PRACTICES, TOOLS, AND EVIDENCE FOR IMPROVING LARGE INTRODUCTORY SCIENCE AND MATH COURSES

Kick-off Retreat: IC2 PROJECT

September 13, 2017

Noah Finkelstein
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PER @ CU-Boulder

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Center for STEM Learning

UNIVERSITY OF COLORADO **BOULDER**

Gene Glass
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Ian Her Many Horses
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Kelly Lancaster
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Kim Trenbath
Krista Marshall
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LaRuth McAfee
Laura Border
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Laurie Langdon

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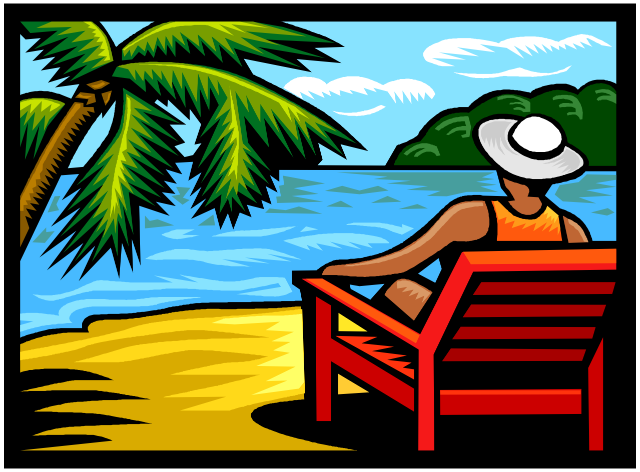
Stephanie Mollborn
Stephanie Rivale
Stephen Butler
Steve Iona
Steve Pollock
Susan Hendrickson
Teresa Foley
Tiffany Ito
Travis Lund
Trish Loeblein
Tyler Schelpat
Ulaff (Benjamin
Uma Swamy
Valerie Otero
Valerie Williams
Victoria Hand
Virginia Ferguson
Wahab Baouchi

Discipline
physics pedagogy astronomy
biology mathematics geology
chemistry engineering
Based
Education
Research
This week:
Porter B121-Tuesday, 3PM
University of Colorado, Boulder

Why Education?

Individual Empowerment



Societal Empowerment

Workforce / Economic Development

Education is by far the biggest and the most hopeful of the Nation's enterprises. Long ago our people recognized that education for all is not only democracy's obligation but its necessity. Education is the foundation of democratic liberties. Without an educated citizenry alert to preserve and extend freedom, it would not long endure.

\- President Truman's Commission on Higher Education for Democracy (1947)
[with the advent of the Cold War]

Inspired by NSB, Sense of Board, 2016

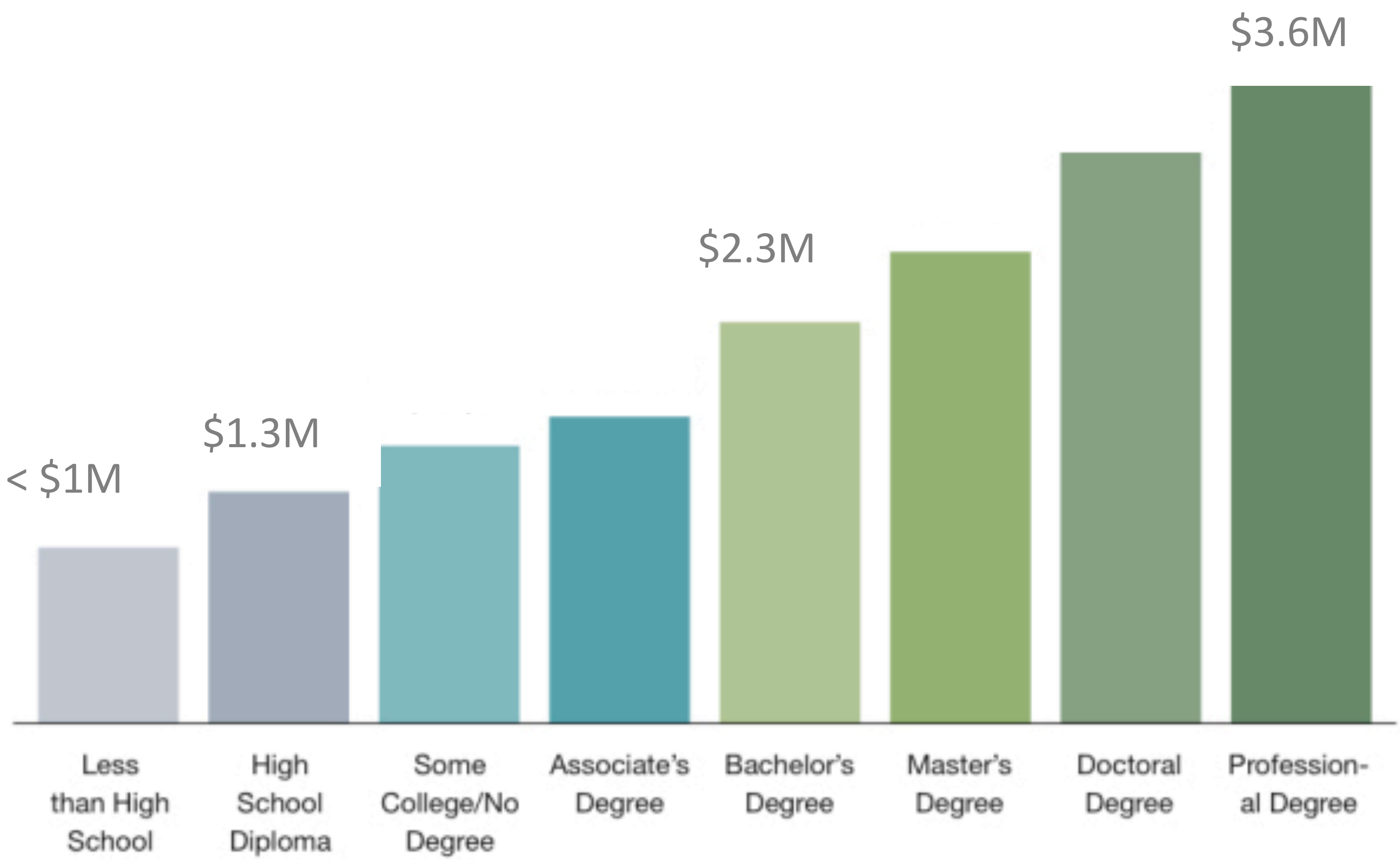
a changing landscape

we know more than ever
about
Education

educational value

personal outcomes of education

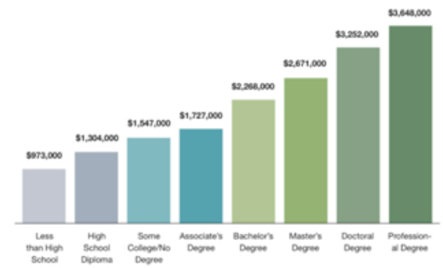
- More income

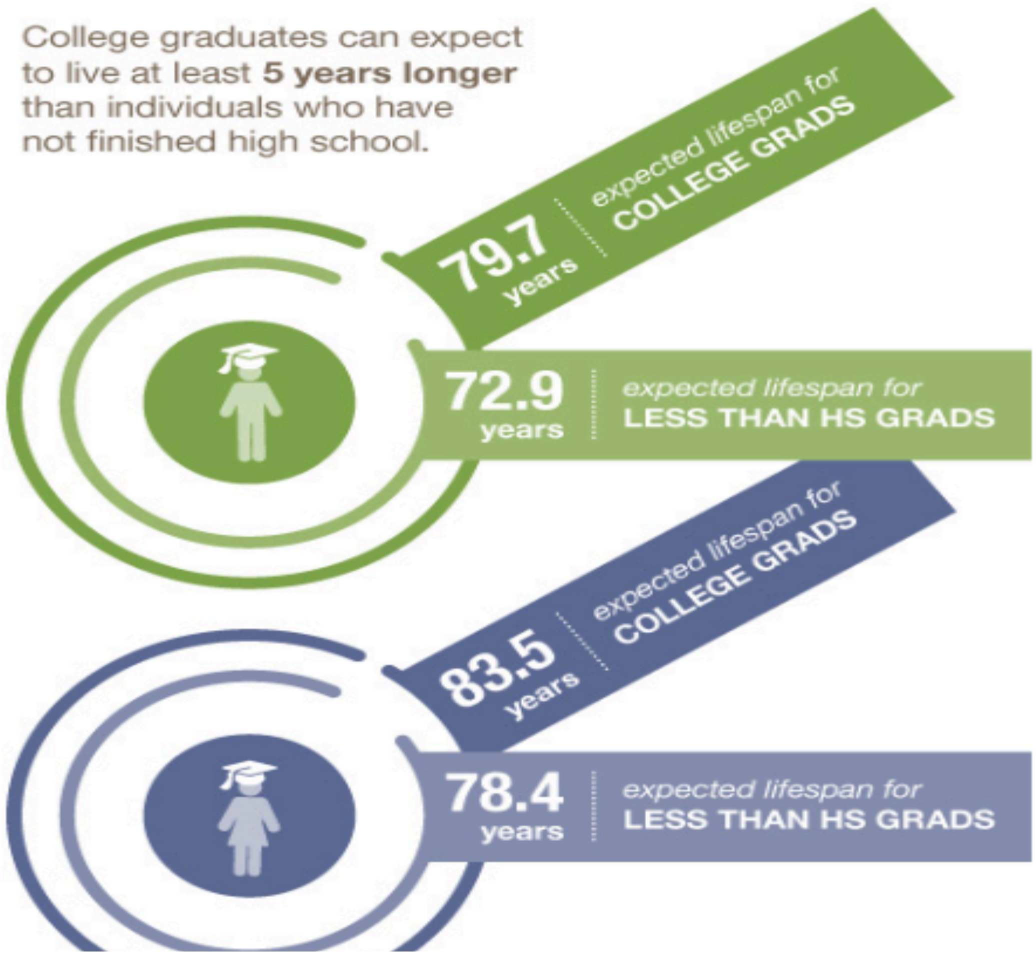


Center for Workforce & Education, 2011

personal outcomes of education

- More income
- A longer life

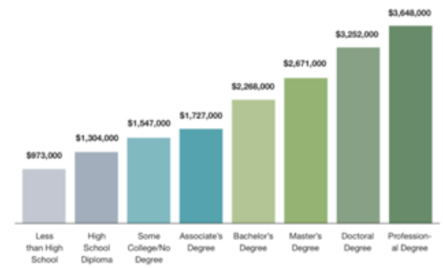


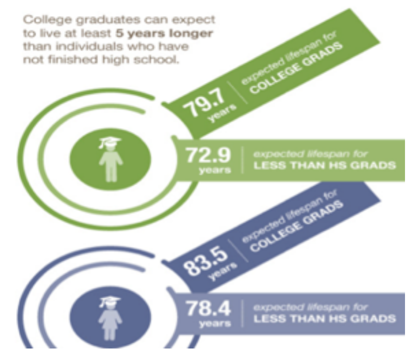


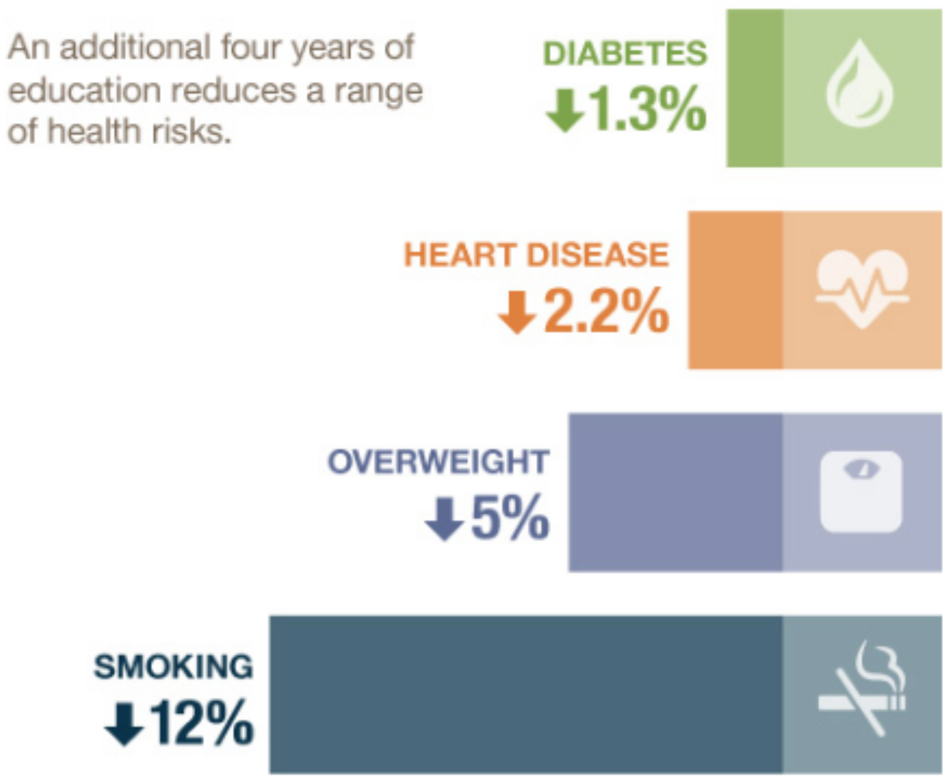
RW Johnson Foundation, 2012

personal outcomes of education

- More income
- A longer life
- A healthier life



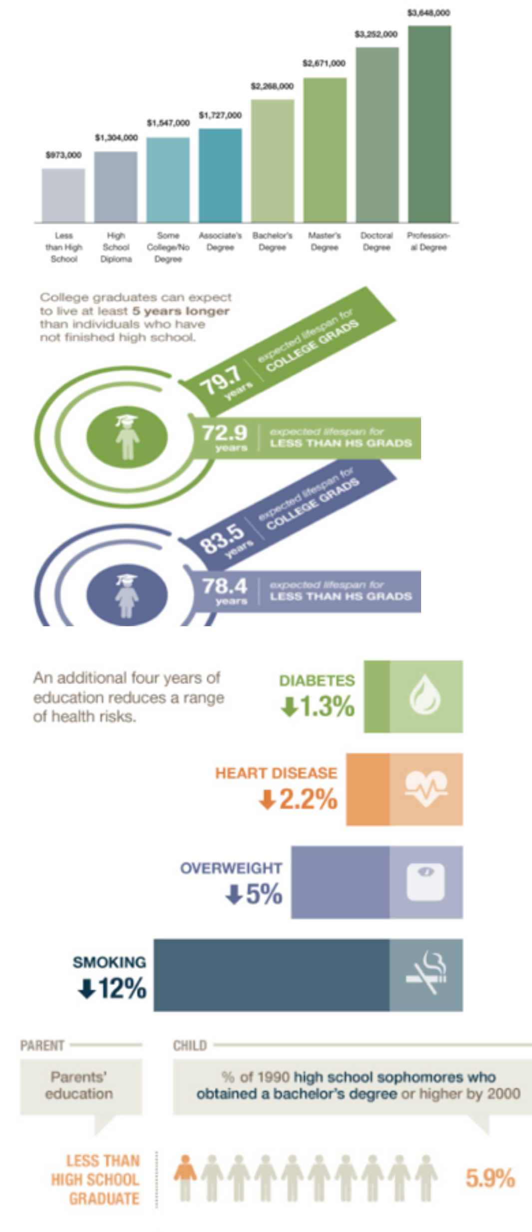




RW Johnson Foundation, 2012

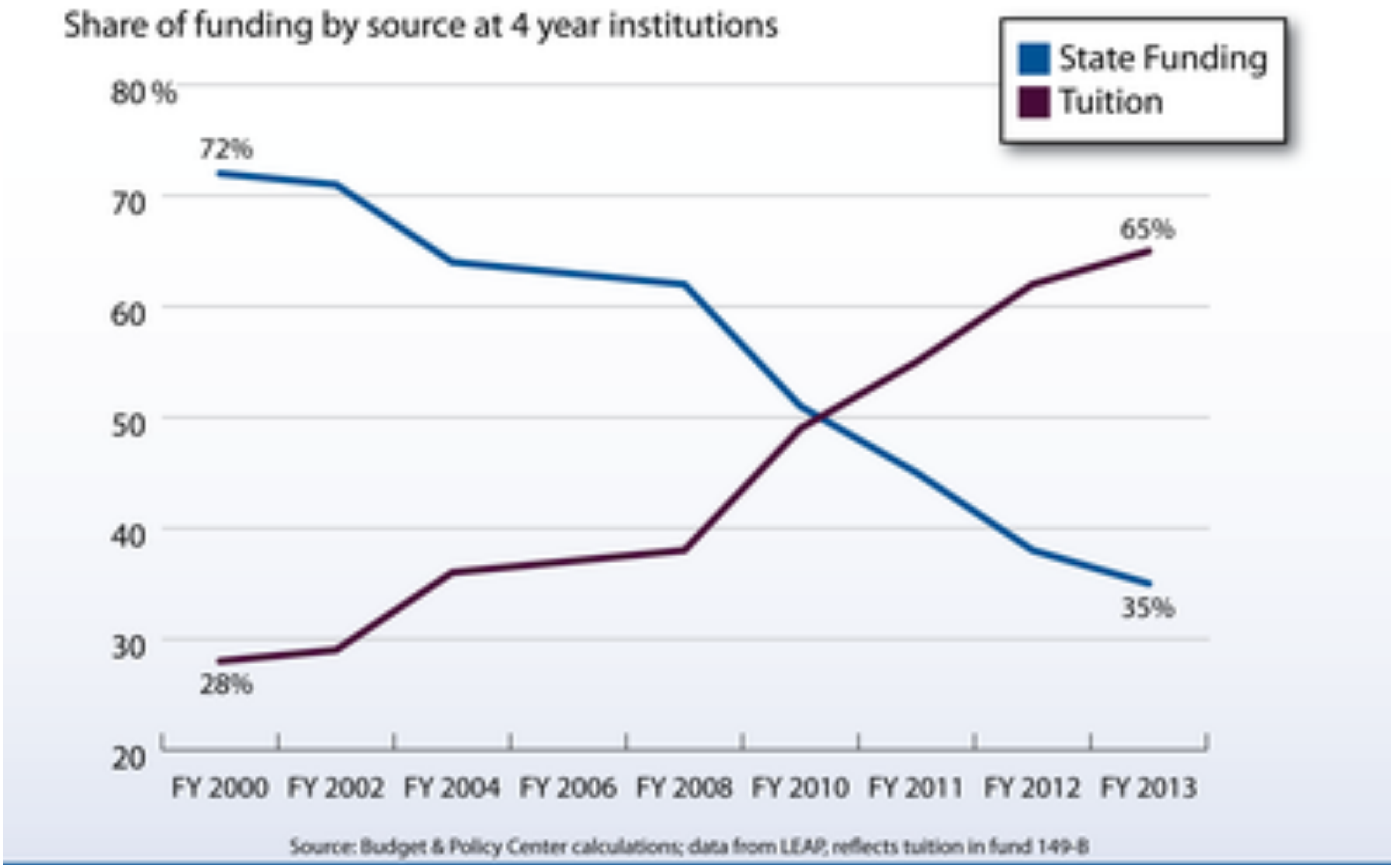
personal outcomes of education

- More income
- A longer life
- A healthier life
- More socially engaged
- Better life for kids



funding

State Funding vs. Tuition



public will

Don't Buy The Hype, College Education Is Not An Investment

+ Comment Now   + Follow Comments

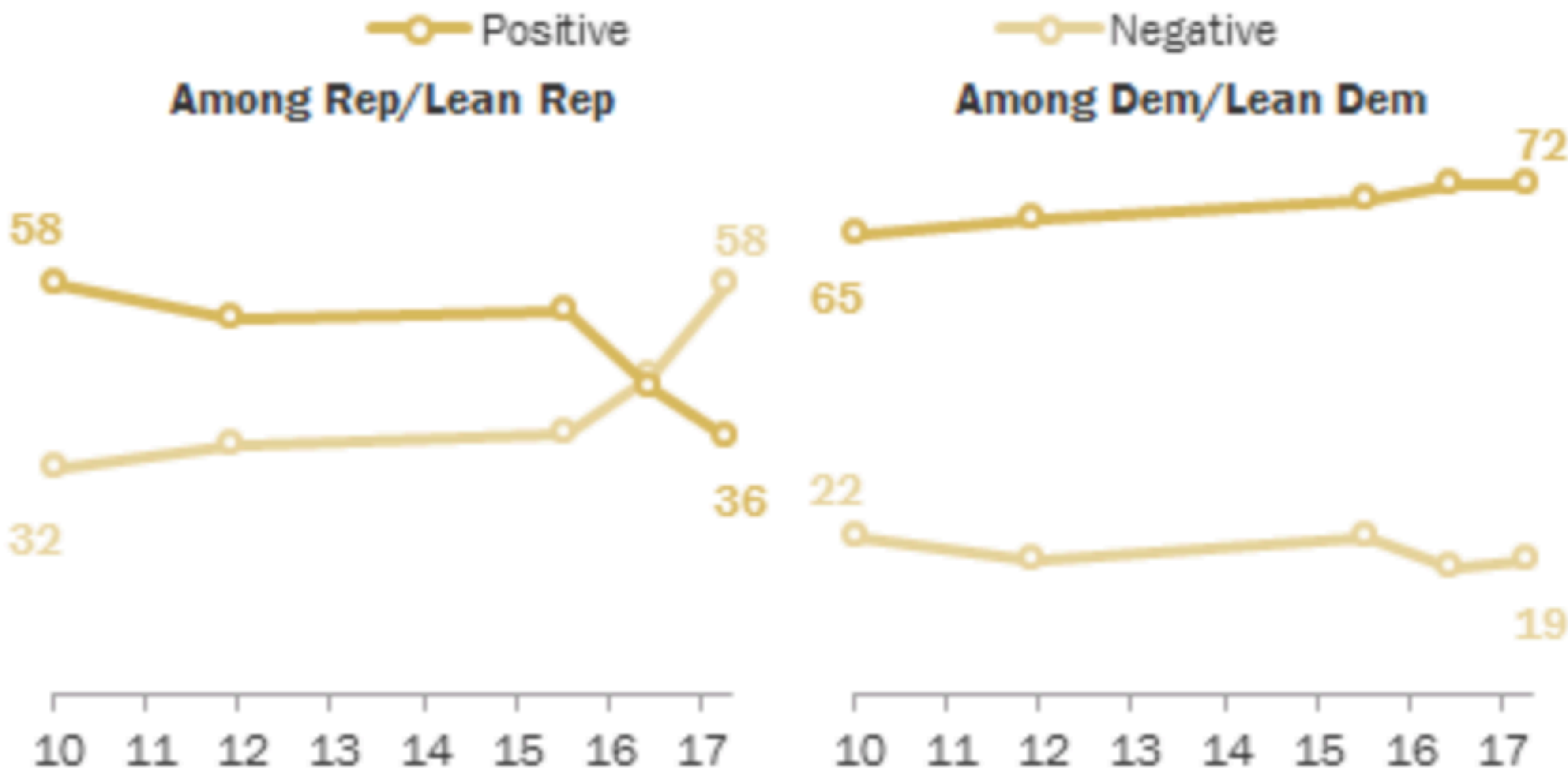
By George Leef

Hardly a day goes by without the publication of articles on the plight of recent college graduates. Large numbers are either unemployed or employed in jobs that don't call for any academic preparation. Many are struggling with the burden of their college loans.

(Photo credit: 401(K) 2013)

In

*% who say **colleges and universities** have a ___ effect on the way things are going in the country*

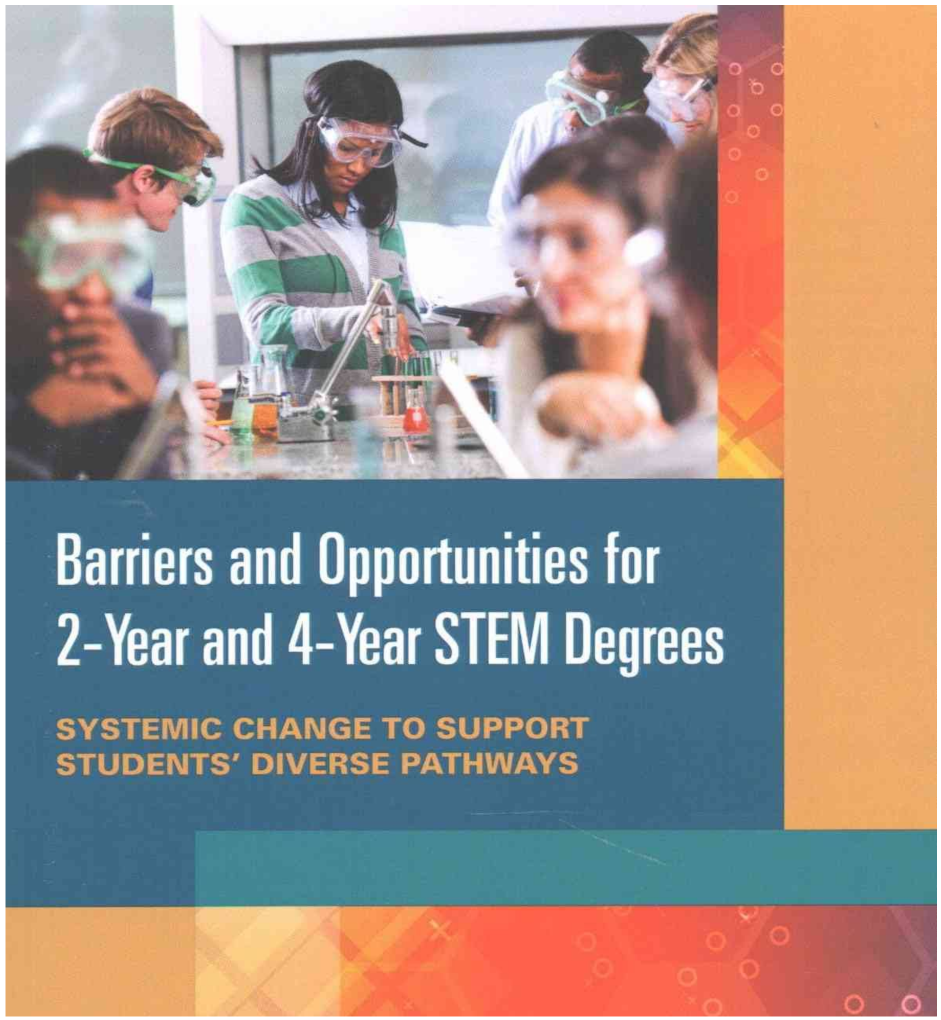


Note: Don't know responses not shown.
Source: Survey conducted June 8-18, 2017.

education for whom?

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

BOARD ON SCIENCE EDUCATION



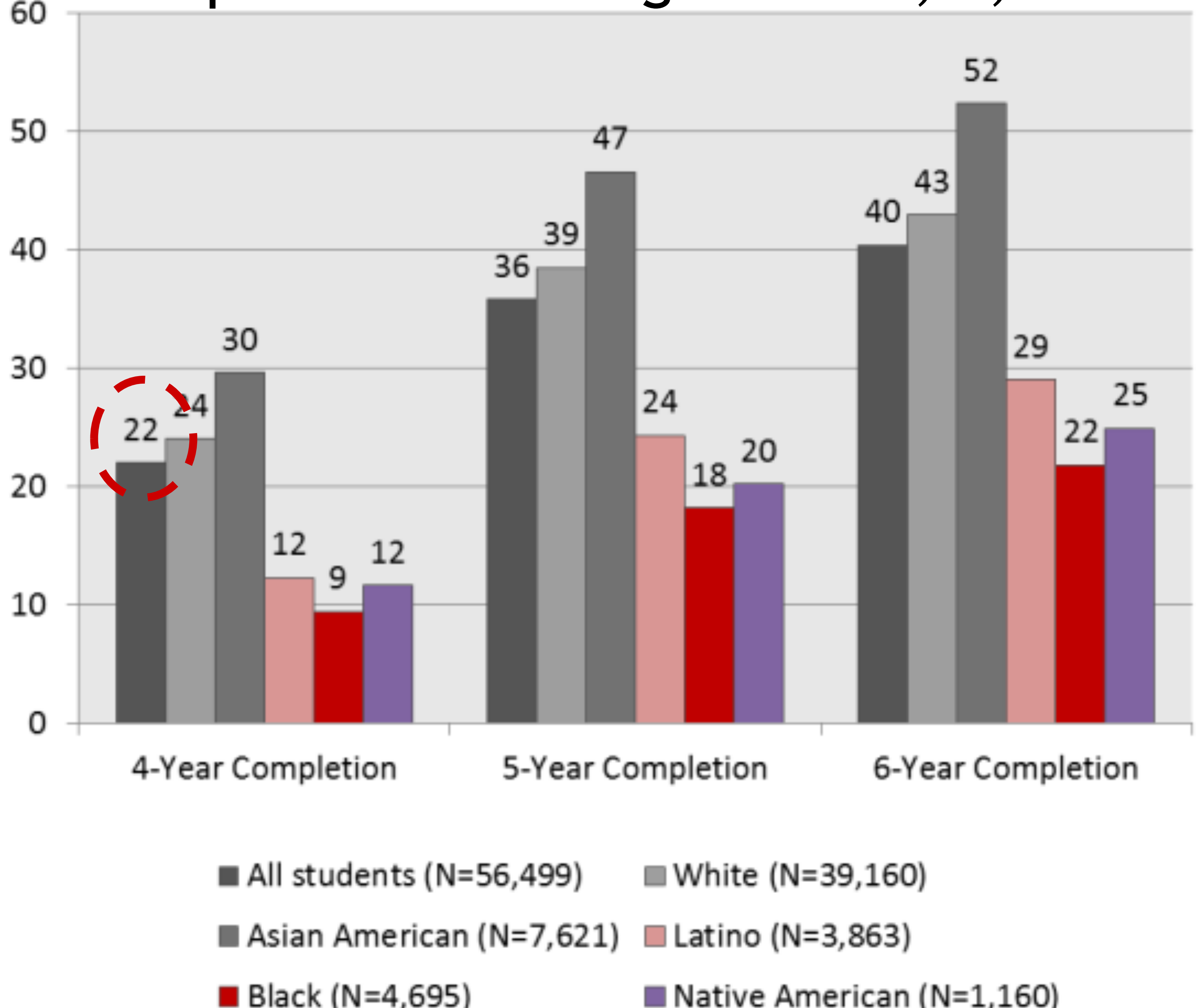
with funding from:
National Science Foundation
S.D. Bechtel Jr. Foundation
Alfred P. Sloan Foundation

Make-up of student body not the same as 25 years ago

Student Characteristics	1987	2012
Aged 25 and Older	37	40
Enrolled in 2-Year Institutions	43	40
Enrolled Part Time	42	50
Minority	20	42
Employed Part-Time	*	40
Employed Full-Time	26	27
Parents	20	26
Single Parent	7	15
Women	54	57

Students more likely to be from minority groups and be single parents.

Cumulative percentage of 2004 STEM aspirants who completed STEM degrees in 4, 5, and 6 years

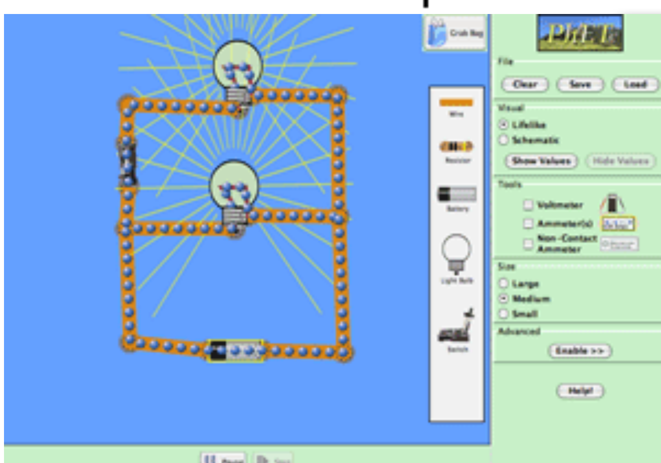


Source: Eagan et al., 2014 (Fig 7)

new models

New Tools

Massive Open Online Course



Established Objectives

AAC&U Member Institutions' Learning Outcomes for All Students

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Knowledge of Human Cultures and the Physical and Natural World

• Humanities	92%
• Sciences	91%
• Social Sciences	90%
• Global/World Cultures	87%
• Mathematics	87%
• Diversity in the United States	73%
• United States History	49%
• Languages Other Than English	42%
• Sustainability	24%

Intellectual and Practical Skills

• Writing skills	99%
• Critical Thinking	95%
• Quantitative Reasoning	91%
• Oral Communication	88%
• Intercultural Skills	79%*
• Information Literacy	76%
• Research skills	65%

Personal and Social Responsibility

• Intercultural Skills	79%*
• Ethical Reasoning	75%
• Civic Engagement	68%

Integrative Learning

• Application of Learning	66%
• Integration of Learning	63%

Employer Priorities for Most Important College Learning Outcomes

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Knowledge of Human Cultures and the Physical and Natural World

• Broad knowledge in the liberal arts and sciences	78% ■
• Knowledge and understanding of democratic institutions and values	87% ■
• Intercultural skills and understanding of societies and cultures outside the US	78% ■

Intellectual and Practical Skills

• Oral communication	85% ◆
• Teamwork skills in diverse groups	83% ◆
• Written communication	82% ◆
• Critical thinking and analytic reasoning	81% ◆
• Complex problem solving	70% ◆
• Information literacy	68% ◆
• Innovation and creativity	65% ◆
• Technological skills	60% ◆
• Quantitative reasoning	56% ◆

Personal and Social Responsibility

• Problem solving in diverse settings	96% ■
• Civic knowledge, skills, and judgment essential for contributing to the community and to our democratic society	86% ■
• Ethical judgment and decision making	81% ◆

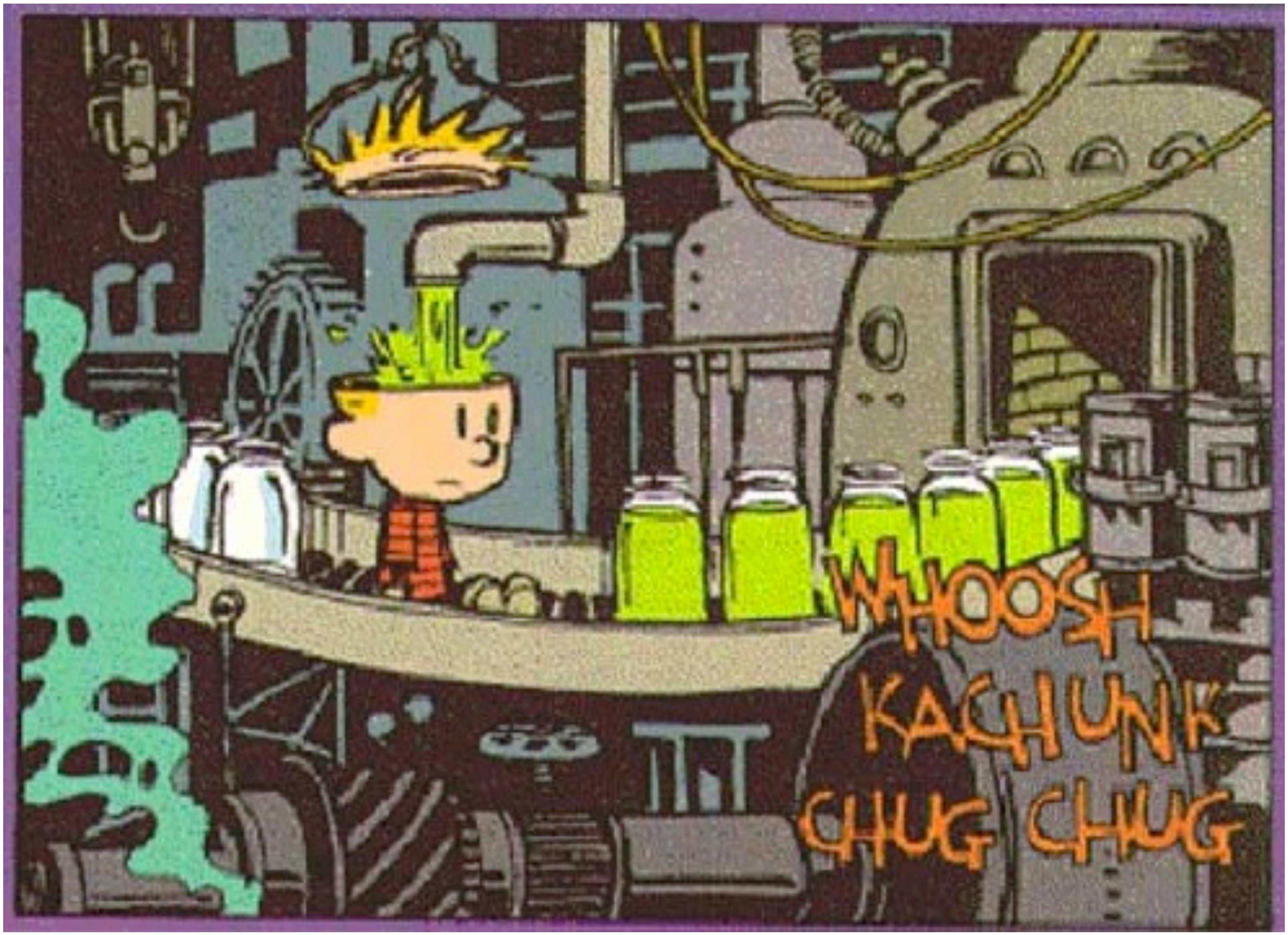
Integrative and Applied Learning

• Applied knowledge in real-world settings	80% ◆

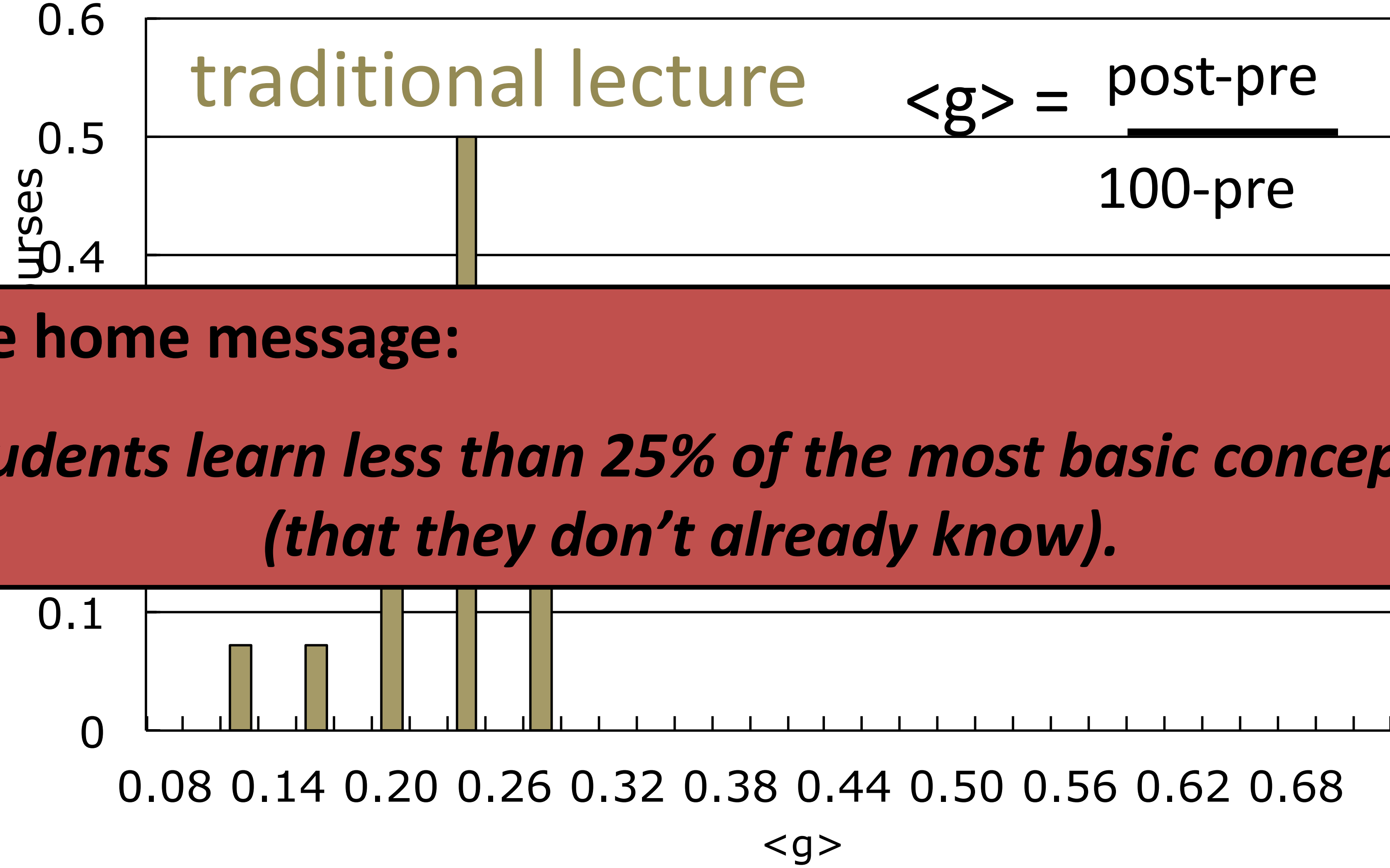
AAC&U 2009 and 2015

(re-) defining education

Prevalent but flawed models…



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).

