EDUCATIONAL TRANSFORMATION AT A CRITICAL TIME:
WHY US AND WHY NOW
THE PROMISES OF DISCIPLINARY ENGAGEMENT

APS- SBF Physics Professor Lecture Series
10 Nov 2016

Instituto de Física
Universidade Federal do Rio de Janeiro

Noah Finkelstein
Physics Department &
Center for STEM Learning
Timmerhaus Teaching Ambassador
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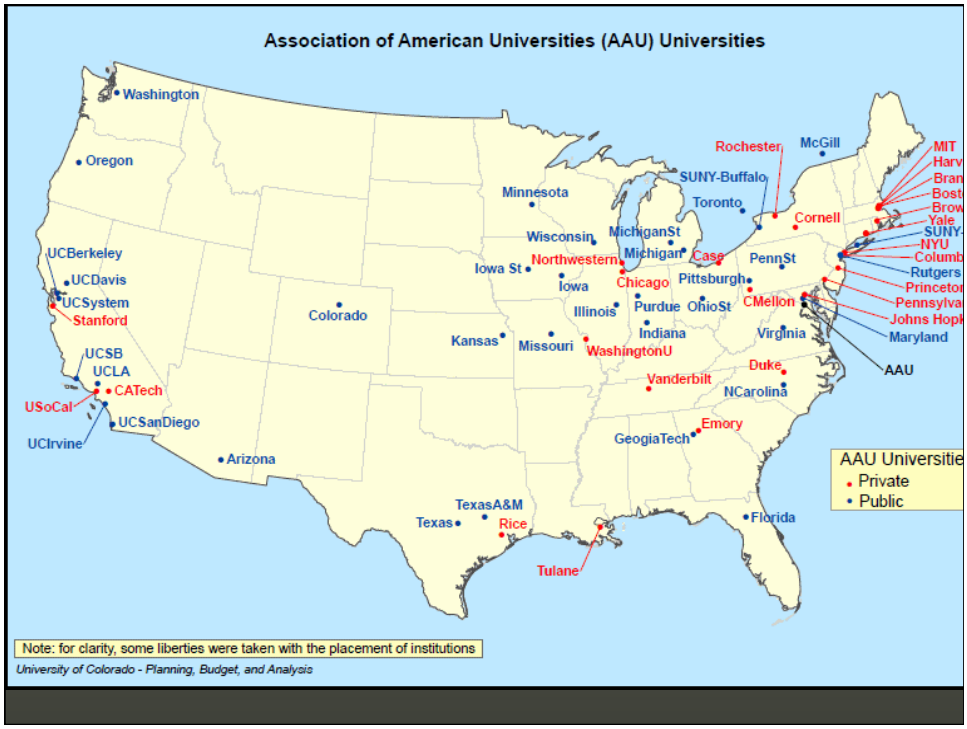
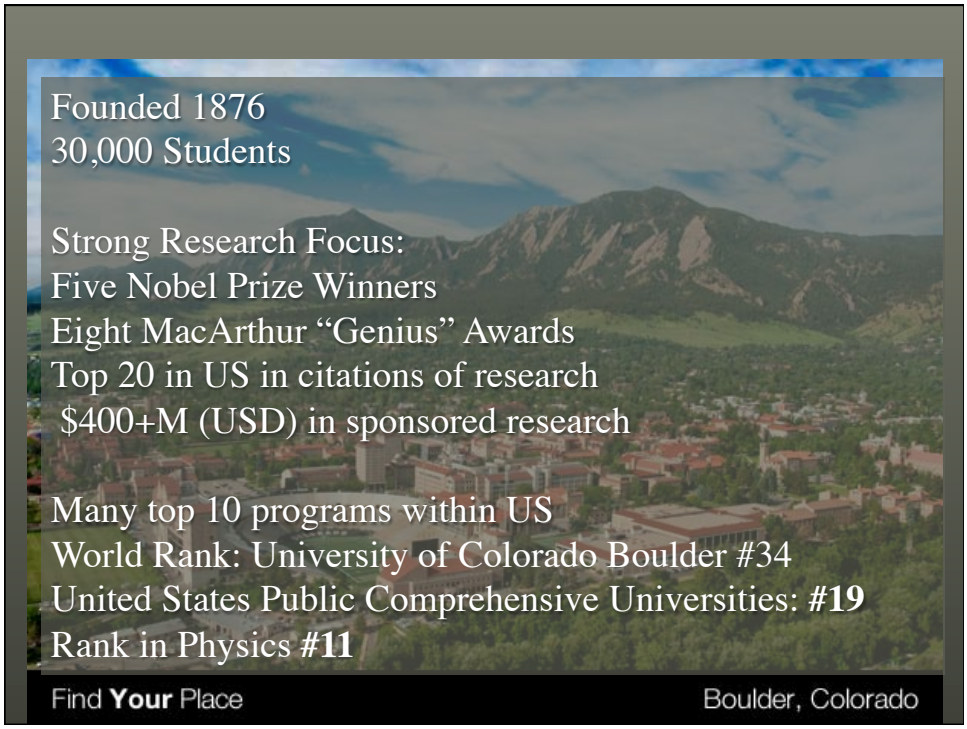
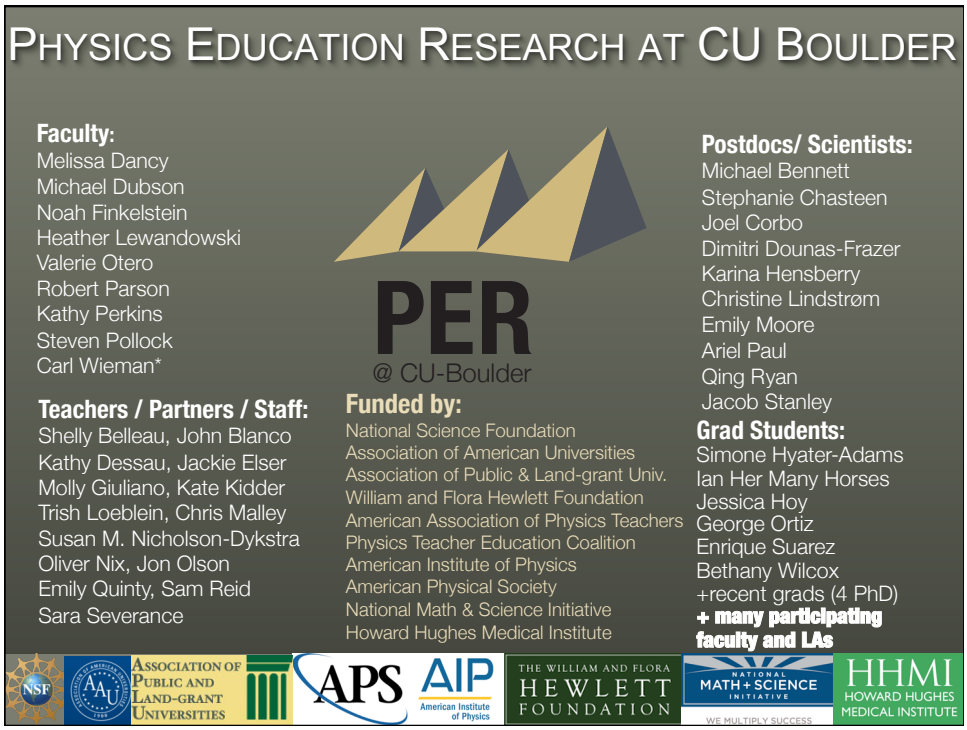



Founded 1876
30,000 Students
Strong Research Focus:
Five Nobel Prize Winners
Eight MacArthur "Genius" Awards
Top 20 in US in citations of research
$400+M (USD) in sponsored research
Many top 10 programs within US
World Rank: University of Colorado Boulder #34
United States Public Comprehensive Universities: #19
Rank in Physics #11
Find Your Place
Boulder, Colorado


PHYSICS EDUCATION RESEARCH AT CU BOULDER
Faculty:
Melissa Dancy
Michael Dubson
Noah Finkelstein
Heather Lewandowski
Valerie Otero
Robert Parson
Kathy Perkins
Steven Pollock
Carl Wieman*
Teachers / Partners / Staff:
Shelly Belleau, John Blanco
Kathy Dessau, Jackie Elser
Molly Giuliano, Kate Kidder
Trish Loeblein, Chris Malley
Susan M. Nicholson-Dykstra
Oliver Nix, Jon Olson
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Christine Lindstrøm
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Qing Ryan
Jacob Stanley
Grad Students:
Simone Hyater-Adams
Ian Her Many Horses
Jessica Hoy
George Ortiz
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Bethany Wilcox
+recent grads (4 PhD)
+ many participating faculty and LAs
NSF
AAU
ASSOCIATION OF PUBLIC AND LAND-GRANT UNIVERSITIES
APS
AIP
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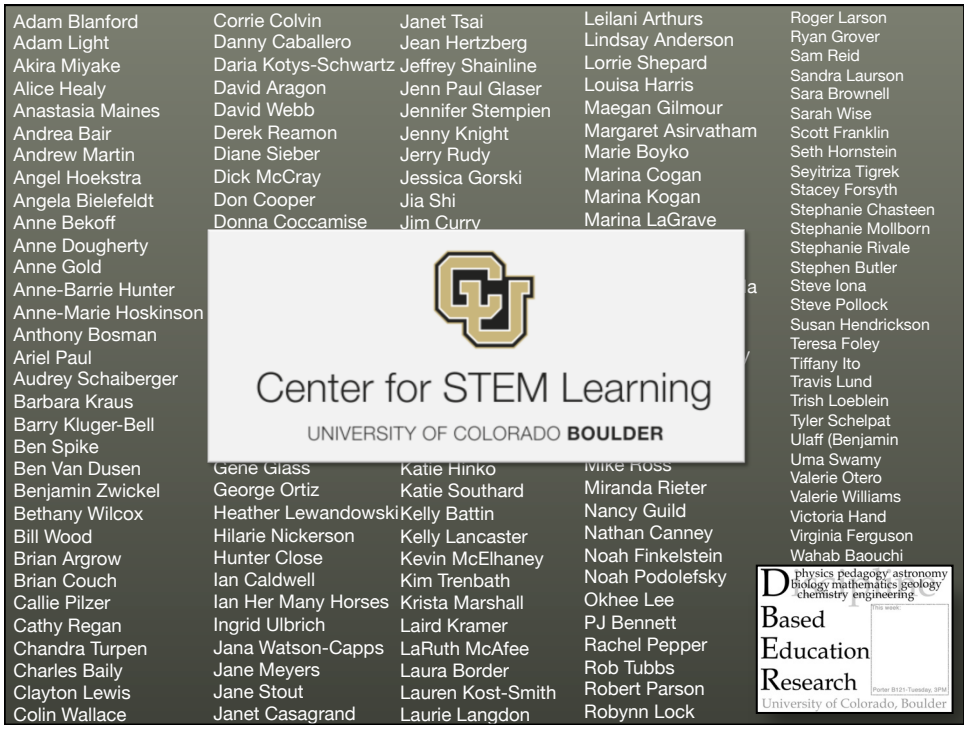
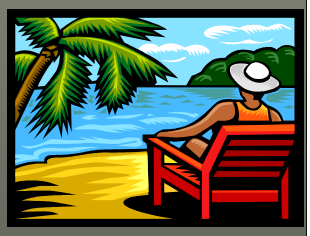
THE WILLIAM AND FLORA HEWLETT FOUNDATION
NATIONAL MATH + SCIENCE INITIATIVE
WE MULTIPLY SUCCESS
HHMI
HOWARD HUGHES MEDICAL INSTITUTE



