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Outline / Framing

• Brief overview of why, what, and how of PER
  – Building on a base
  – Theoretical models & educational practices

• Impacts
  – Introductory physics (results, replicability)
  – Longitudinal study
  – K12 teacher recruitment and prep
  – Upper division and gender issues (if time!)
How are we doing: Harvard

From Mazur 1997
Find the current through the 2 Ohm resistor and the potential difference between points a and b.

In the circuit shown, explain what happens when the switch is closed…

a) To the current through the battery
b) To the brightness of the bulbs

From Mazur 1997
Overview of PER

- Investigating education scientifically
- Far more to our classes than what is traditionally evaluated

- Physics education research has something to say about this
  - Models of student learning
  - Tools for measurements
  - Evidence of impact
  - Curricula / approaches

Theory \rightarrow Experiment \rightarrow Application
PER: the field

Rapidly growing

- Journals (Physical Review, AJP, ...)
- APS, PERC
- NSF funding
- >50 institutions with PER groups or faculty
Building on a base: Studying Science Education Scientifically

- Theoretical frames
- Student concepts and engagement
- Data
- Curricular reforms
- Classroom practice
Take home message:

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

Hestenes, Wells, Swackhamer, Phys Teacher 30 (1992) p. 141
R. Hake, ”…A six-thousand-student survey…” AJP 66, 64-74 (‘98).
why does this happen?
Trad’l Model of Education

Instruction via transmission

Individual Content (e.g. circuits)
2000 years ago

Today

Built in to our classes?
PER Theoretic Background

Individual

Prior knowledge

Instruction via transmission

Active construction

Content

transmissionist

constructivist
Novice vs. Expert:

\[ f(x) = e^{-x^2} \]

So clear...

2 = 2nd floor
x = 1st floor
e = basement

of course!

ZZZ...

2 more minutes...

M. Dubson
actively engaging students is important
Back to the FCI

traditional lecture  interactive engagement

\[ \langle g \rangle = \frac{\text{post-pre}}{100-\text{pre}} \]

R. Hake, "...A six-thousand-student survey..." AJP 66, 64-74 ('98).
Many PER curricular innovations
Phys lecture
3-600 students
3 lectures/wk
(No lab)

Interactive Lectures
Peer Instruction,
pers. resp. system

Online HW System
CAPA or MP

Text
trad or PER based

U. Washington Tutorials
50 min/wk, 30 students, 1 grad TA
+ undergrad Learning Assistant
(Weekly prep + LA seminar)
Pedagogy of clickers

• Peer instruction
• Feedback
  – To students
  – To faculty
• Reasoning
  – Thinking about thinking
• Elicit/confront/resolve
Tutorials in Introductory Physics

Reconceptualize Recitation Sections

• Materials
• Classroom format / interaction
• Instructional Role
• Use of Learning Assistants
Tutorial vs. Trad'l Recitation
Tutorial Success (at UW)

Replication (at CU)

S. Pollock, PERC 2004

Finkelstein & Pollock, Phys Rev: ST PER, 2005
CU: Pre-Post FMCE scores

PRETEST

Spring  Fall

R. Hake, "...A six-thousand-student survey..." AJP 66, 64-74 (’98).
Other classes?
Physics 2: BEMA pre/post

F04 (N=319) Post: 59%
S05 (N=232): 59%

Handoff to non-PER faculty

• Use same materials
• Same TA / LA training
• Same course structure /exams etc...

... everything looks the same...(except the instructor)
1120 BEMA pre/post
1120 BEMA pre/post

Non-PER Faculty
1st Time Teaching with Tutorials
Pre: 25
Post: 50
<g> = .33
1120 BEMA pre/post

Non-PER Faculty

2nd Time Teaching (+ PER backup)

Pre: 26
Post: 56

$<g> = 0.40$
actively engaging is important

what people know affects what they learn

contexts shape what students learn (content and beliefs)
Replication, but with strong variations
Why?
F04 (N=319) Pretest: 26%  
S05 (N=232): 27%

Beyond the FMCE: Exam comparisons

N.B. 12 points is roughly 1 letter grade.
Impact on different pretest populations: "high starters" 50<pre<93%
does it last?
Longitudinal

Upper division majors’ BEMA scores

<table>
<thead>
<tr>
<th>Grade in course</th>
<th>f04-f05</th>
<th>s06-s07</th>
<th>Grads</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3.1 ±.1)</td>
<td></td>
<td></td>
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<tr>
<td>(3.0 ±.1)</td>
<td></td>
<td>(3.2)</td>
<td></td>
</tr>
<tr>
<td>(3.3 ±.1)</td>
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</table>

Yellow: students who had been E&M LAs

S. Pollock, 2007 PERC Proc. 951, p.172
### Clickers in Upper-division at CU

<table>
<thead>
<tr>
<th>Course</th>
<th>Sp04</th>
<th>Sp09</th>
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<tbody>
<tr>
<td>Mech &amp; Math I</td>
<td></td>
<td>⭐</td>
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<tr>
<td>Mech &amp; Math II</td>
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<td>⭐</td>
</tr>
<tr>
<td>EM I</td>
<td>⭐</td>
<td>⭐</td>
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<tr>
<td>EM II</td>
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</tr>
<tr>
<td>QM I</td>
<td>⭐</td>
<td>⭐</td>
</tr>
<tr>
<td>QM II</td>
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<tr>
<td>Solid State</td>
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<td>Stat Mech</td>
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<td>⭐</td>
</tr>
<tr>
<td>Optics</td>
<td></td>
<td>⭐</td>
</tr>
<tr>
<td>Grad AMO</td>
<td></td>
<td>⭐</td>
</tr>
</tbody>
</table>

> 12 non-PER ★ and 2 PER ★ faculty
CU Model of Teacher Prep

• Begin *within* science departments
• Learning Assistants:
  Use undergrads to implement research-based materials
  – Improve education of all students
  – Model best-practices for all students
  – Increase likelihood students engage in teaching
  – Improve content mastery of future teachers

Conclusions

• Educational practice is a researchable endeavor
  – We can make systematic progress
  – Imperative to include scientists
• Possible to achieve dramatic repeated results
• CU model strongly couples:
  – Reform and Research
  – K12 Teacher prep

It’s not about our teaching, it’s about student learning
Questions?

Much more at: per.colorado.edu
Or stem.colorado.edu