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

Attitudes and Beliefs*
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%)

Education?

bringing new members into a community
ways of walking, talking and acting like a …

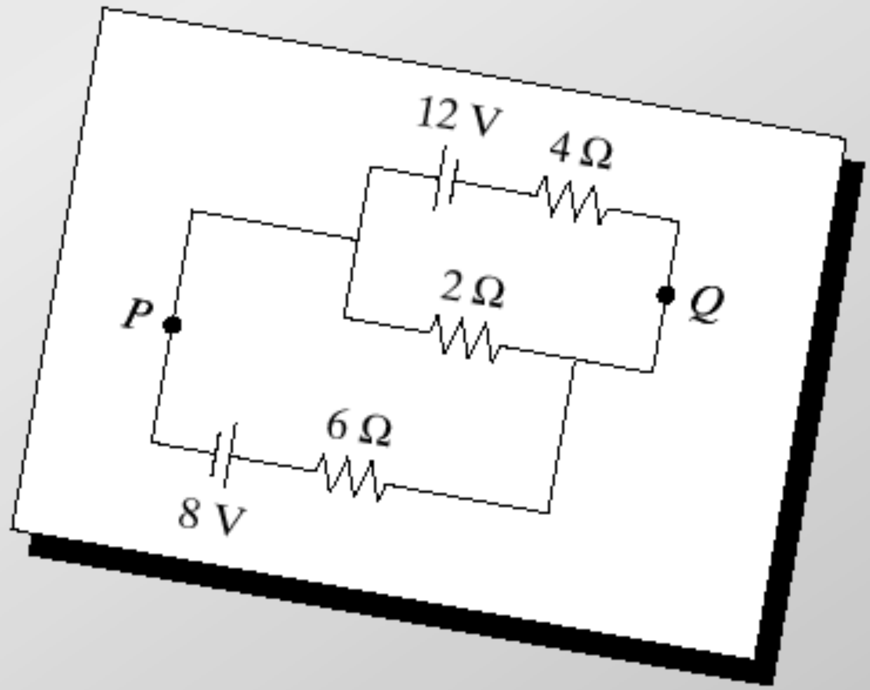
Not: simply the transfer of information

But my students learn . . .

Calculate:

(*a*) current in 2-Ω resistor

(*b*) ...

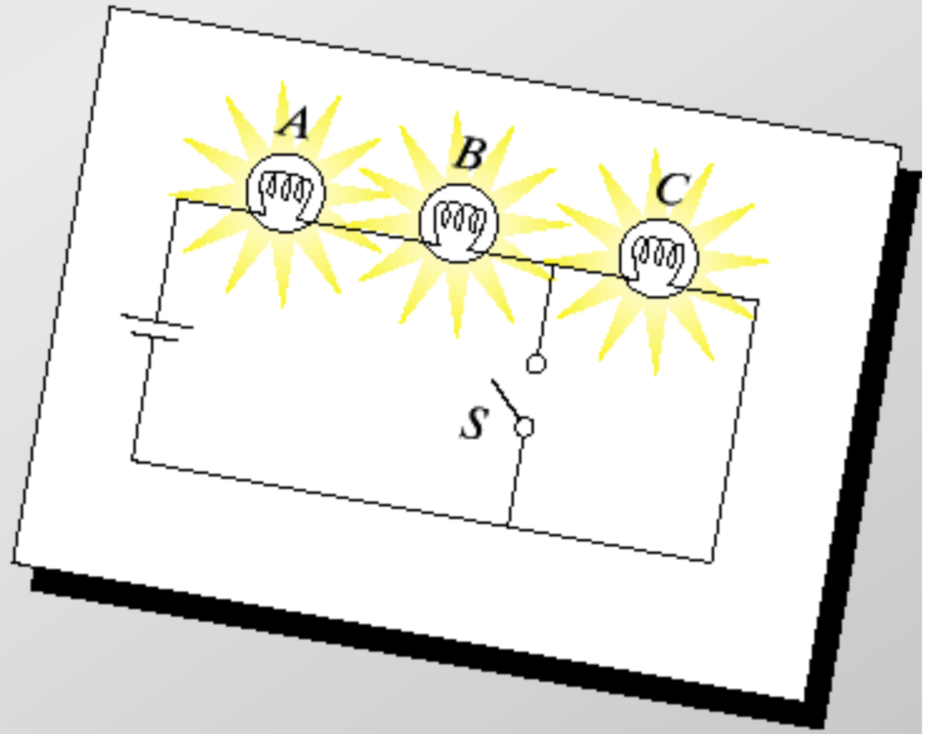


Mazur (1997; 2004)

When *S* is closed, what happens to:

(*a*) intensities of A and B?

(*b*) ...



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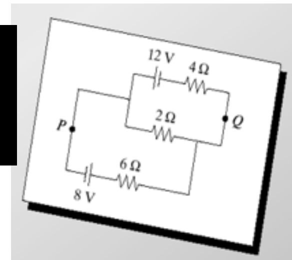

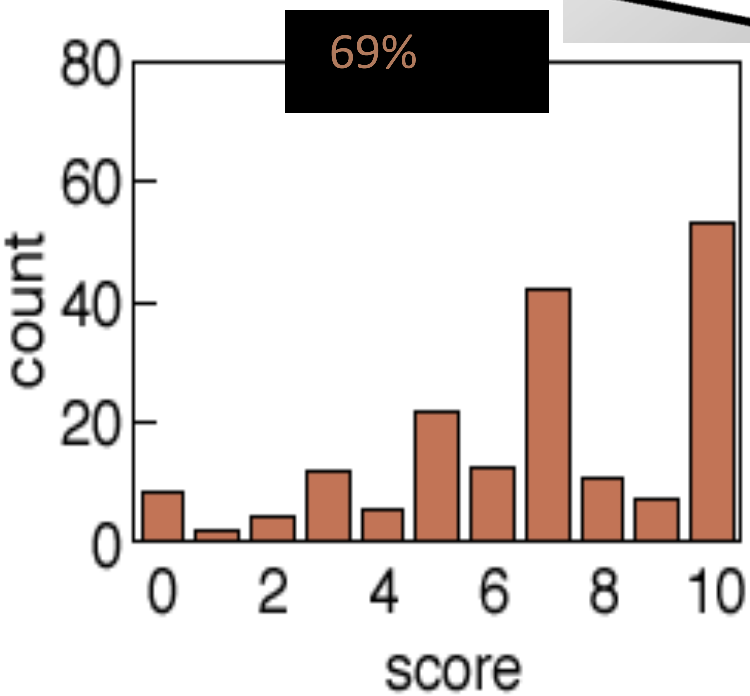

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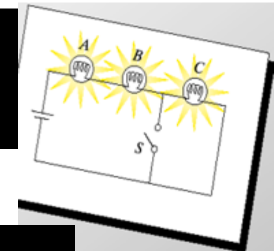
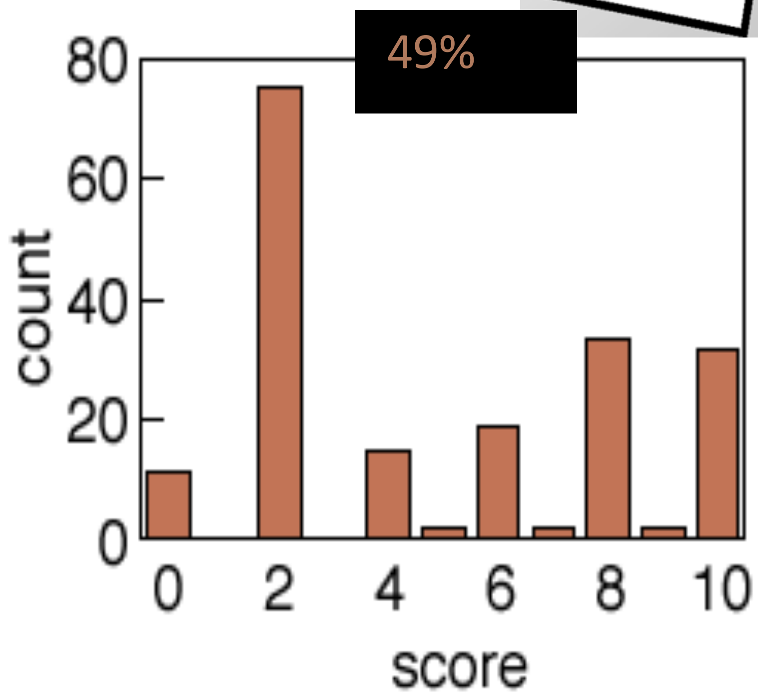
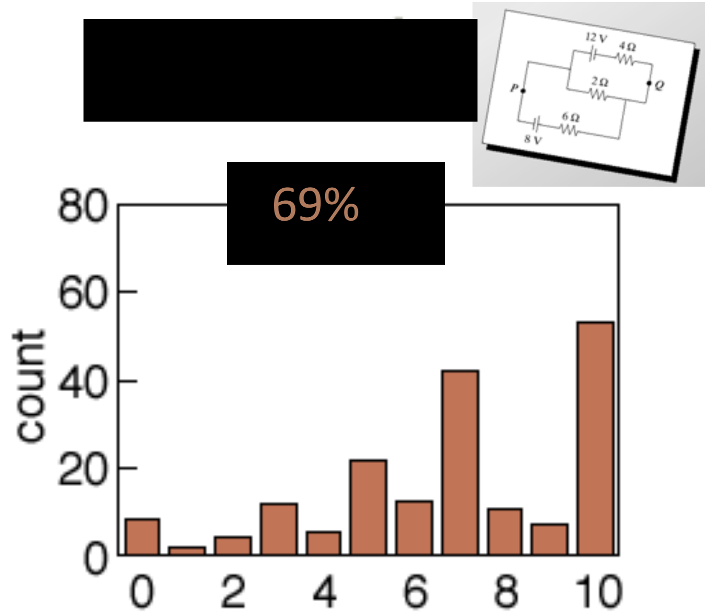
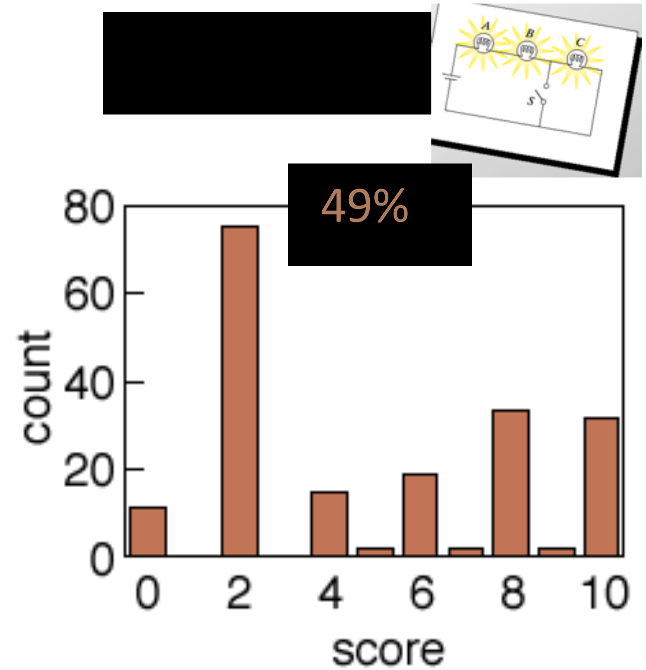
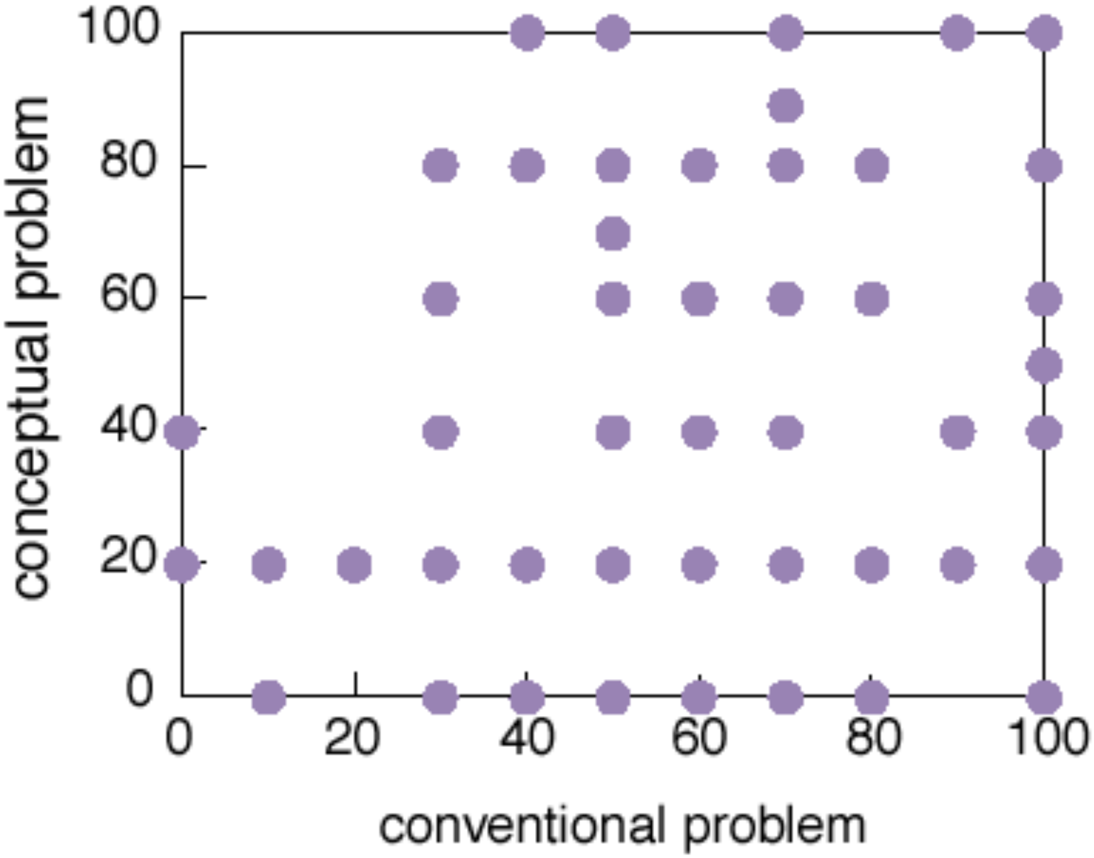





[redacted]
12 V
4 Ω
2 Ω
6 Ω
8 V
P
Q
69%
count
80
60
40
20
0
2
4
6
8
10

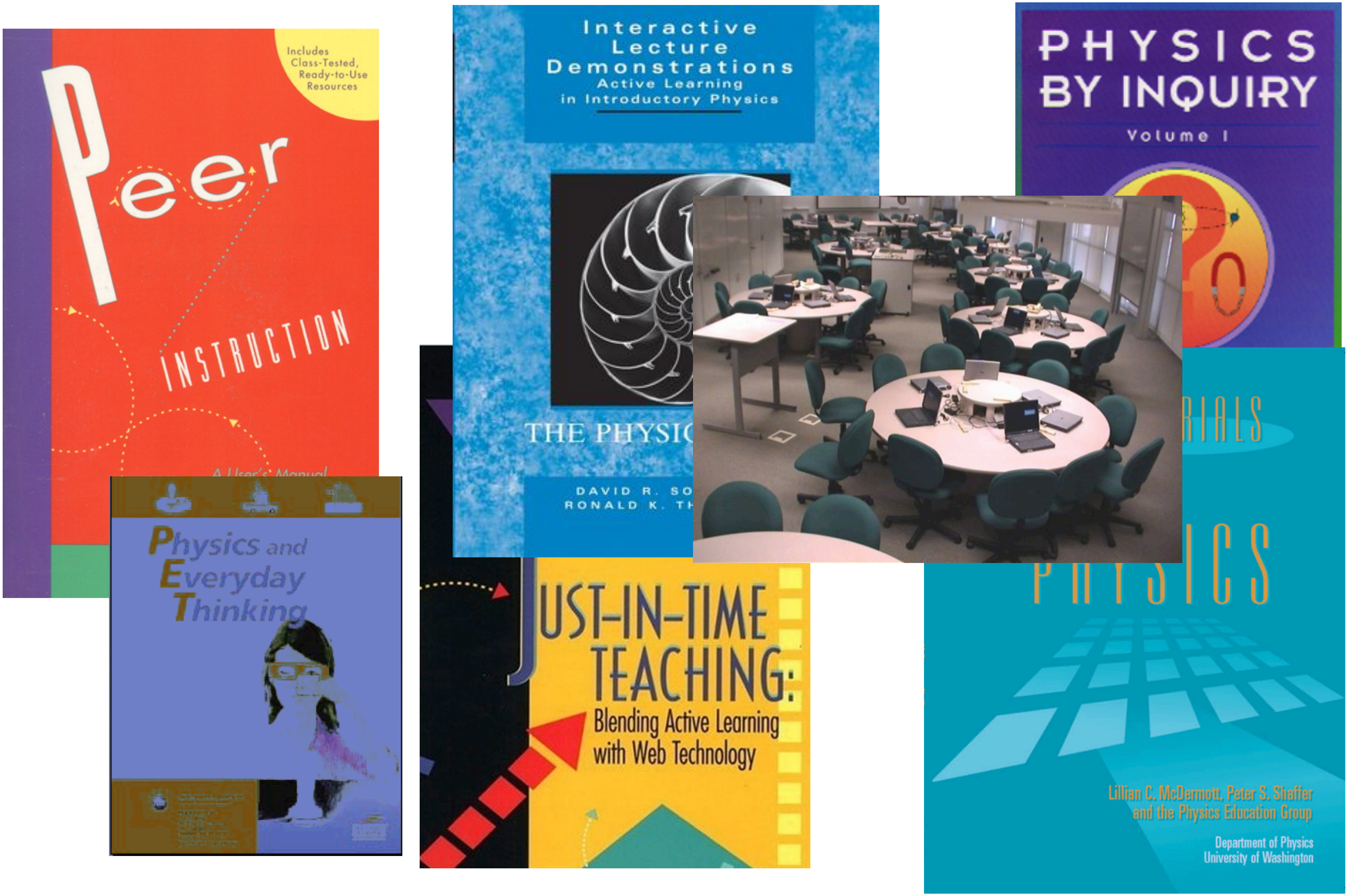

[redacted]
A
B
C
S
49%
count
80
60
40
20
0
2
4
6
8
10
score


conceptual problem
100
80
60
40
20
0
20
40
60
80
100
conventional problem


students debate

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

Many (research-validated) innovations



Proceedings of the National Academy of Sciences of the United States of America PNAS

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

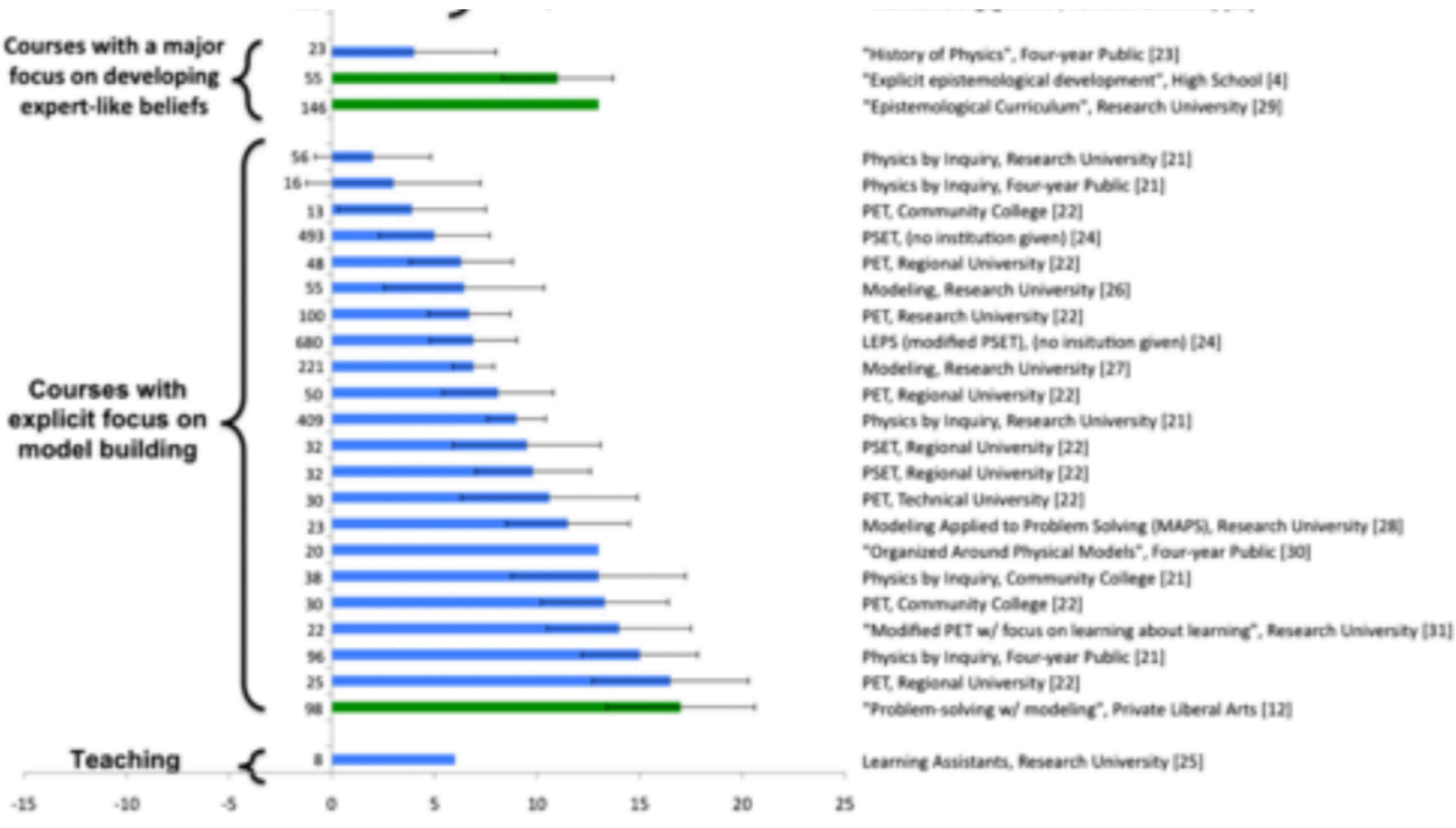
Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

2014

Meta-analysis of 225 studies
Mean effect size 0.5 std. dev.

“If the experiments analyzed here had been conducted as randomized controlled trials of medical interventions, they may have been stopped for benefit”

Beyond Concepts . . .

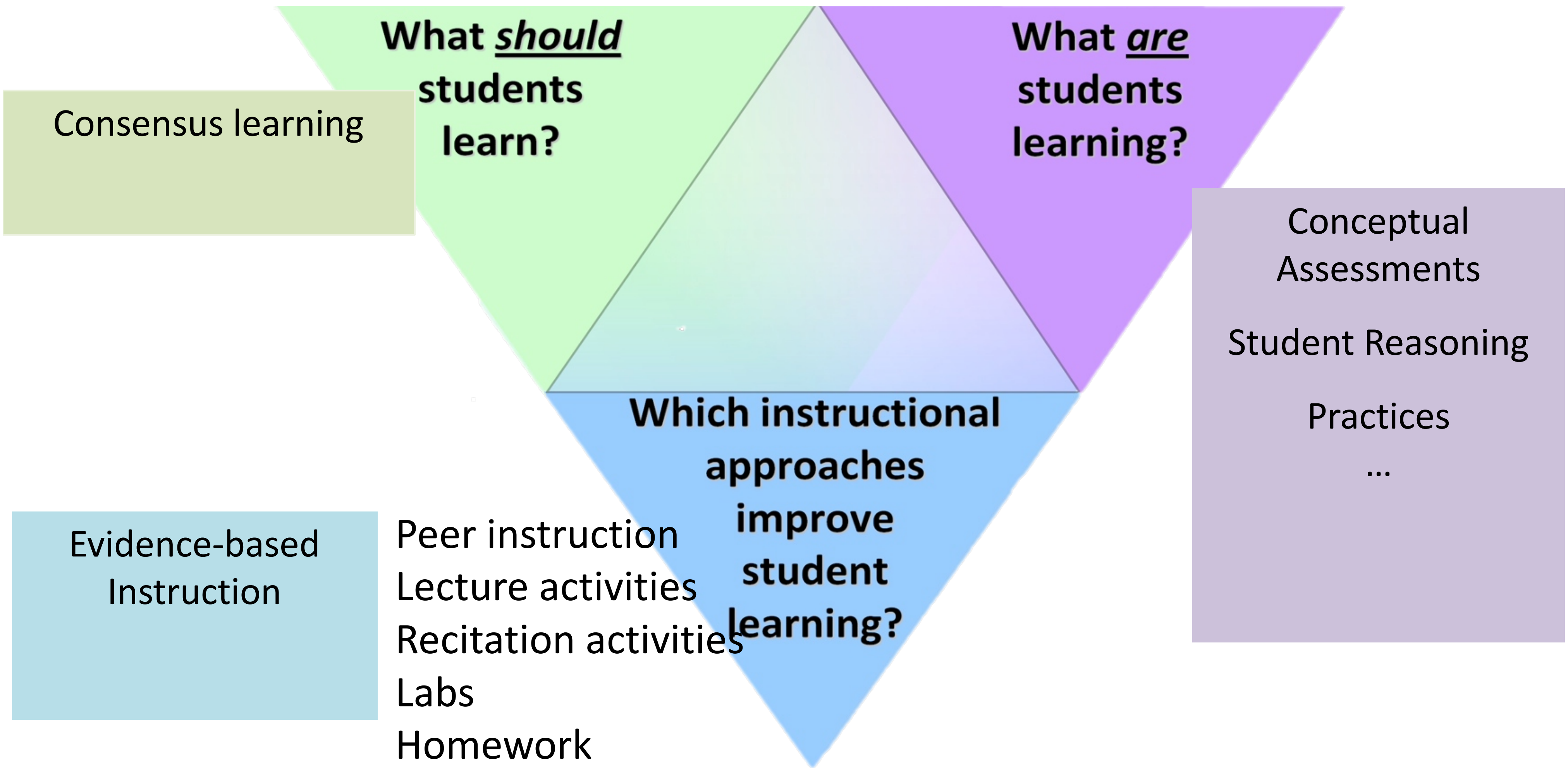


How physics instruction impacts students' beliefs about learning physics: A meta-analysis of 24 studies

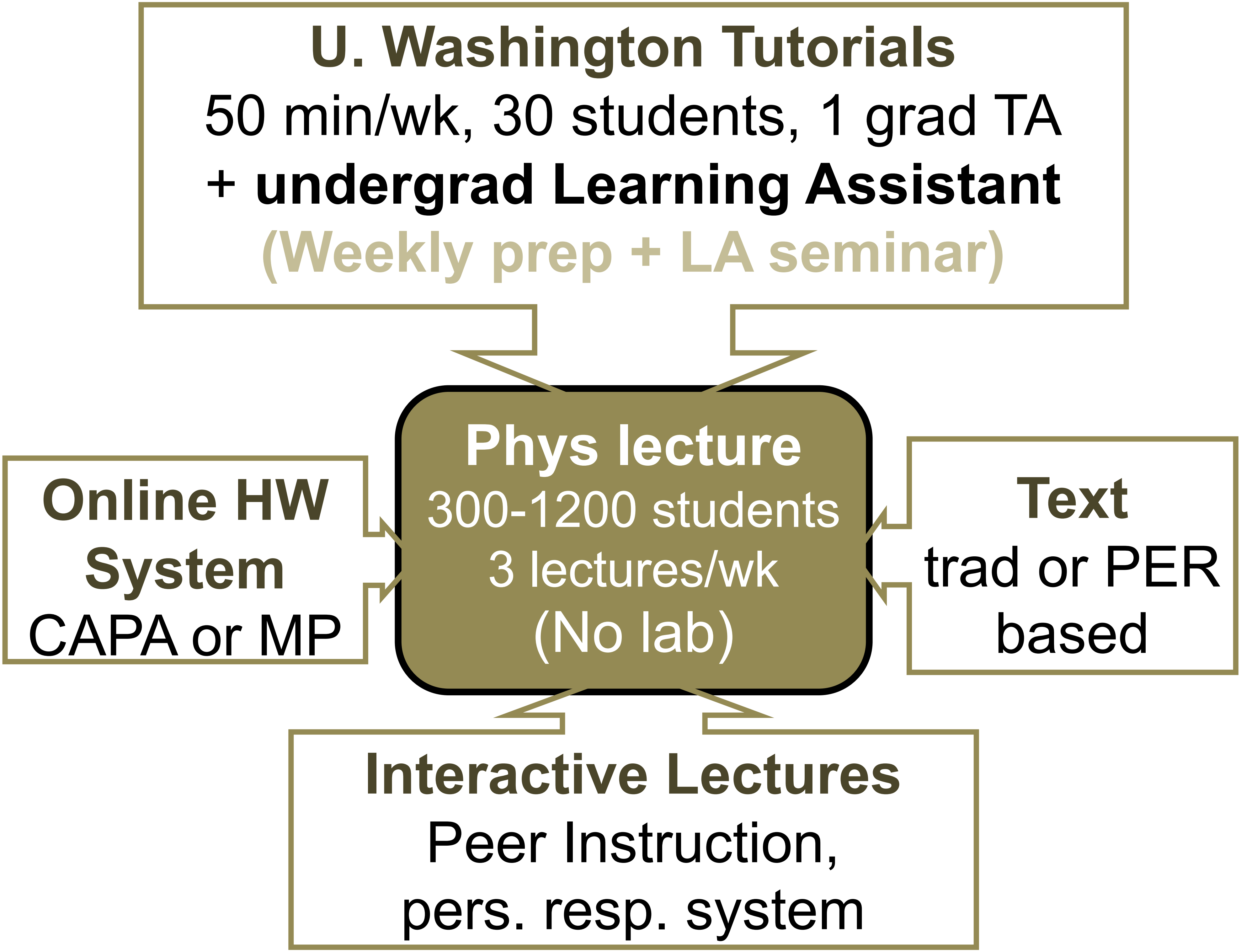
Adrian Madsen, Sarah B. McKagan, and Eleanor C. Sayre
Phys. Rev. ST Phys. Educ. Res. **11**, 010115 – Published 2 June 2015

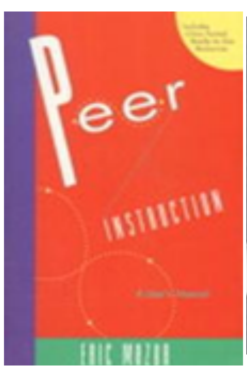
modest reframing of class tools and context

Course transformation using Backwards Design



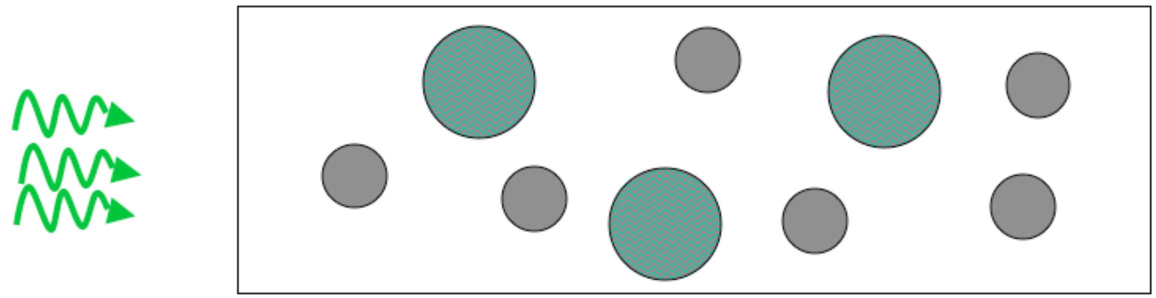
SEI, C. Wieman et al, www.colorado.edu/sei


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

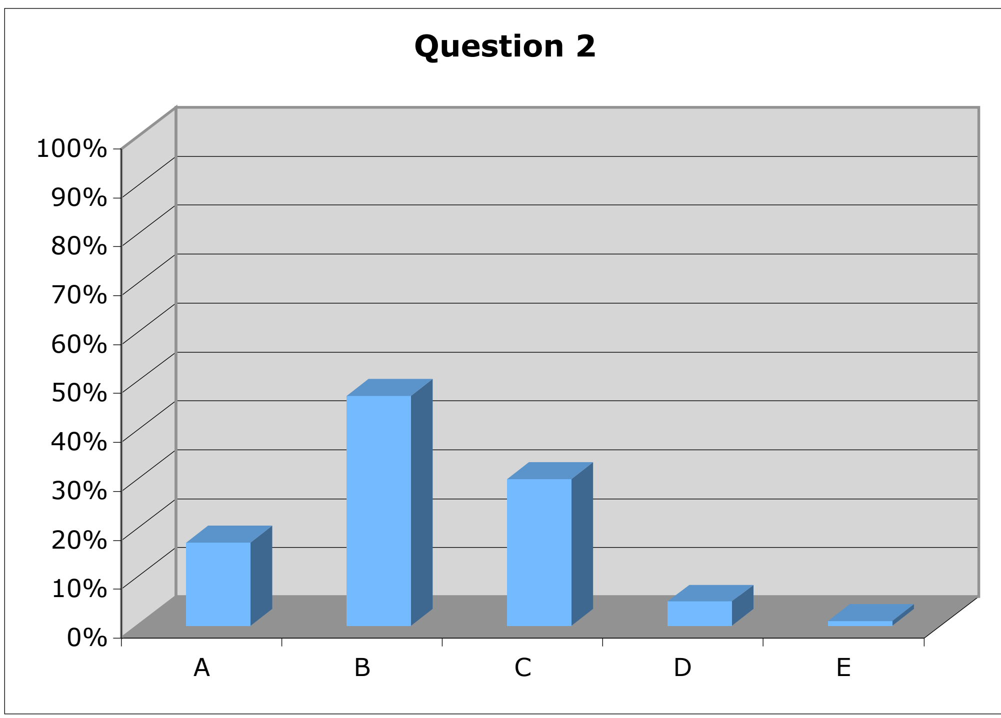

Peer
INSTRUCTION

Personal Response System

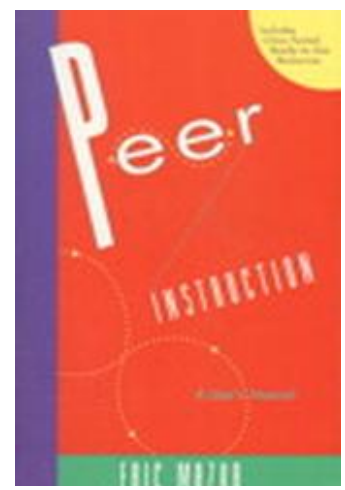
Consider ***this*** glass tube full of atoms, discharge lamp



Expect that on average



s will come out right hand end of tube
ut right
er as go in
ne out.