Why Education?

Individual Empowerment



Societal Empowerment

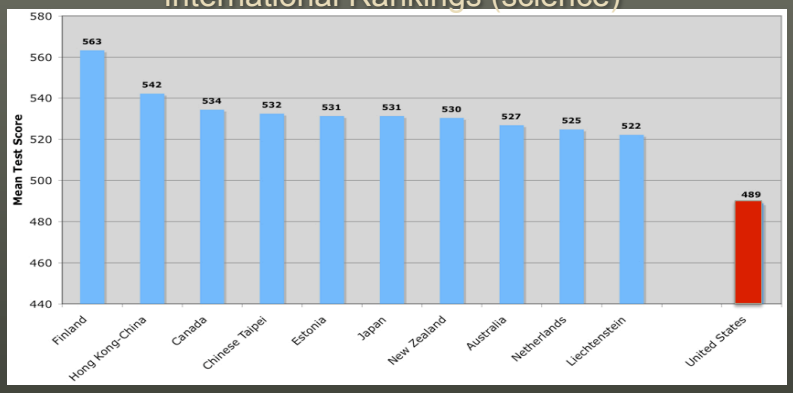
Workforce / Economic Development

Grand Challenges in US Education

Better education

U.S. ranks:
21 out of 30 in science
25 out of 30 in math
- PISA 2006

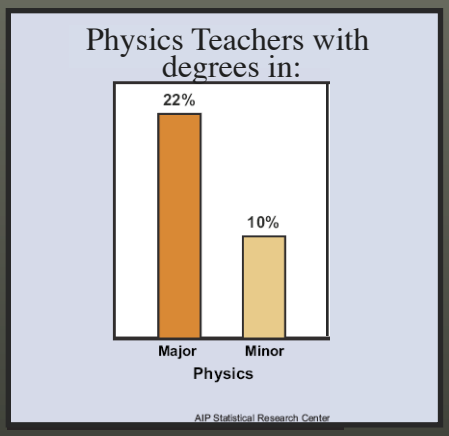
International Rankings (science)



Grand Challenges in US Education

Better education
More and better teachers

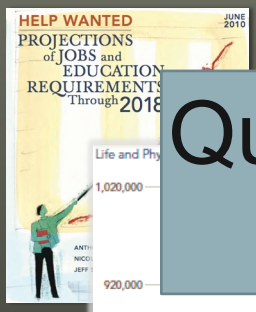
2/3 Physics Out of Field
Less than 50% stay



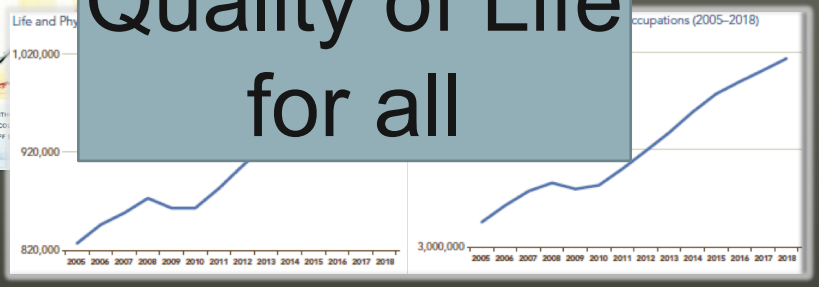
Grand Challenges in US Education

Better education
More and better teachers
More and better STEM grads

1 Million more STEM grads needed by 2018
and growing

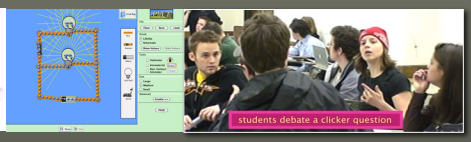


Quality of Life for all

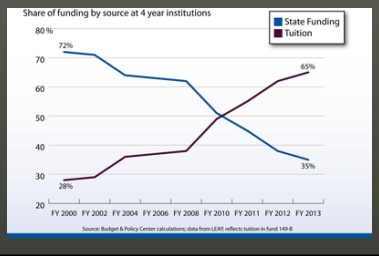


In the midst of dramatic change

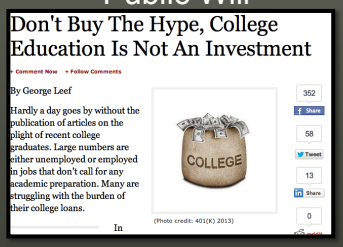
New Models/Modes of Education



Financial Structures



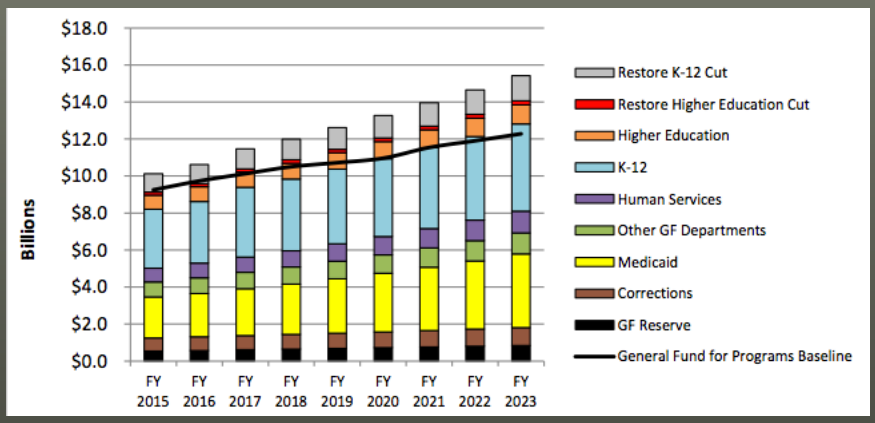
Public Will



TUITION AND EXPENSES

Cost of Attendance	In-state:	$29,215
	Out-of-state:	$52,763
Tuition and Fees	In-state:	$11,531
	Out-of-state:	$35,079
Room and Board		$13,590
Books and Supplies		$1,800
Other Expenses		$2,294

Colorado, a national leader

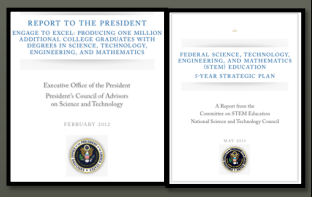


Forecast from CU-VP and CFO Dec 13

A Era of Significant Attention:

the National Academies

the White House



Professional Organizations Societies

AAU · Association of Public and Land-grant Universities · APS physics

Higher Education & Disciplines: key levers in education

Educational Research in Disciplines

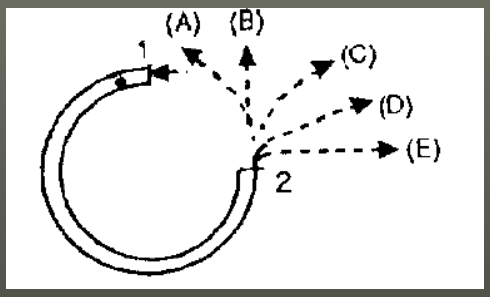
A possible "tipping" point

- **Force Concept Inventory***
- Multiple choice survey, (pre/post)
- Experts (especially skeptics!)

  necessary (not sufficient) indicator of conceptual understanding.

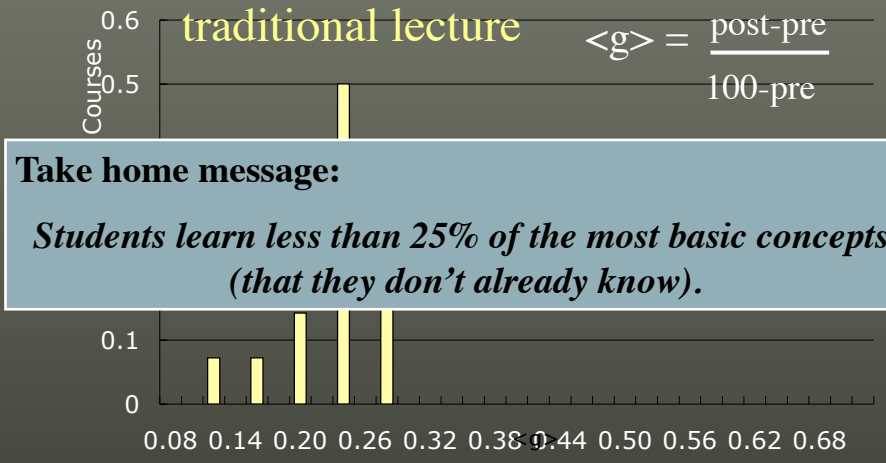
* Hestenes, Wells, Swackhamer, Physics Teacher 20, (92) 141

Sample question



Looking down at a track (flat on table), a ball enters at point 1 and exits at point 2. Which path does it follow as it exits (neglect all friction)?

