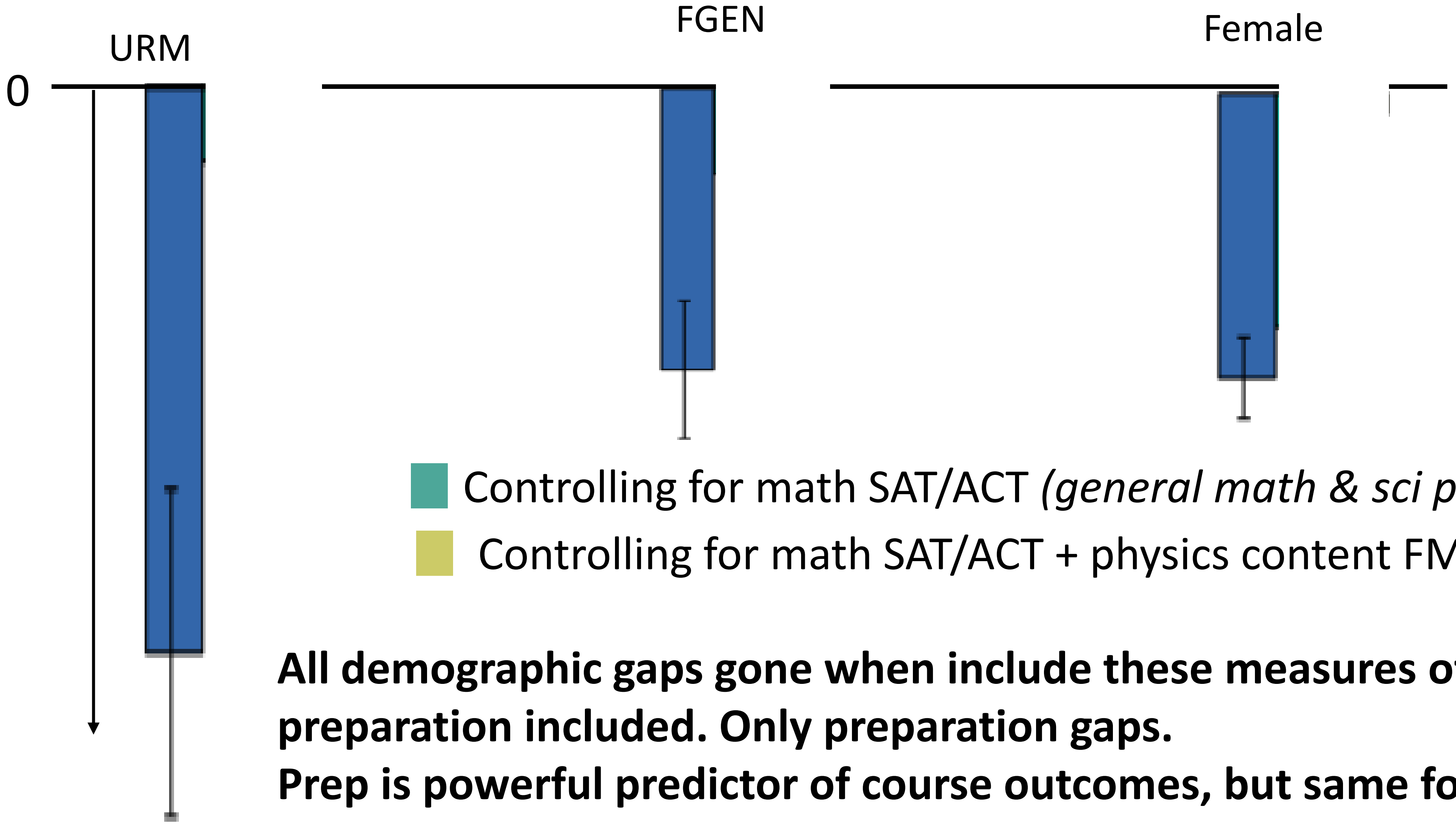
Good teaching methods not enough?

Other factors?

Got data on many things.
Lots of statistics
(multivariable regression)

<u>What matters?</u>
math taken?– no
demographics?