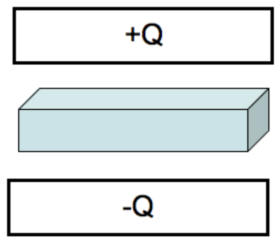
Clicker Questions

- Allowed students to **discuss & debate challenging, high-level ideas**

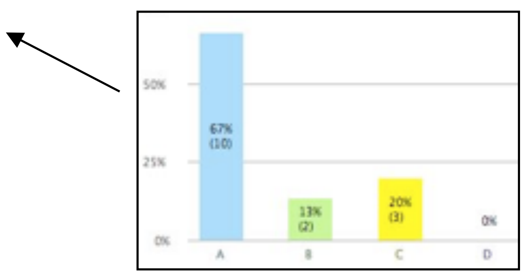
An ideal (large) capacitor has charge Q. A neutral *linear* dielectric is inserted into the gap (with given dielectric constant)

Where is D discontinuous?

i) near the free charges on the plates
ii) near the bound charges on the dielectric surface



A) i only B) ii only C) i and ii ONLY
D) i and ii but also other places E) none of these/other



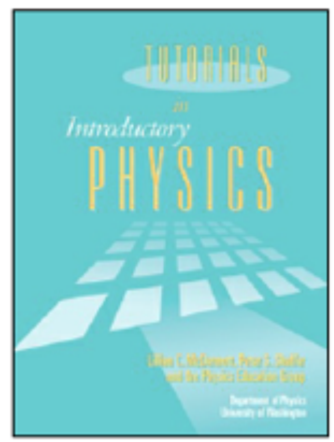
Freely Available Resources:

- Banks of Clicker Questions
  - Upper-level courses
  - Intro-level too
- Clicker Video Guides for Teachers

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

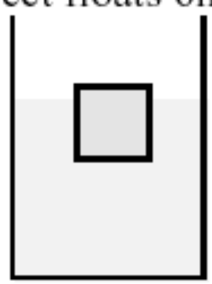
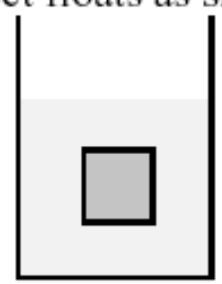
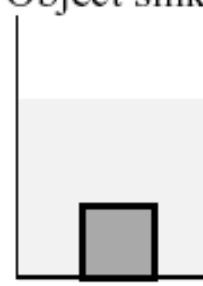
Hands-on, Inquiry-based, Guided, Research-based

Assignment 11M: Name ____________________

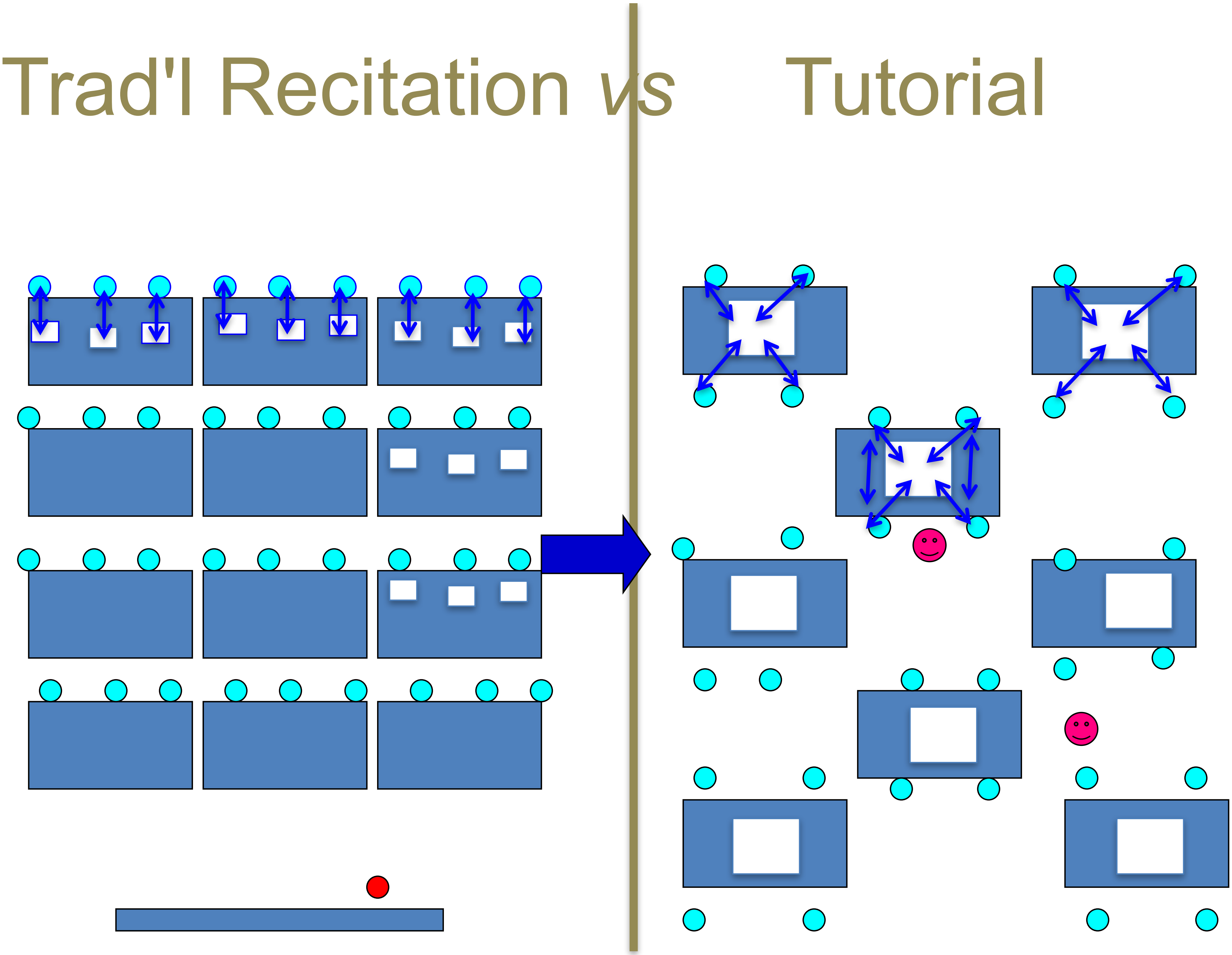
Buoyancy Tutorial section____________________

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 $m_{\text{object}} \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.	Is $m_{\text{object}} \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.	Is $m_{\text{object}} \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.

Trad'l Recitation *vs* Tutorial



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

LA Colorado Learning Assistant Model

University of Colorado Boulder

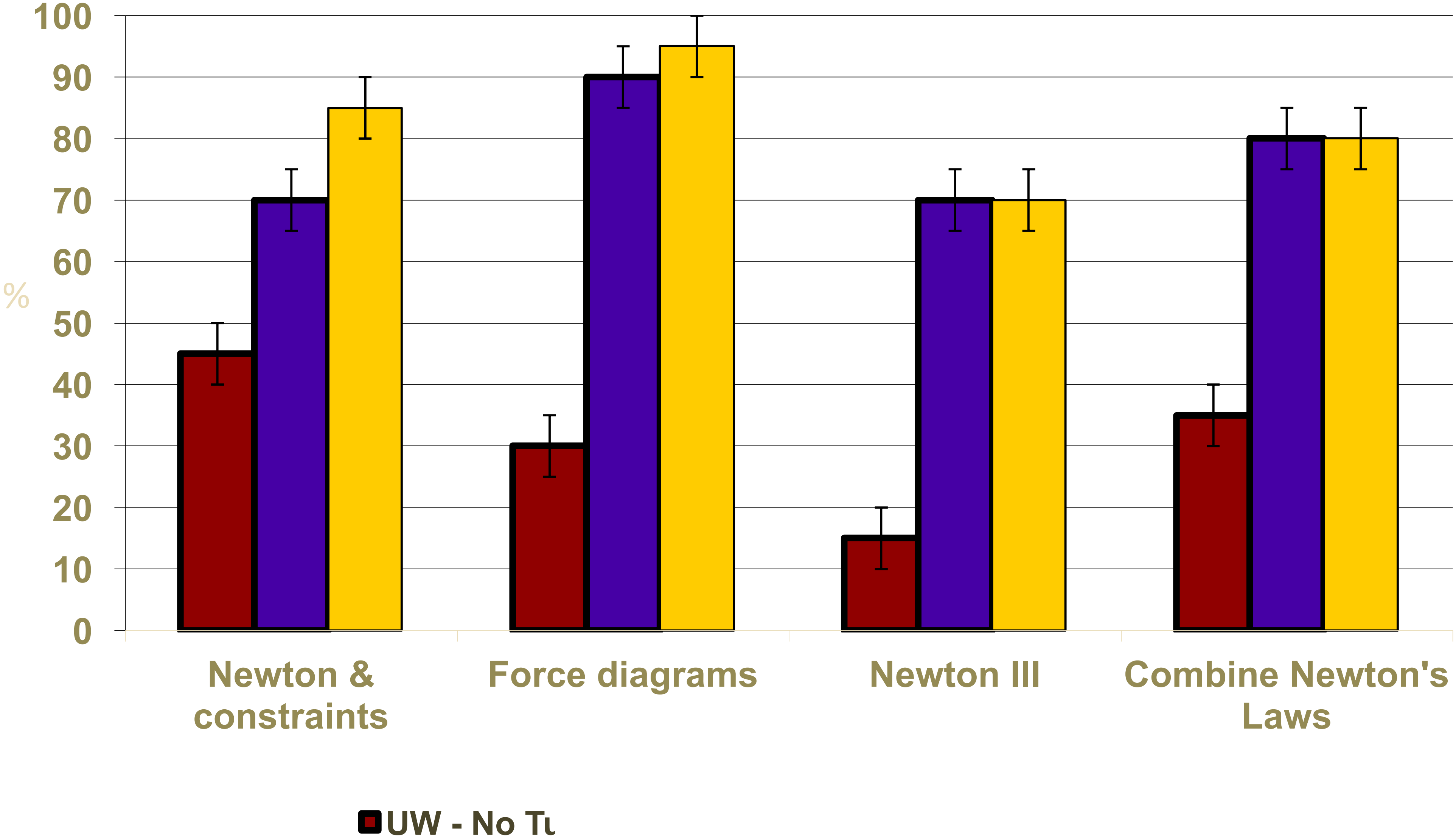
Valerie Otero

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

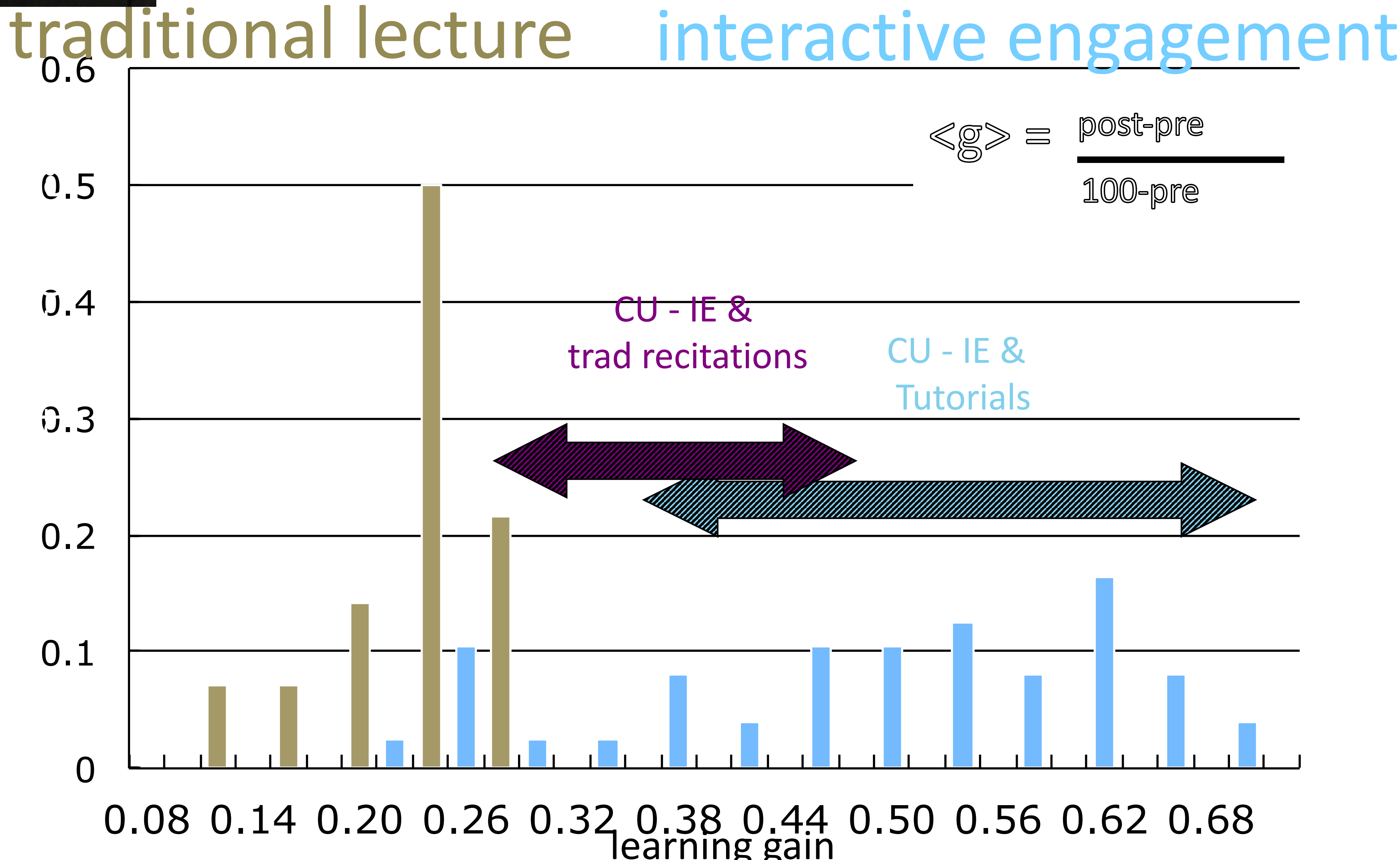
Impact and Reproducibility



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

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

Engagement in Learning

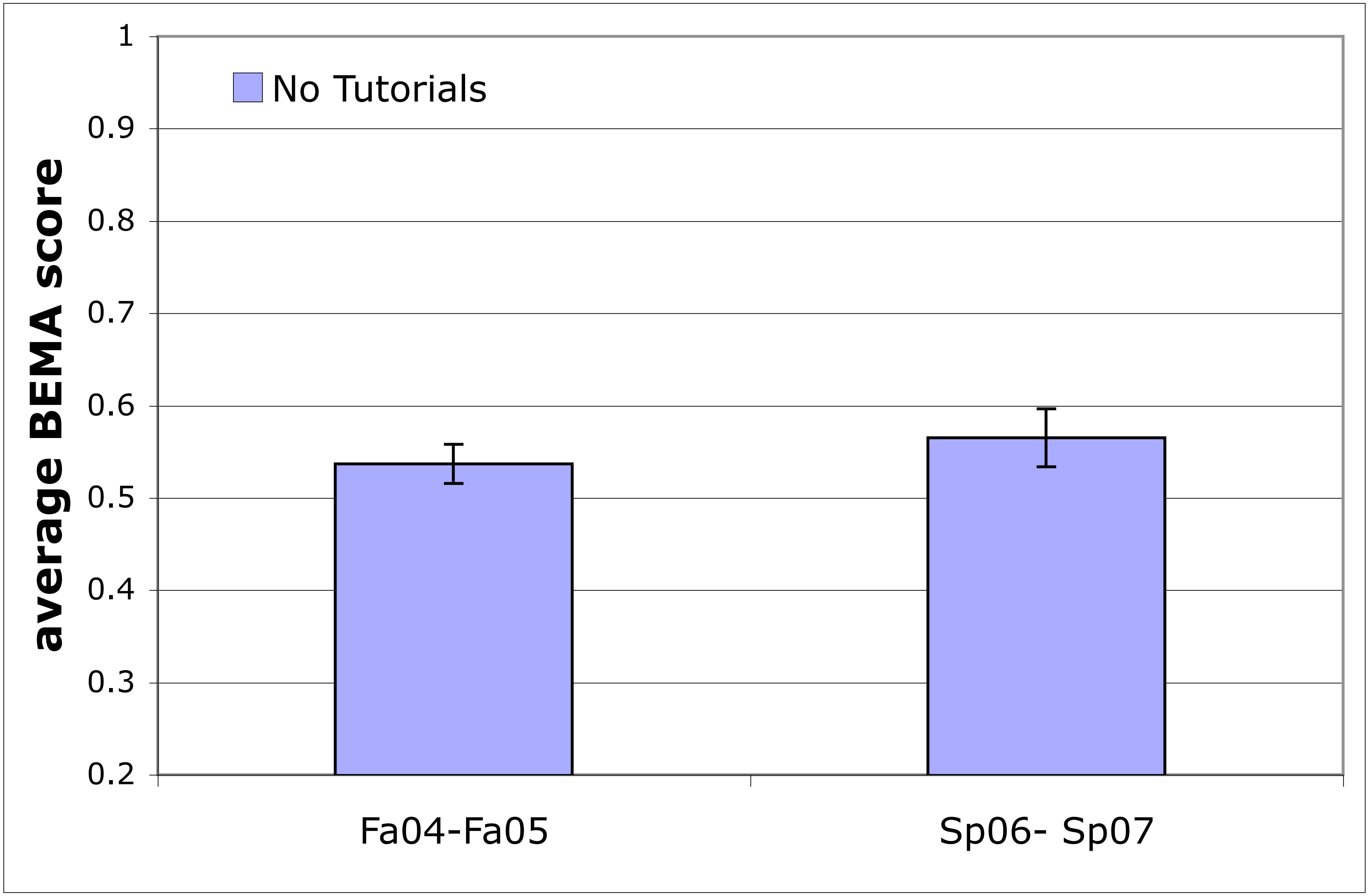


R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).

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

Lasting Impacts
Longitudinal Studies

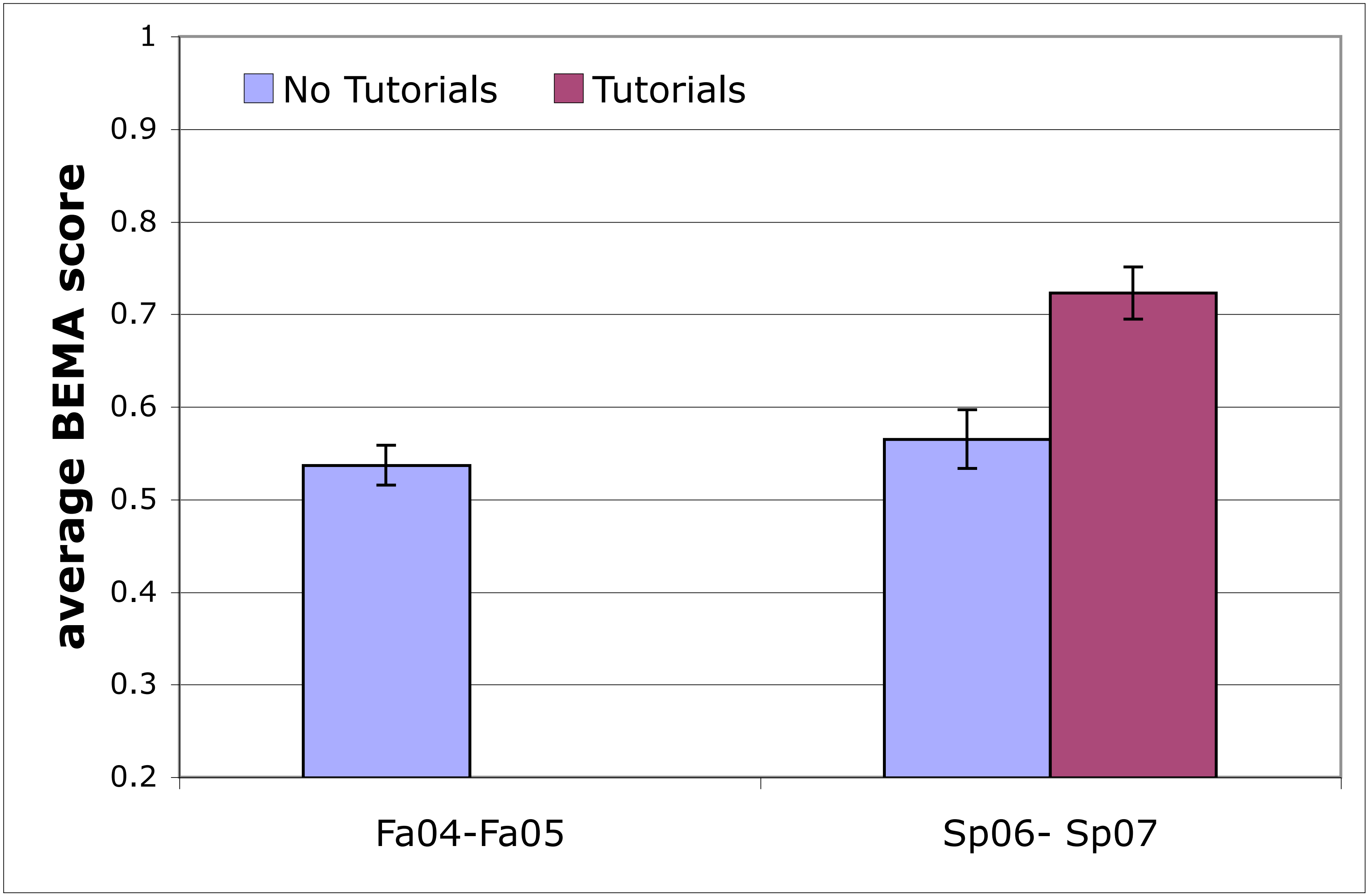
How Junior level E&M fair on BEMA?



After completing Jr Level E/M (3310 or 3320)

Only students who took Phys 2 (1120) *without* Tutorials

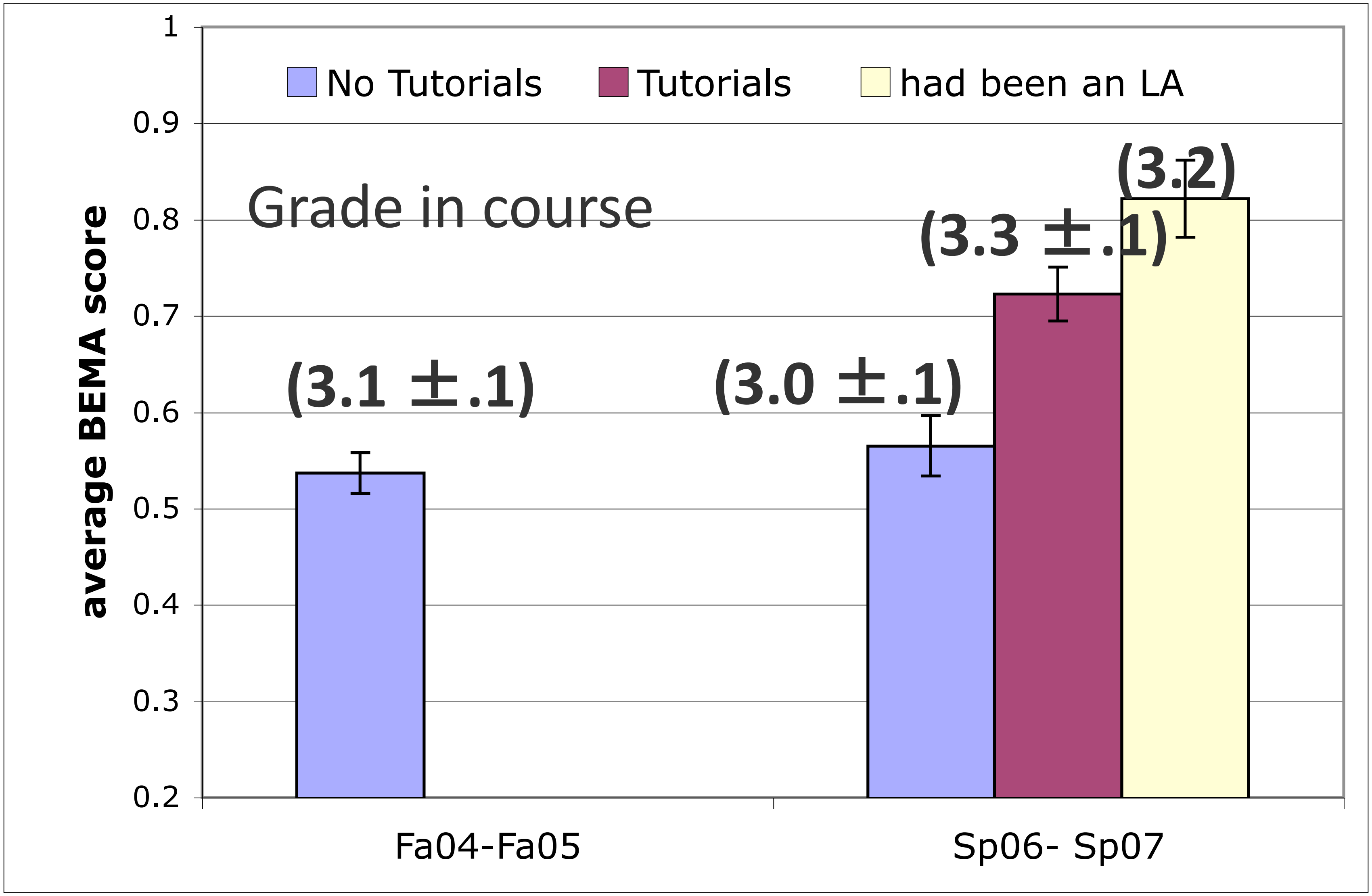
Impact of Tutorials



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

Middle & Upper Division

S. Pollock

S. Chasteen, N. Finkelstein, R. Pepper, K. Perkins
D. Caballero, C. Baily, B. Wilcox

H. Lewandowski

B. Zwickl, T. Hirokawa, N. Finkelstien

Why transform upper division?

Lecture with clickers

Washington Tutorials

?

Can our majors learn better from interactive techniques adapted from introductory physics?

Upper-div Clickers at CU

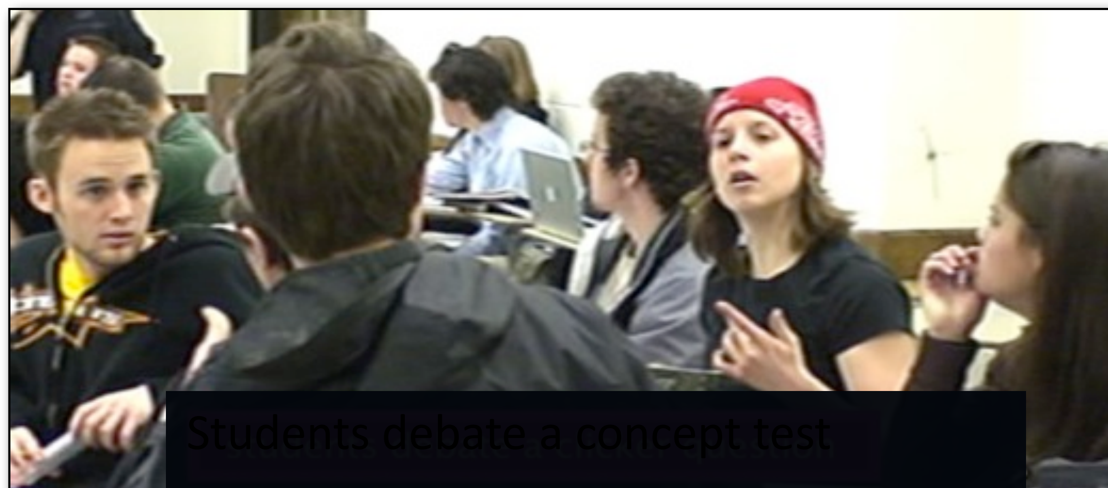
Term	04 S	04 F	05 S	05 F	06 S	06 F	07 S	07 F	08 S	08 F	09 S	09 F	10 S	10 F	11 S	11 F
Mech Math I							✓		✓					★✓	✓	✓
Mech MathII								✓			✓		✓			✓
EM I										★✓	★✓	✓	✓		✓	✓
EM II											✓	✓	✓		★✓	✓
QM I										✓	✓	✓	✓	✓	✓	✓
QM II										★	★✓		✓			✓
Stat Mech	★✓		✓			✓	✓			✓	✓	✓	✓	✓	✓	
Solid State		■		■		■		■	✓	■	✓	■	✓	■	✓	■
Plasma	■		■		■		■		■		■		■		■	
Nuclear/HE		■		■		■		■		■		■		■		■

★ PER faculty

Case study: E&M I

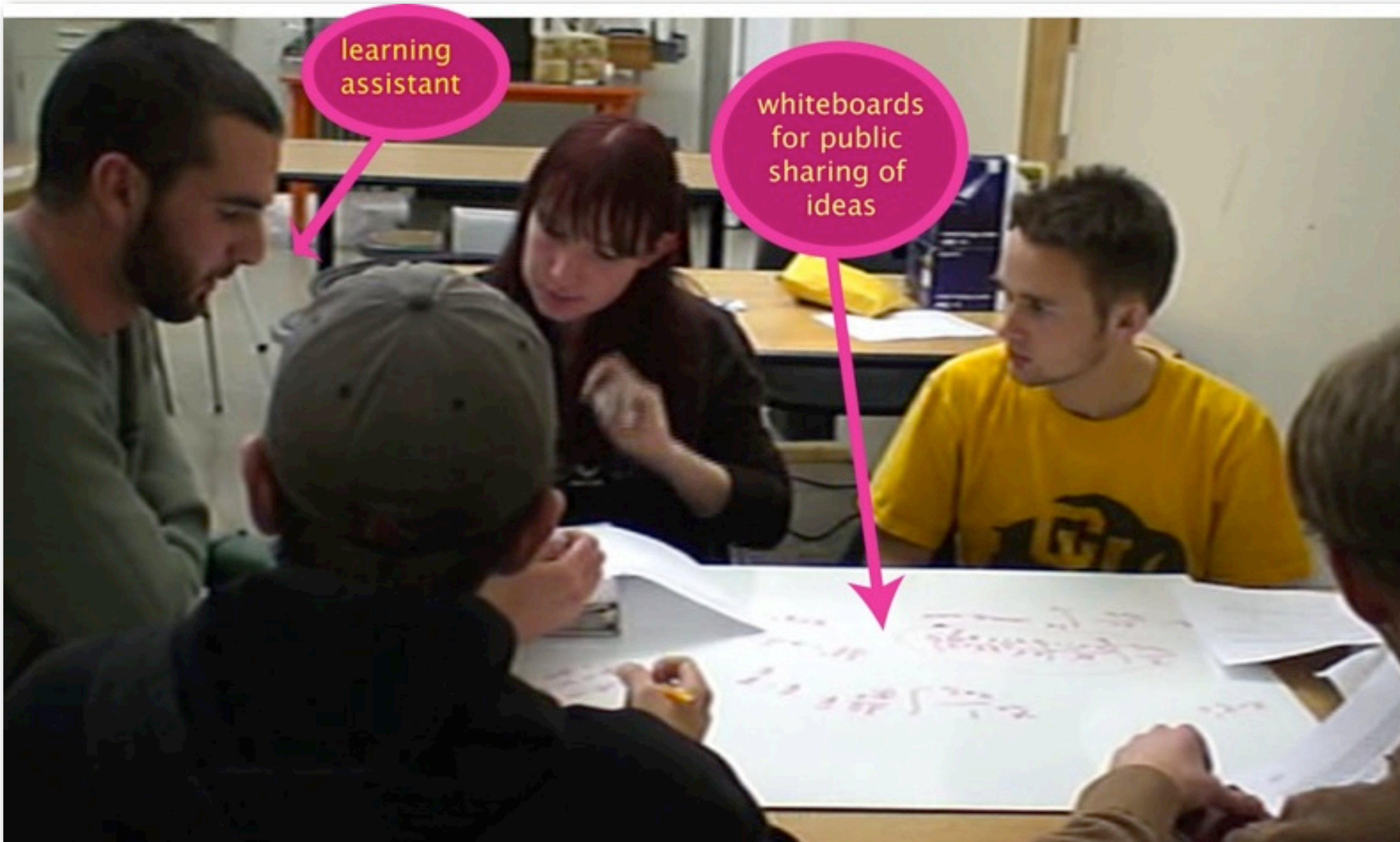
- Interactive classroom
- Concept Tests
- Modified Homework
- Help Sessions
- Weekly Tutorials

- Institutional support
  - SEI postdoc involvement
  - Learning Assistant
- Faculty collaboration
- Explicit learning goals



Tutorials

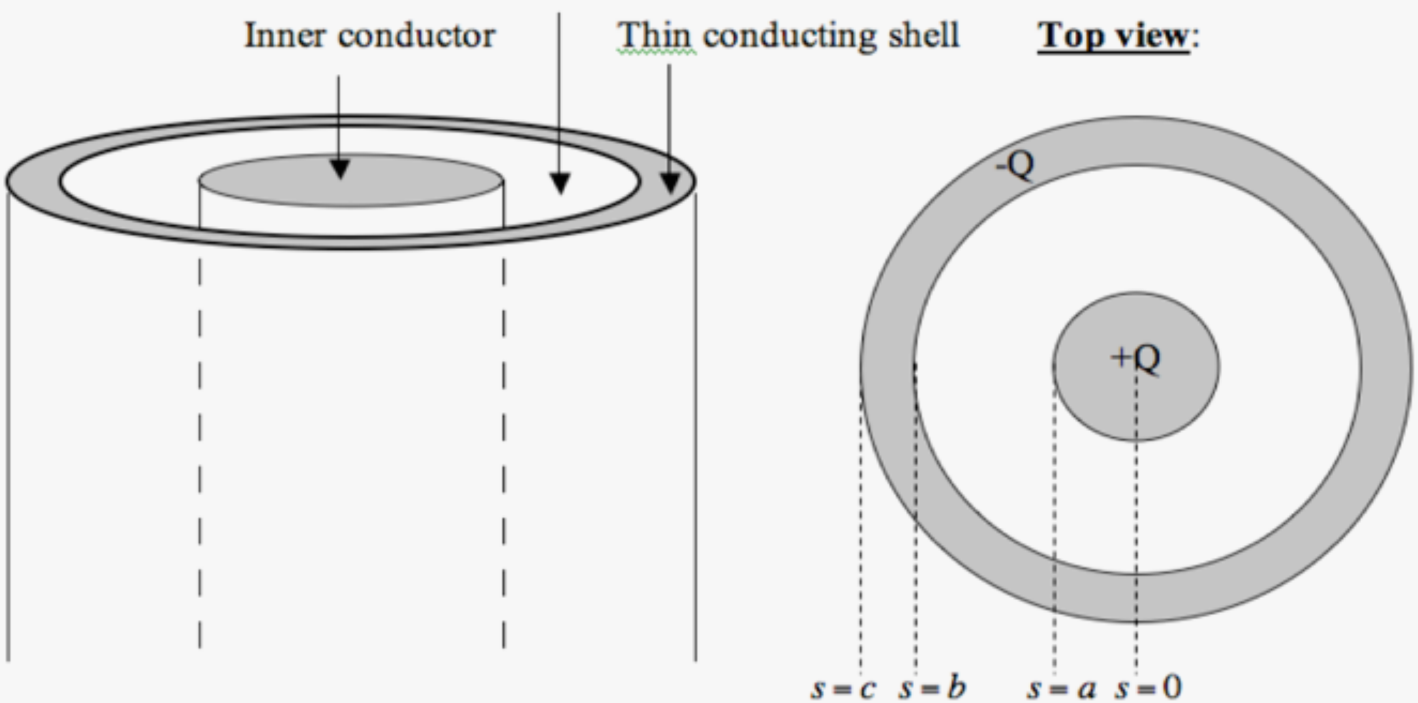
Optional, weekly. 50% attendance. Test-bed - chance to do demos.



