New pedagogies for higher education in science and engineering

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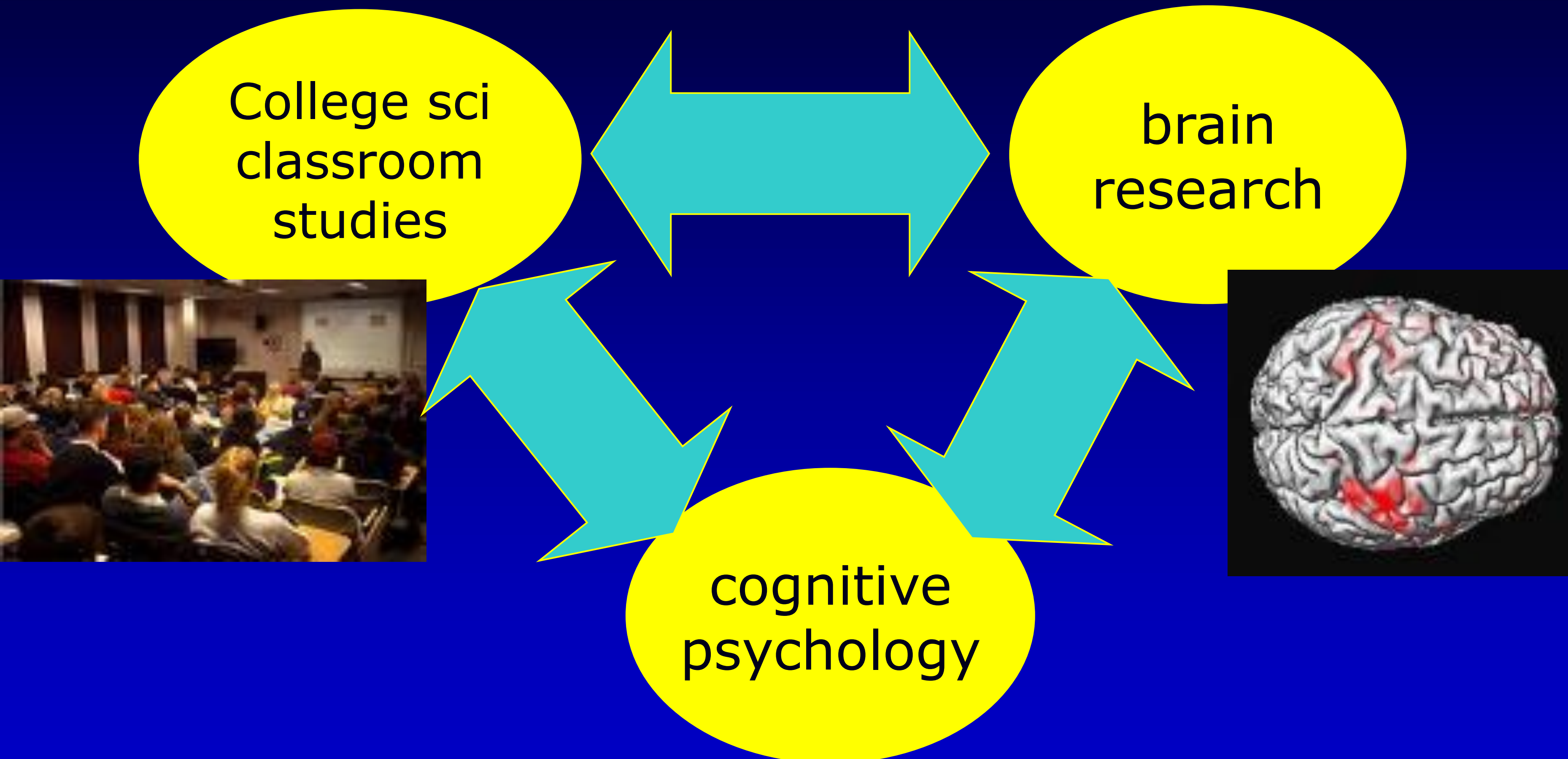
<u>My two perspectives & parts of talk</u>