Origin of performance gaps by demographic groups



Controlling for math SAT/ACT *(general math & sci prep)*

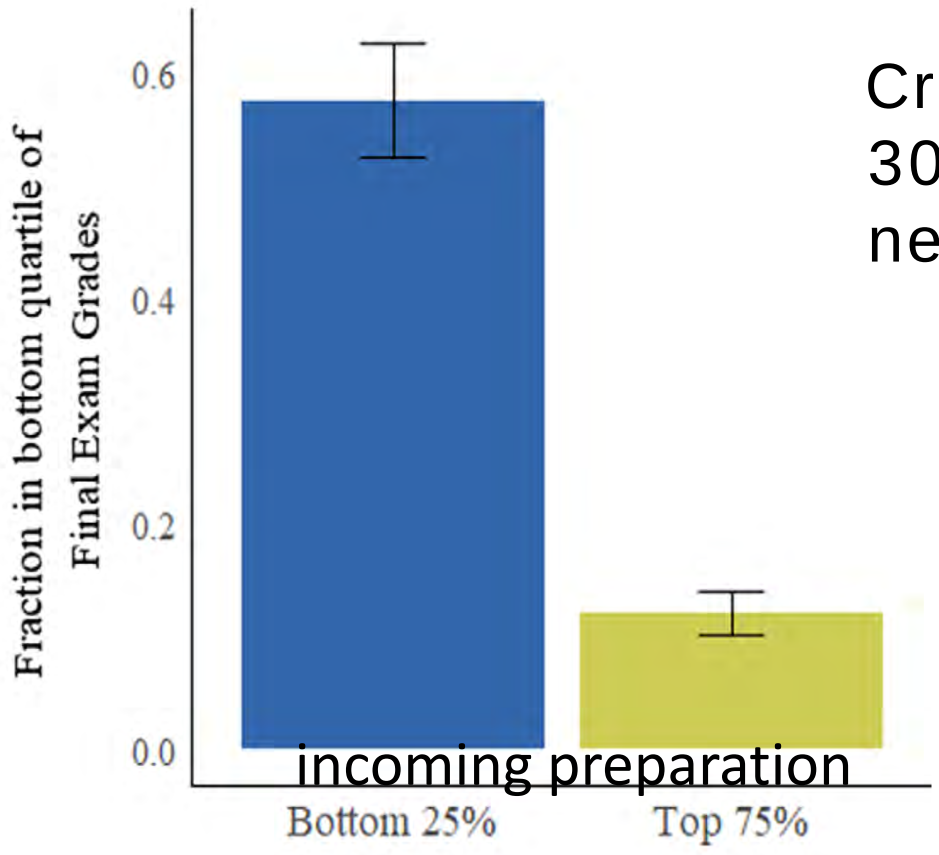
Controlling for math SAT/ACT + physics content FMCE

All demographic gaps gone when include these measures of prior preparation included. Only preparation gaps.
Prep is powerful predictor of course outcomes, but same for all students.

Demographic gaps or preparation gaps?: The large impact of incoming preparation on performance of students in introductory physics
Salehi, Burkholder, Lepage, Pollock, and Wieman Phys. Rev. Phys. Educ. Res. 15, 020114 (2019)

Why does this dependence of grades on prior preparation matter?

Doing poorly in physics 1 is barrier to physics & engineering major.
"Failure analysis"—how does probability of failing depend on preparation?



Created our own diagnostic test.
30 minutes, explains ~ ½ variance,
nearly all the failure risk.

Differences in "K-12 educational quality"
amplified by college teaching.

Stanford and Colorado (and Cornell) **very different student populations, but similar dependence on preparation factors!**

$\Rightarrow$ *nature of the teaching, not the students.*

Optimizing coverage and pace for top 1/3 of the preparation.
Confusing educational privilege with talent.

Solution—**match curriculum to the students and many more can succeed***

*Preliminary indications--"An equitable and effective approach to introductory mechanics", https://arxiv.org/abs/2111.12504, Burkholder, Salehi, Sackeyfio, Mohamed-Hinds, Wieman

Creating a course in which all students can suceed

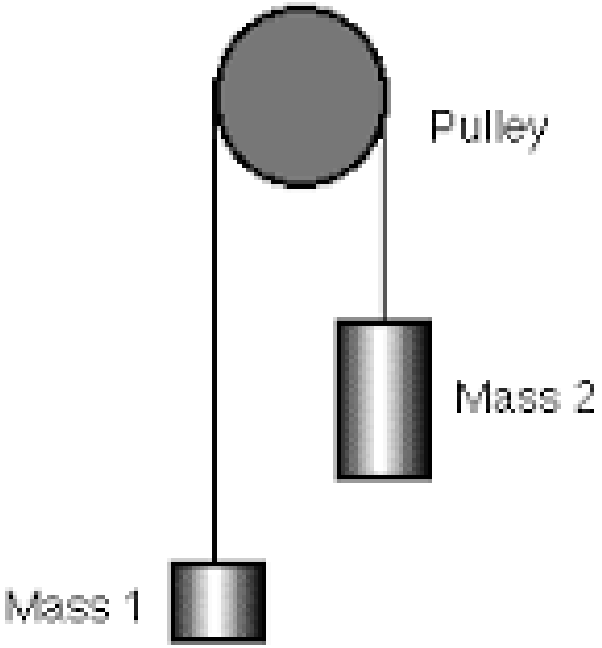
Alternative approach– teach physics not covered in high school, but still leave students with skills to succeed in subsequent courses (engineering, etc.)*