Tutorials

Part 1 – Conceptually Understanding Conductors

A coax cable is essentially one long conducting cylinder surrounded by a conducting cylindrical shell. Draw the charge distribution (little + and – signs) if the inner conductor has a total charge +Q on it, and the outer conductor has a total charge –Q. Be precise about exactly where the charge will be on these conductors, and how you know.



Clicker Questions

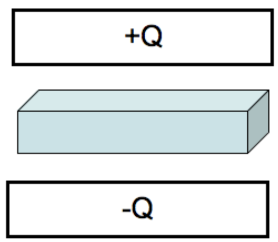
- Allowed students to **discuss & debate challenging, high-level ideas**

An ideal (large) capacitor has charge Q. A neutral *linear* dielectric is inserted into the gap (with given dielectric constant)

Where is D discontinuous?

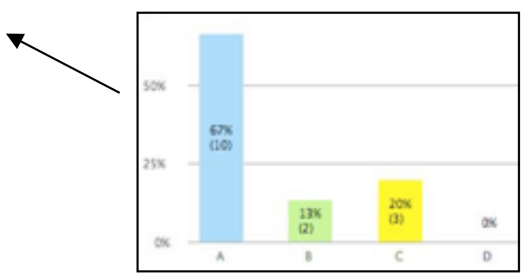
i) near the free charges on the plates

ii) near the bound charges on the dielectric surface



A) i only B) ii only C) i and ii ONLY

D) i and ii but also other places E) none of these/other



Freely Available Resources:

- Banks of Clicker Questions
  - Upper-level courses
  - Intro-level too
- Clicker Video Guides for Teachers

Did it Work? Assessments

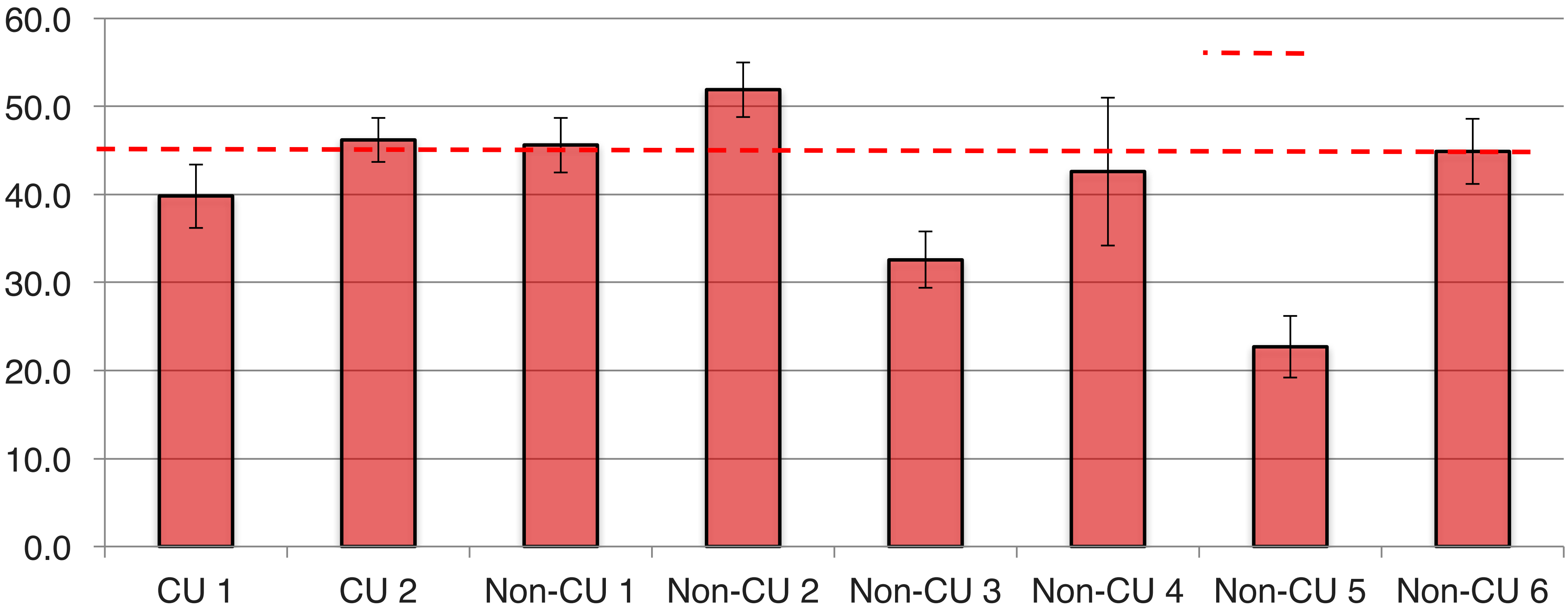
- Compared **Traditional (**8 courses) & **Transformed** (8 courses) at CU and elsewhere (N=493).

- Common **traditional exam questions** (5)

- Developed **Colorado Upper-Division Electrostatics Assessment (CUE)**
  - Faculty-driven & Research-validated
  - High internal statistical consistency
  - High inter-rater reliability

Chasteen et al, JCST 40 (2011) p. 70; Wilcox et al Phys Rev (2016)

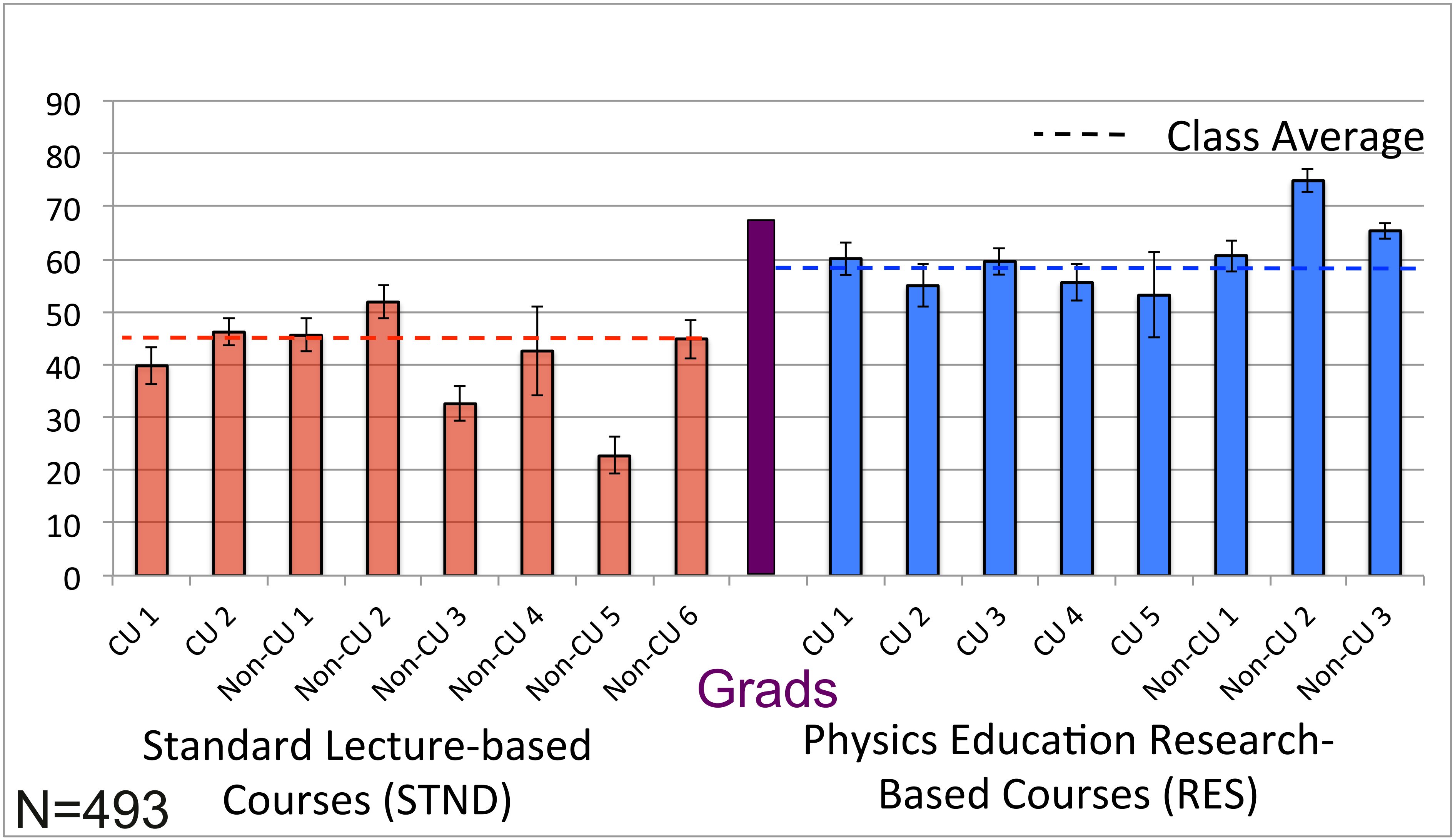
CUE results: Trad courses



Standard Lecture-based Courses (STND)

Chasteen et al, PERC 2011, AJP (2012)

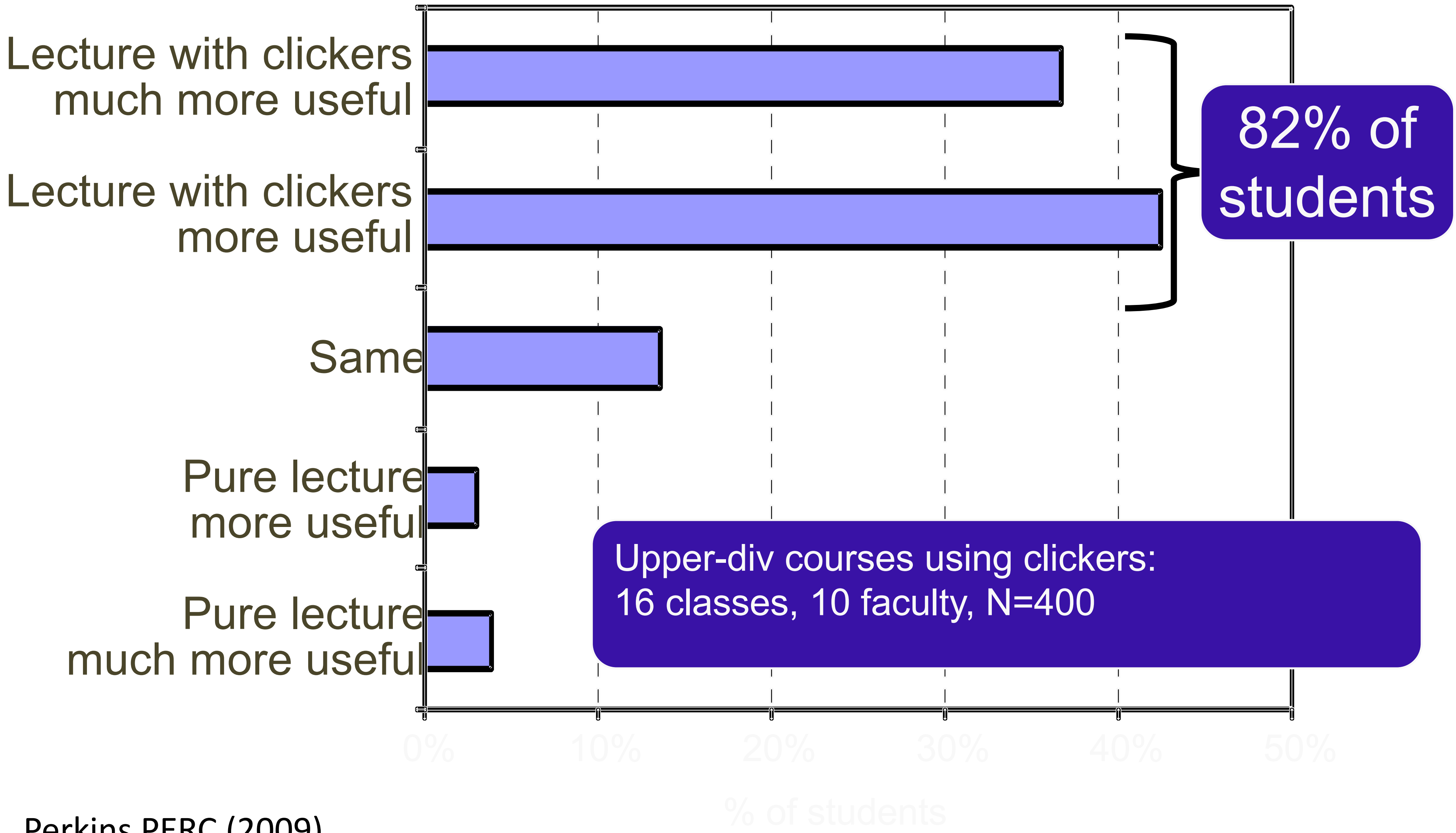
CUE Results: Comparison



Chasteen et al, PERC 2011, AJP (2012)

Students Find Clickers Useful

Q: How useful for your learning is the addition of clicker questions compared to pure lecture with no clicker questions?



Perkins PERC (2009)

Using a Research-based Approach to Transform Upper-division Laboratory Courses

Heather Lewandowski

Takako Hirokawa
Noah Finkelstein
Ben Zwickl

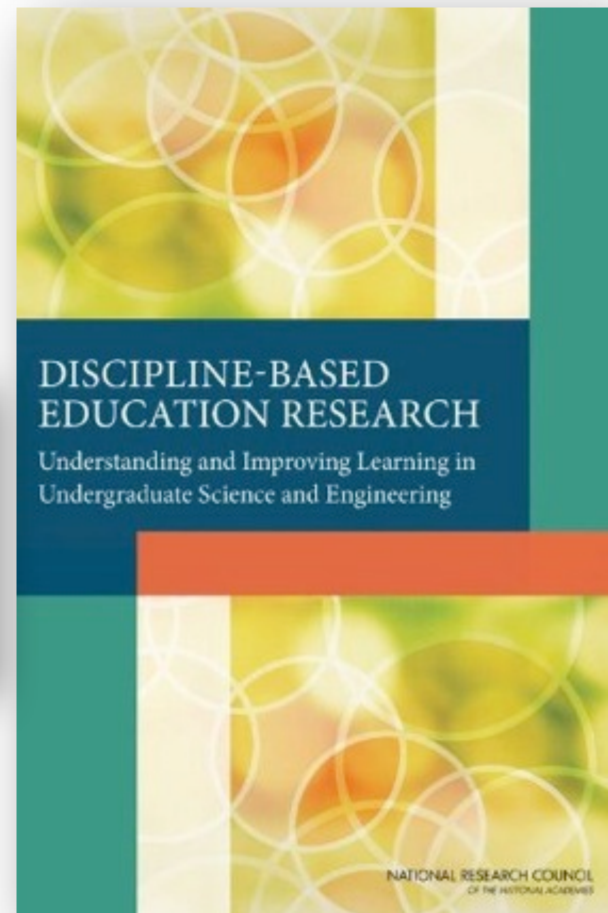
Physics Department
JILA
University of Colorado

New Directions in Physics Education Research

Lectures ⇨ Labs

Introductory ⇨ Upper-division

> *"Across the disciplines in this study, the role of the laboratory class is poorly understood."*

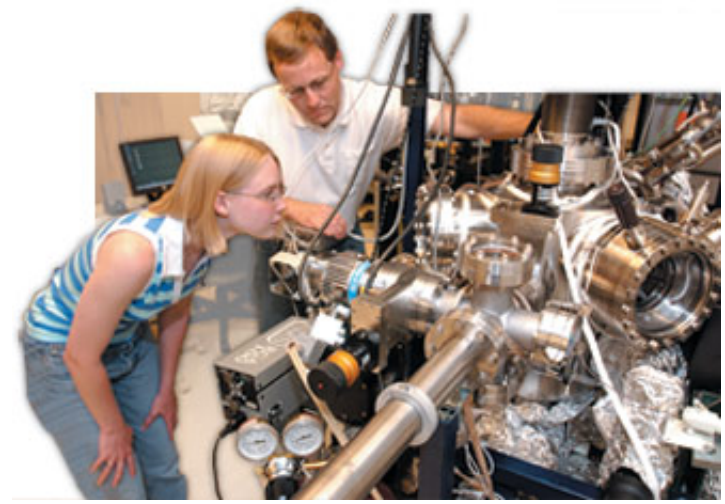


NRC Report on Discipline-Based Education Research (2012)

A broad goal for labs

To prepare students for ***participation in undergraduate research, graduate school, and research careers.***

From macdailynews.com

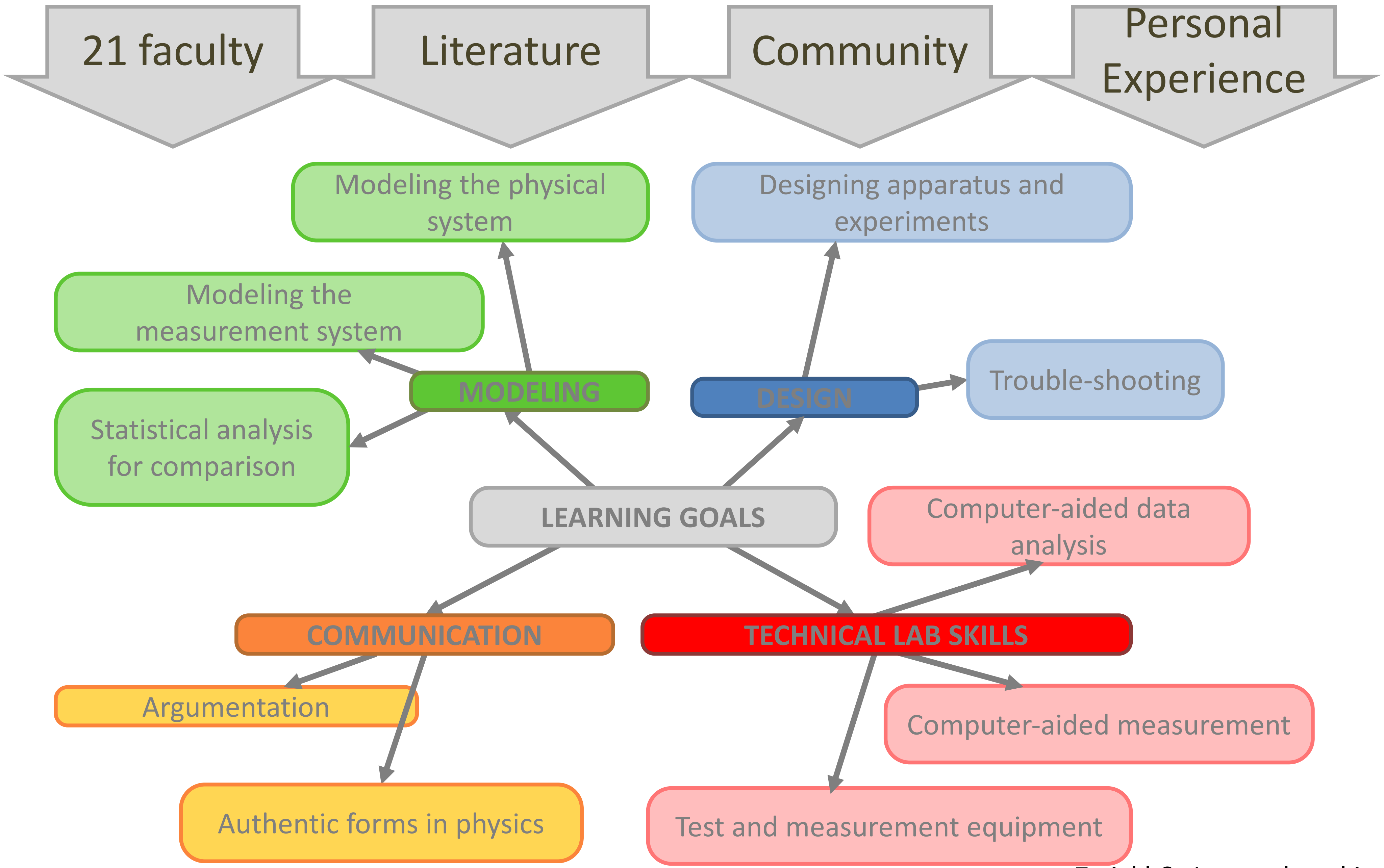


Undergraduate researcher at
University of Wisconsin Eau Claire

Students

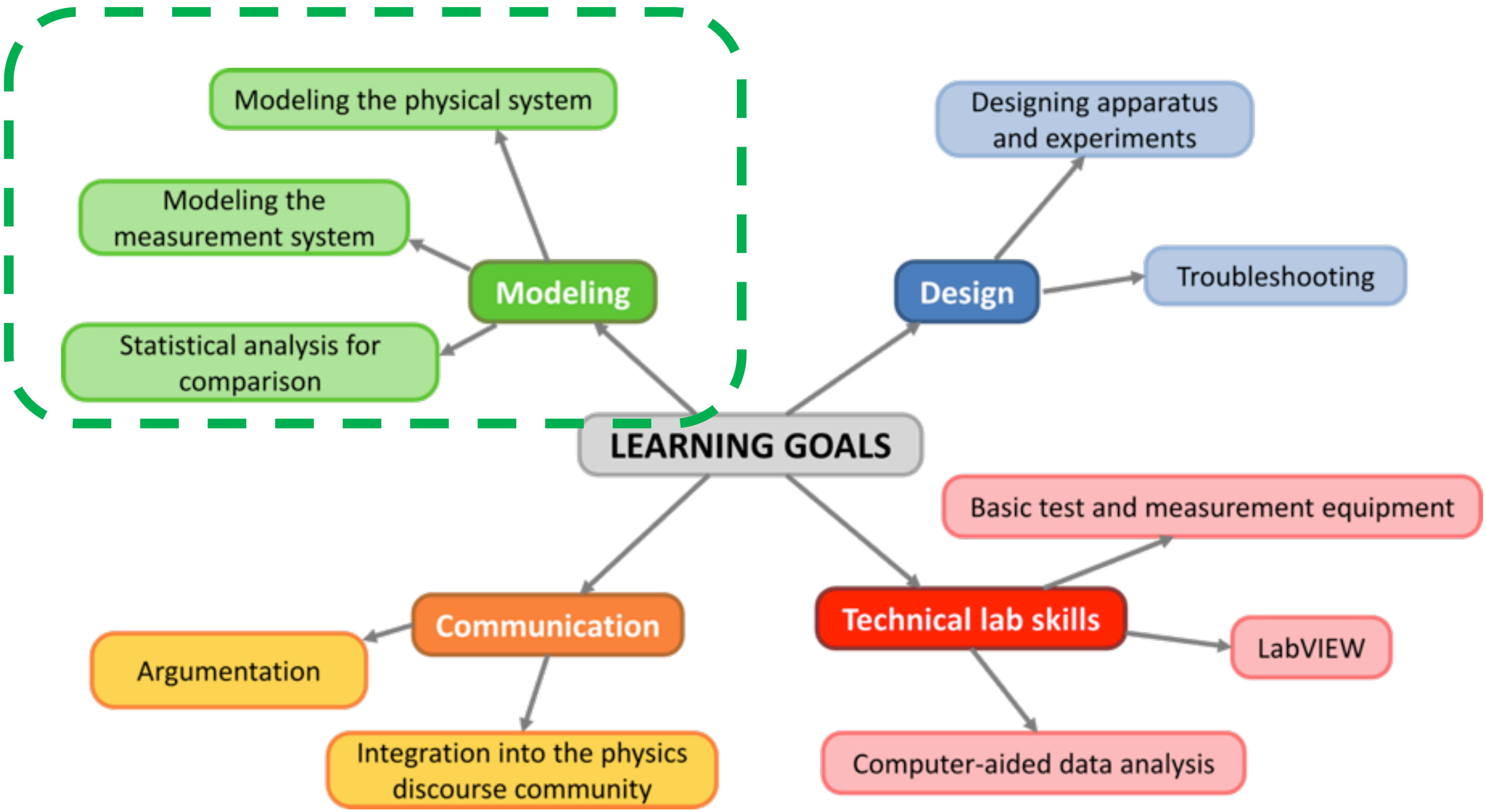
Researchers

Development of Learning Goals

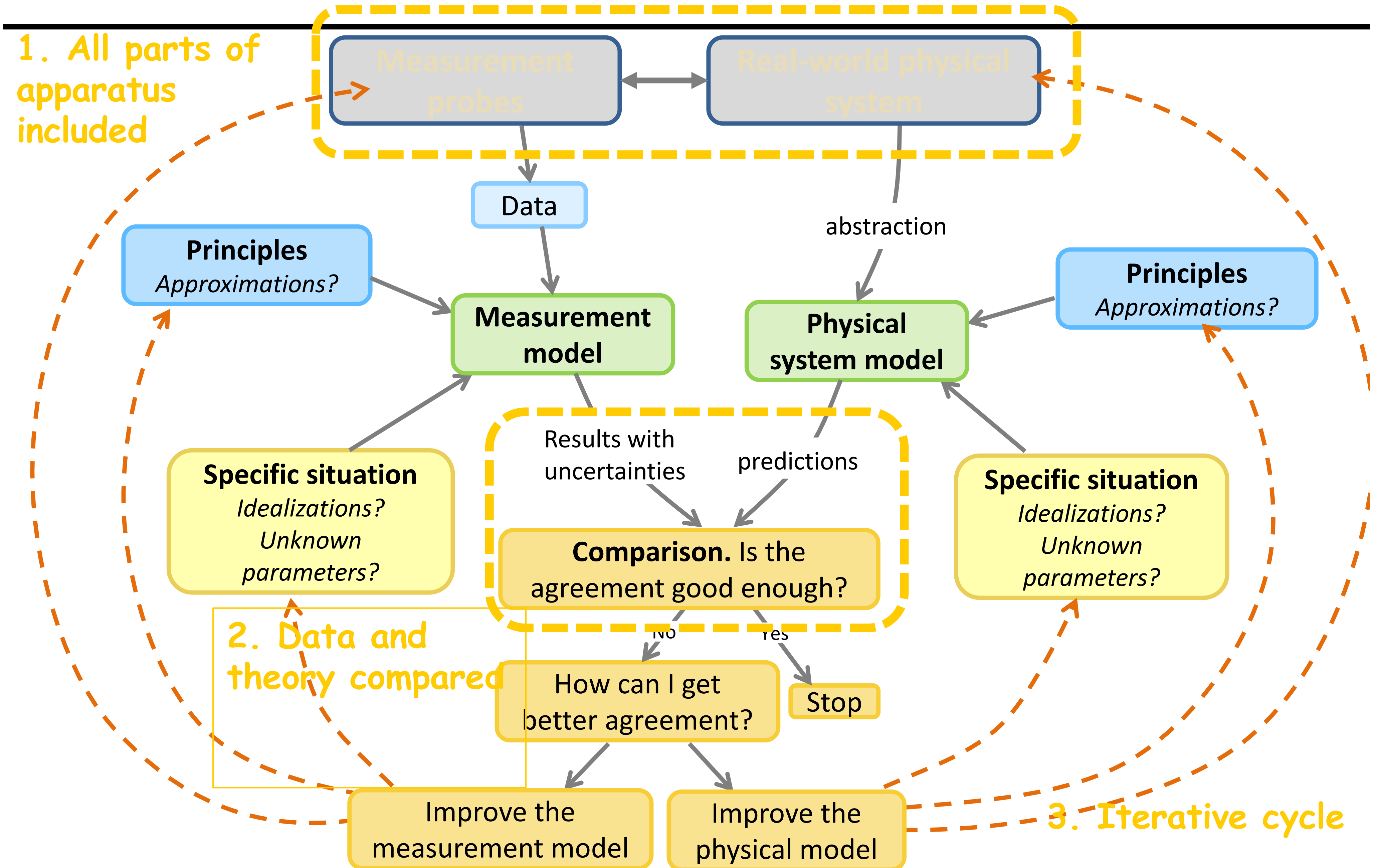


Zwickl & Lewandowski

Learning Goals



A Modeling Framework for Labs



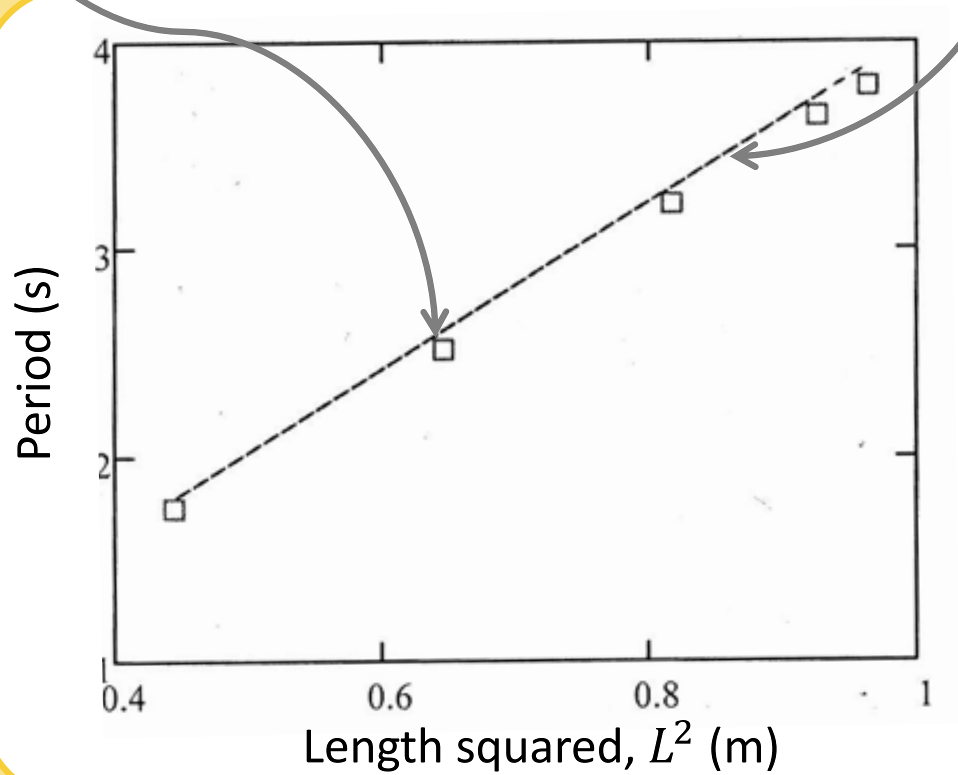
Zwickl & Lewandowski

Comparison between data and predictions

Data from photogate

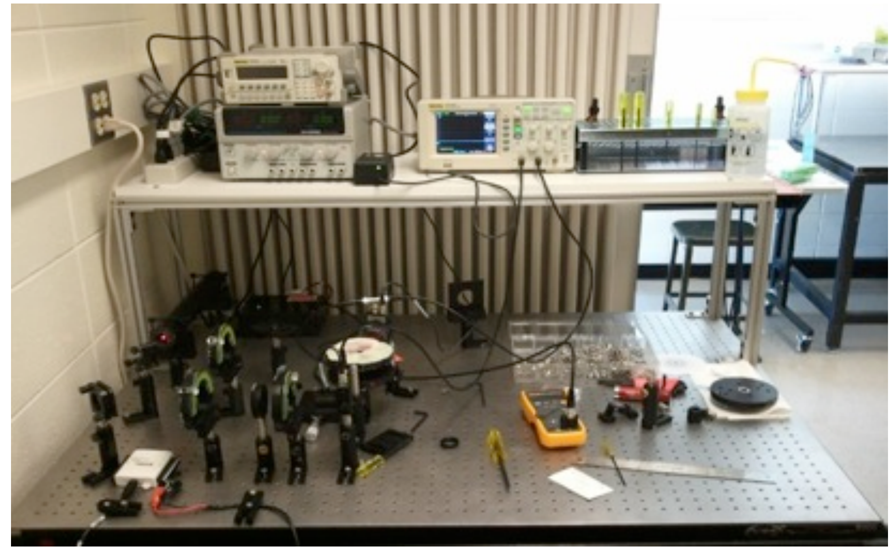
Predictions from model of pendulum

Comparison. Is the agreement good enough?



Implementing Change at Colorado

Physical Transformation



Standard optics workstation

New:

- 10 versatile optics workstations
- research grade equipment
- 80% of components common to all labs.
- 20% specialized equipment

Integrating Lecture and Lab

Old:

- Lecture remote
- Lecture topics tangential.