We are not teaching students



Take home message:

Students learn less than 25% of the most basic concepts (that they don't already know).

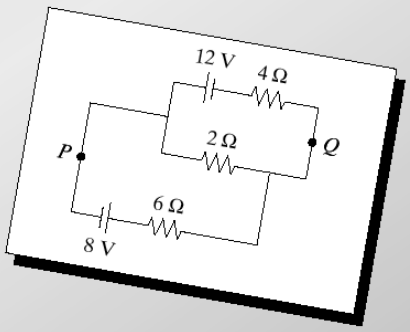
R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).

But my students learn . . .

Calculate:

(*a*) current in 2-Ω resistor

(*b*) …

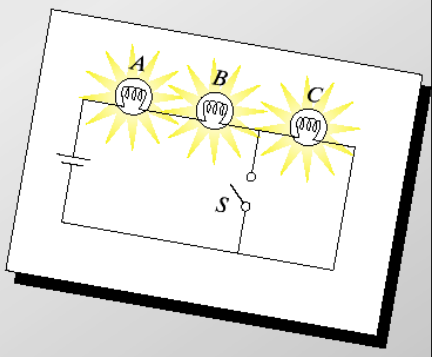


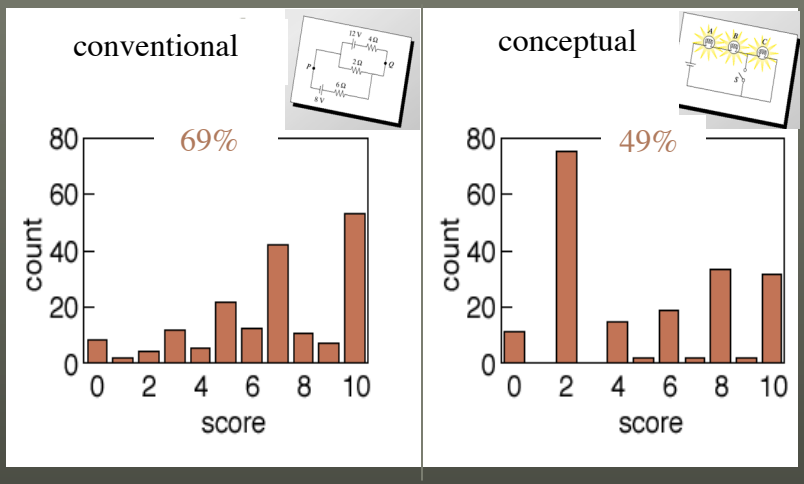
Mazur (1997; 2004)

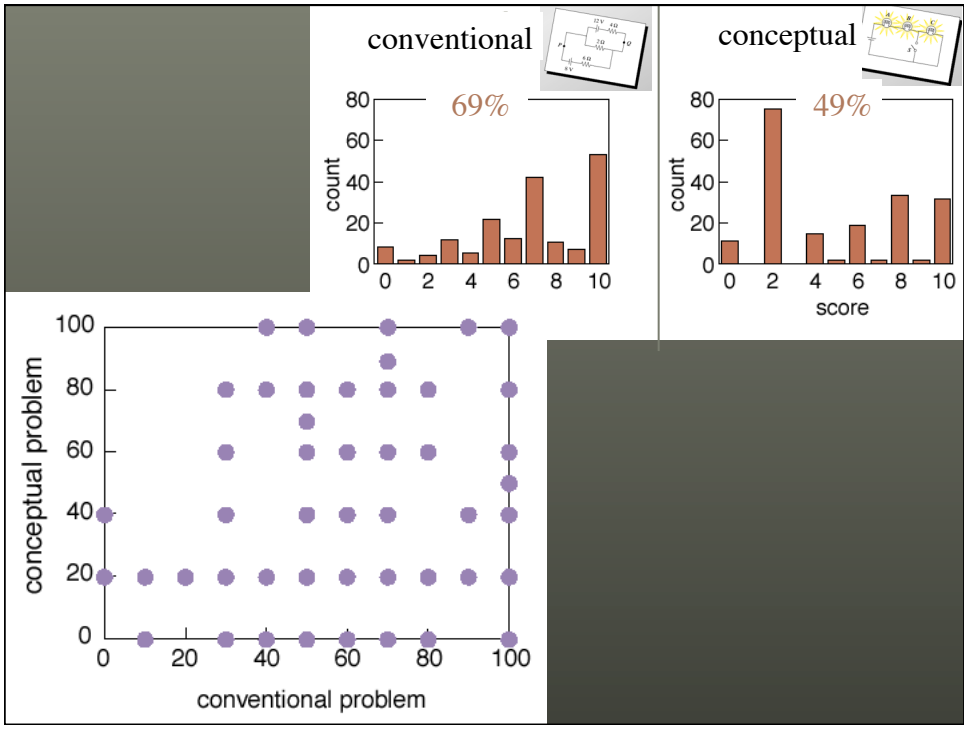
When *S* is closed, what happens to:

(*a*) intensities of A and B?

(*b*) …







Attitudes & Beliefs:

Attitudes and Beliefs*

Assessing the "hidden curriculum" - beliefs about physics and learning physics

Examples:

- "I study physics to learn knowledge that will be useful in life."
- "To learn physics, I only need to memorize solutions to sample problems"

*Adams et al, (2006). Physical Review: Spec. Topics: PER, 0201010

CLASS categories

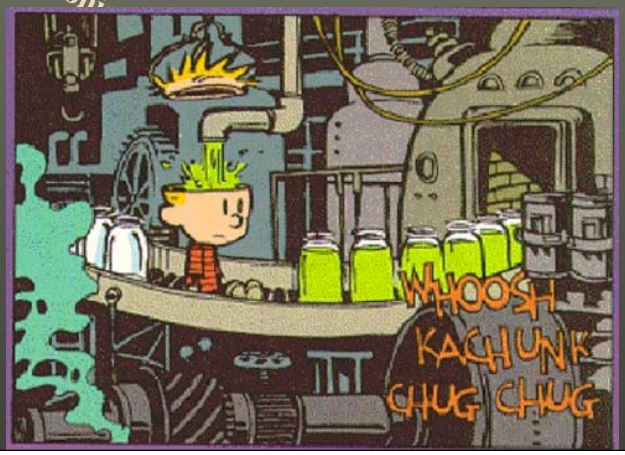
	Shift (%) ("reformed" class)
Real world connect...	-6
Personal interest.....	-8
Sense making/effort...	-12
Conceptual.....	-11
Math understanding...	-10
Problem Solving.....	-7
Confidence.....	-17
Nature of science.....	+5
	(All ±2%)

modeling
education and learning

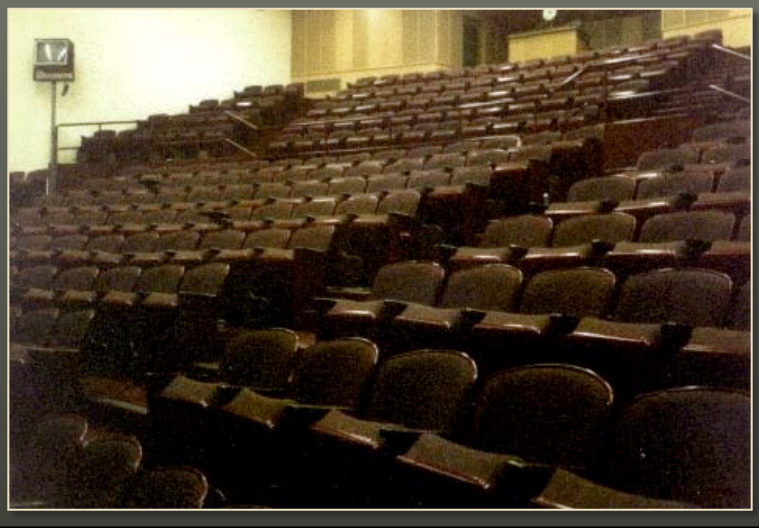
Trad'l Model of Education

Individual ← Instruction via transmission — Content (e.g. circuits)

transmission:



Built in to our classes?



Education?

Enculturation,

socialization of individuals into a cultural system
ways of walking, talking and squawking…

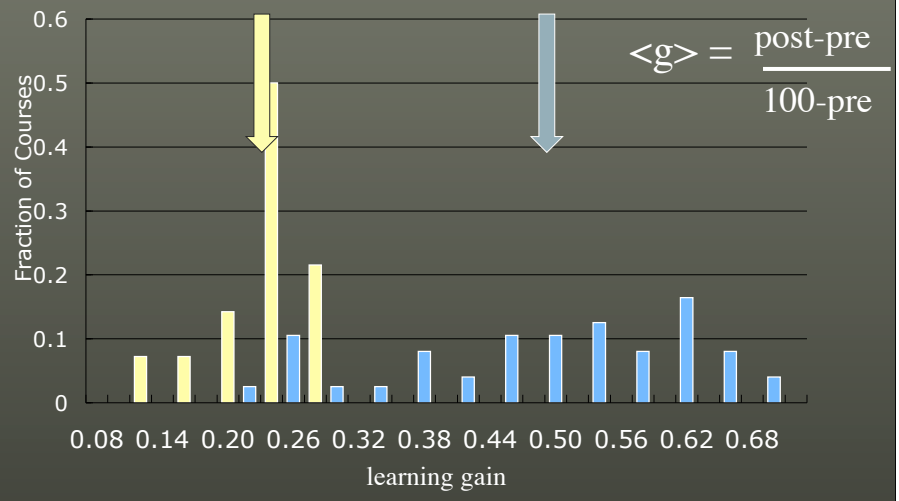
Not: simply the transfer of information

Many (research-validated) curricular innovations

Teach by actively engaging students…
based on what they know . . .