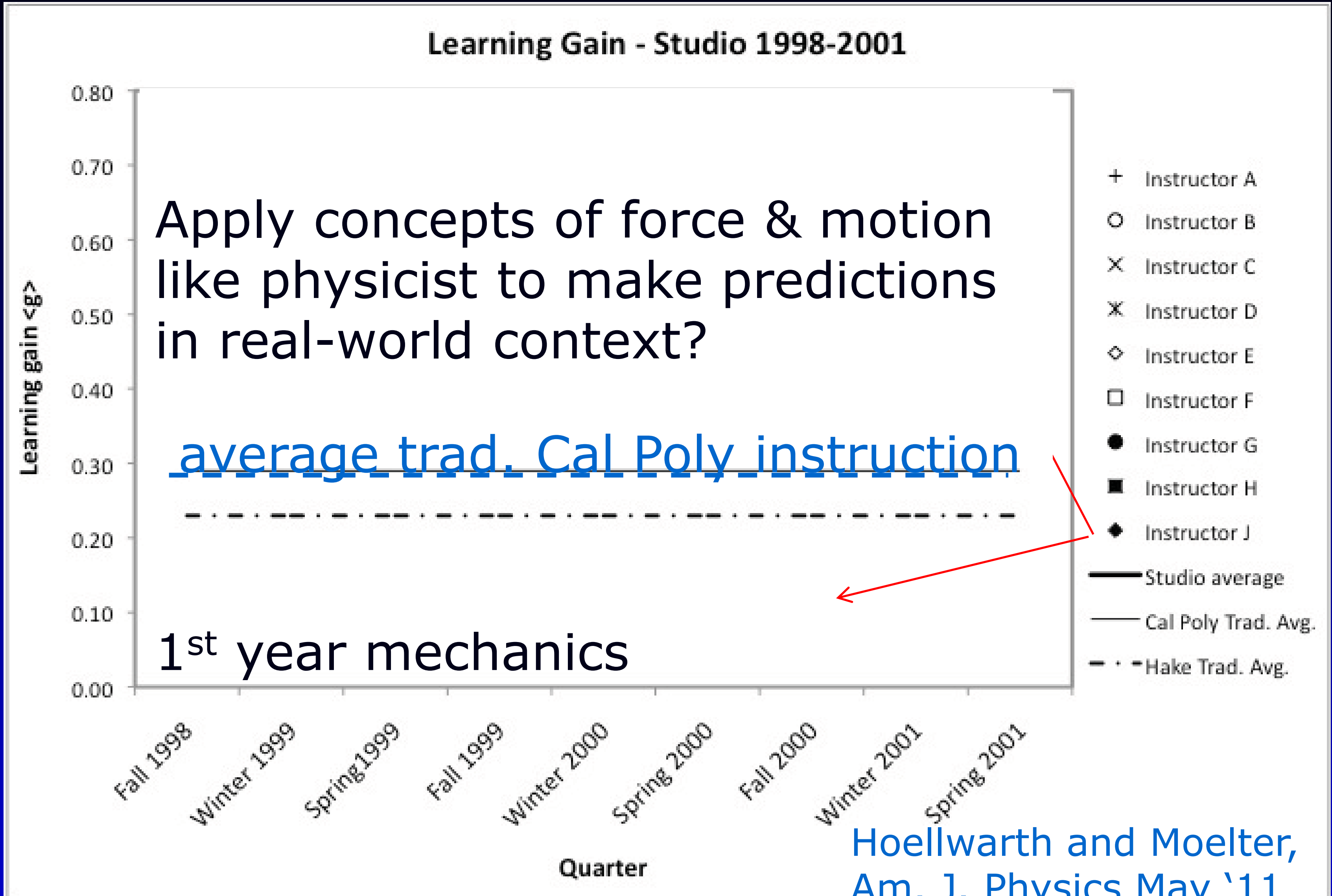
I. Research on teaching and learning of science at undergraduate level. (~ 25yrs)
Controlled experiments ⇨ New insights and results.

II. Research on Institutional change-
Science Ed. Initiatives– U. British Columbia & U. Col.
(Change/improve how entire departments teach?)

Discussion and questions

Major advances past 1-2 decades
⇒ Guiding principles for achieving learning





Apply concepts of force & motion like physicist to make predictions in real-world context?