New:

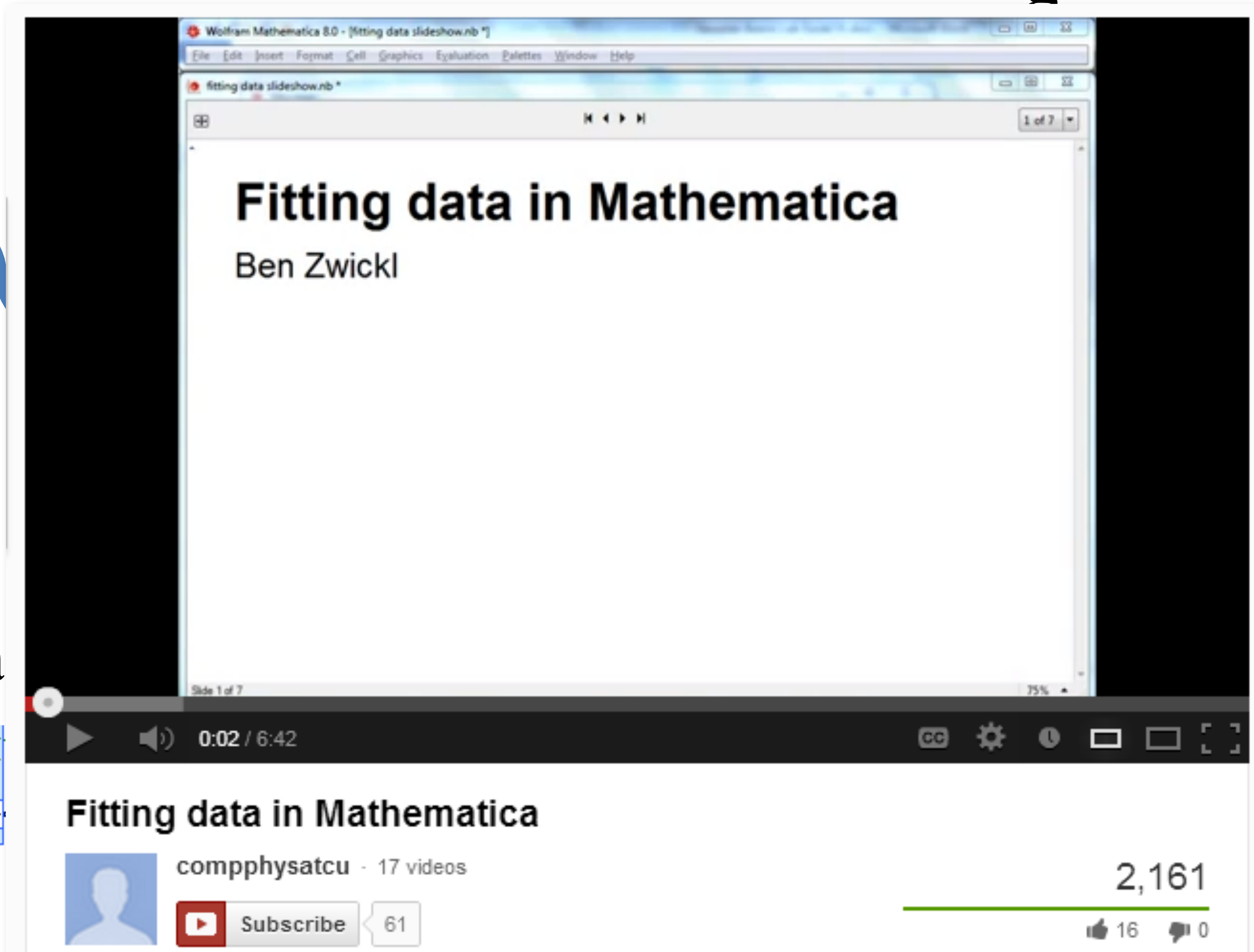
- Room adjacent to lab space
- Collaborative workspace
- Lab skill activities /tutorials in
  - Mathematica
  - LabVIEW
  - Error analysis
- oral presentations

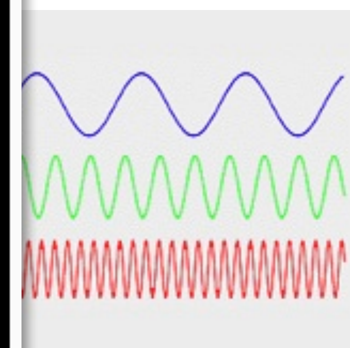
A New Suite of Lab Skill Activities

Mathematica (data analysis and plotting)

Digital Sampling

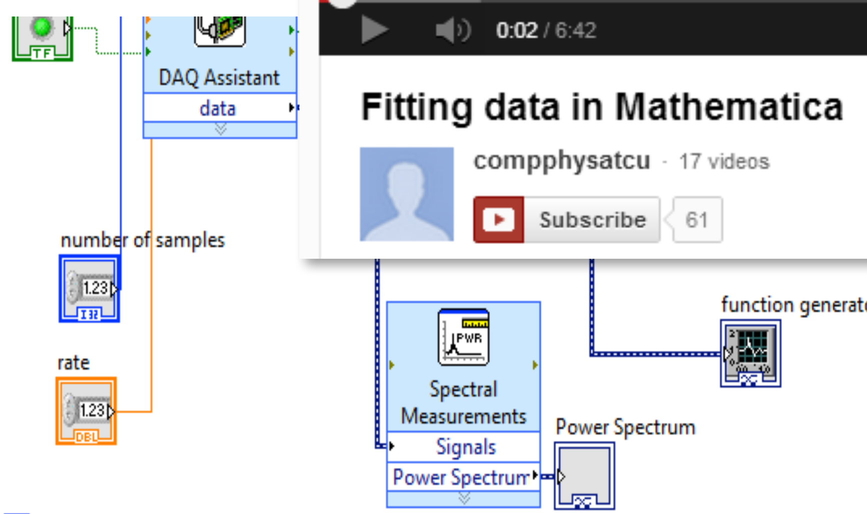
er Analysis

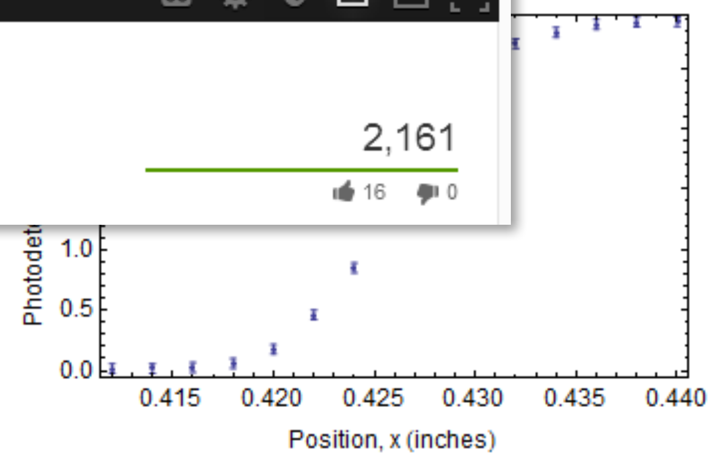




LabVIEW a

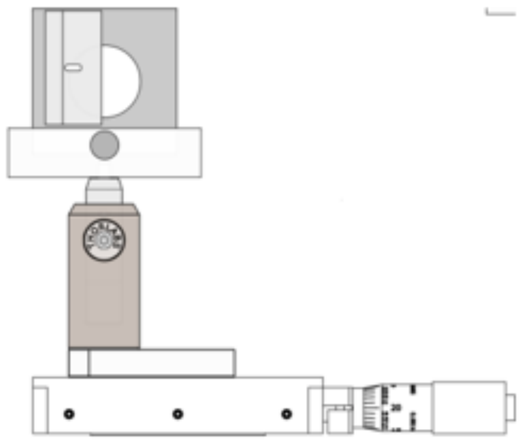
l Fitting



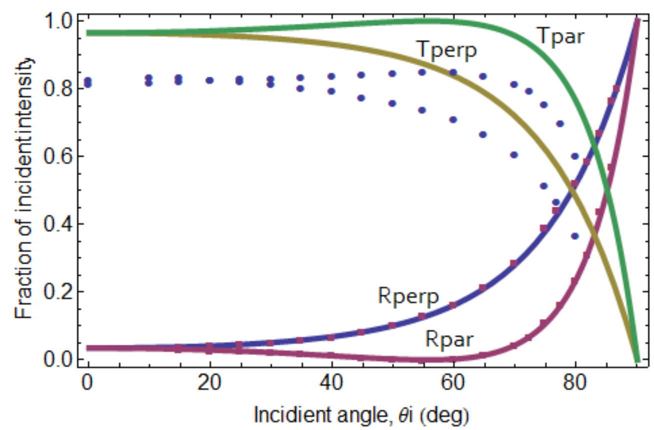


Five Redesigned Optics Labs (emphasize modeling)

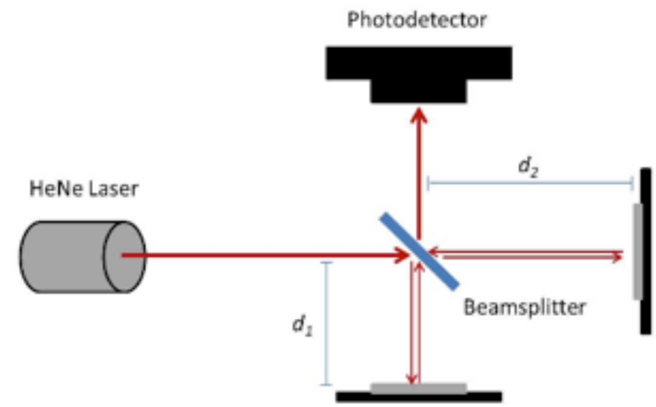
Gaussian Laser Beams



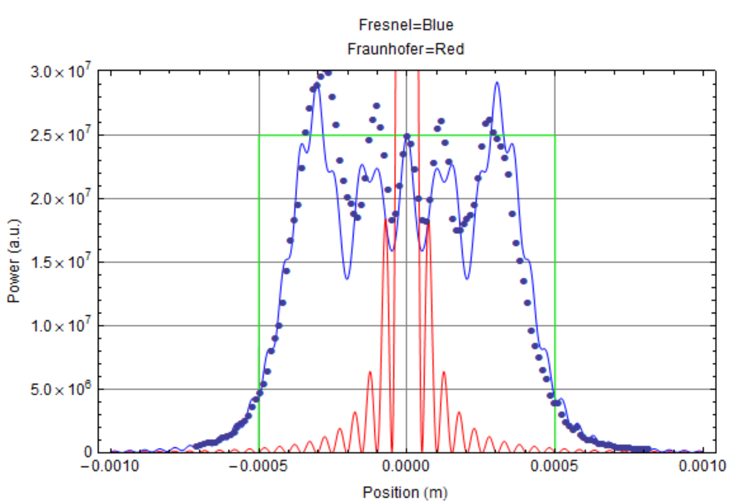
Polarization of Light



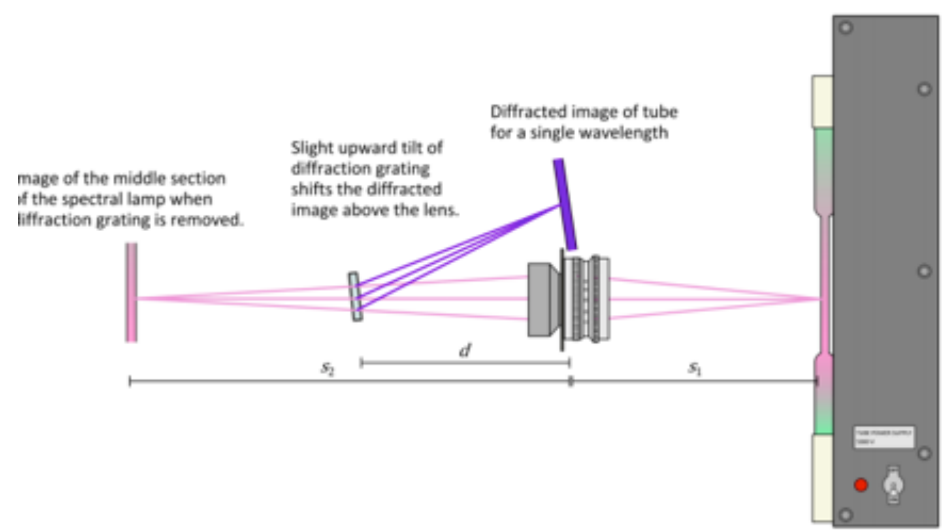
Interferometry



Diffraction and Fourier Optics



Build a Spectrometer



E-CLASS

Colorado Learning Attitudes about Science Survey for Experimental Physics

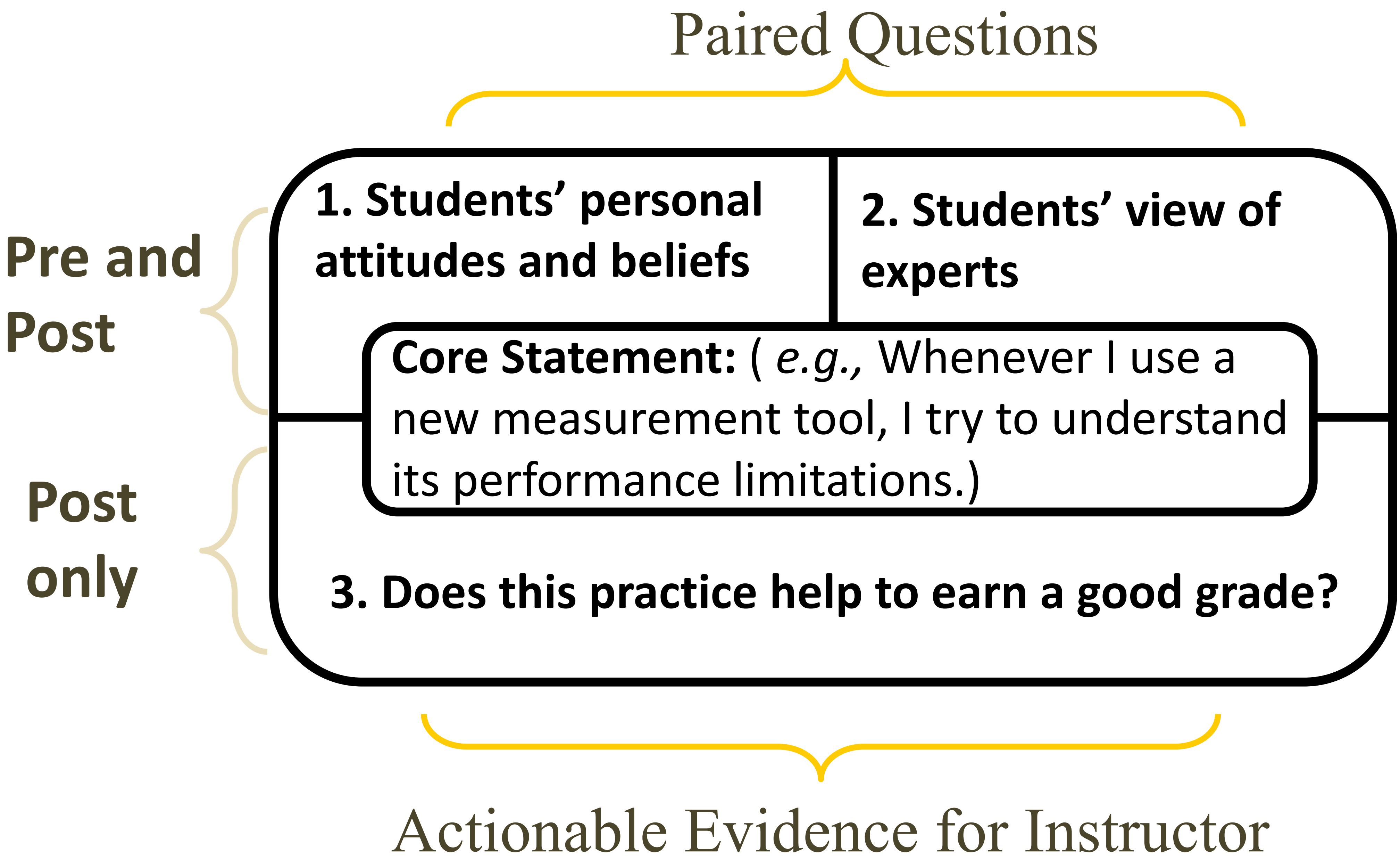
1) Survey on experimental physics

2) Validated for all levels

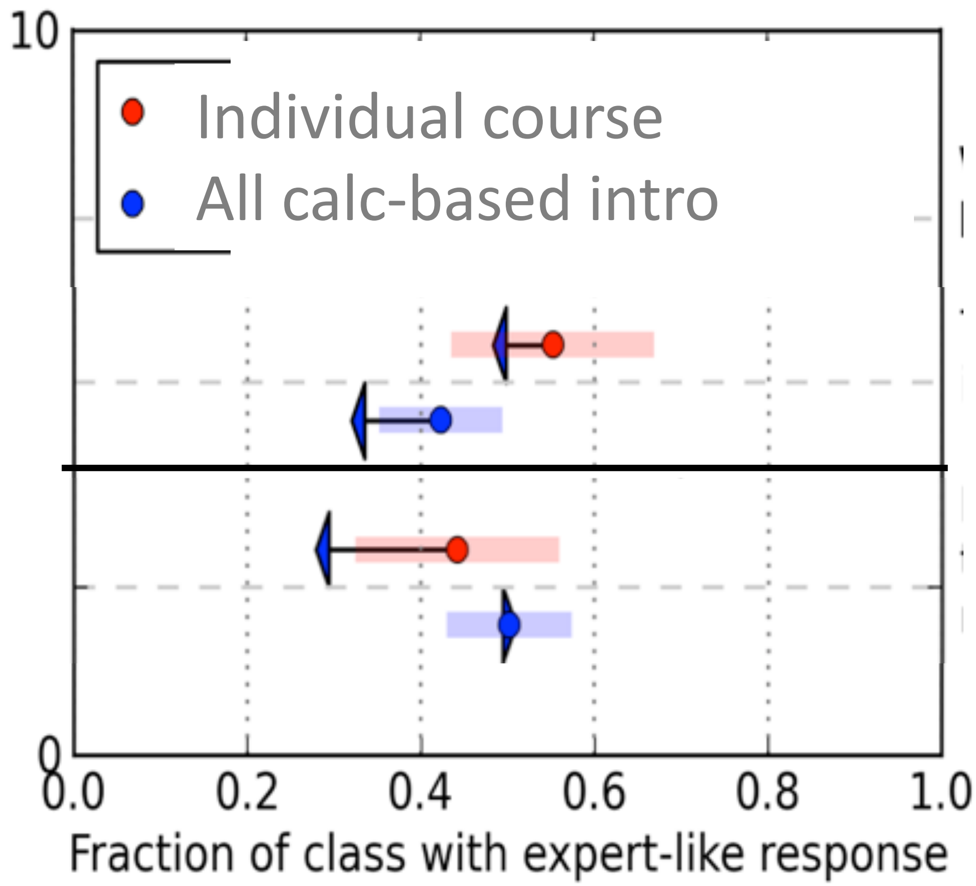
3) A common tool for all experimental environments

https://jila.colorado.edu/lewandowski/research/e-class-colorado-learning-attitudes-about-science-survey-experimental-physics

E-CLASS Design



Comparing one course to others



The primary purpose of doing a physics experiment is to confirm previously known results.

Doing error analysis usually helps me understand my results better.

Pilot E-CLASS Survey

23 Institutions

28 Courses

> 2000 Students

Current E-CLASS survey

10,000's Students!

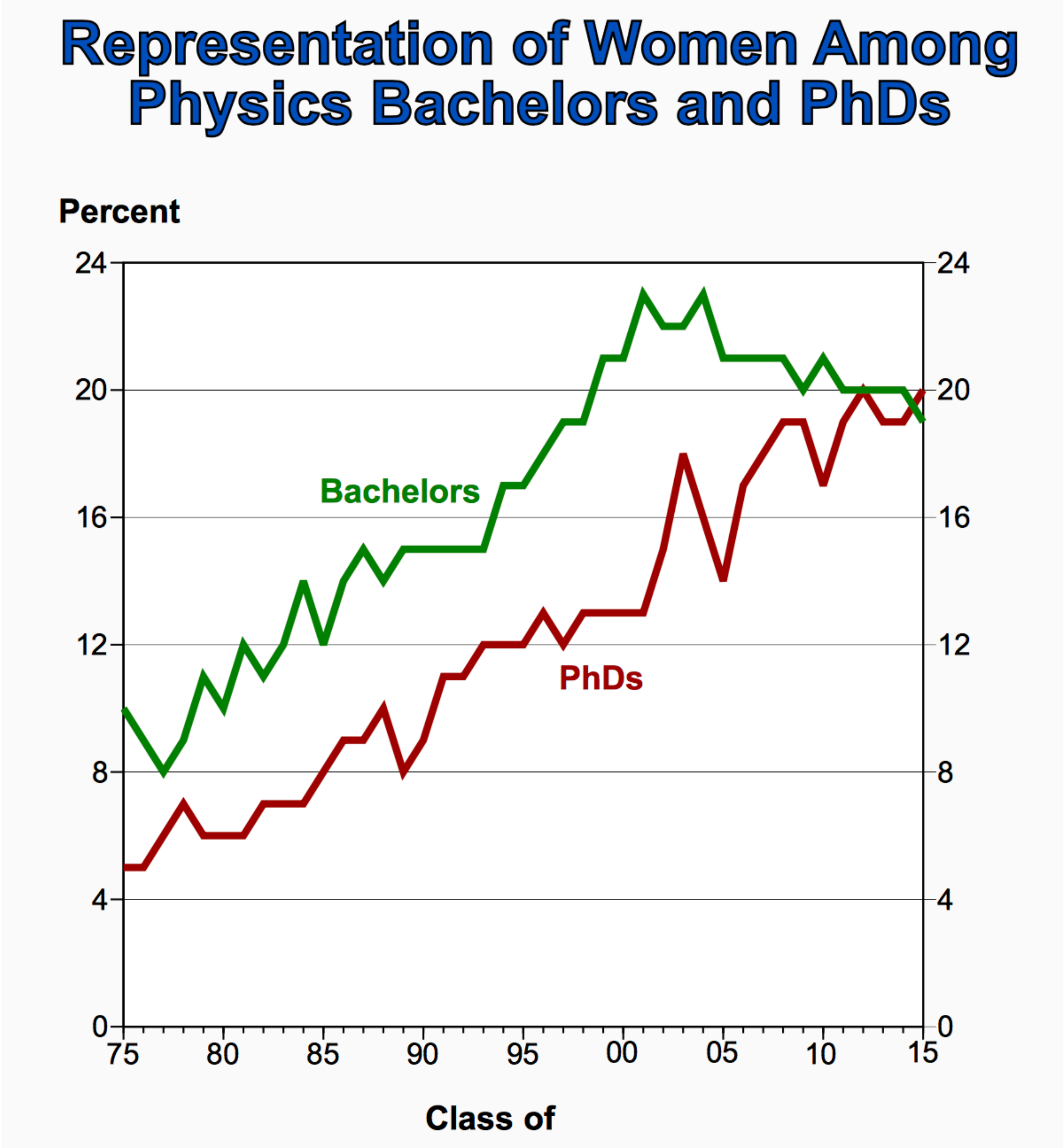
Used at all levels (intro. to advanced) and
at all institutions (community college to R1, MOOC)

per.colorado.edu

Developing identities, belonging, and tools for inclusion of women in physics

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


Representation of Women Among Physics Bachelors and PhDs
Percent
Bachelors
PhDs
24
20
16
12
8
4
0
75
80
85
90
95
00
05
10
15
Class of

AIP

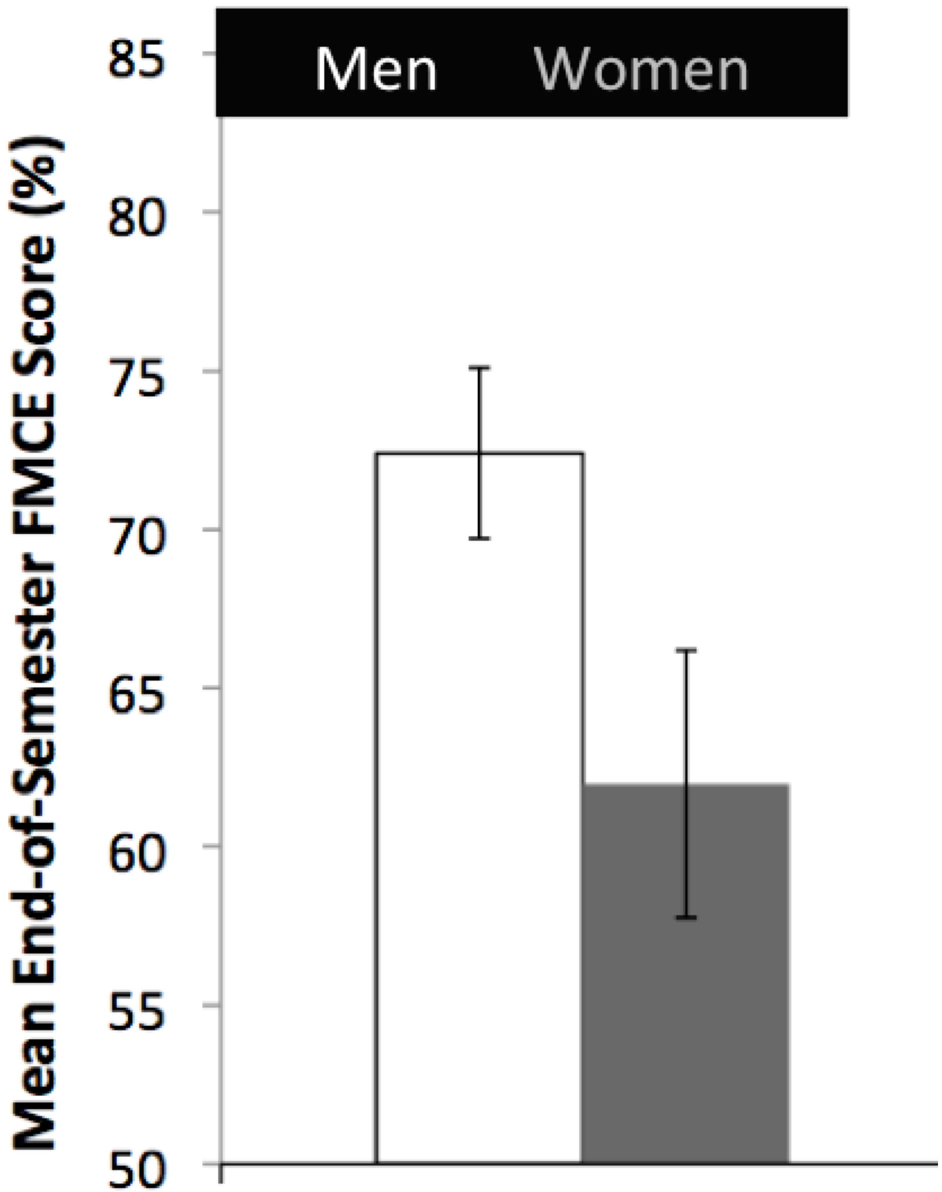
Sense of Physics Identity

"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]

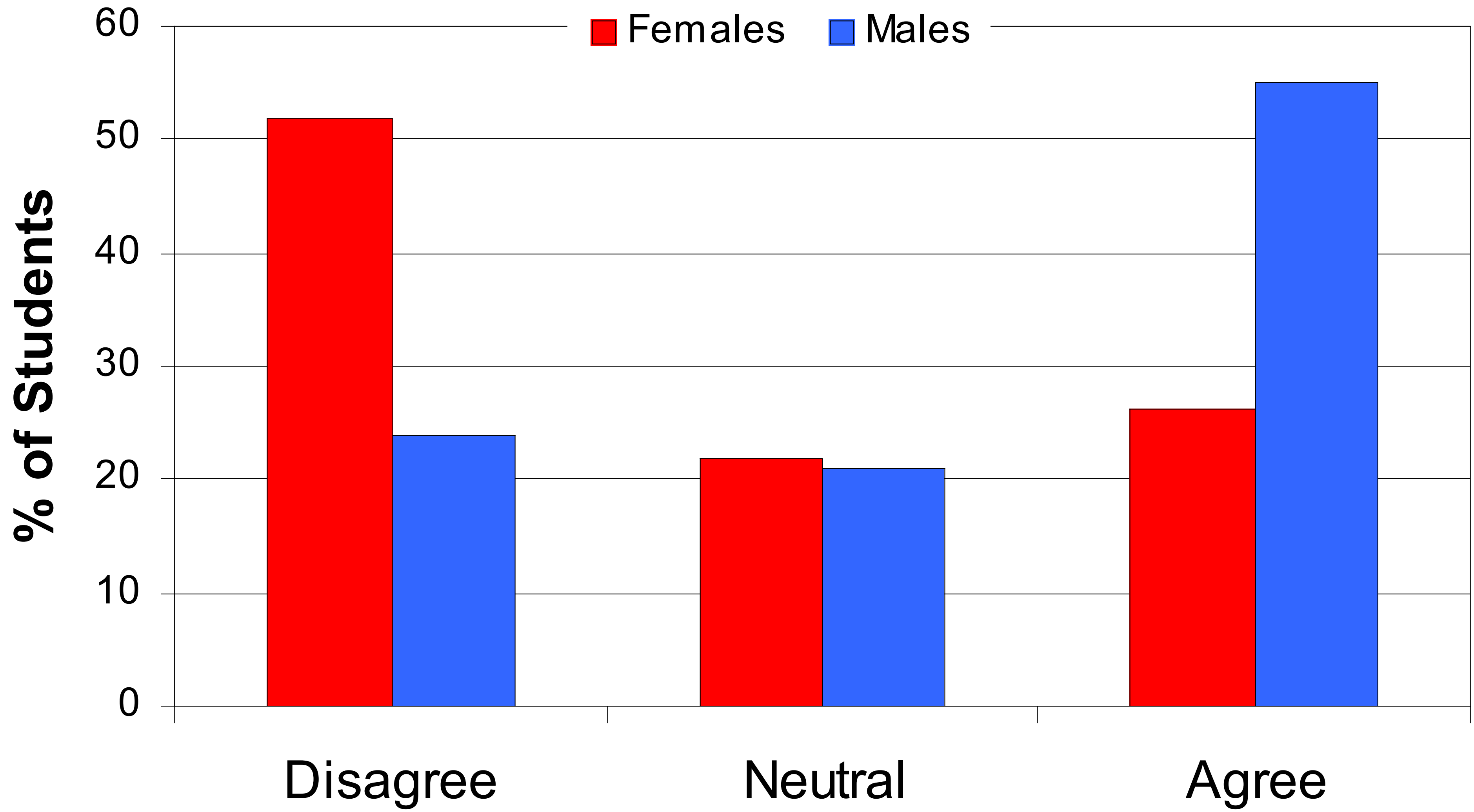
[1] J. Lave & E. Wenger, *Situated Learning*, 1991.
[2] N.W. Brickhouse, et. al. *J. Res. Sci. Teach*. **37**, 441 (2000).

Gender Gaps

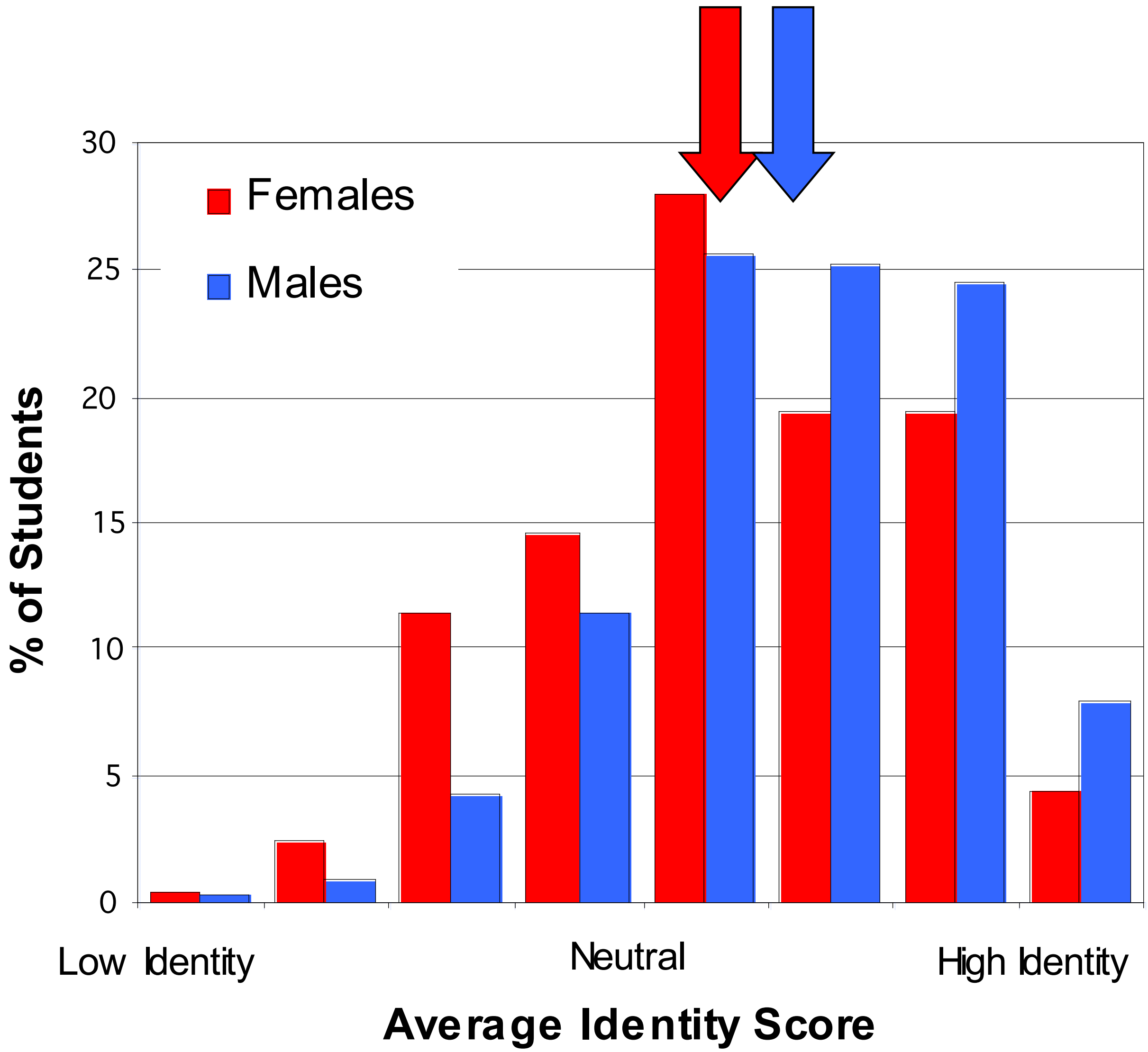


Miyake, Kost, et al, *Science* Dec 2010

I feel like I could be a good physicist.



Physics Identity
(7 questions)



	Identity
FMCE Posttest	0.24*
Course Grade	0.32*

Kost Smith 2012

Physics Self-Efficacy

The beliefs that people have about their ability to complete a specific task.[3]

SE beliefs influence choices and effort.[3]

Four sources of self-efficacy[4]:

Mastery experience

Vicarious experience

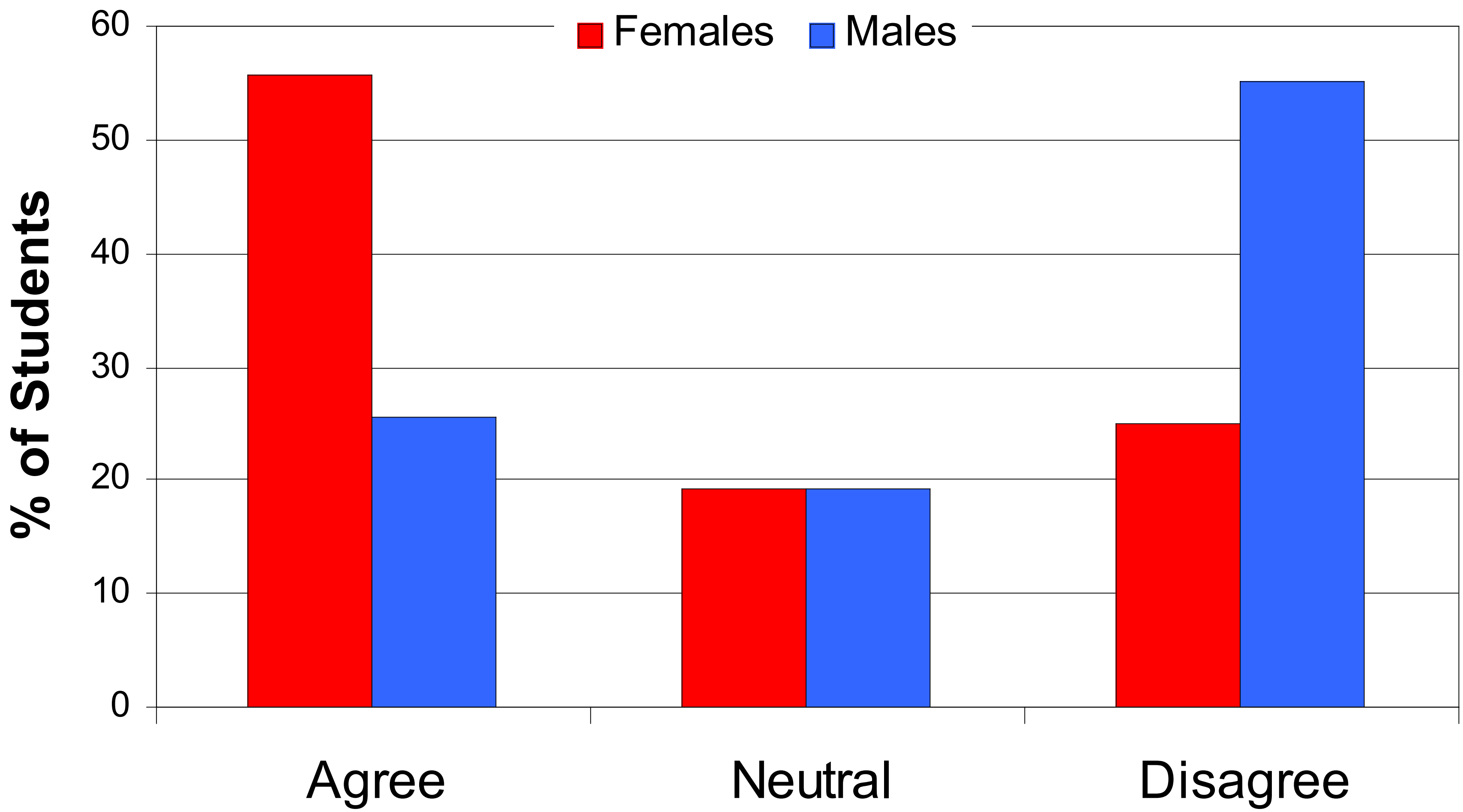
Verbal and social persuasions

Emotional and physiological responses

[3] A. Bandura, *Psych. Rev*. **84**, 191 (1977). [4] E.L. Usher & F. Pajares, *Rev. Ed. Res*. **78**, 751 (2008).
[5] H. Fencl & K. Scheel, *J. Col. Sci. Teach*. **35**, 20 (2005).