Engagement Improves Learning

traditional lecture interactive engagement



R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).
Pollock & Finkelstein, Physical Review, 4, 010101 (2008).

"If the experiments analyzed here had been conducted as randomized controlled trials of medical interventions, they may have been stopped for benefit" -Freeman, PNAS 2014

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

examining the how and the why…
focusing on context

Sure it works in practice,
but does it work in theory?

Foregrounding Context in PER

Artifact / Frames of Context	i. Tools	ii. Practices	iii. Norms
a. Individ'l	Representation Analogy PhET	Tch to Lrn Physics Labs Talking Physics	Class (beliefs) Interp in QM
b. Course	Sims in Class Clickers in Class Using Reps & Analogy	Course Redesign Clicker Use Tutorials	Tutorial Adaptation Tchng Interpret. Gender intervention
c. Depart'l	Faculty use of PER Frameworks of change	TA, PD, Fac Dvmt Community Partnr	Dept'l norms Partnership in Phys Inclusion

Sample applications

Artifact / Frame of context	i. Tools	ii. Practices	iii. Norms
a. Individ'l	Representation Analogy PhET	Learning by	CLASS-
b. Course	Studies of Use of Rep Analog		
c. Depart'l	Faculty us based m		ce of dept'l norms

Identity & Belong

Transforming Courses:
lower division to upper division

Creating & Studying New Classroom Models

With M. Dubson, D. Lieberman, J. Olsen, E. Johnsen
with Kost Smith (2011), Ito, Cohen, Miyake, Stoutz Pollock
With SPollock, K. Perkins, H. Lewendowski, B. Zwickl

Sample applications

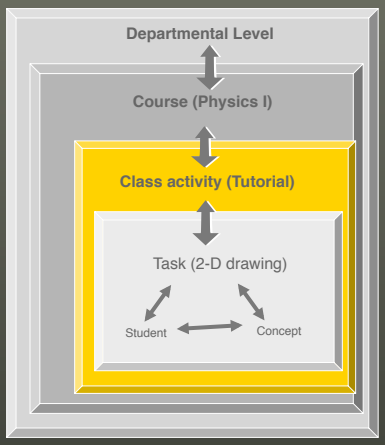
Artifact / Frame of context	i. Tools	ii. Practices	iii. Norms
a. Individ'l	Representation Analogy PhET	Learning by teaching	CLASS- Student attitudes and beliefs (ABs)
b. Course	Studies of Sim Use of Reps a Analogies		
c. Depart'l	Faculty use of PER-based materials	Programs in grad, p.d., and fac prep CU STOMP	Influence of dept'l norms

Transforming Courses:
lower division to upper division

With SPollock, K. Perkins, H. Lewendowski, B. Zwickl

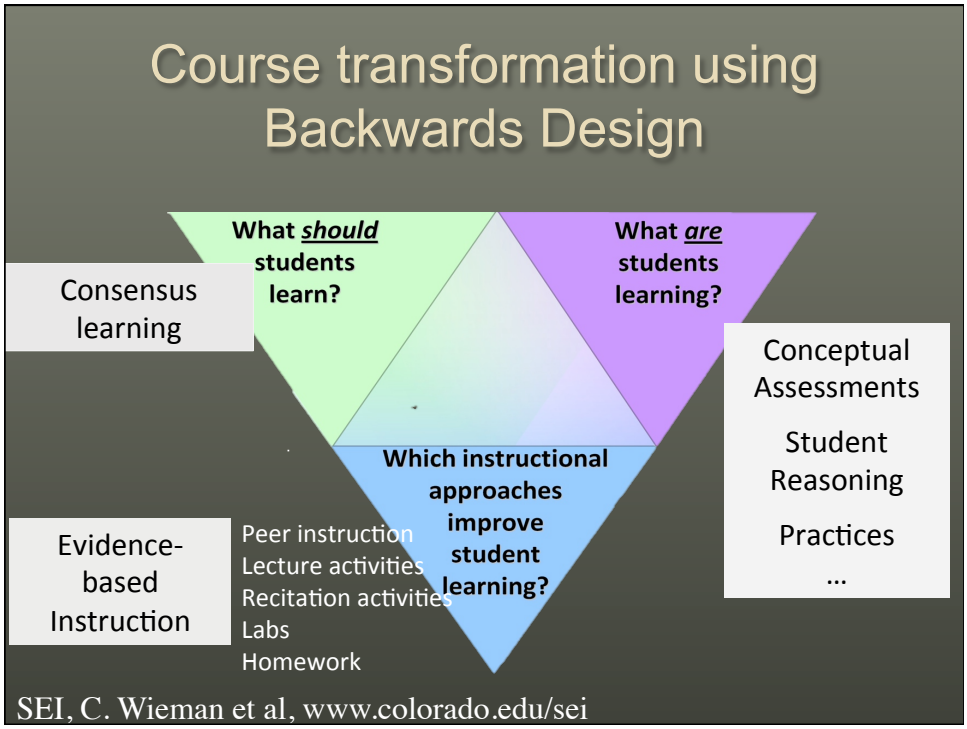
Embedded Context(s)

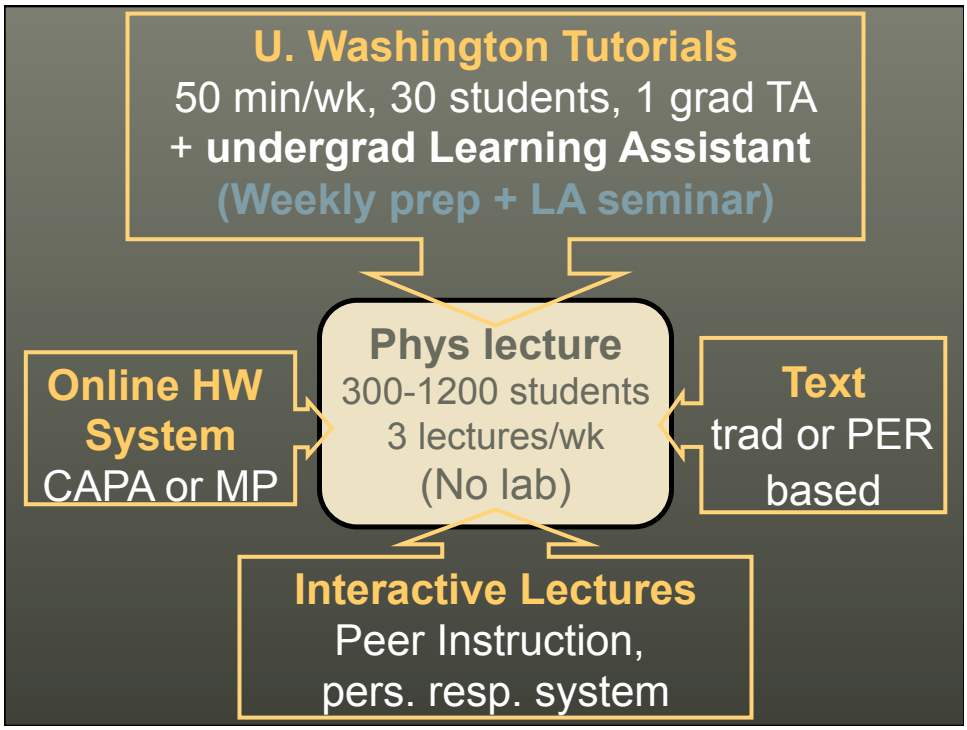
Frames of Context



Finkelstein, N. (2005). *Int. J. Science Education.*

modest reframing of class tools and context

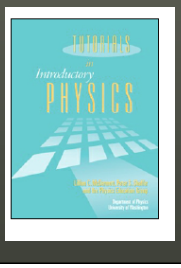

Course transformation using Backwards Design
What *should* students learn?
What *are* students learning?
Consensus learning
Conceptual Assessments
Student Reasoning
Practices
…
Which instructional approaches improve student learning?
Evidence-based Instruction
Peer instruction
Lecture activities
Recitation activities
Labs
Homework
SEI, C. Wieman et al, www.colorado.edu/sei


U. Washington Tutorials
50 min/wk, 30 students, 1 grad TA
+ undergrad Learning Assistant
(Weekly prep + LA seminar)
Online HW System
CAPA or MP
Phys lecture
300-1200 students
3 lectures/wk
(No lab)
Text
trad or PER based
Interactive Lectures
Peer Instruction,
pers. resp. system

Tutorials in Introductory Physics

Reconceptualize Recitation Sections

- Materials
- Classroom format / interaction
- Instructional Role



Proven Curricula

D.E. Trowbridge and L. C. McDermott, "Investigation of student understanding of the concept of acceleration in one dimension," *Am. J. Phys.* **49** (3), 242 (1981).

D.E. Trowbridge and L. C. McDermott, "Investigation of student understanding of the concept of velocity in one dimension," *Am. J. Phys.* **48** (12), 1020 (1980)

R.A. Lawson and L.C. McDermott, "Student understanding of the work-energy and impulse-momentum theorems," *Am. J. Phys.* **55** (9), 811 (1987)

L.C. McDermott and P.S. Shaffer, "Research as a guide for curriculum development: An example from introductory electricity, Part I: Investigation of student understanding." *Am. J. Phys.* **60** (11), 994 (1992); Erratum to Part I, *Am. J.* Phys. 61 (1), 81 (1993).