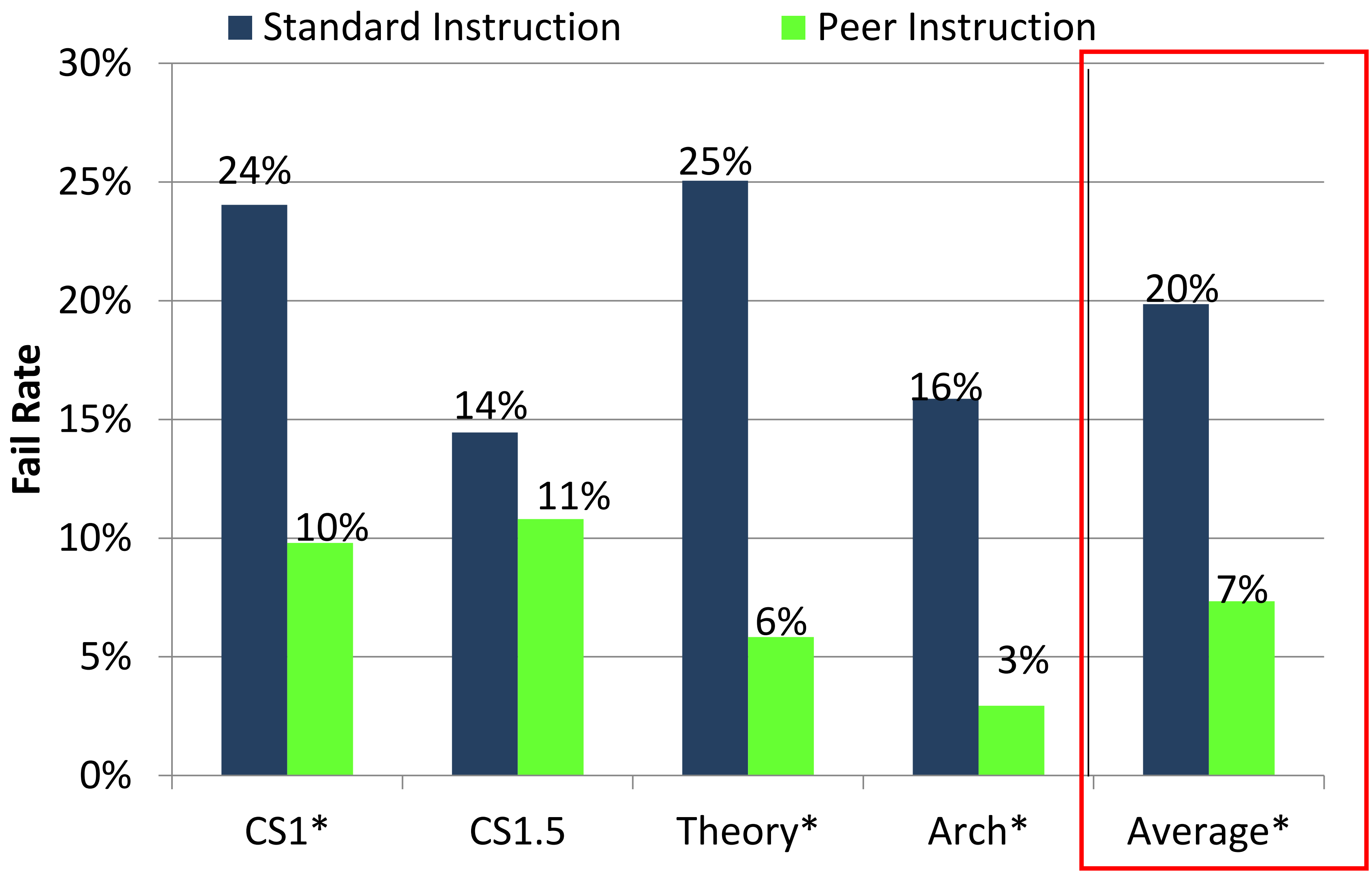
average trad. Cal Poly instruction

1st year mechanics

Hoellwarth and Moelter, Am. J. Physics May '11

9 instructors, 8 terms, 40 students/section.
Same instructors, different methods, better learning!

U. Cal. San Diego, Computer Science
Failure & drop rates– *Beth Simon et al., 2012*



same instructors, different teaching methods, 1/3 the failure rate

Learning **in the in classroom***

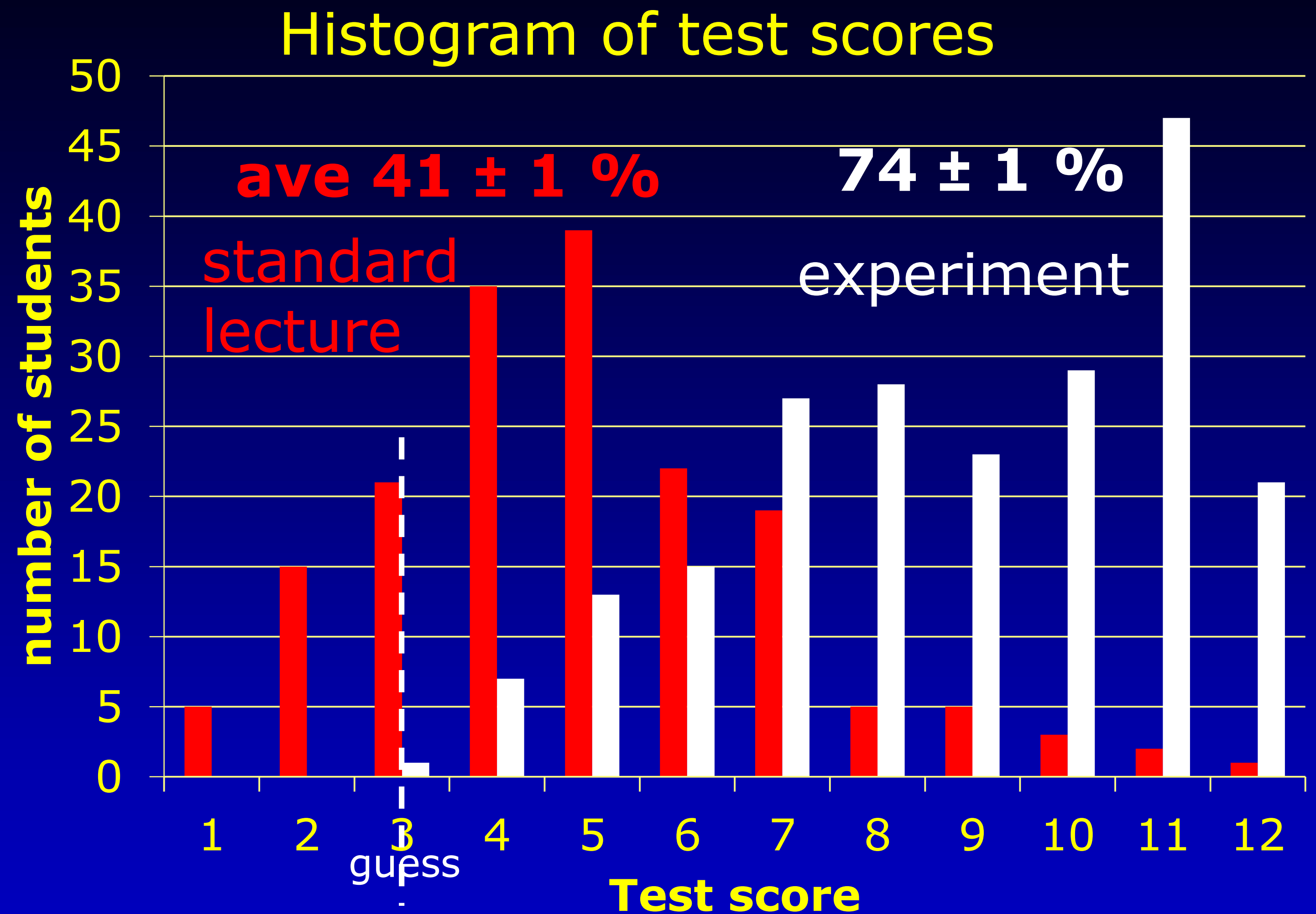
Comparing the learning in two ~identical sections of 1st year college physics. 270 engin. students each.