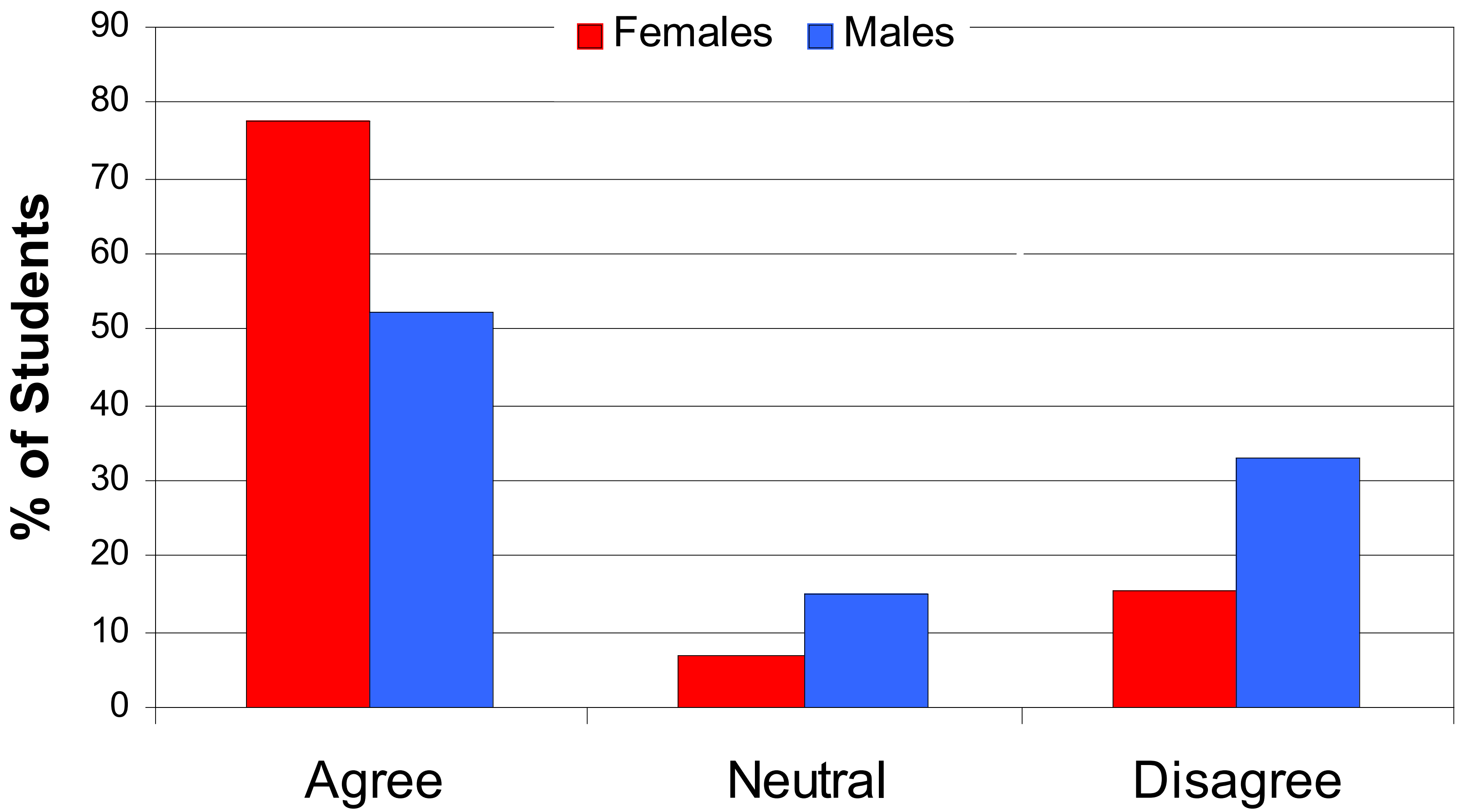
Physics Self-Efficacy

Physics makes me feel uneasy.

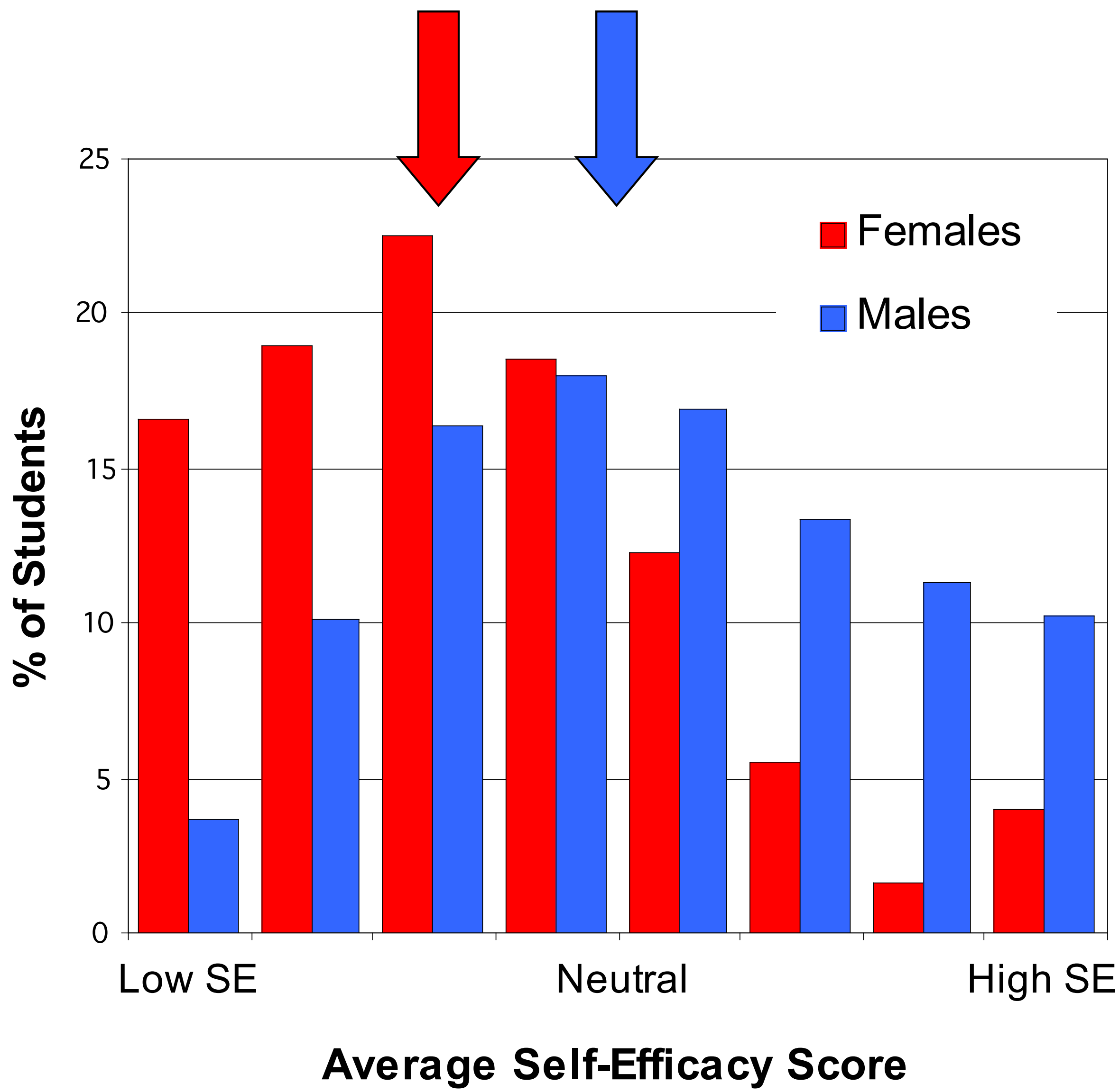


Physics Self-Efficacy

- I worried about my ability to solve physics problems on exams.

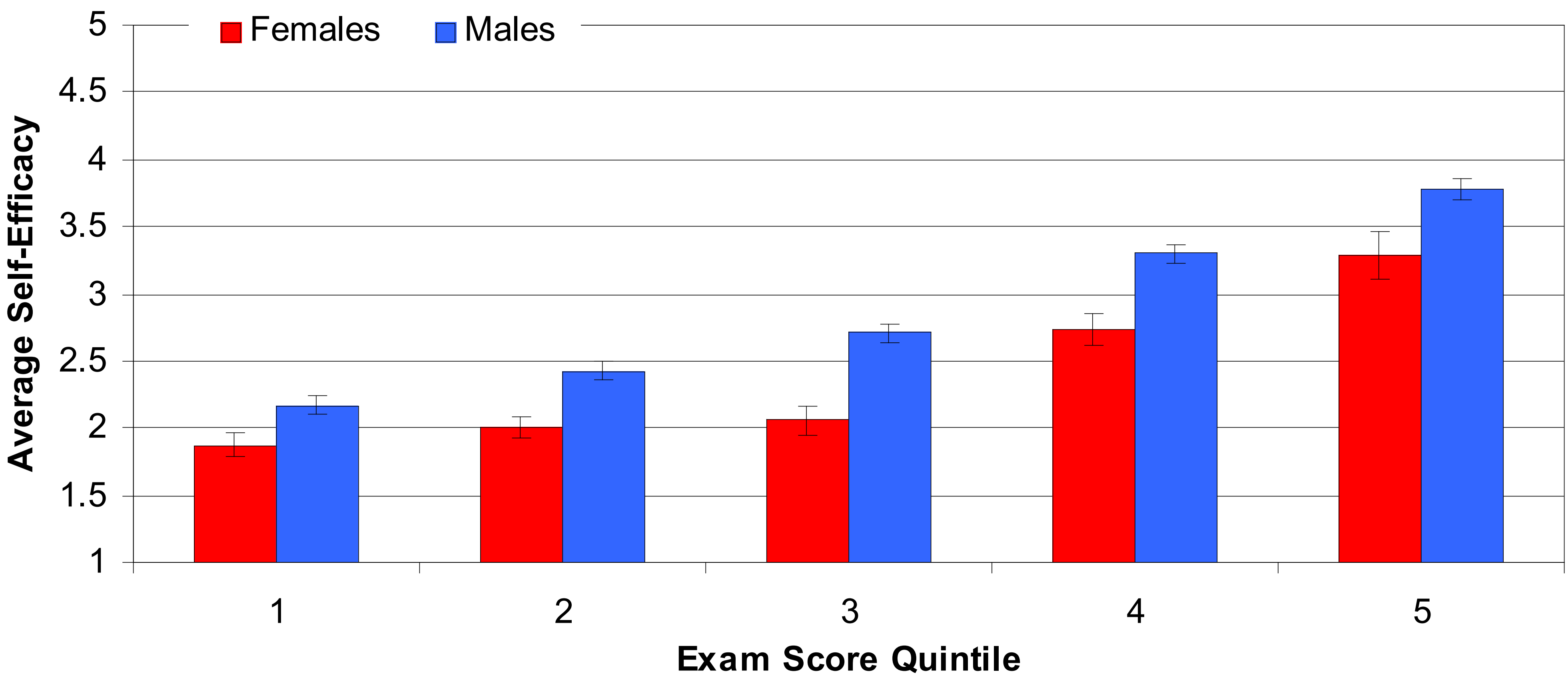


Physics Self-Efficacy
(4 questions)



	Self-Efficacy
FMCE Posttest	0.38*
Course Grade	0.50*

Controlling for Exam Score



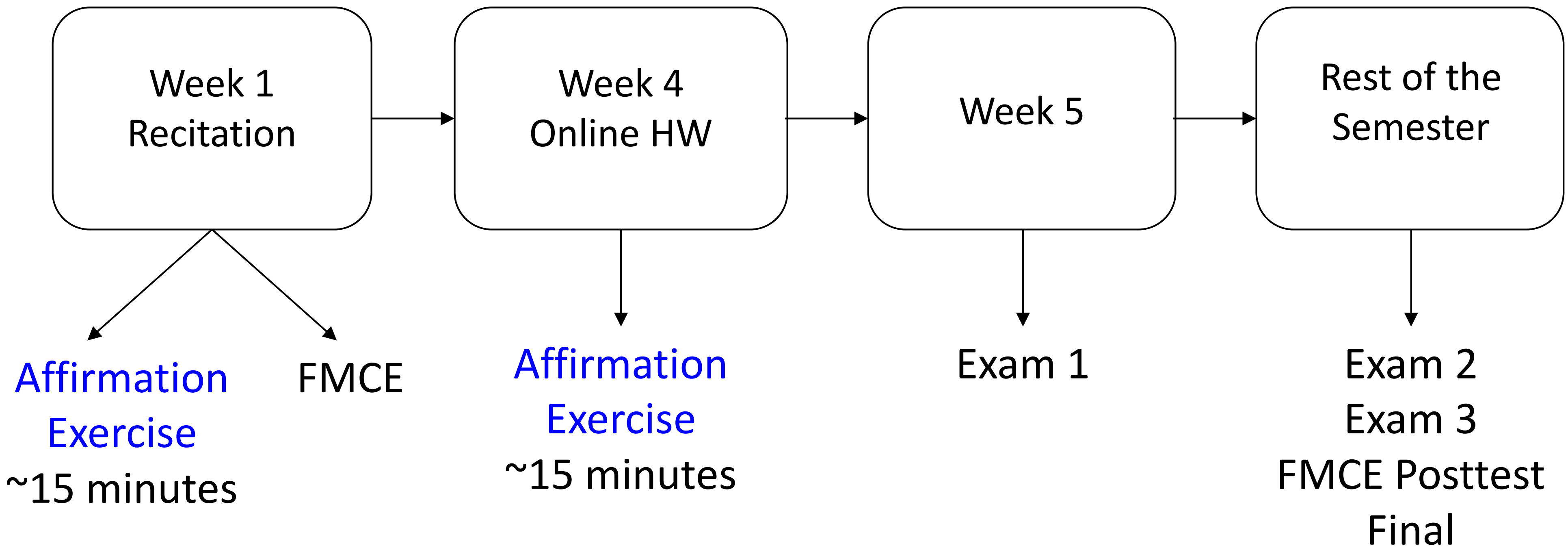
Even when controlling for exam score,
females have significantly lower self-efficacy than males.

Self-Affirmation

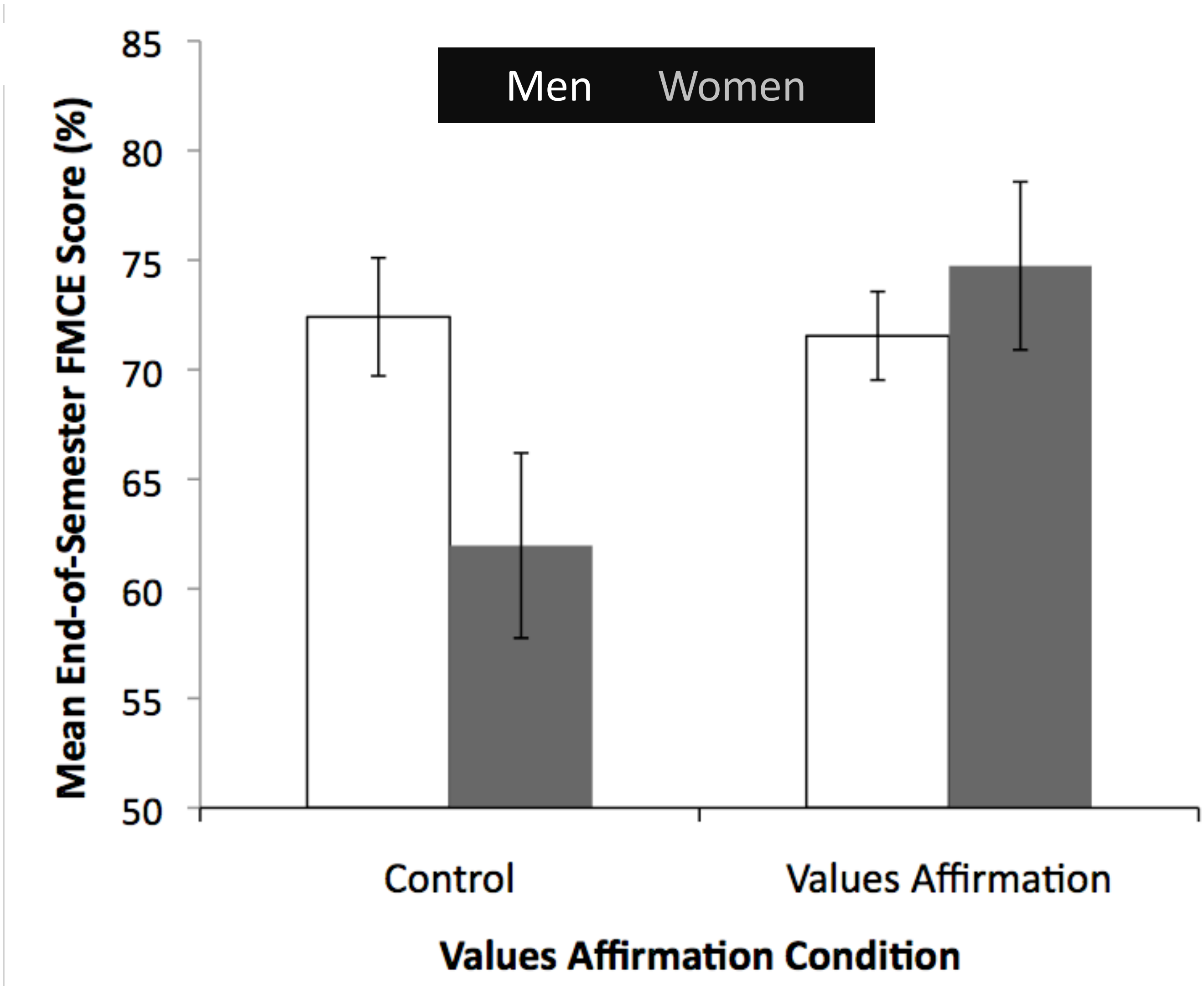
- ST works by threatening one’s self-integrity and identity
- By affirming one’s worth and integrity, through **self-affirmation**, can alleviate ST

Experimental Design

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

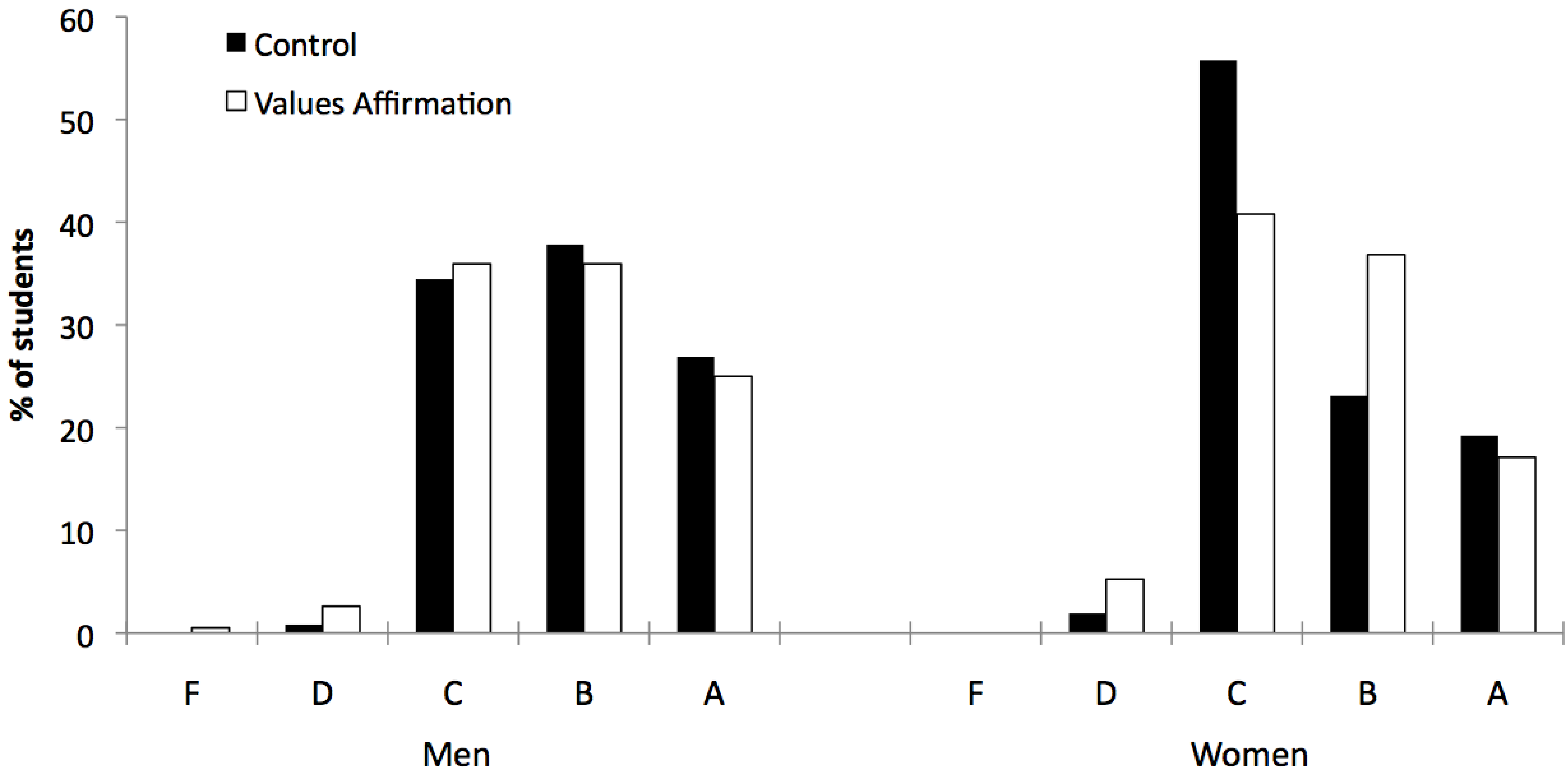


Affirmation Impact



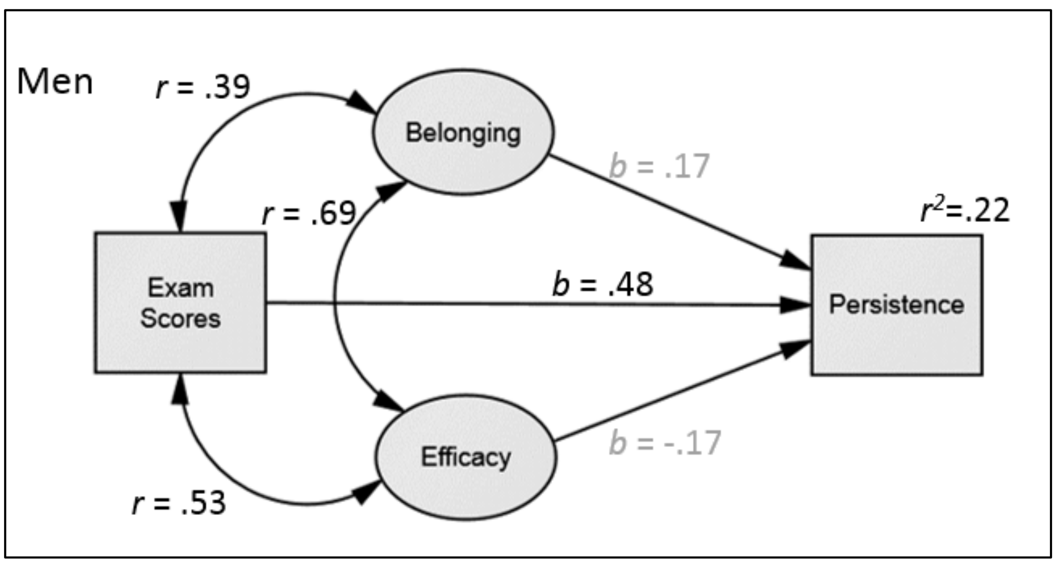
Miyake, Kost, et al, *Science* Dec 2010

Affirmation Impact: Grades



Miyake, Kost, et al, Science Dec 2010

Survey of Physics 1

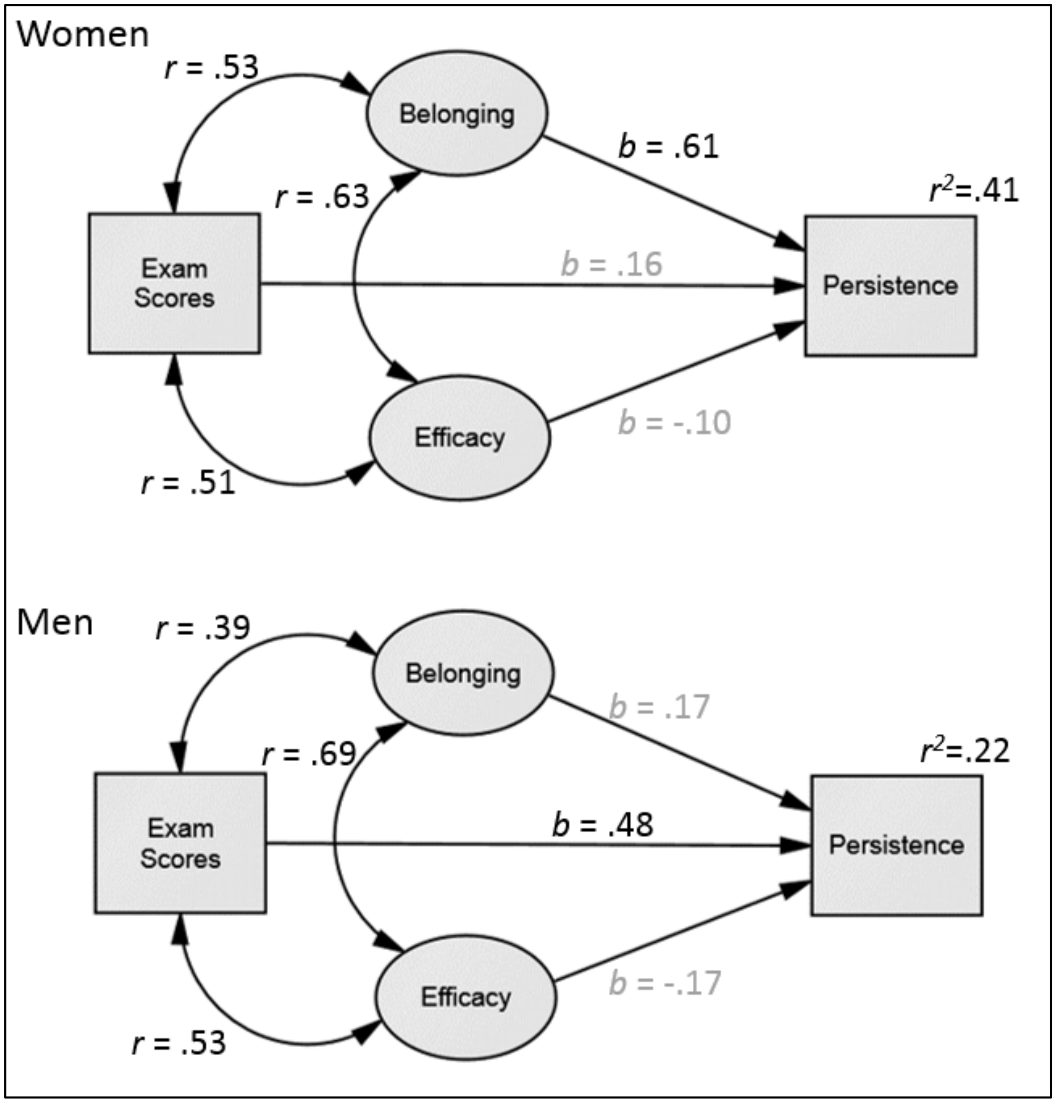


Lewis (2017)

Psychology of Women Quarterly
1-17

DOI: 10.1177/0361684317720186
journals.sagepub.com/home/pwq
SAGE

Survey of Physics 1

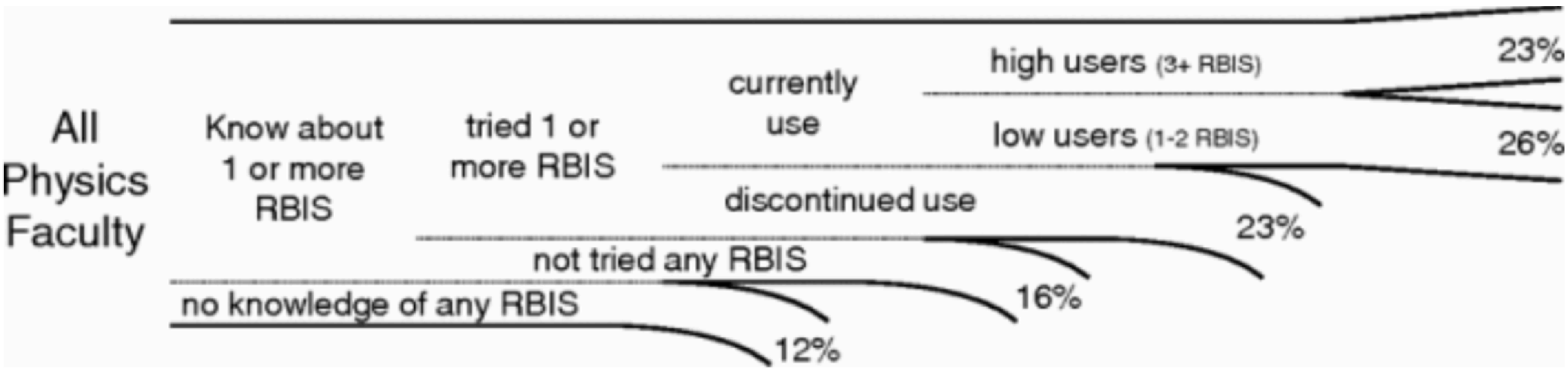


Lewis (2017)

Psychology of Women Quarterly
1-17

DOI: 10.1177/0361684317720186
journals.sagepub.com/home/pwq
SAGE

Faculty Use/ Engagement



Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process?

Charles Henderson, Melissa Dancy, and Magdalena Niewiadomska-Bugaj
Phys. Rev. ST Phys. Educ. Res. **8**, 020104 – Published 31 July 2012

Facilitating Change in STEM Undergraduate Education

Keeping the Good things Going: Study and Improvement of Change Strategies in STEM Education

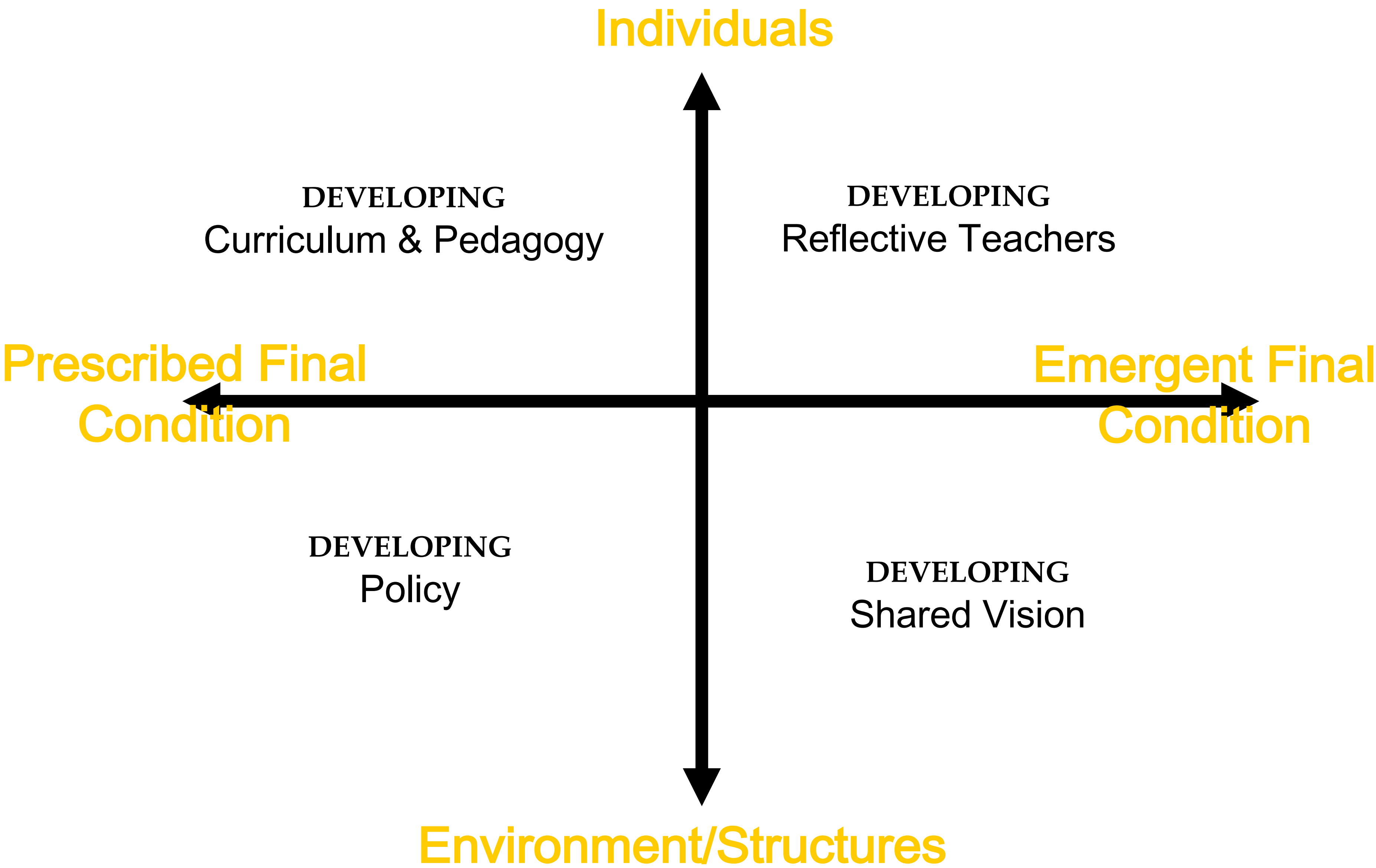
Henderson, C., Beach, A., & Finkelstein, N. (2011) Facilitating Change in Undergraduate STEM Instructional Practices: An Analytic Review of the Literature, *Journal of Research in Science Teaching*, **48** (8), 952-984.

The Big Question

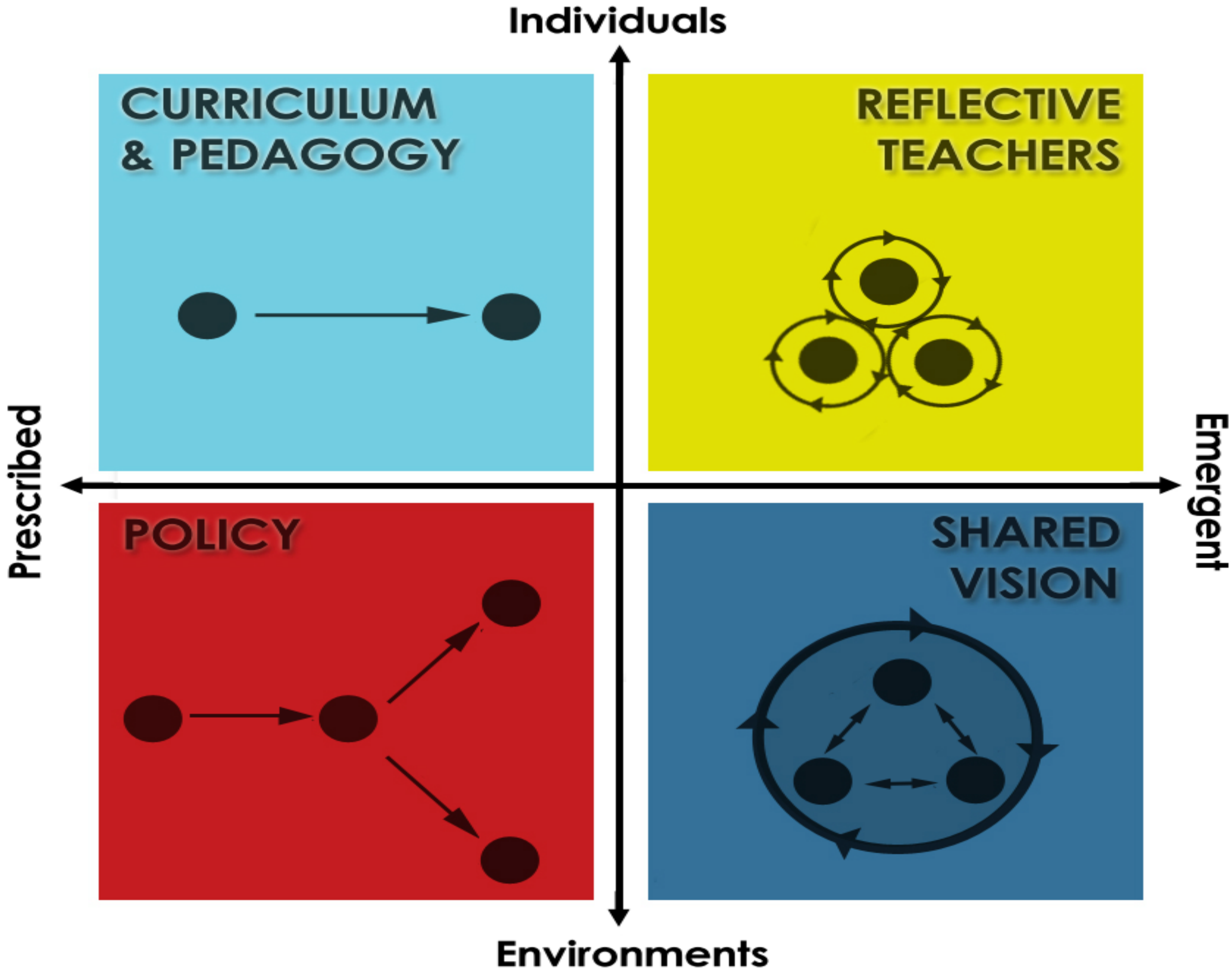
How to encourage the spread of research-based ideas to all instructors/classrooms?