P.S. Shaffer and L.C. McDermott, "Research as a guide for curriculum development: An example from introductory electricity, Part II: Design of instructional strategies." Am. J. Phys. 60 (11), 1003 (1992)

L.C.McDermott, P.S. Shaffer and M. Somers, "Research as a guide for curriculum development: An illustration in the context of the Atwood's machine," Am. J. Phys.62 (1) 46-55 (1994).

More: see http://www.phys.washington.edu/groups/peg/pubsa.html

Tutorial Materials

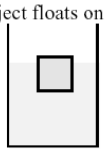
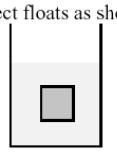
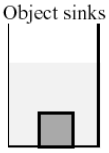
Hands-on, Inquiry-based, Guided, Research-based

Assignment 11M:
Buoyancy

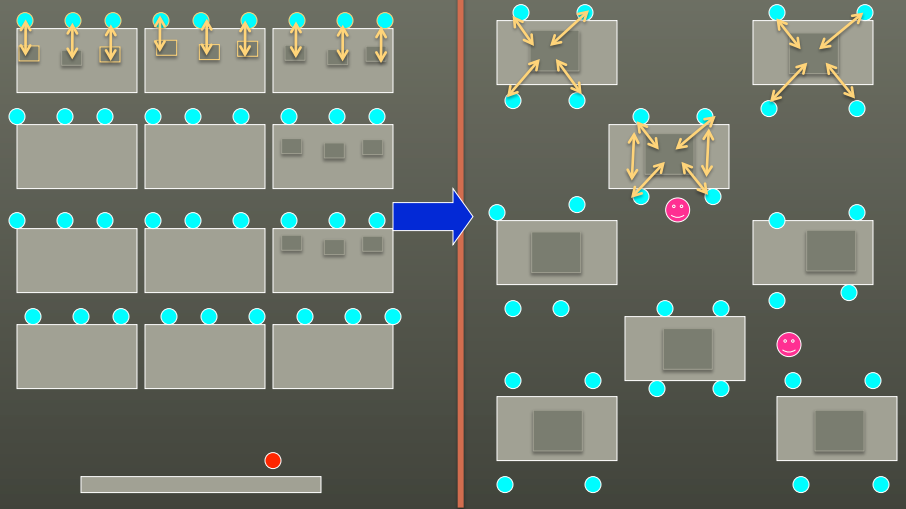
Name _____
Tutorial section_____

1. Three objects are at rest in three beakers of water as shown.

   a. Compare the mass, volume, and density of the objects to the mass, volume, and density of the displaced water. Explain your reasoning in each case.

Object floats on top	Object floats as shown	Object sinks
		
Is m_{object} $\begin{pmatrix}>\\<\\=\end{pmatrix}$ $m_{displaced\ water}$? Explain	Is m_{object} $\begin{pmatrix}>\\<\\=\end{pmatrix}$ $m_{displaced\ water}$? Explain	Is m_{object} $\begin{pmatrix}>\\<\\=\end{pmatrix}$ $m_{displaced\ water}$? Explain

Trad'l Recitation *vs* Tutorial



Experiential Learning Model for STEM Education, Faculty Development, and Teacher Preparation

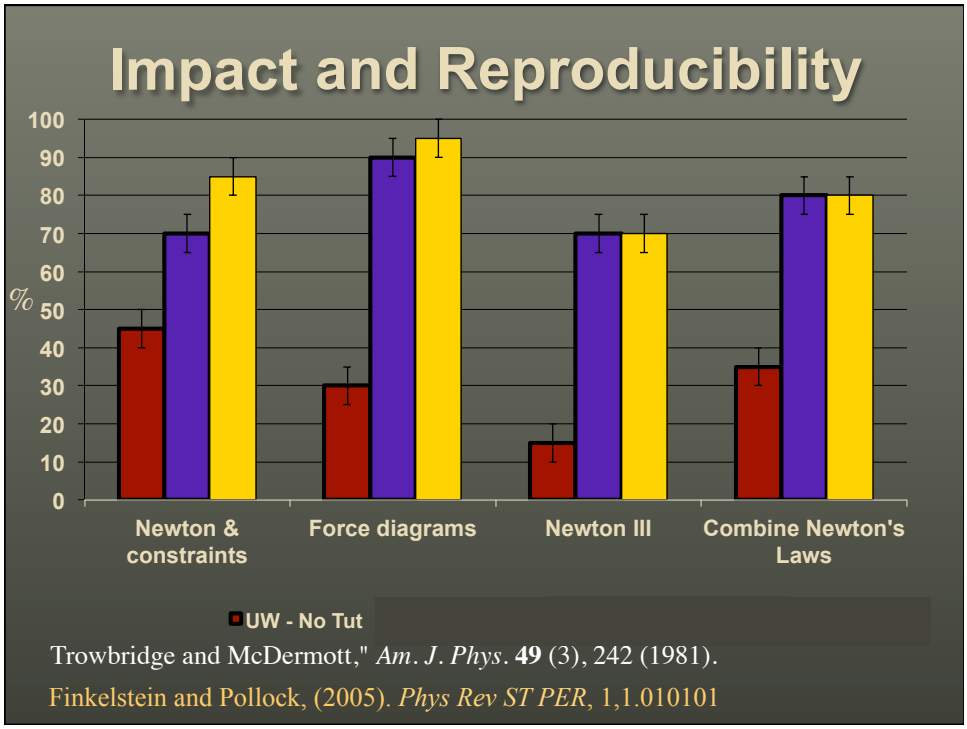
COLORADO LEARNING ASSISTANT MODEL
UNIVERSITY OF COLORADO BOULDER

Valerie Otero

V. Otero, N.D. Finkelstein, S.J. Pollock and R. McCray (2006). *Science*, **313**, 445

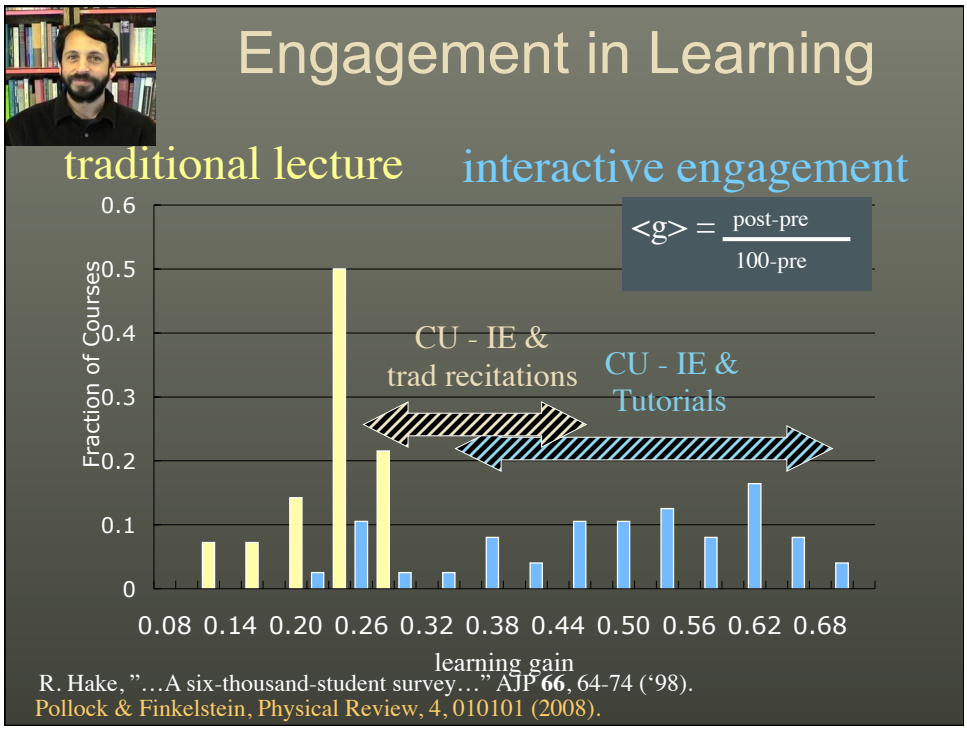
Courses Transformed using Learning Assistants (LAs)

These LAs make up the pool from which we recruit (and prepare) new K-12 teachers



Trowbridge and McDermott," *Am. J. Phys.* **49** (3), 242 (1981).

Finkelstein and Pollock, (2005). *Phys Rev ST PER*, 1,1.010101

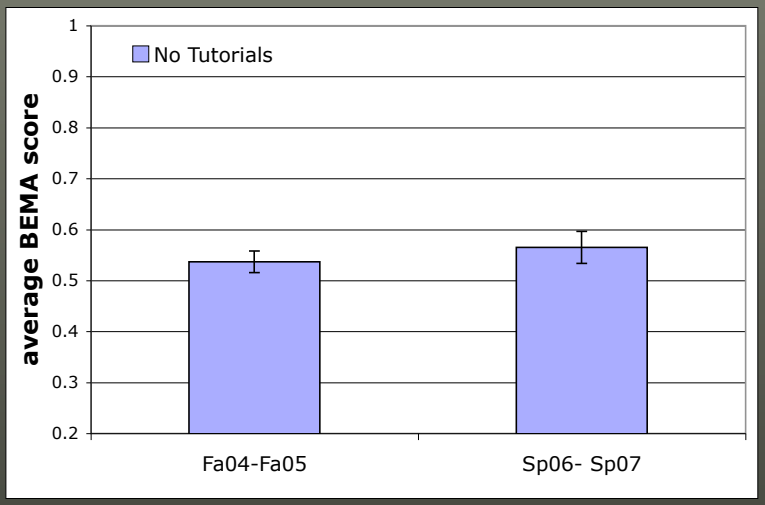


R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).

Pollock & Finkelstein, Physical Review, 4, 010101 (2008).