Control--standard lecture class– highly experienced Prof with good student ratings.
Experiment–- physics postdoc trained in principles & methods of effective teaching.

They agreed on:

- Same learning objectives
- Same class time (3 hours, 1 week)
- Same exam (jointly prepared)- start of next class

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



Clear improvement for <u>entire</u> student population.

Evidence from the Classroom

~ 1000 research studies from undergrad STEM

- greater learning
- lower failure rates
- benefits all, but at-risk most

Massive meta-analysis
all sciences & eng. similar.
PNAS Freeman, et. al. 2014

<u>Underlying theory</u>- holds consistently
*The development of expertise**
(and why confident applies even where no data)

Learn by explicitly practicing desired thinking with targeted guiding feedback—how to improve.

Teacher as "cognitive coach"

- designing practice tasks
  (what is expertise, how to practice, proper level)
- feedback/guidance on learner performance
- why worth learning--motivation

embodied in the teaching used in studies shown

* "Deliberate Practice", A. Ericsson research
accurate, readable summary in "Talent is over-rated", by Colvin

Applying in the classroom (& homework)

1. Targeted pre-class readings (information transfer)

2. Questions or tasks to solve--

2. Questions or tasks to solve–
explicitly practice using components of sci & engin. expertise

- concepts and mental models + selection criteria
- recognizing what information is needed to solve, what irrelevant
- does answer/conclusion make sense?- ways to test
- ….

Knowledge important, but only as integrated part with how to and when to use.

Applying in the classroom (& homework)

1. Targeted pre-class readings

2. Questions to solve--
respond with clickers or on worksheets, discuss with neighbors. Instructor listening in, briefly helps.

3. Discussion by instructor follows, not precedes.
(but still talking ~50+% of time)

4. Activities address motivation (relevance) and prior knowledge.

These methods consistently improve student learning. Same instructional cost.

Why not being universally used?
(and why you need to be careful what institutions you look to as educational models)

II. Making effective research-based teaching the norm (lessons from Sci. Educ. Initiatives UBC & Col.

Why demonstrably more effective teaching methods not being widely adopted?

Incentives are against at all levels– fac., dept, admin.
Research productivity <u>only thing measured</u> and rewarded in US universities.
No data on teaching methods even collected!

No meaningful data⇨ research prominence misguided proxy for educational quality.
Best and richest research institutions get the best/most-favored students. Meaningless models.

e.g. Stanford– faculty know far less about teaching than fac at SF State Univ. or Foothill Community Coll.

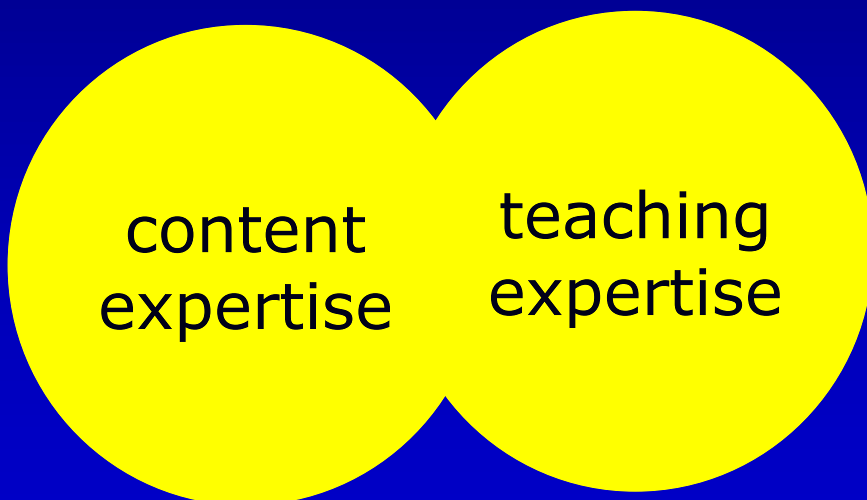
& Stanford does far less to measure student success and try to optimize.
Outputs more sensitive to teaching at SFSU & FCC.

Harvard fairly similar to Stanford.

How Brazilian universities might jump ahead in educational effectiveness

Measure and reward what matters–use of most effective research-based teaching methods.

(and support faculty to learn teaching expertise, ~~50 hours training)



How to measure what matters?

"A better way to evaluate undergraduate science teaching"
Change Magazine, Jan-Feb. 2015, Carl Wieman