Facilitating Change in STEM Undergraduate Education

Each Strategy has a Unique Emphasis



How they Work



C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952-984 (2011).

Three Groups - One Common Goal

- Transform undergraduate education from the instruction paradigm to the learning paradigm*

The Instruction Paradigm

Traditional Physics class at University of Rochester

The Learning

Clicker use at UC Riverside

White boards at Western Michigan University

Workshop Physics Classroom at Dickinson College

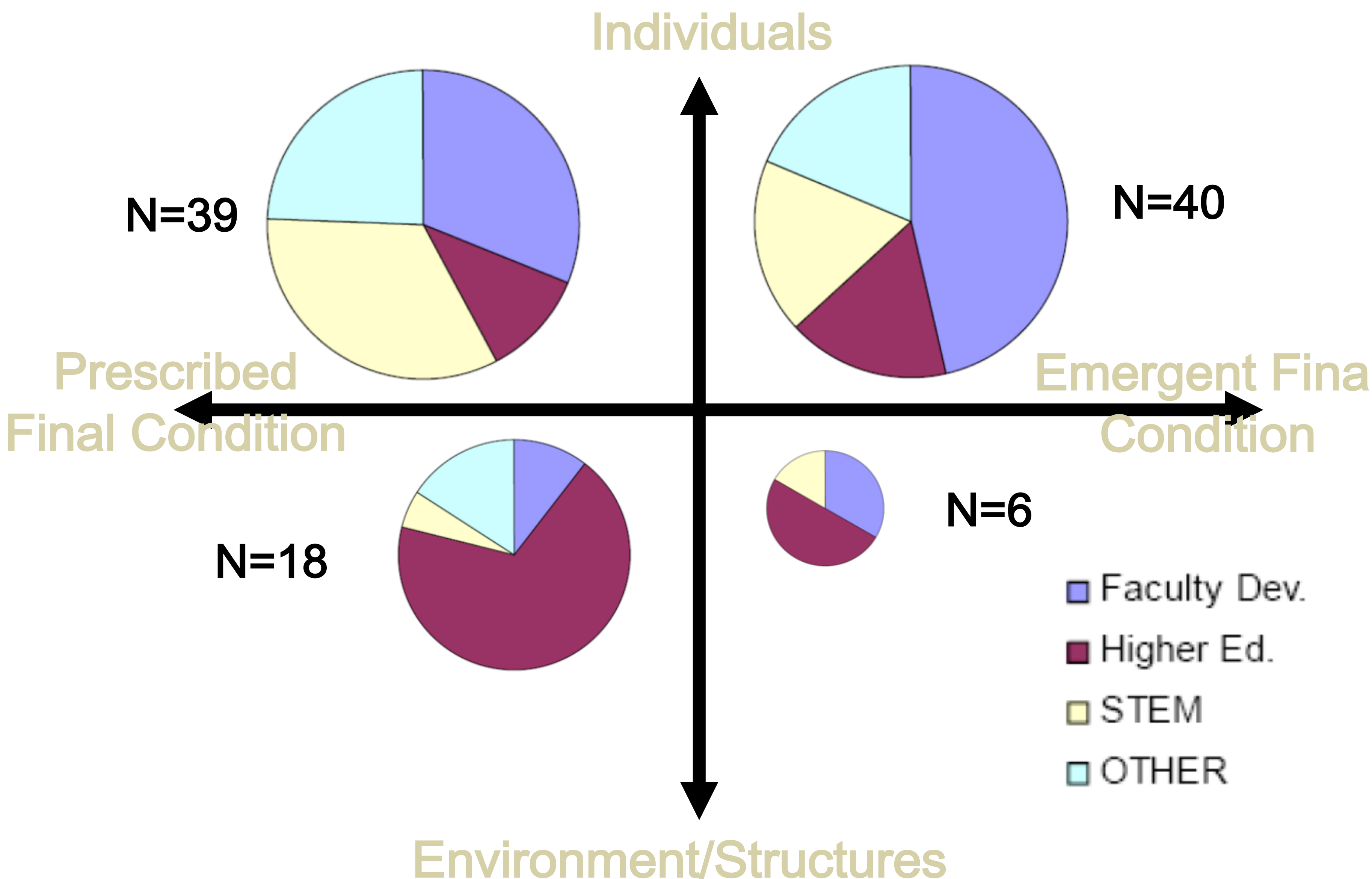
SCALE-UP Physics class at Clemson University

*From Barr, R. B. and Tagg, J. (1995) From teaching to learning - a new paradigm for undergraduate education. *Change* (November/December), 13-25.

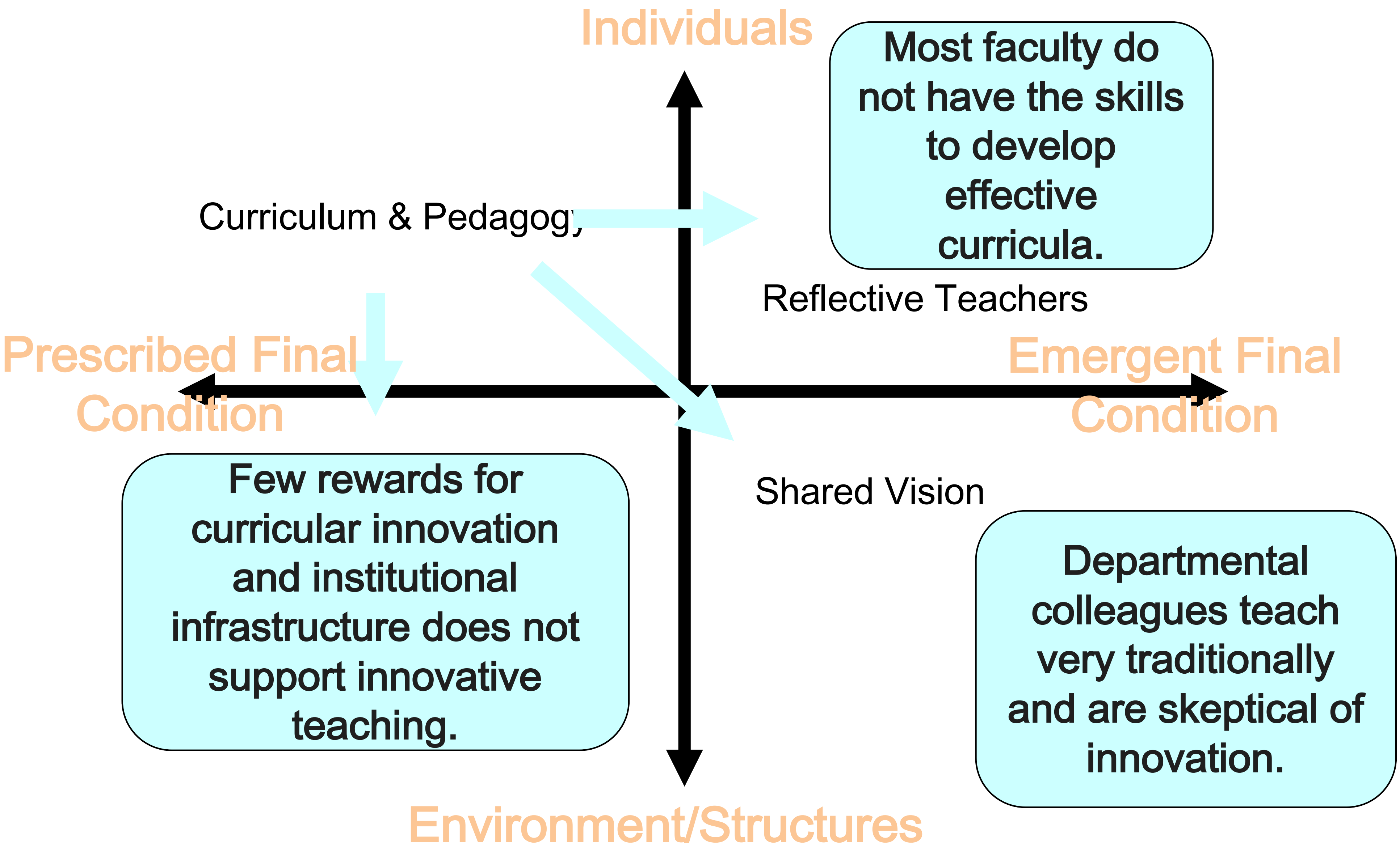
Four Categories of Change Strategies developed from an interdisciplinary literature review

For more details:
Henderson, C., Beach, A., Finkelstein, N., & Larson, R. S., (2008, June). Preliminary Categorization of Literature on Promoting Change in Undergraduate STEM. Paper presented at the Facilitating Change in Undergraduate STEM symposium, Augusta, MI.
<http://www.wmich.edu/science/facilitating-change/PreliminaryCategorization.pdf>

Discipline of Authors Align as Expected



Each change strategy sees areas of influence of other strategies as outside of their control



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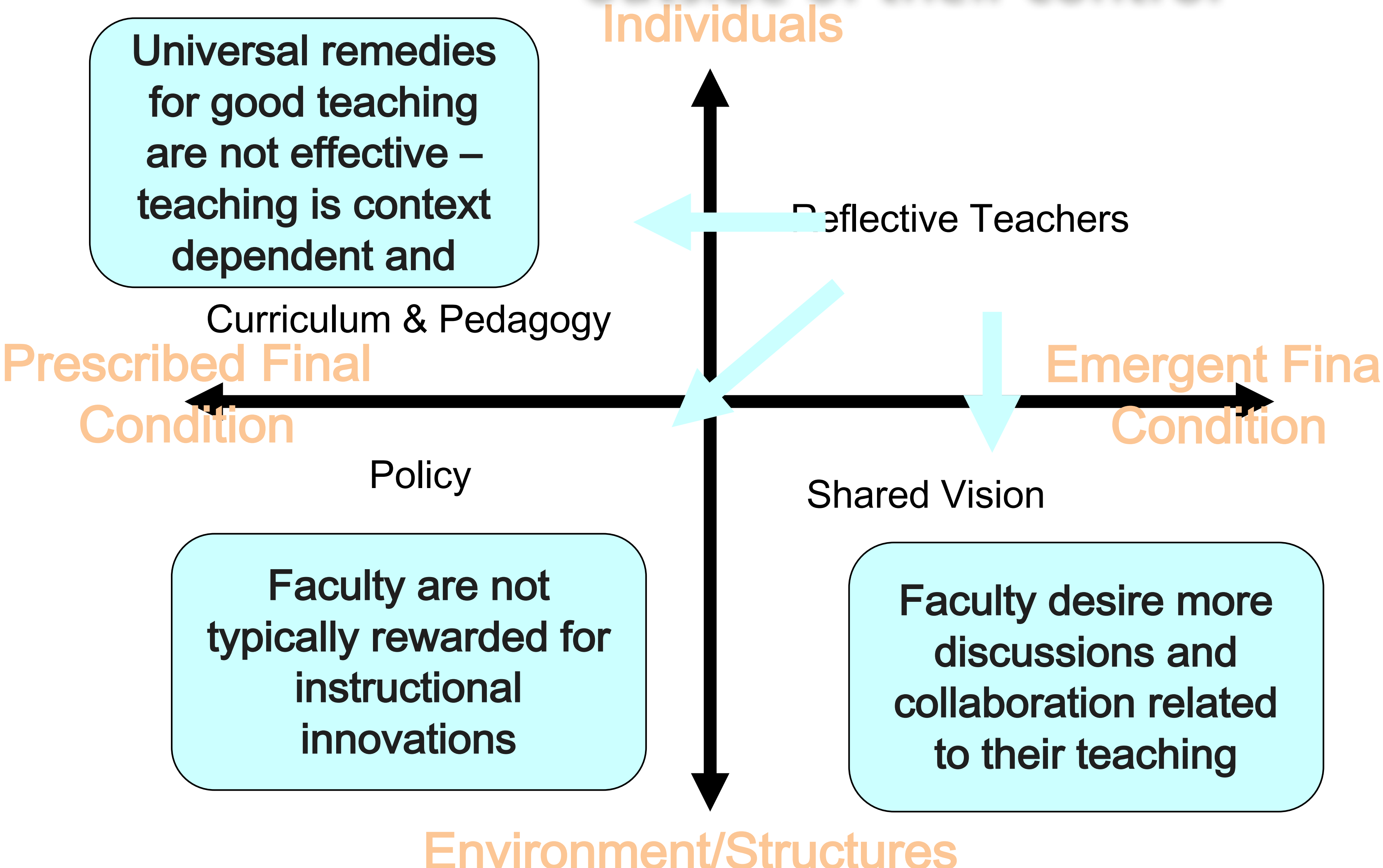
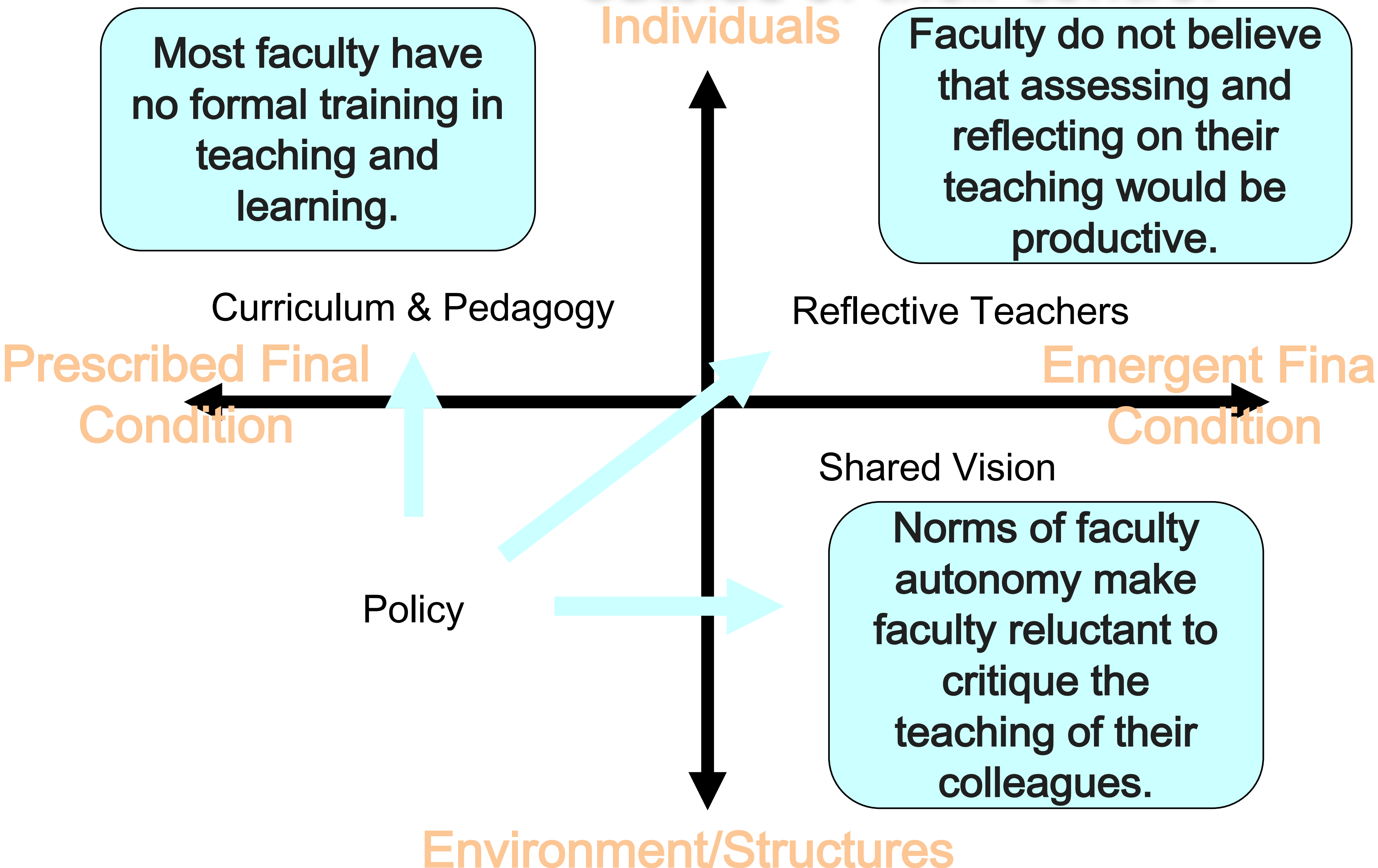
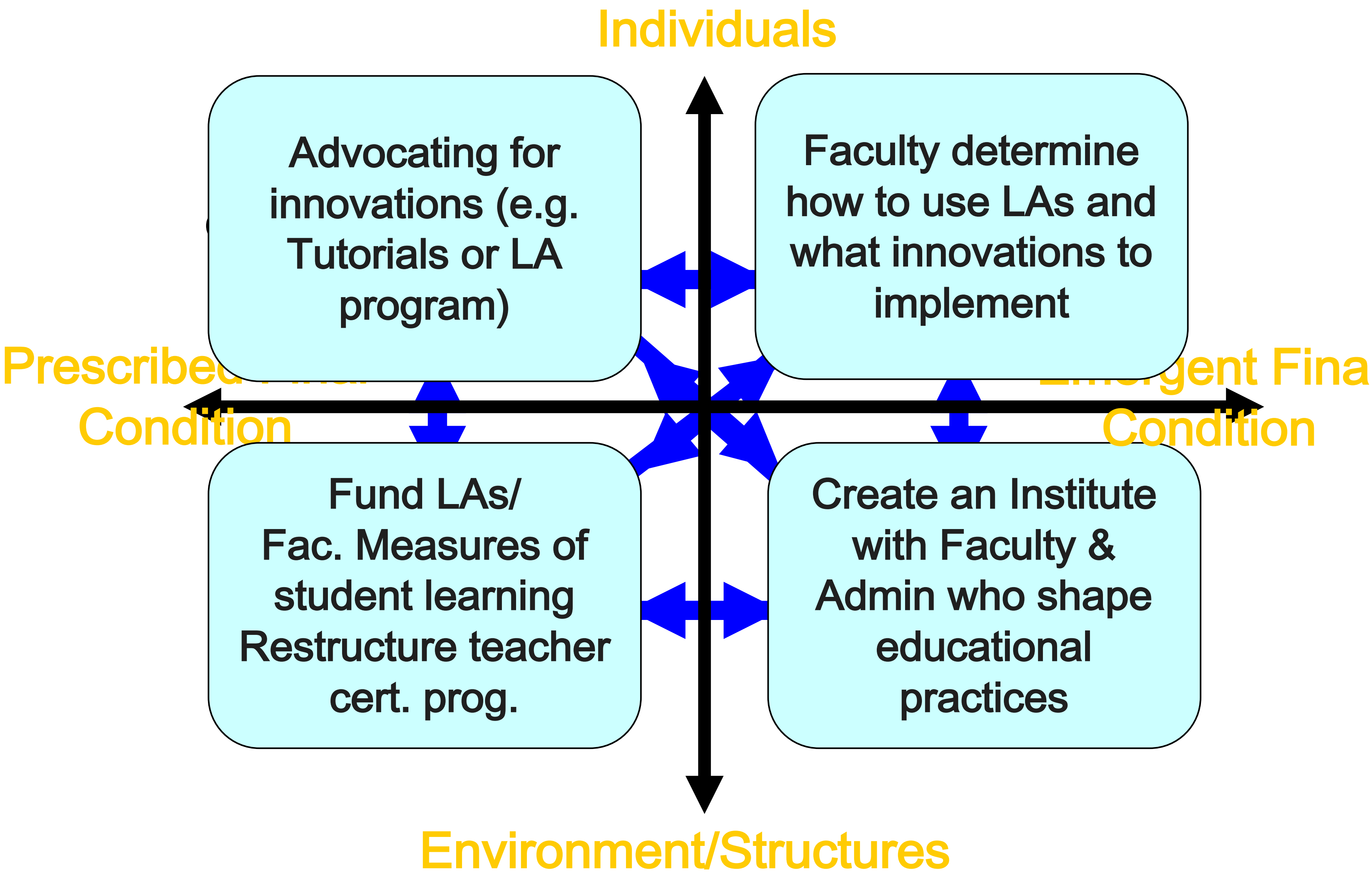


Each change strategy sees areas of influence of other strategies as outside of their control



Revisiting Colorado's Approach



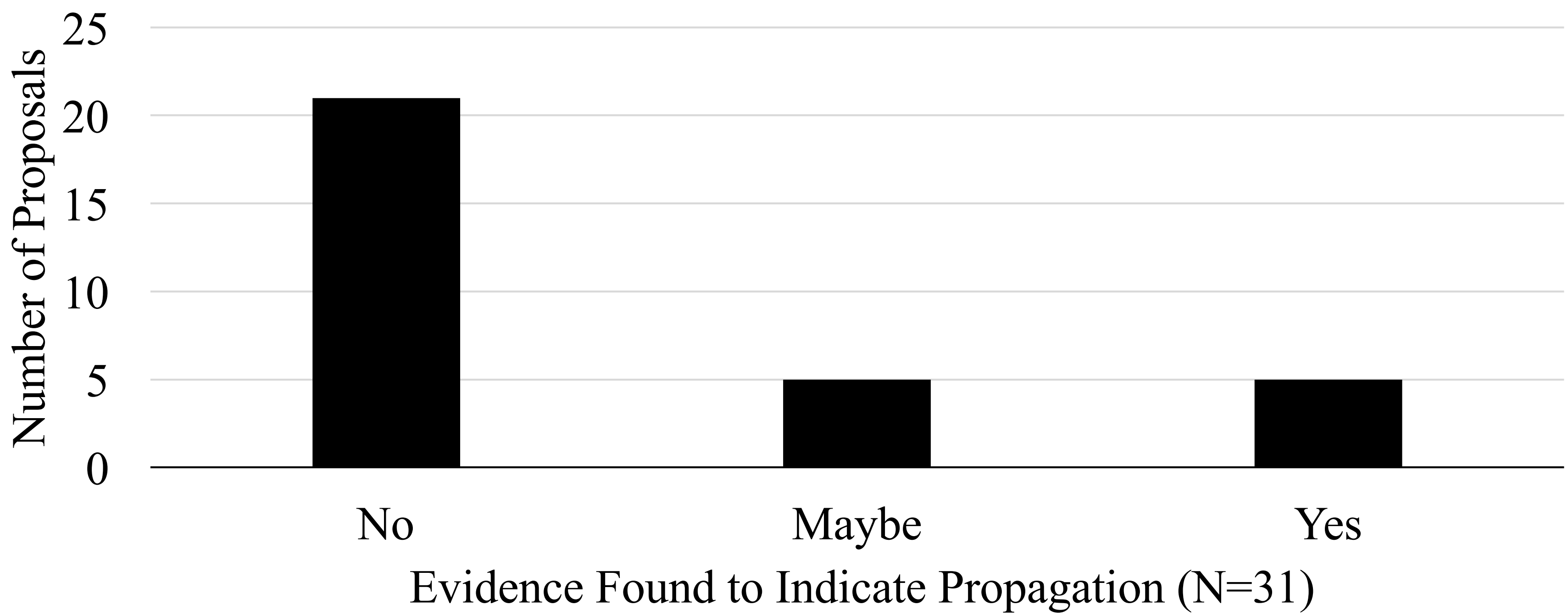
STEM Institutional Transformation Action Research (SITAR) Project

Center for STEM Learning
UNIVERSITY OF COLORADO BOULDER

Daniel Reinholz, Joel C. Corbo
Melissa Dancy, Stanley Deetz, **Noah Finkelstein**

We know change needs modeling

From a cohort of NSF awards designed for transformation



"We found no evidence of successful propagation for most projects"

Stanford, C.; Cole, R. S.; Froyd, J.; Friedrichsen, D.; Khatri, R.; Henderson, C. (submitted) "Designing for sustained adoption: An analysis of propagation plans in NSF-funded education development projects?

Overall Project Goal

"To influence the culture of STEM departments at AAU universities so that they will use sustainable, student-centered, evidence-based, active learning pedagogy in their classes, particularly at the first-year and sophomore levels."

— Association of American Universities

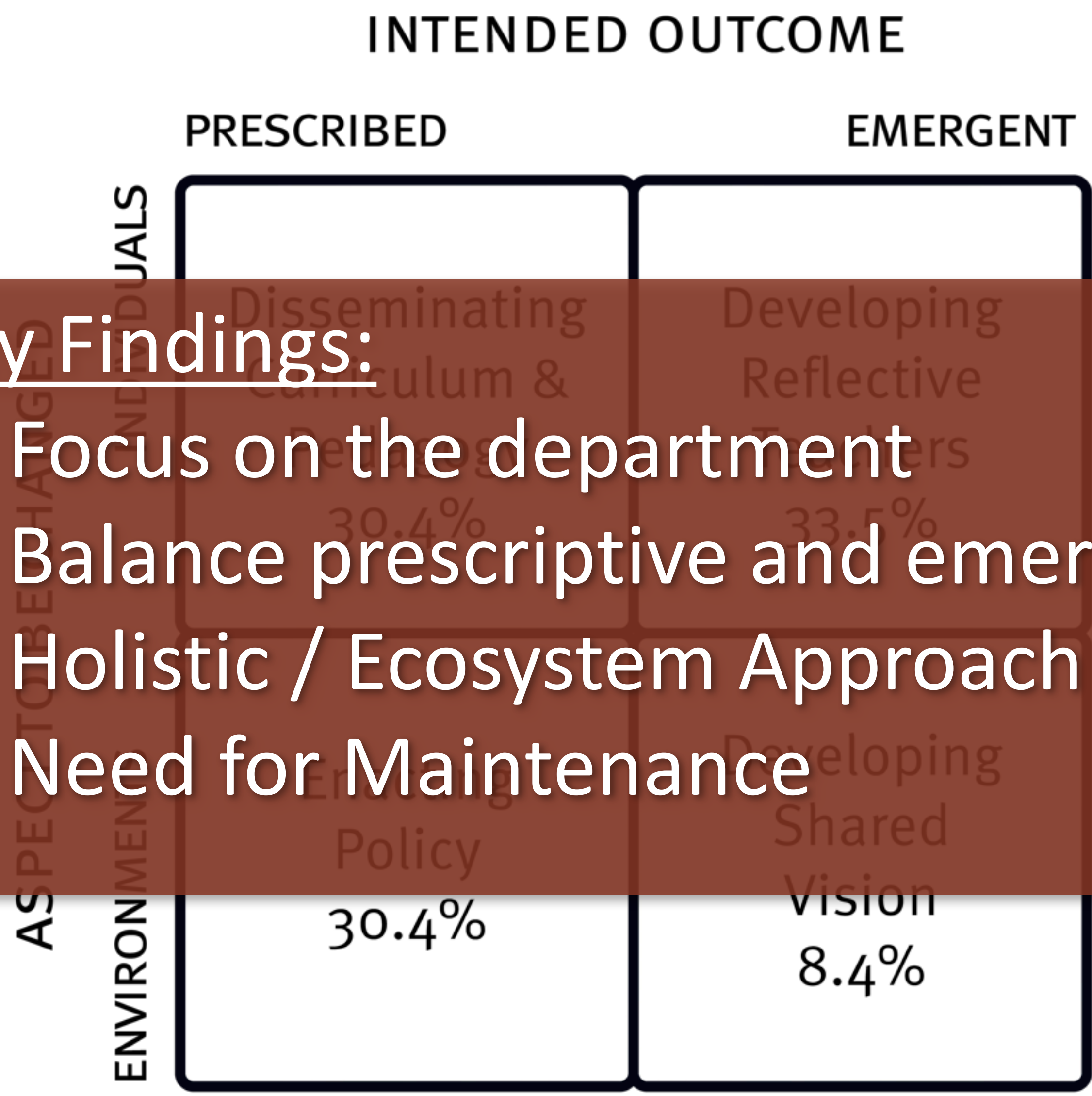
Culture

| ˈkəlCHər |

Historically evolving collective use of tools, norms practices

That which fills in between our knowledge/ understanding and our need to act.

Drawing from Change Literature



<u>Key Findings:</u>

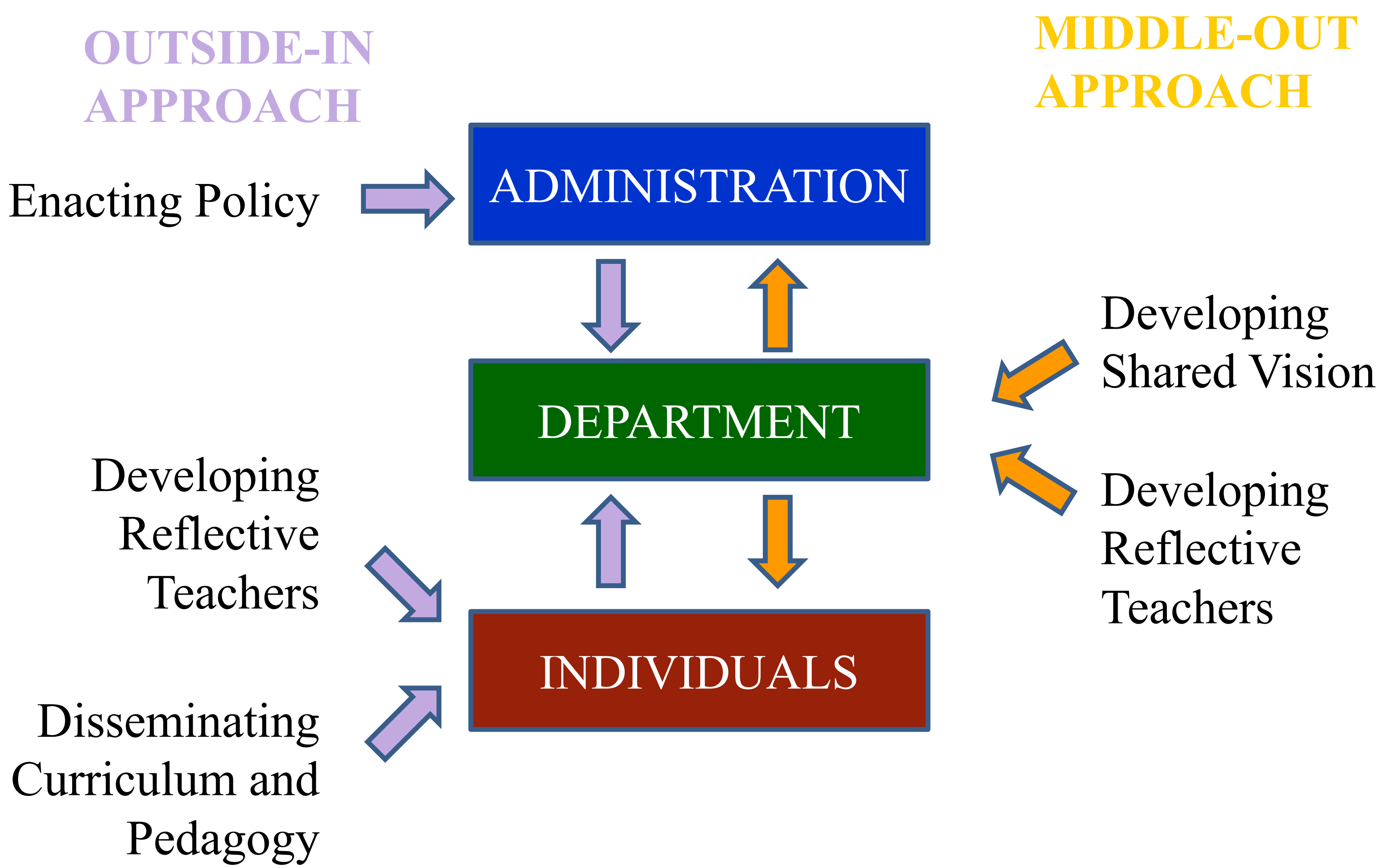
- Focus on the department
- Balance prescriptive and emergent
- Holistic / Ecosystem Approach
- Need for Maintenance

Henderson, Beach, and Finkelstein, *J. Res. Sci. Teach.* **48**, 952–984 (2011)

Departmental Cultural Commitments

- Students as partners in the education process.
- Education designed around learning outcomes.
- Decisions are evidence-based.
- Active collaboration & positive communication
- Department as a “learning organization.”
- Value inclusiveness, diversity and difference.

Two Approaches to Change



Daniel L. Reinholz, Joel C. Corbo, Melissa H. Dancy, Noah Finkelstein, Stanley Deetz
Transforming Institutions: 21st Century Undergraduate STEM Education (2015)

	Interactions Across Levels			External Forces
	Admin. on	**Depts. on**	**Faculty on**	**AAU Project on**
Admin.	-	Determining priorities for allocation resources	Grassroots faculty committees	Framework for Teaching Excellence
Depts.	Setting campus priorities and initiatives	-	Voting, governance, and committee work	Visioning & Alignment
Faculty	Measures of teaching effectiveness	Norms for teaching evaluation	-	Departmental Action Teams

Middle-Out Implementation

Success convinces Administrative to support & amplify dept'l changes

Department culture aligned with core commitments

Positive student outcomes emerge through individual actions

Work with department(s) to facilitate a process designed to align with core commitments & dept'l goals

Outside-In Implementation

Encourage student-centered shifts in **individuals**' beliefs & practices

Assessments: (Formative)

- Assessment as a lever
- Encourage reflective practice

Departmental Action Teams (DATs):

- Address departmental issue
- Achieve long-term stability
- Draw from SoTL, FLC, SEI

Outside-In Implementation

Encourage student-centered shifts in **individuals**' beliefs & practices

<u>Assessments: (Formative)</u>

- Assessment as a lever
- Encourage reflective practice

<u>Departmental Action Teams (DATs):</u>

- Address departmental issue
- Achieve long-term stability
- Draw from SoTL, FLC, SEI

Outside-In Implementation

Encourage development of **administrative** structures that value student-centered education

Faculty Senate/ Taskforce:
- (Re)Define teaching excellence

Senior Administration:
- Require evidence of educational impacts

Centralized Tools/ Resources:
- Accessible Tools
- Inform Educational Practices

Encourage student-centered shifts in **individuals**' beliefs & practices

Outside-In Implementation

Encourage development of **administrative** structures that value student-centered education

Encourage departmental shifts from "above" and "below"

Encourage student-centered shifts in **individuals'** beliefs & practices

Faculty Senate/ Taskforce:

- (Re)Define teaching excellence

Senior Administration:

- Require evidence of educational impacts

Centralized Tools/ Resources:

- Accessible Tools
- Inform Educational Practices

<u>Assessments: (Formative)</u>

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Encourage student-centered shifts in **individuals**' beliefs & practices

<u>Assessments: (Formative)</u>

- Assessment as a lever
- Encourage reflective practice

<u>Departmental Action Teams (DATs):</u>

- Address departmental issue
- Achieve long-term stability
- Draw from SoTL, FLC, SEI

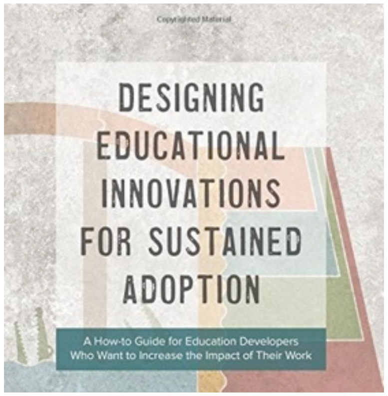
faculty

Departmental Action Teams

- Draw from FLCs, Communities of Practice

- Dept'l Focus & collective outcomes

- Enculturation, learning, sustaining



faculty

Departmental Action Teams

STEM Institutional Transformation Action Research (SITAR) Project

Departmental Action Teams (DATs)

A Departmental Action Team (DAT) is a new type of faculty working group created as a part of the AAU-funded SITAR Project, which aims to **sustainably improve undergraduate STEM education** across CU's campus. DATs are facilitated by SITAR Project team members to support faculty members within a department to **identify an educational issue of broad-scale importance** that they want to address and to **make sustainable changes** by designing and implementing new **structures** and shifting departmental **culture** to address the issue.

Motivation

Research shows that educational issues rarely "stay solved" on their own. Unless there is explicit attention to sustaining improvements, it is unlikely that they will last. Accordingly, a DAT aims to create new structures within a department for supporting continuous improvement so that positive changes do not atrophy over time. By investing in the creation of these structures, it will be much easier for a department to make further improvements down the road.

Additionally, an educational change will only be sustained if a department's culture and the change are aligned with each other. Thus, DATs think explicitly about departmental culture when planning and implementing new structures. Part of the DAT's work may involve facilitating a cultural shift within the department to help the department better achieve the goals that motivated the creation of the DAT in the first place.