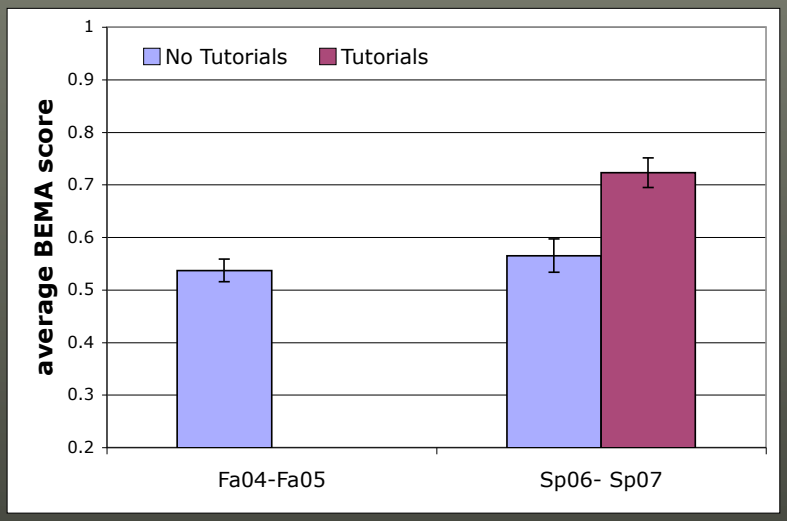
Lasting Impacts Longitudinal Studies

How Junior level E&M fair on BEMA?



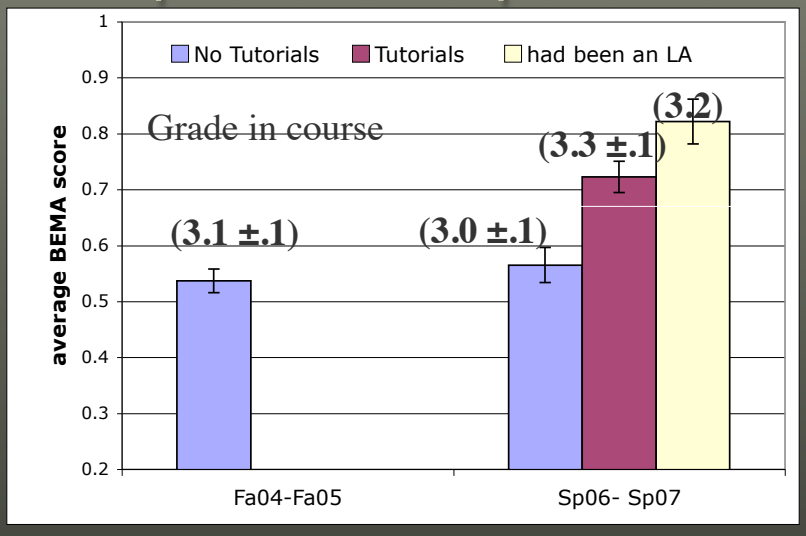
After completing Jr Level E/M (3310 or 3320)
Only students who took Phys 2 (1120) *without* Tutorials

Impact of Tutorials

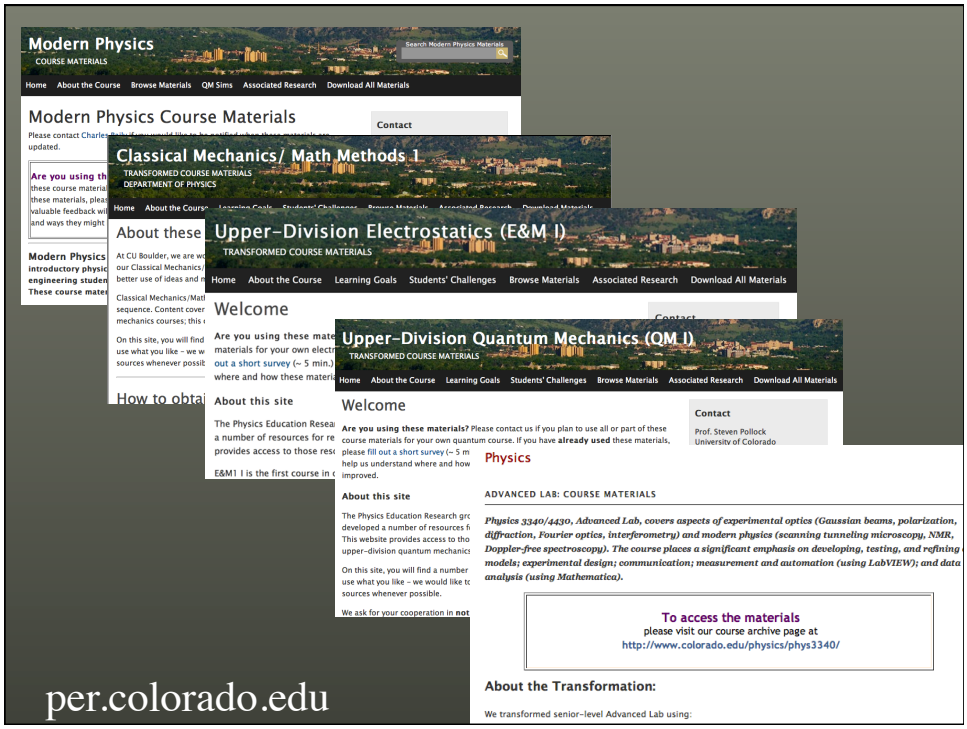


Red bins: students who had taken Freshman physics (1120) *with* Tutorials (~2 years prior)

Impact of LA experience



Beige: students who had been 1120 LAs



Identity & Belonging

Artifact / Frame of context	i. Tools	ii. Practices	iii. Norms
a. Individ'l	Representation Analogy PhET	Learning by	CLASS-
b. Course	Studies of Sims, Use of Reps and Analogies	Tutorials	reforms
c. Depart'l	Faculty use of PER-based materials	Programs in grad, p.d., and fac prep CU STOMP	Influence of dept'l norms

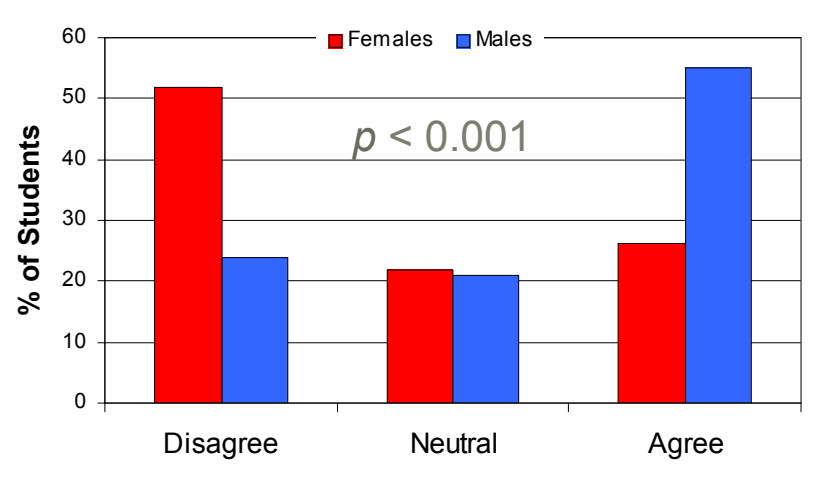
Identity & Belonging in STEM Education

with Kost-Smith (2011), Ito, Cohen, Miyake, Stout, Lewis, Pollock

NSF 0448176, CAREER: Physics Education and Contexts of Student Learning.

Physics Identity

I feel like I could be a good physicist.



Sense of Physics Identity

Jane G. Stout,[1] Tiffany A. Ito,[1] Lauren E. Kost-Smith,[2] Geoff L. Cohen,[3] Noah D. Finkelstein,[1] Akira Miyake,[1] & Steven J. Pollock[1]
[1] University of Colorado Boulder [2] Northwestern University [3] Stanford University

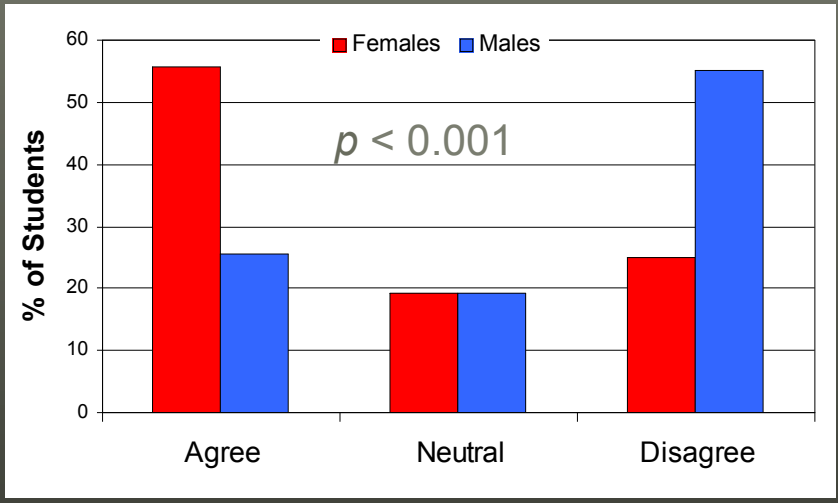
"The way a person understands and views himself, and is viewed by others" [1]

"who they think they are … and who they want to be." [2]

[1] J. Lave & E. Wenger, *Situated Learning*, 1991.
[2] N.W. Brickhouse, et. al. *J. Res. Sci. Teach.* **37**, 441 (2000).