Teach real-world problem solving.

- Realistic problems
- Problem solving decisions made explicit

*E. Burkholder, ... C. Wieman, Equitable approach to introductory calculus-based physics courses focused on problem solving, Phys. Rev. Phys. Educ. Res. 18, 020124 –2022

Physics class problems vs Real world problems



typical physics text problem
Calculate the acceleration of the masses. Assume massless pulley and string and no friction.

A real world ("authentic") problem
You are an engineer designing a pinball machine. Determine the necessary spring constant of the spring needed to launch a typical pinball to the top of the game.
Requires many more decisions.

Course provided repeated opportunities to engage in research-based practices and decisions required for effective problem-solving.

- Solving real world problems
- Using problem solving template, making decisions (below).
- Working in small groups guided by instructor, regular feedback.

Wieman Group Research

How experts in science, engineering, and medicine solve authentic problems.

Process defined by making set of decisions with limited information.

Same set of 29 decisions, all science & engineering!

- Decide: what concepts/models relevant
- Decide: What information relevant, irrelevant, needed.
- Decide: what approximations are appropriate.
- Decide: potential solution method(s) to pursue.
- ....
- Decide: does solution/conclusion make sense, how to test?

but, **making** the decisions requires specialized disciplinary knowledge. Organized to optimize.

Argenta Price, Shima Salehi, Karen Wang, Michael Flynn, Candice Kim, Eric Burkholder, CBE-LSE

Practicing making problem-solving decisions
in authentic problem context, using subject knowledge.

brain
"exercise"

Nearly all these decisions removed from typical course problems!
Students learn information, not how to use!

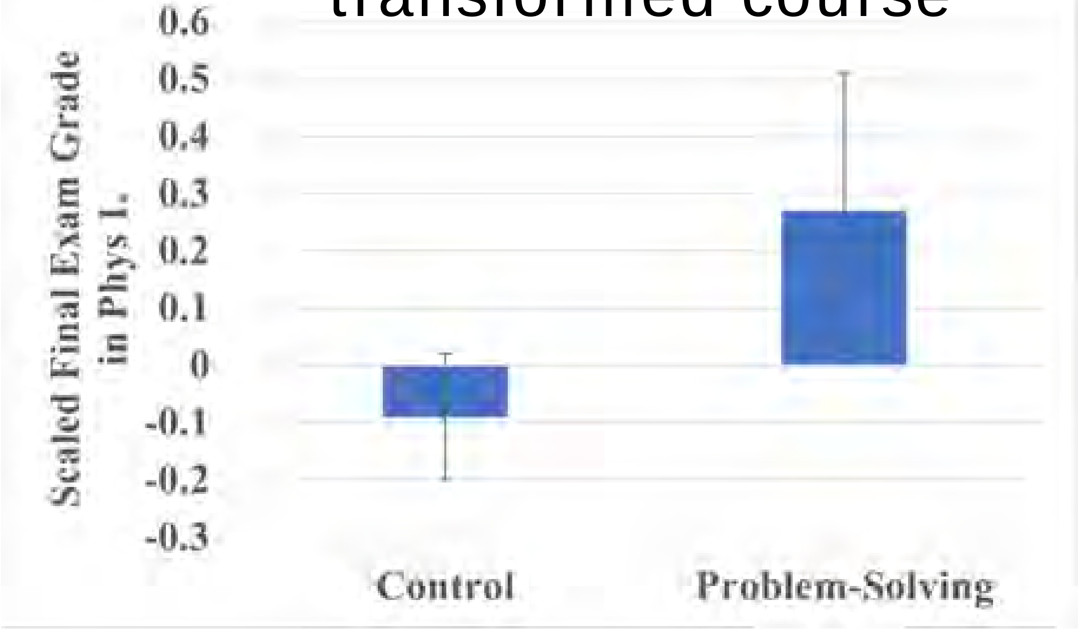
* "Deliberate Practice", A. Ericsson research. See "Peak;…" by Ericsson for readable summary