Way to characterize teaching practices ~10 min. to complete

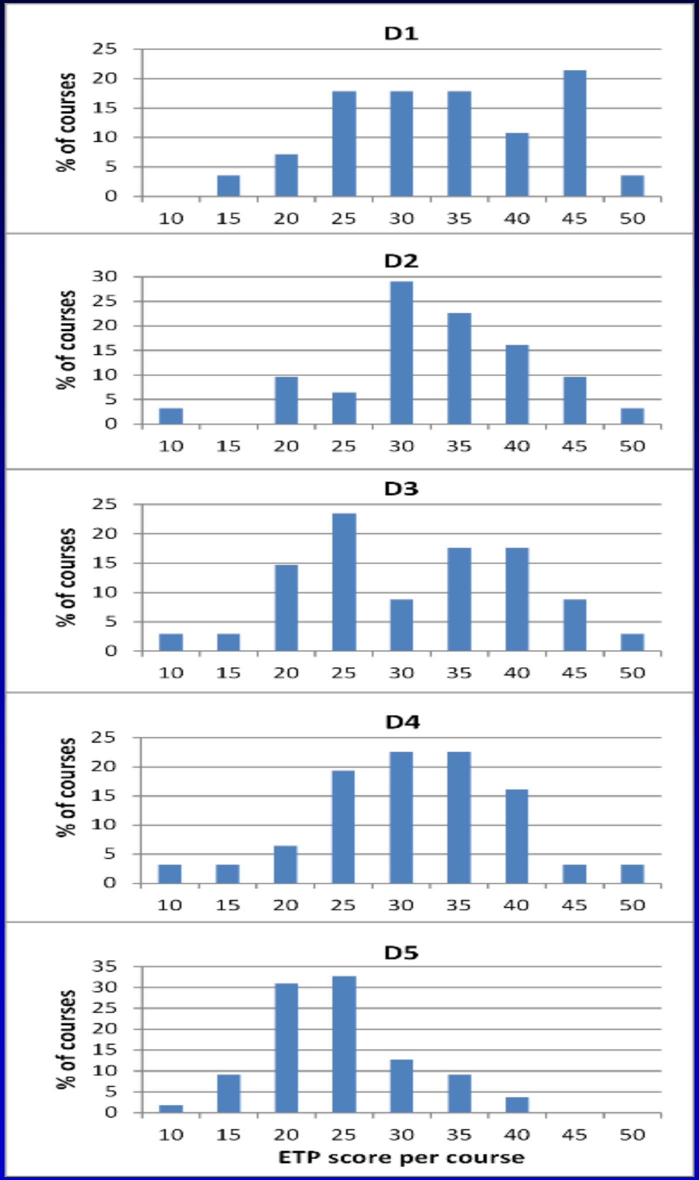
CBE—Life Sciences Education
Vol. 13, 552–569, Fall 2014

"The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science"