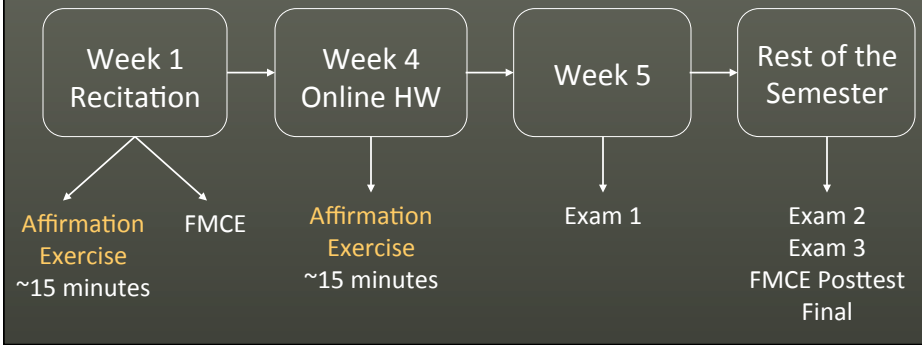
Physics Self-Efficacy

Physics makes me feel uneasy.

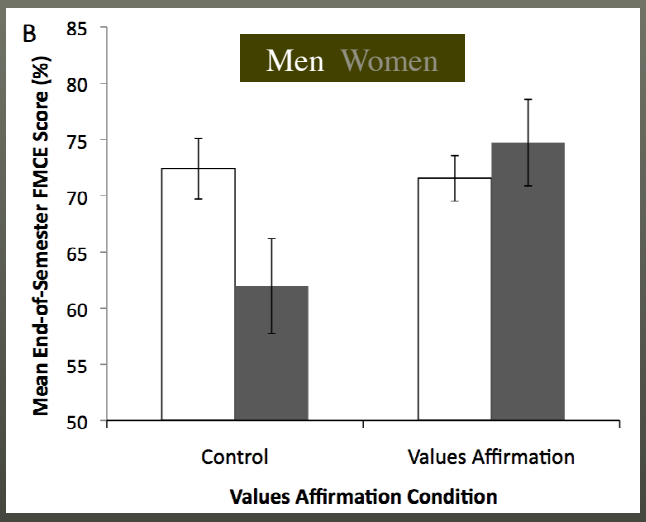


Experimental Design

- 2 X 2 randomized design:
  - gender (M,F) X condition (affirmation, control)
- Administer affirmation exercise 2 times

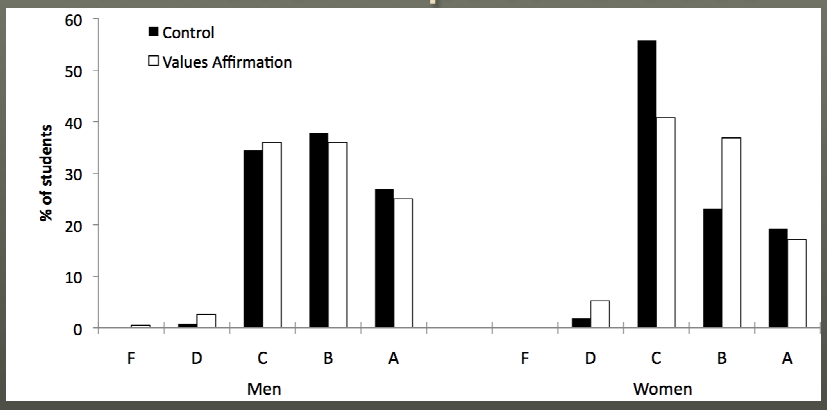


Affirmation Impact



Miyake, Kost, et al, *Science* Dec 2010

Affirmation Impact: Grades

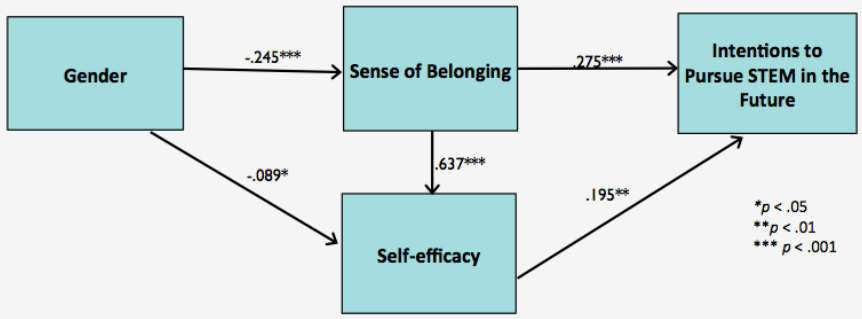


Miyake, Kost, et al, Science Dec 2010

Belonging and Participation

via structural equation modeling

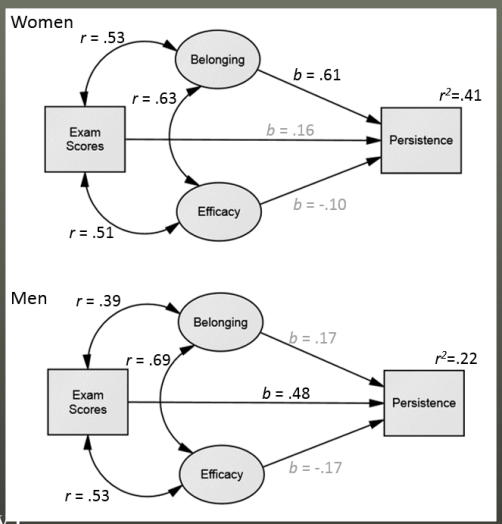
Women's lower sense of belonging leads to lower self-efficacy and intentions to pursue STEM in the future



Jane G. Stout,[1] Tiffany A. Ito,[1] Lauren E. Kost-Smith,[2] Geoff L. Cohen,[3] Noah D. Finkelstein,[1] Akira Miyake,[1] & Steven J. Pollock[1]

[1] University of Colorado Boulder [2] Northwestern University [3] Stanford University

Survey of Physics 1



Lewis (in review)

Sample applications

Artifact / Frame of context	i. Tools	ii. Practices	iii. Norms
a. Individ'l	Representation Analogy PhET	Learning by teaching	CLASS-Student attitudes and beliefs (ABs)
b. Course	Studies of Sims, Use of Reps and Anal	Course Practices Clicker Use	Secondary adaptation of eforms
c. Depart'l	Faculty us based materials	CU STOMP	ce of dept'l norms

Creating & Studying New Classroom Models

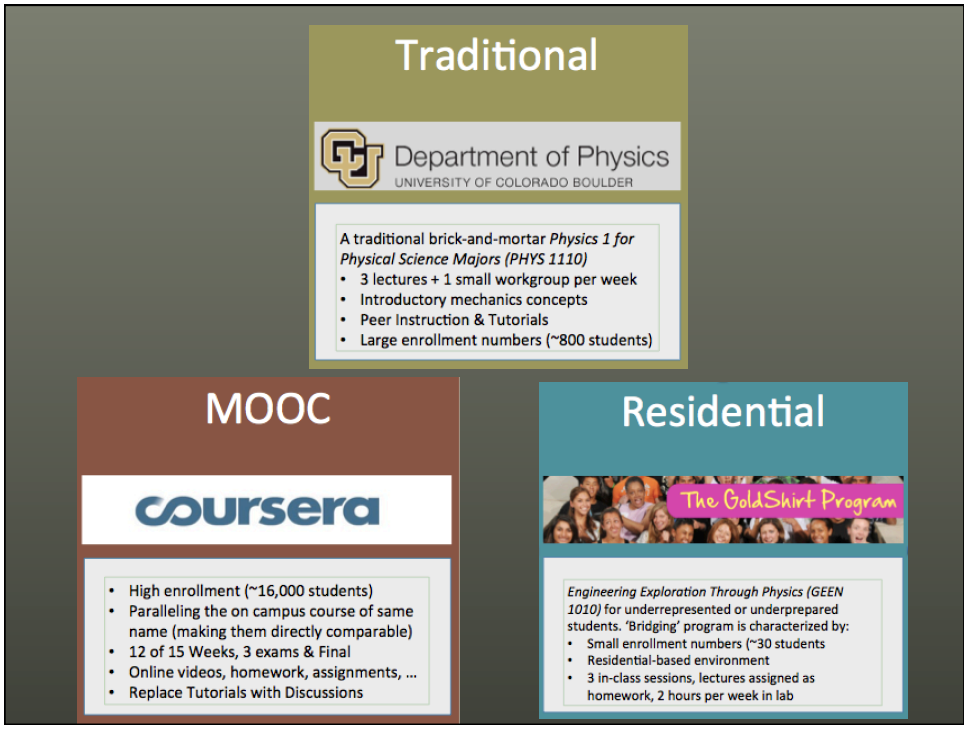
With M. Dubson, D. Lieberman, J. Olsen, E. Johnsen

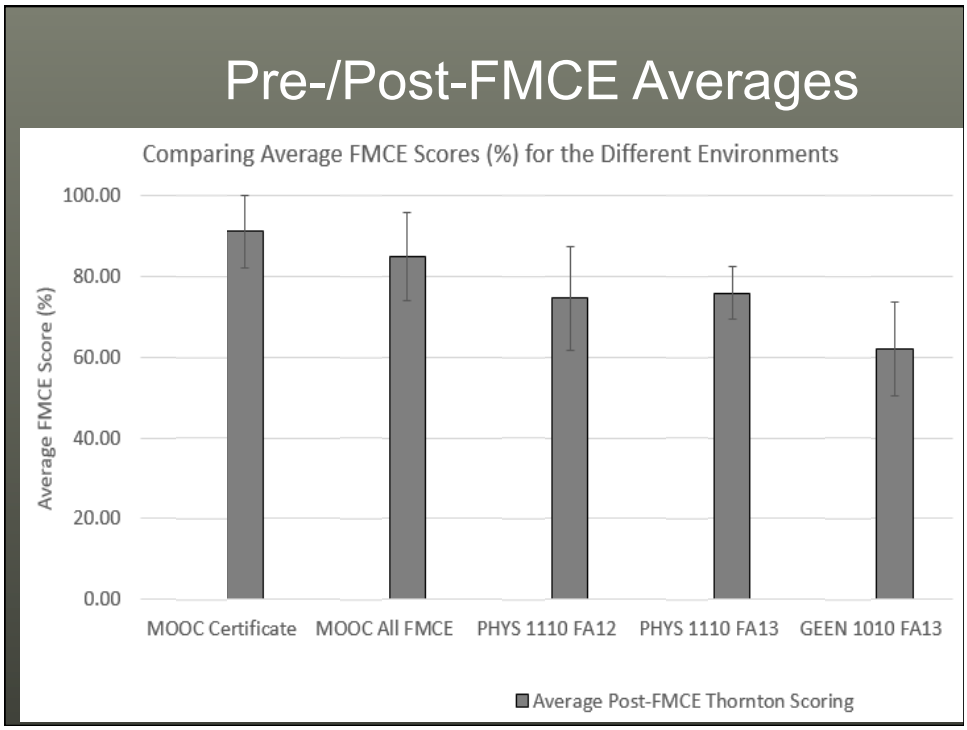
NSF 0448176, CAREER: Physics Education and Contexts of Student Learning.