Problem-solving template– used throughout course

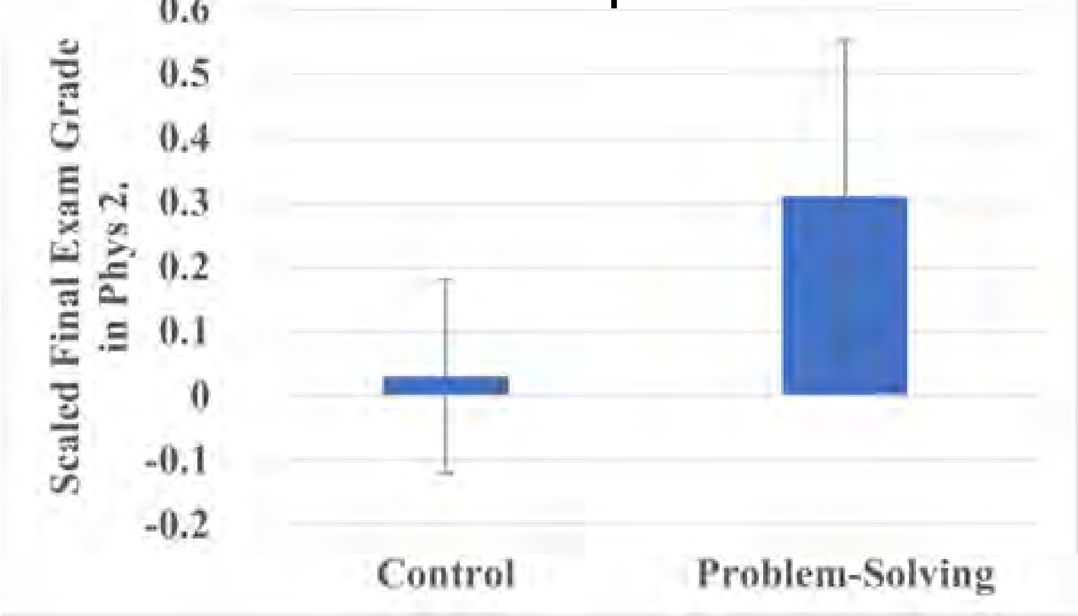
Problem-Solving Practice [32]	**Problem-Solving Decisions**	**Template Steps**
Problem Definition	• Decide what the goals for this problem are	N/A
Problem Framing	• Decide what are important underlying features • Decide which predictive frameworks are relevant • Decide what information is relevant/important and what is needed. • Decide what are related problems seen before • Decide how predictive frameworks need to be modified to fit this situation	• Visual Representation • Relevant Concepts • Similar Problems • Assumptions and Simplifications • Information Needed
Problem Decomposition and Planning	• Decide how to decompose problem into more tractable sub-problems • Decide what to prioritize • Decide what information is needed to solve the problem • Decide on specific plan for getting additional info.	• Solution Plan • Rough Estimate
Data Interpretation	• Decide what calculations are needed • Decide whether newly obtained information matches expectations	• Execution • Compare to Estimate
Reflection on Solution	• Decide whether assumptions still make sense • Decide whether additional information is needed • Decide how well the solution holds	• Check Limits • Check Units • Getting Unstuck

Course Results

transformed course



subsequent course



control –traditional content and pedagogy

Students learned more & less dependent on incoming preparation

correlation with incoming preparation measure

control 0.55-0.62, problem solving 0.14-0.26

Conclusion-- Brain learns what it practices. Develops new capabilities.
Have been confusing educational privilege with ability.
Good teaching allows nearly all students to succeed.

<u>Good References:</u>

- D. Schwartz et. al. *"The ABCs of how we learn"*
- Wieman, *"Improving How Universities Teach Science"*

- A Detailed Characterization of the Expert Problem-Solving Process in Science and Engineering: Guidance for Teaching and Assessment, A. Price et al, ://doi.org/10.1187/cbe.20-12-0276
- Equitable approach to introductory calculus-based physics courses focused on problem solving, E. Burkholder, … C. Wieman, Phys. Rev. Phys. Educ. Res. 18, 020124 –2022
- Demographic gaps or preparation gaps?: The large impact of incoming preparation on performance of students in introductory physics, S. Salehi, et al., Phys. Rev. Phys. Educ. Res. 15, 020114 –2019

Teaching to think (*make decisions*) like expert, what research says is important