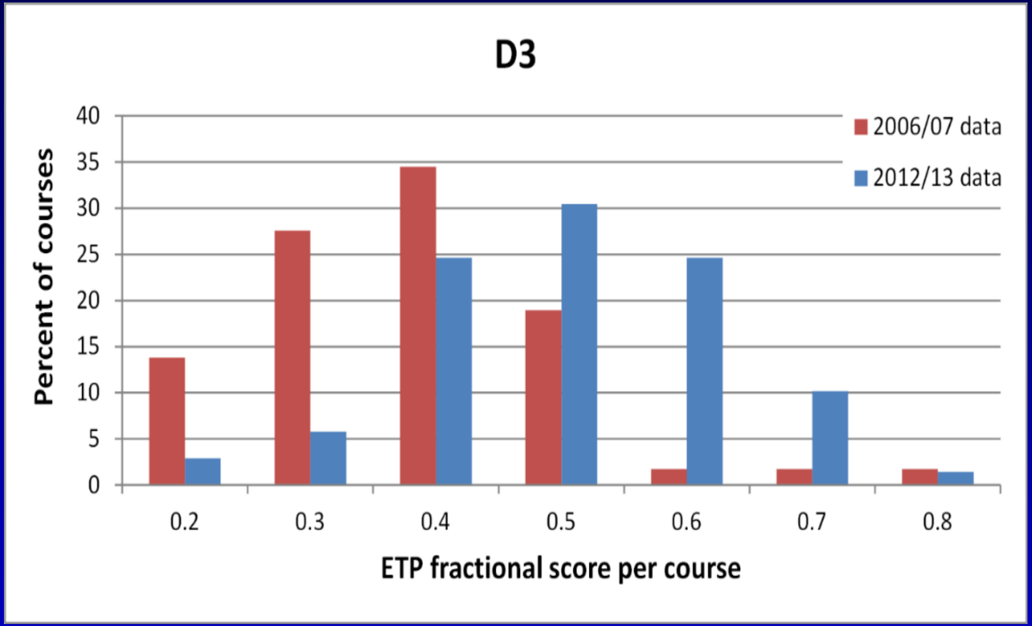
Carl Wieman* and Sarah Gilbert†

http://www.cwsei.ubc.ca/resources/TeachingPracticesInventory.htm

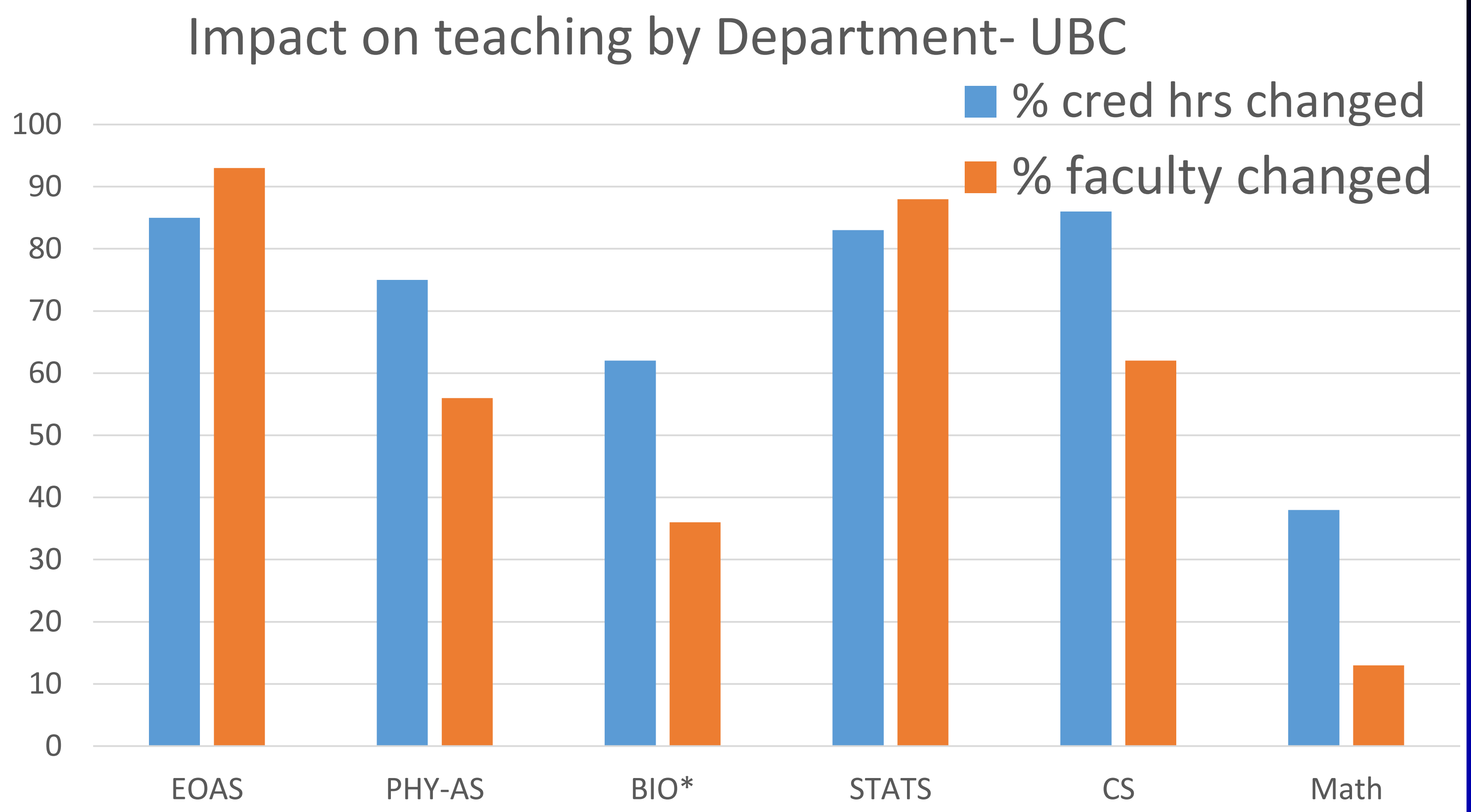
Effective teaching practices, ETP, scores various math and science departments at UBC



Extent of use of practices that improve learning--ETP



before and after for dept that made serious effort to improve teaching



totals 171 faculty, 168 courses, 139,000 cred hrs/yr (>50%)

Existence proof SEI– it is possible to get large scale adoption of good teaching methods at large public research-intensive university. Same cost.

<u>Cautionary note– beware of the hype about</u>
1)small classes and
2) use of technology

What the research says:

1. Optimized classroom setup (small classes, tables)

Many studies on optimum pedagogy vs. lecture, all size (<250) S & E. classes, gain x 1.5-3.
One small study on optimum pedagogy small well designed classroom vs. large lecture theatre, gain x 1.1.

2. Use of Educational Technology

Danger!

Far too often used for its own sake! *(online lectures)*
Evidence shows little value.