Affordances of MOOCs and humans:

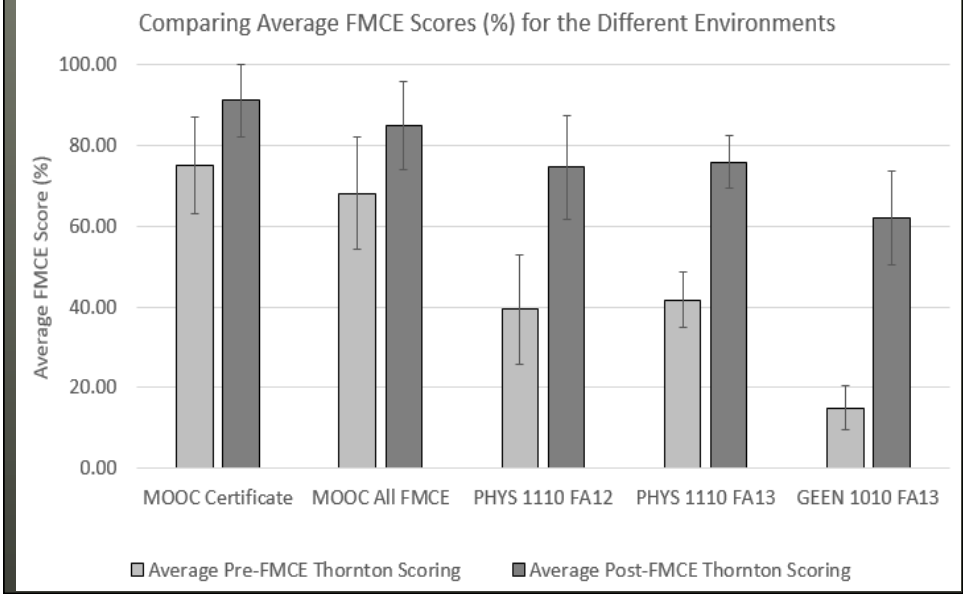
A study comparing in-person and MOOC instruction in Physics 1

Noah Finkelstein, Michael Dubson, David Lieberman,
Katherine Goodman, Edmond Johnsen, and Jack Olsen


Traditional
Department of Physics
UNIVERSITY OF COLORADO BOULDER
A traditional brick-and-mortar *Physics 1 for Physical Science Majors (PHYS 1110)*
• 3 lectures + 1 small workgroup per week
• Introductory mechanics concepts
• Peer Instruction & Tutorials
• Large enrollment numbers (~800 students)
MOOC
coursera
• High enrollment (~16,000 students)
• Paralleling the on campus course of same name (making them directly comparable)
• 12 of 15 Weeks, 3 exams & Final
• Online videos, homework, assignments, ...
• Replace Tutorials with Discussions
Residential
The GoldShirt Program
Engineering Exploration Through Physics (GEEN 1010) for underrepresented or underprepared students. 'Bridging' program is characterized by:
• Small enrollment numbers (~30 students
• Residential-based environment
• 3 in-class sessions, lectures assigned as homework, 2 hours per week in lab

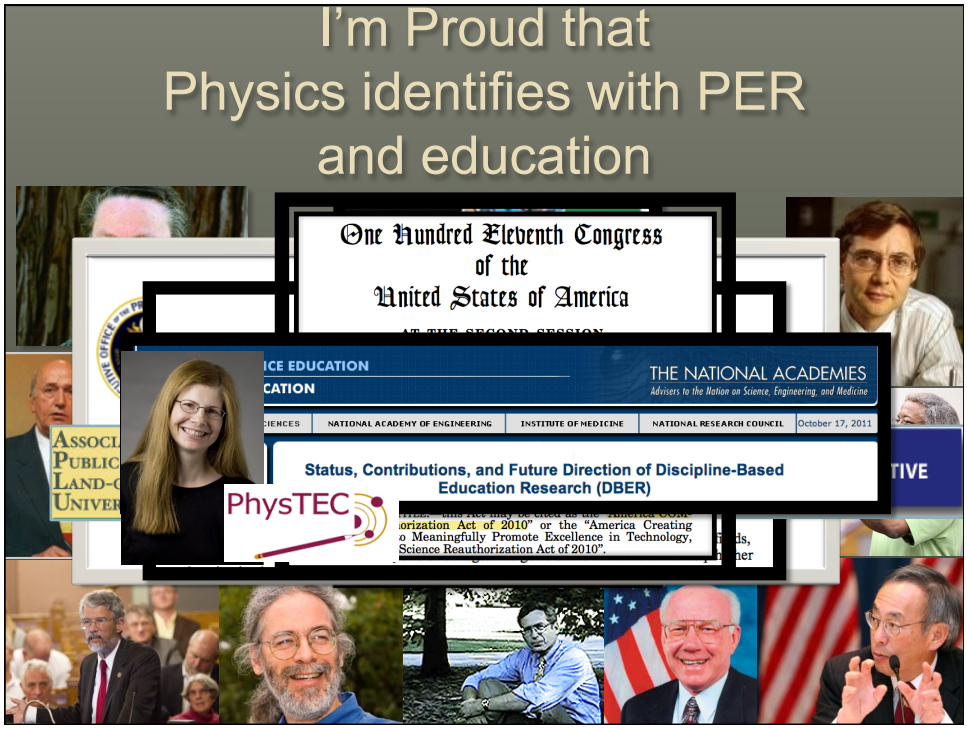

Pre-/Post-FMCE Averages
Comparing Average FMCE Scores (%) for the Different Environments
Average FMCE Score (%)
100.00
80.00
60.00
40.00
20.00
0.00
MOOC Certificate
MOOC All FMCE
PHYS 1110 FA12
PHYS 1110 FA13
GEEN 1010 FA13
Average Post-FMCE Thornton Scoring

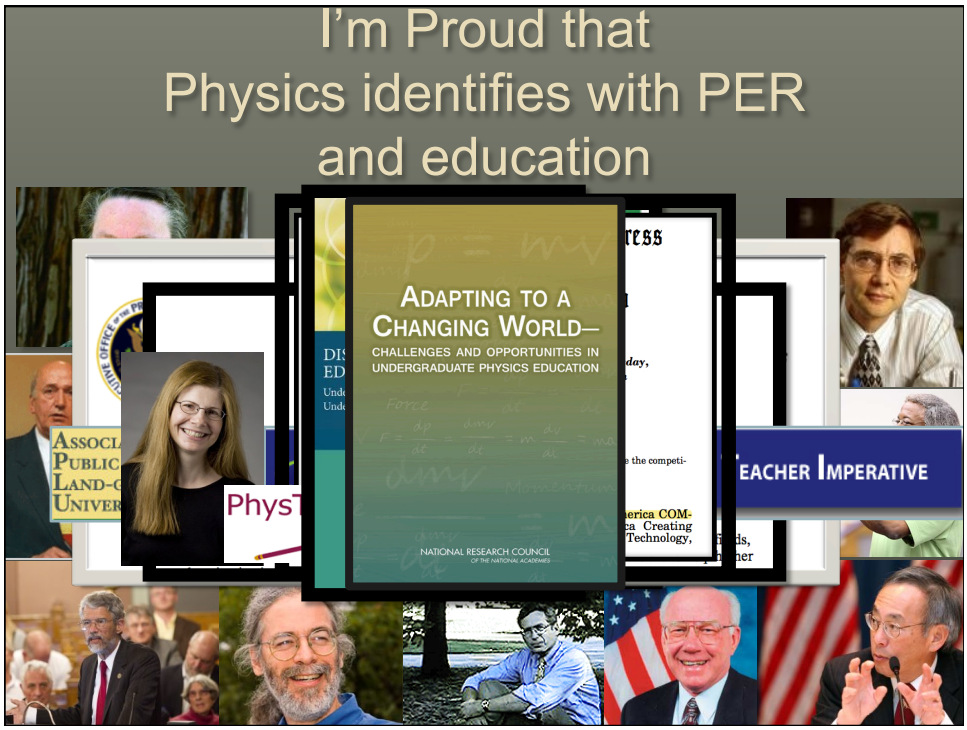
Pre-/Post-FMCE Averages



We know a great deal about:

- Student reasoning in STEM
- Student practices
- Faculty use of tools practices and norms
- Course tools, practices, norms
- Departmental tools, practices, norms
- Institutional tools, practices, norms


I'm Proud that
Physics identifies with PER
and education
One Hundred Eleventh Congress
of the
United States of America
THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE
NATIONAL RESEARCH COUNCIL
October 17, 2011
Status, Contributions, and Future Direction of Discipline-Based Education Research (DBER)
PhysTEC


I'm Proud that
Physics identifies with PER
and education
ADAPTING TO A CHANGING WORLD—
CHALLENGES AND OPPORTUNITIES IN UNDERGRADUATE PHYSICS EDUCATION
NATIONAL RESEARCH COUNCIL
EACHER IMPERATIVE

We are the ones involved where it matters most

We are the ones involved where it matters most


Fin
Much more at: per.colorado.edu