Structure

A DAT consists of a self-selected group of about 4-8 participants; these participants are primarily faculty within a single department, but may also include postdoctoral researchers, students, or staff. The members of a DAT have agency in choosing its focus; DAT members select an educational issue of shared interest within their department and work collaboratively to address it.

DATs meet regularly, typically for an hour every other week for two or more semesters. Between meetings, DAT members assign their own "homework," determining what needs to be done and how much time they will commit. DAT members also decide whether or not they would like to schedule additional meetings. Thus, the work of the DAT is entirely participant driven.

The DAT is facilitated by external facilitators that are part of the SITAR team. These facilitators bring expertise in educational research and institutional change, help coordinate logistics, and help the group work together in a collaborative fashion.

Departmental Action Teams: Supporting faculty learning through departmental change

We introduce a new type of faculty working group, called a Departmental Action Team (DAT). A DAT is a self-selected group of 4-8 participants, consisting primarily of faculty within one department. DAT members select an educational issue of shared interest and work collaboratively to create new departmental structures to sustainably address it. DATs are distinct from but draw from Faculty Learning Communities (FLCs); we distinguish DATs and FLCs using three frameworks. To illustrate the application of these frameworks we describe an extended example of one DAT that was a part of a larger project focused on institutional change.

Introduction

To date, most efforts to improve education in universities have focused on the development and dissemination of teaching innovations (Bennett & Bennett, 2003; Henderson, Beach, & Finkelstein, 2011). While many powerful teaching strategies have been developed through these efforts (e.g., Freeman et al., 2014), analysis of their dissemination has brought attention to the difficulty of supporting and sustaining the use of these strategies (Henderson & Dancy, 2009; Henderson, Dancy, & Niewiadomska-Bugaj, 2012; Kezar, 2011). As a result, we have yet to see widespread change in teaching practices in undergraduate education (Austin, 2011; Fairweather, 2008). Thus, there is an urgent need to create new models and approaches for effecting *and sustaining* educational change.

This paper introduces a new type of faculty working group, a Departmental Action Team (DAT), which helps address this need. A DAT is a self-selected group of mostly faculty within a single department with three primary goals: (1) to influence departmental culture by addressing an educational issue of departmental interest, (2) to sustain improvements related to the issue by creating lasting structural changes, and (3) to provide a collaborative, community-building experience for DAT members. DATs are departmentally-focused, faculty-driven, team-based, and focused on creating sustainable changes from the offset; thus, the DAT model has a strong

Outside-In Implementation

Encourage development of **Administrative** structures that value student-centered education

Faculty Senate/ Taskforce:

- (Re)Define teaching excellence

Senior Administration:

- Require evidence of educational impacts

Centralized Tools/ Resources:

- Accessible Tools
- Inform Educational Practices

Encourage student-centered shifts in **individuals'** beliefs & practices

Evidence-based Tools / Practices

- Visualization of Instructional Practices
- Visualization of Student Pathways
- Tools for Physical Plant

Faculty Practices ←→ Administrative Priorities

Visualizing Instructional Practice

Arts & Sciences Support of Education Through Technology
UNIVERSITY OF COLORADO **BOULDER**

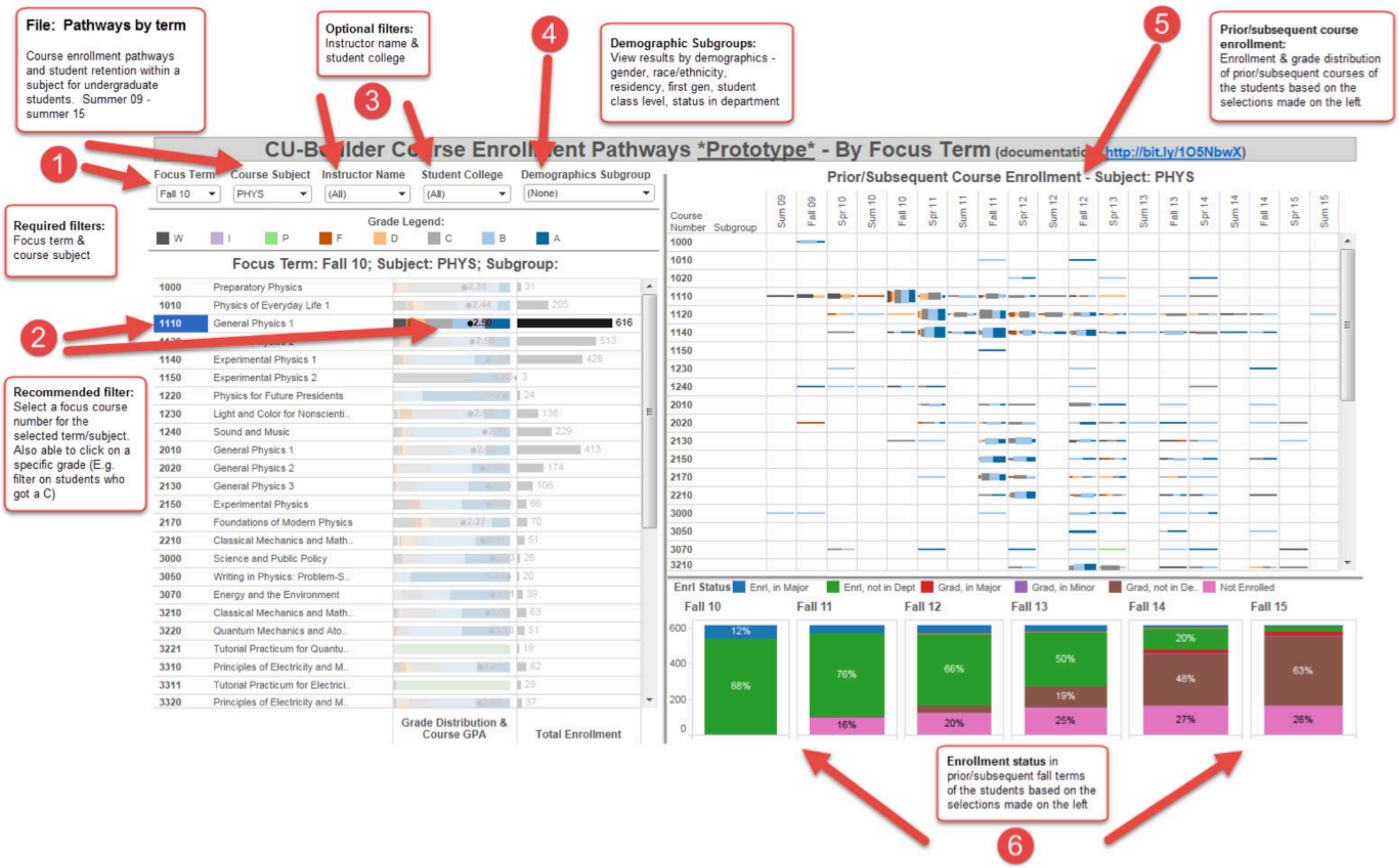
About Us | Events | Communities | **Programs & Services** | Resources | Assessm

Home > Programs & Services > Visualizing Instructional Practices Service

Visualizing Instructional Practices Service

ASSETT's Visualizing Instructional Practices (VIP) Service provides faculty within the College of Arts and Sciences with a new way of reflecting on their teaching, by describing what happens across a class period. This service benefits faculty who are interested in gaining new insights into the patterns of their class activities, in documenting changes as they try out new methods of teaching, and in having new ways to communicate about their teaching with colleagues.

Data Analytics: Student Pathways

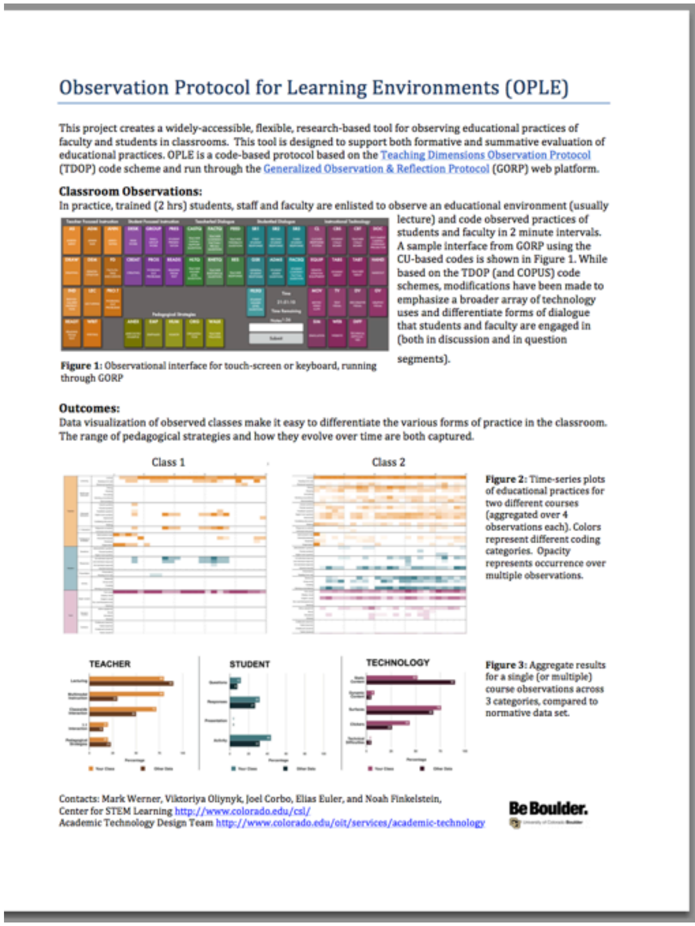


Design Principles of Educational Space

drafted and approved by the
Provost's Learning Spaces Committee 2016

1. Spaces should enable student-centered and interactive pedagogy by being reconfigurable and allowing student and faculty mobility.
2. Technology and tools that directly support learning of disciplinary core ideas, formative assessment, collaborative construction, and inquiry into teaching should be accessible to faculty and students.
3. Spaces should ensure environmental quality, that is, physical characteristics that matter for attention, engagement, and learning.
4. Spaces should follow principles of Universal Design for Learning (UDL), that is, the space should be instrumented so as to provide options for communication to maximize access to all learners.
5. There should be limited numbers of design configurations.
6. Ensure faculty are supported in effective practices in using these spaces.
7. Situate efforts to redesign spaces and create new ones within broader campus initiatives and priorities.

Write-ups Available



Observation Protocol for Learning Environments (OPLE)

This project creates a widely-accessible, flexible, research-based tool for observing educational practices of faculty and students in classrooms. This tool is designed to support both formative and summative evaluation of educational practices. OPLE is a code-based protocol based on the Teaching Dimensions Observation Protocol (TDOP) code scheme and run through the Generalized Observation & Reflection Protocol (GORP) web platform.

Classroom Observations:
In practice, trained (2 hrs) students, staff and faculty are enlisted to observe an educational environment (usually lecture) and code observed practices of students and faculty in 2 minute intervals. A sample interface from GORP using the CU-based codes is shown in Figure 1. While based on the TDOP (and COPUS) code schemes, modifications have been made to emphasize a broader array of technology uses and differentiate forms of dialogue that students and faculty are engaged in (both in discussion and in question segments).

Figure 1: Observational interface for touch-screen or keyboard, running through GORP

Outcomes:
Data visualization of observed classes make it easy to differentiate the various forms of practice in the classroom. The range of pedagogical strategies and how they evolve over time are both captured.

Class 1 | Class 2

Figure 2: Time-series plots of educational practices for two different courses (aggregated over 4 observations each). Colors represent different coding categories. Opacity represents occurrence over multiple observations.

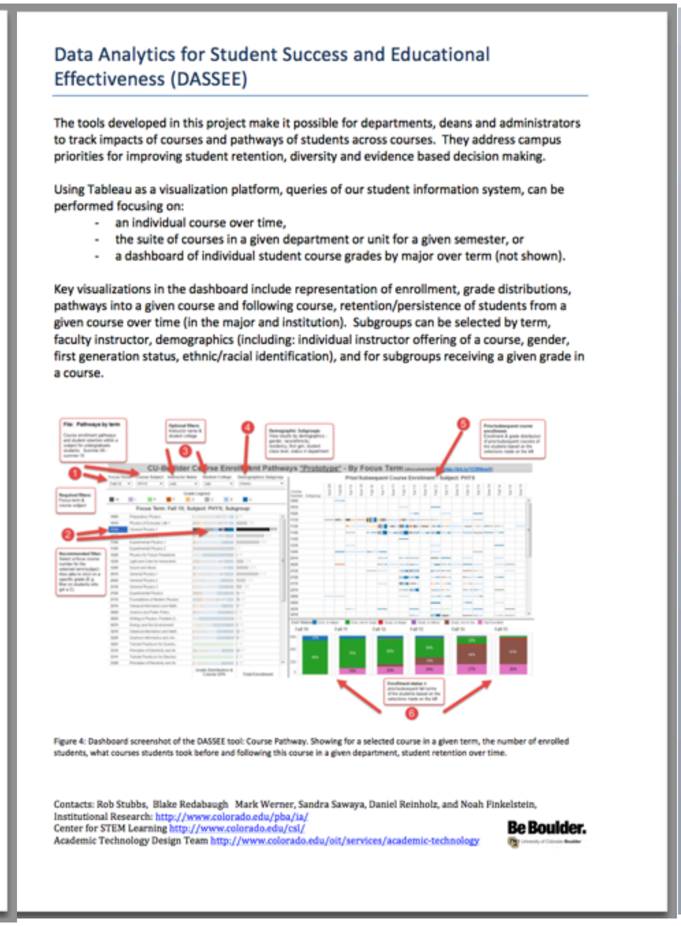
TEACHER | STUDENT | TECHNOLOGY

Figure 3: Aggregate results for a single (or multiple) course observations across 3 categories, compared to normative data set.

Contacts: Mark Werner, Viktoriya Oliynyk, Joel Corbo, Elias Euler, and Noah Finkelstein,
Center for STEM Learning http://www.colorado.edu/csl/
Academic Technology Design Team http://www.colorado.edu/oit/services/academic-technology

Be Boulder.

Observation



Data Analytics for Student Success and Educational Effectiveness (DASSEE)

The tools developed in this project make it possible for departments, deans and administrators to track impacts of courses and pathways of students across courses. They address campus priorities for improving student retention, diversity and evidence based decision making.

Using Tableau as a visualization platform, queries of our student information system, can be performed focusing on:

- an individual course over time,
- the suite of courses in a given department or unit for a given semester, or
- a dashboard of individual student course grades by major over term (not shown).

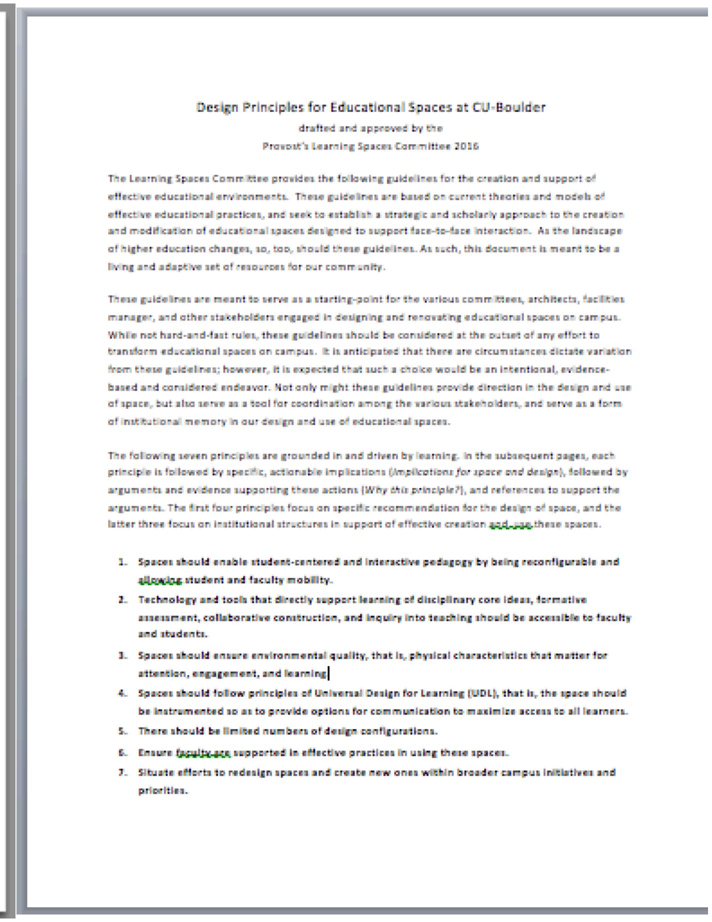
Key visualizations in the dashboard include representation of enrollment, grade distributions, pathways into a given course and following course, retention/persistence of students from a given course over time (in the major and institution). Subgroups can be selected by term, faculty instructor, demographics (including: individual instructor offering of a course, gender, first generation status, ethnic/racial identification), and for subgroups receiving a given grade in a course.

Figure 4: Dashboard screenshot of the DASSEE tool: Course Pathway. Showing for a selected course in a given term, the number of enrolled students, what courses students took before and following this course in a given department, student retention over time.

Contacts: Rob Stubbs, Blake Redabaugh Mark Werner, Sandra Sawaya, Daniel Reinholz, and Noah Finkelstein,
Institutional Research: http://www.colorado.edu/pba/ia/
Center for STEM Learning http://www.colorado.edu/csl/
Academic Technology Design Team http://www.colorado.edu/oit/services/academic-technology

Be Boulder.

Analysis



Design Principles for Educational Spaces at CU-Boulder
drafted and approved by the
Provost's Learning Spaces Committee 2016

The Learning Spaces Committee provides the following guidelines for the creation and support of effective educational environments. These guidelines are based on current theories and models of effective educational practices, and seek to establish a strategic and scholarly approach to the creation and modification of educational spaces designed to support face-to-face interaction. As the landscape of higher education changes, so, too, should these guidelines. As such, this document is meant to be a living and adaptive set of resources for our community.

These guidelines are meant to serve as a starting-point for the various committees, architects, facilities manager, and other stakeholders engaged in designing and renovating educational spaces on campus. While not hard-and-fast rules, these guidelines should be considered at the outset of any effort to transform educational spaces on campus. It is anticipated that there are circumstances dictate variation from these guidelines; however, it is expected that such a choice would be an intentional, evidence-based and considered endeavor. Not only might these guidelines provide direction in the design and use of space, but also serve as a tool for coordination among the various stakeholders, and serve as a form of institutional memory in our design and use of educational spaces.

The following seven principles are grounded in and driven by learning. In the subsequent pages, each principle is followed by specific, actionable implications (*Implications for space and design*), followed by arguments and evidence supporting these actions (*Why this principle?*), and references to support the arguments. The first four principles focus on specific recommendation for the design of space, and the latter three focus on institutional structures in support of effective creation and use these spaces.

1. **Spaces should enable student-centered and interactive pedagogy by being reconfigurable and allowing student and faculty mobility.**
2. **Technology and tools that directly support learning of disciplinary core ideas, formative assessment, collaborative construction, and inquiry into teaching should be accessible to faculty and students.**
3. **Spaces should ensure environmental quality, that is, physical characteristics that matter for attention, engagement, and learning**
4. **Spaces should follow principles of Universal Design for Learning (UDL), that is, the space should be instrumented so as to provide options for communication to maximize access to all learners.**
5. **There should be limited numbers of design configurations.**
6. **Ensure faculty are supported in effective practices in using these spaces.**
7. **Situate efforts to redesign spaces and create new ones within broader campus initiatives and priorities.**

Design

Towards a Framework for Supporting and Assessing Teaching Quality at CU-Boulder

Noah Finkelstein, Jessica Keating, Joel Corbo
University of Colorado Boulder

Daniel Bernstein
University of Kansas

Daniel Reinholz,
San Diego State

And Leadership at CU and 12 Departments

Aligning Practice to Policies

Changing the Culture to Recognize and Reward Teaching at Research Universities

Association of American Universities
Inquiry · Innovation · Impact

RESEARCH CORPORATION *for* SCIENCE ADVANCEMENT
A foundation dedicated to science since 1912.

TOWARDS A FRAMEWORK FOR SUPPORTING AND ASSESSING TEACHING QUALITY AT CU-BOULDER

> *[The University of Colorado Boulder should] enhance efforts to upgrade the prestige, respect and reward structure for excellence in the scholarship of teaching; . . . Develop frameworks in which teaching excellence and dedication are evaluated with a level of scrutiny comparable to how research and creative work is scrutinized.*
>
> *Recommendation 7*
> *Academic Affairs Persistence Committee*
> *Co-Chairs: M. Grant & J. Cox*

Executive Summary

The University of Colorado Boulder requires that "[d]ossiers for comprehensive review, tenure, or promotion must include multiple measures of teaching" (J. Cox, 2007). However, at present we do not have a well-defined framework to guide individuals or departments in the selection and interpretation of such measures, which makes it difficult to assess teaching quality and support faculty growth in their teaching in a systematic way.

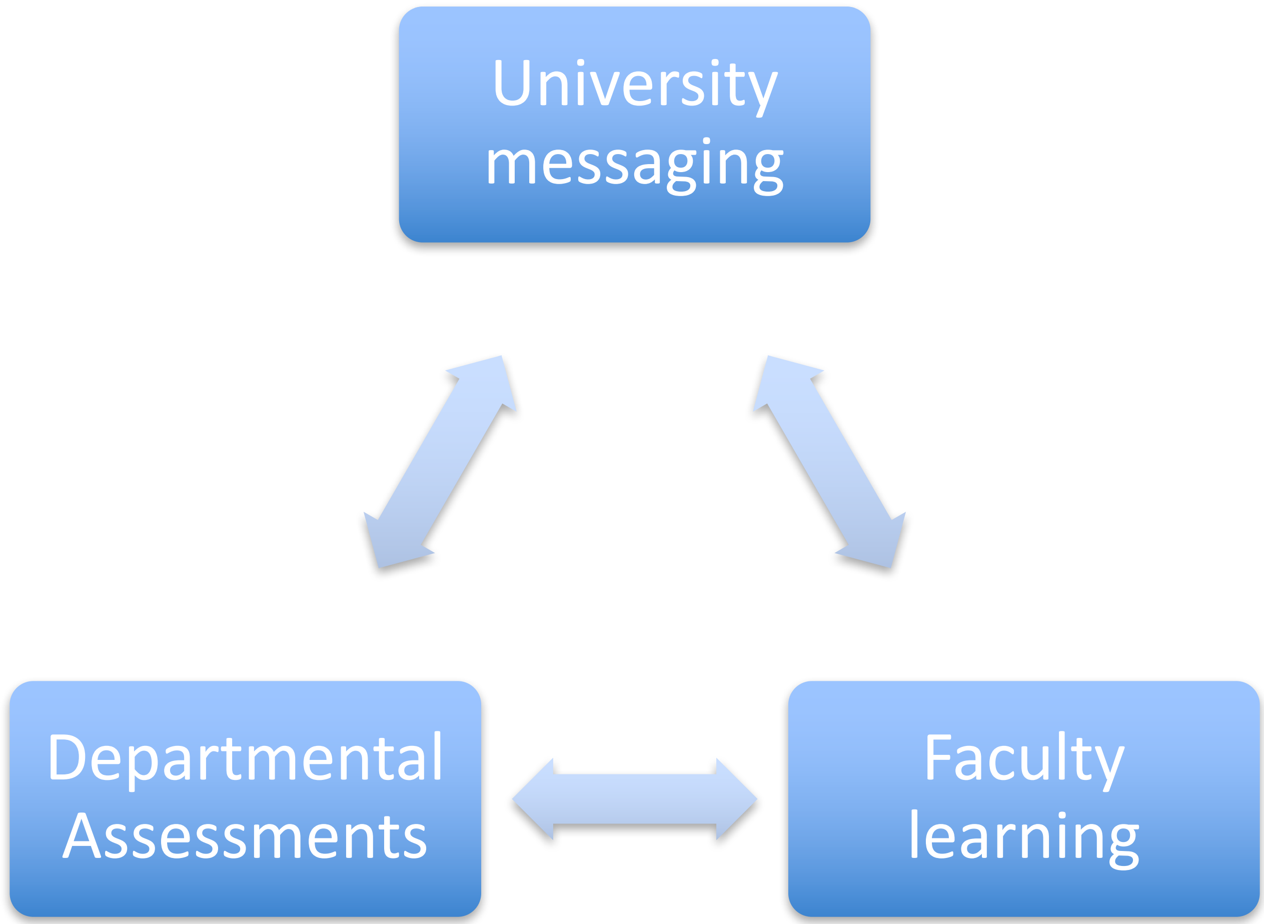
This paper outlines a framework for supporting and assessing teaching quality for all instructors across all departments on campus that is grounded in the scholarship of higher education, including the work of Bernstein and colleagues (2002, 2010) and Glassick and colleagues (1997). This framework defines teaching as a scholarly activity like research. It assesses teaching in terms of six core components of scholarly activity—clear goals, adequate preparation, appropriate methods, significant results, effective presentation, and reflective critique—through the use of three "voices" —those of a faculty member, his or her students, and his or her peers. The framework also supports improved teaching, by providing mechanisms for assessment to help faculty to improve in their practices. These framework categories are held constant across all departments; however, the interpretation of these categories and their relative weights would be defined at a department-by-department level, thus specifying in a clear way what is meant by "multiple measures." This would provide the university with a common approach to assessment while preserving disciplinary identity and specificity.

In addition to presenting this framework, we suggest a strategy for implementation that will lead to its campus-wide adoption. This strategy is not a top-down mandate. Instead, it focuses on bringing together key faculty leaders and departments and providing them with a structure to help them co-create, test, and evaluate the framework in a relatively low-stakes context (merit raises, rather than tenure and promotion). This is an opt-in model, with pilot departments choosing to engage and become leaders in this process. Thus, this strategy empowers the community to voluntarily engage in the exploration of new ways of assessing teaching and to adopt the framework because they see its value. Finally, we present a set of examples of ways in which teaching can be assessed that aligns with the framework in order to provide context to the reader.

[The University of Colorado Boulder should] enhance efforts to upgrade the prestige, respect and reward structure for excellence in the scholarship of teaching; . . . Develop frameworks in which teaching excellence and dedication are evaluated with a level of scrutiny comparable to how research and creative work is scrutinized.

Recommendation 7
Academic Affairs Persistence Committee
Co-Chairs: M. Grant & J. Cox

Benefits


University messaging
Departmental Assessments
Faculty learning

Components of a Framework

Teaching as Scholarly Activity

1. **Clear goals.**
2. **Adequate preparation.**
3. **Appropriate methods.**
4. **Significant results.**
5. **Effective presentation.**
6. **Reflective critique.**

Glassick, C. E., Huber, M. T., & Maeroff, G. I. (1997). *Scholarship Assessed: Evaluation of the Professoriate. Special Report*. SF, CA: Jossey Bass Inc.

Process for Developing & Enacting a Framework

Parallel & Intertwined Endeavors

Administrative Commission

Department		Campus
Dept's Engagement Small Group (DAT)	→	**Campus Taskforce** Dept, deans, key stakeholders
Framework-> Rubric Engagement of Dept	⇄	Revisiting/ Defining Framework, Support, FLC
Defining Pilot work resources/merit / p&t	⇄	Engaging campus Educating Eval Comm's

Administrative Call / Celebration

Department		Campus
Dept's Engagement Pilot approach	⇄	**Campus Rev. Comms** Support & Educ.

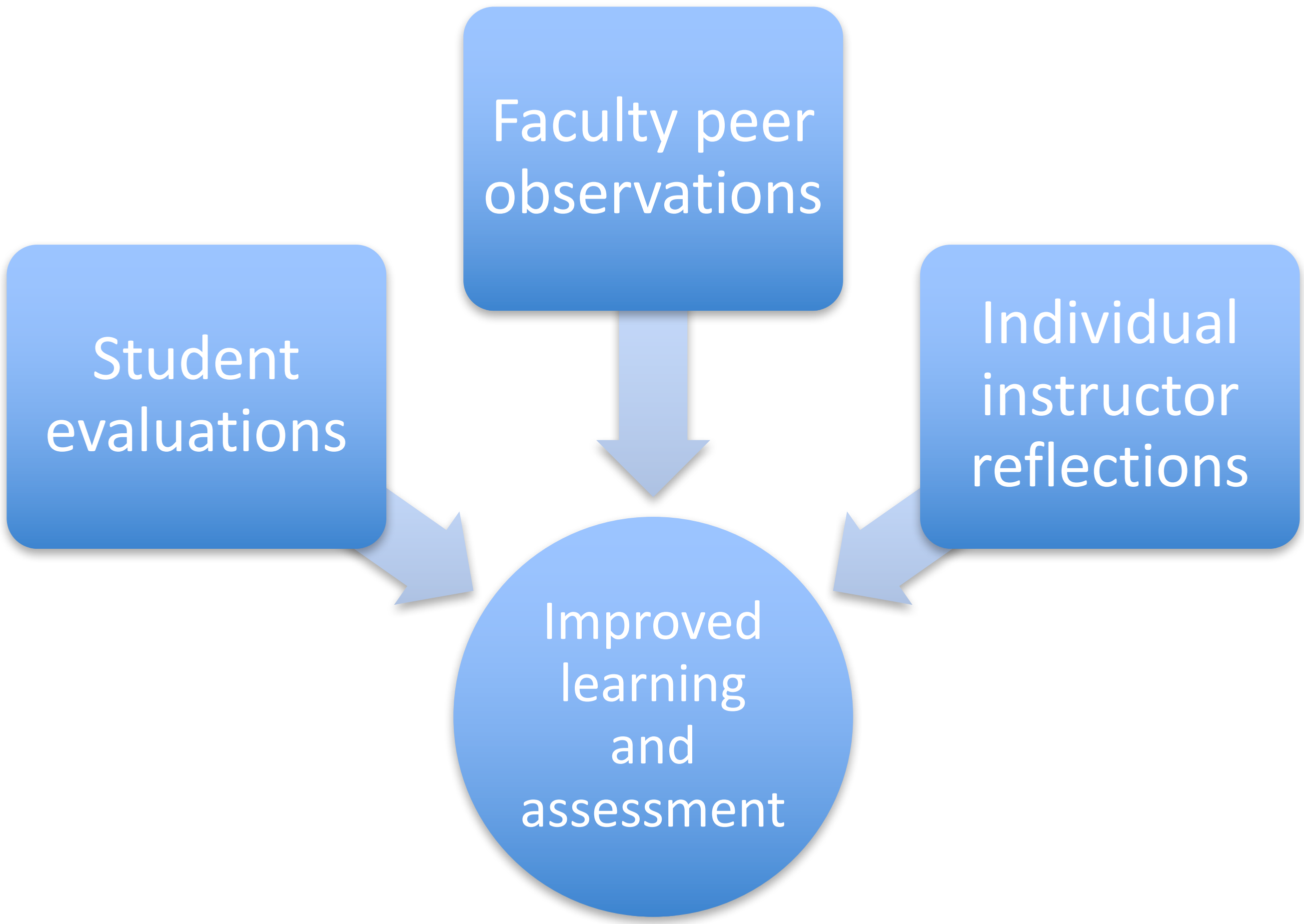
From Framework to Rubrics

- Departmentally-specific rubrics
- Draw from components of scholarly activity, three voices, or other resources
- This is a pilot version (living document)

Components	Entry into teaching	Basic Skill	Professional	Advanced
Goals of the course or other learning activity	Course/activity goals are absent, unclear, or inappropriate.	Course/activity goals are well articulated and appropriate to the course and to the curriculum.	Course/activity goals identify intellectually challenging and enduring targets and/or are especially well matched to students.	Course/activity goals identify levels of performance that represent excellence and are of interest to many stakeholders.
Preparation for the course or learning activity	Teacher is not adequately knowledgeable and/or has no background in teaching.	The teaching is based on prior scholarship in its area, including current content as well as pedagogical methods and conceptual frames.	The teacher's preparation includes broad synthesis of prior work in content as well as practice in pedagogical methods and conceptual frames.	The teacher acquires and integrates knowledge and skills drawn from the literature of multiple disciplines, both in content and pedagogy.
Methods used to conduct the teaching	No apparent rationale for teaching methods is used; there is no instructional design.	The work follows the conventions of teaching practices within its domain of discipline and institution.	The teaching takes full advantage of effective methods discussed within its discipline.	The work generates new practices that will enable others to improve or enhance their teaching.
Evidence gathered to demonstrate the impact of the teacher's work	There s no measure of student learning, or assessment methods do not match espoused goals.	There is evidence linking students' performance to espoused goals.	Student performances indicate that deep and/ or broad learning is taking place.	The learning demonstrated is exemplary in either depth of learning and/or in breadth of students' success.
Reflection on the teaching and its impact on student learning	The teacher provides no indication of having reflected on or learned from prior teaching.	The teacher articulates lessons learned from reflecting on prior teaching.	The teacher has examined the impact on students' performance within a conceptual framework and adjusted practices based on reflection.	Enhanced achievement of learning goals results form reflection on evidence within a conceptual framework, or the teacher revises the conceptual framework based on student learning outcomes.
Communication of teaching results to others	The practice and results of teaching are kept private.	The teacher's work and students' performances are publicly accessible for others to use, to build on, and to review critically.	The teacher's reflective work has been read and adjustments in practice have arisen through the public discourse.	The teacher's work has had an impact on the practices and inquiry of many others and has contributed to related conceptual frameworks.

Bernstein, U. Kansas

Three Voices (Sources of Data)



CURRICULUM ALIGNMENT

	Factors	Weight	0 (not observed)	1 (initial stages)	2 (average)	3 (very good)	4 (excellent, exemplar)	Final Score
A. CORE CONCEPTS								0
1	**Evolution core concept integrated into curriculum**		Concept not included in any courses	Students are only minimally exposed to this concept	Students are exposed to this concept in significant detail in at least one required course	Students are exposed to this concept in significant detail in at least one course and implicit understanding is expected in additional courses	Students get multiple opportunities to explore this concept in order to complete their degree	
2	**Structure and function core concept integrated into curriculum**		Concept not included in any courses	Students are only minimally exposed to this concept	Students are exposed to this concept in significant detail in at least one required course	Students are exposed to this concept in significant detail in at least one course and implicit understanding is expected in additional courses	Students get multiple opportunities to explore this concept in order to complete their degree	
3	**Information flow, exchange and storage core concepts integrated into curriculum**		Concept not included in any courses	Students are only minimally exposed to this concept	Students are exposed to this concept in significant detail in at least one required course	Students are exposed to this concept in significant detail in at least one course and implicit understanding is expected in additional courses	Students get multiple opportunities to explore this concept in order to complete their degree	
4	**Pathways and transformations of energy and matter core concept integrated into curriculum**		Concept not included in any courses	Students are only minimally exposed to this concept	Students are exposed to this concept in significant detail in at least one required course	Students are exposed to this concept in significant detail in at least one course and implicit understanding is expected in additional courses	Students get multiple opportunities to explore this concept in order to complete their degree	
5	**Systems core concept integrated into curriculum**		Concept not included in any courses	Students are only minimally exposed to this concept	Students are exposed to this concept in significant detail in at least one required course	Students are exposed to this concept in significant detail in at least one course and implicit understanding is expected in additional courses	Students get multiple opportunities to explore this concept in order to complete their degree	

Pilot Adoption by Departments

- SITAR team and 8 department chairs meet
  - 12 departments choose to opt-in In each department
  - 2-3 faculty members lead
- Across departments
  - Faculty leads work together
  - Working group (like a Faculty Learning Community or Departmental Action Team)

External Recognition and Support

NSF

BAY VIEW
ALLIANCE

Association
of American
Universities
Inquiry · Innovation · Impact

RESEARCH CORPORATION
for SCIENCE ADVANCEMENT
A foundation dedicated to science since 1912.

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

Many resources for change

Association of American Universities

STEM Education Initiative

Best resources are here…

Caltech Center for Teaching, Learning & Outreach

Resources Faculty TAs Students Outreach Technology Caltech Project for Effective Teaching Core

TeachWeek 2017 About CTLO Events Announcements

Planning & Teaching Courses | Teaching for Inclusion & Diversity | Books & Articles | Teaching Awards | Photographs

LINKS TO CALTECH TEACHING AND LEARNING RESOURCES

Please explore CTLO's on-demand resources on teaching in the following areas:

- Planning and Teaching Courses
- Teaching for Inclusion and Diversity
- Books and Articles
- Caltech Teaching Awards

The offices below also support teaching and learning through services and resources for students and faculty:

- **Academic Media Technologies**: audio visual services and digital media solutions, strategies, and recommendations.
- **Center for Diversity**: leadership, outreach, policy and programming support for the campus-wide diversity initiatives associated with faculty, postdoctoral scholars, students and staff.
- **Counseling Center**: free for all students, regardless of insurance plan.
- **Dean's Office, Undergraduates**:

Fin

Much more at: *per.colorado.edu*

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