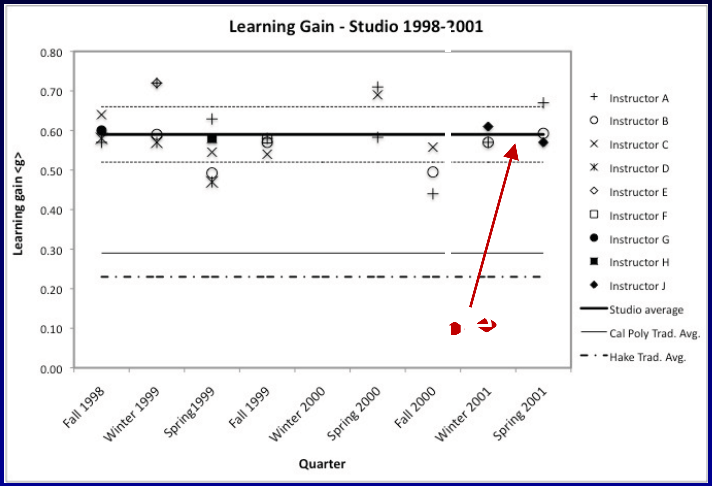
Opportunity

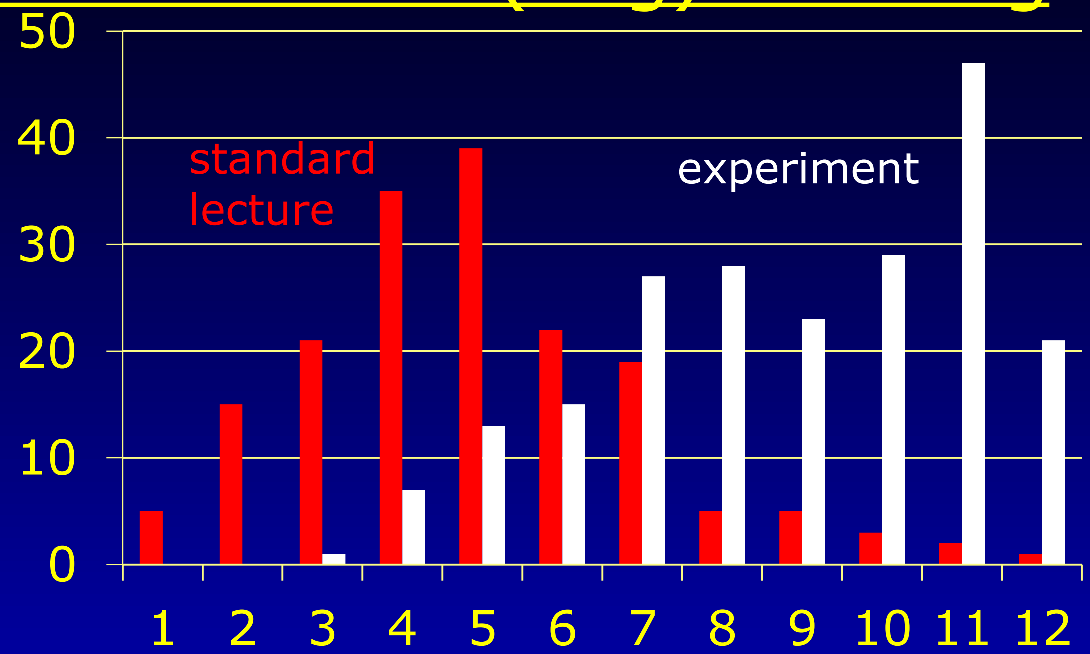
Valuable tool ***if*** used to supporting principles of effective teaching and learning.

Extend instructor capabilities.
Examples shown.

- Assessment (pre-class reading, online HW, clickers)
- Feedback (more informed and useful with enhanced communication tools)
- Novel instructional capabilities (PHET simulations)
- Novel student activities (simulation based problems)

A scientific approach to Science (Eng) teaching





Potential for large improvements

Good References:

S. Ambrose et. al. "How Learning works"

Colvin, "Talent is over-rated"

cwsei.ubc.ca-- many resources, references, effective clicker use booklet and teaching videos

Core features of SEI– contrast with usual faculty development (CTL…)

Department centered- entire dept's

Competitive grant program. $$$$ one time

$5 M Col. , $10 M UBC. Per 6 depts

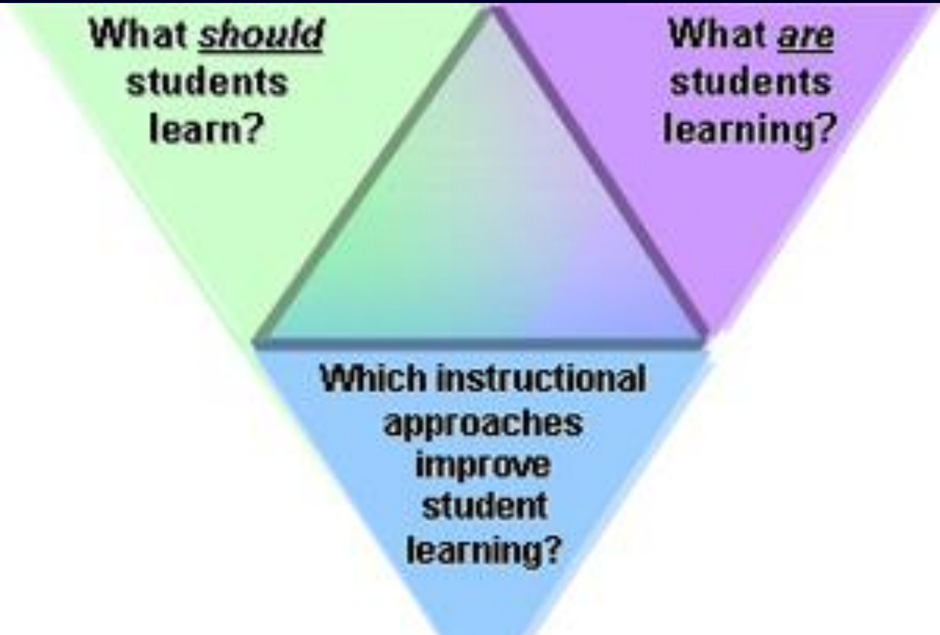
Sci. Ed. Specialists **in** Dept. Sci + Ed expertise

→

Faculty transform via course transformation (extended process)

Major one-time investment ⇒ permanent impact??

Transform faculty by supporting them in transforming courses



"SEI Trinity" for courses

1st: Decide on learning goals. (what should students be able to *do*?)

2nd: Better assessment

3rd: Add research-based teaching methods to improve student learning.

(technology to improve effectiveness & save time)

Materials etc. saved, reused, improved

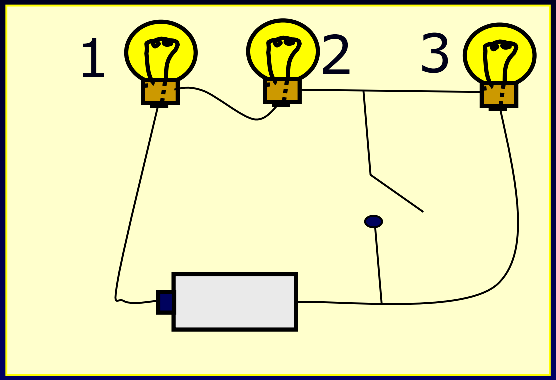
III. How to apply in classroom?
(best opportunity for feedback & student-student learning)
"Expertise-centered classroom"

example– large intro physics class

<u>Teaching about electric current & voltage</u>

1. Preclass assignment--Read pages on electric current. Learn basic facts and terminology without wasting class time. Short online quiz to check/reward.

2. Class starts with question:



When switch is closed, bulb 2 will

a. stay same brightness,

b. get brighter

c. get dimmer,

d. go out.

answer & reasoning

3. Individual answer with clicker

(accountability=intense thought, primed for learning)

4. Discuss with "consensus group", revote.

Listening in! What aspects of student thinking like physicist, what not?

5. Demonstrate/show result

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

Students practicing physicist thinking—

feedback that guides thinking—other students, informed instructor, demo

Continue practice in homework and exams

~ 30 extras below

Perfection in class is not enough!

Not enough hours

- Activities that prepare them to learn from class (targeted pre-class readings and quizzes)

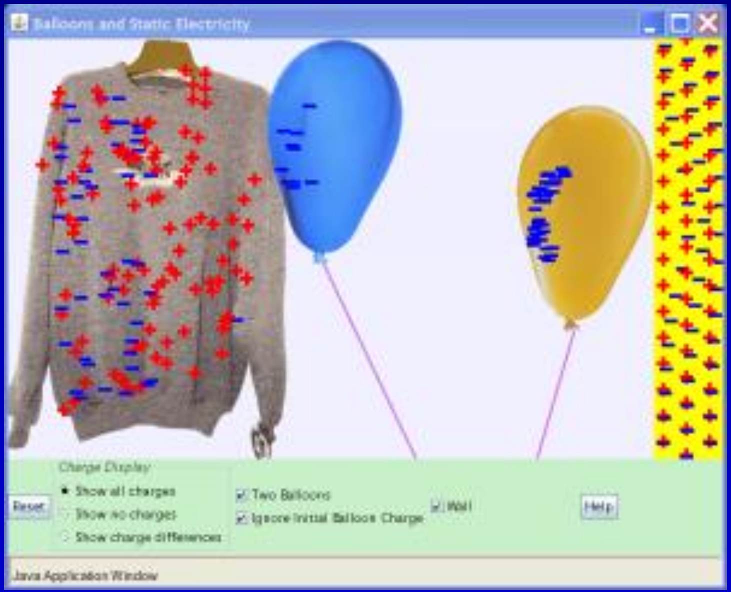
- Activities to learn much more after class
  good homework–-
  - builds on class
  - explicit practice of all aspects of expertise
  - requires reasonable time
  - reasonable feedback

Highly Interactive educational simulations--

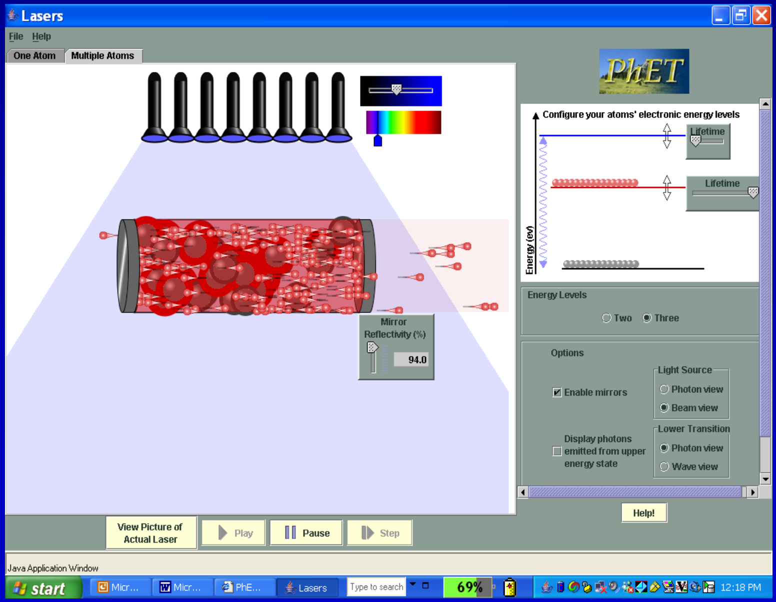
phet.colorado.edu >100 simulations

FREE, Run through regular browser. Download

Build-in & test that develop expert-like thinking and learning *(& fun)*



balloons and sweater



laser

Two sections the same before experiment.
(different personalities, same teaching method)

	Control Section	Experiment Section
Number of Students enrolled	267	271
Conceptual mastery(wk 10)	47± 1 %	47 ± 1%
Mean CLASS (start of term) (Agreement with physicist)	63±1%	65±1%
Mean Midterm 1 score	59± 1 %	59± 1 %
Mean Midterm 2 score	51± 1 %	53± 1 %
Attendance before	55±3%	57±2%
Engagement before	45±5 %	45±5 %

UBC CW Science Education Initiative and U. Col. SEI

Changing educational culture in <u>major research university science departments</u>
necessary first step for science education overall

- Departmental level

 ⇒**scientific approach to teaching, all undergrad courses = learning goals, measures, tested best practices Dissemination and duplication.**

All materials, assessment tools, etc to be available on web

I. Expertise research*

historians, scientists, chess players, doctors,...

Expert competence =

•factual knowledge

• **Mental organizational framework** ⇒ retrieval and application

or ?

patterns, relationships, scientific concepts

•**Ability to monitor own thinking and learning**
("Do I understand this? How can I check?")

New ways of thinking-- everyone requires MANY hours of intense practice to develop.
Brain changed

*Cambridge Handbook on Expertise and Expert Performance