Physics Education Research in the Advanced Undergraduate Classroom

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University of St Andrews 600 YEARS

University of St Andrews
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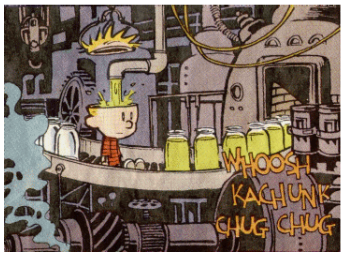
Outline

- Short background on introductory course transformations at CU Boulder:
  - Interactive engagement and peer instruction
  - Trad. HW sessions replaced by small group work
- Transforming advanced courses:
  - Model for course transformation
  - Interactive engagement in advanced classrooms
  - How do we know it's working?
  - Is this relevant to St Andrews?

Traditional model of teaching: "transmitting knowledge"



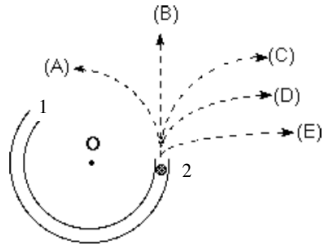
A Wakeup Call

Force Concept Inventory (FCI) *

- 30 questions
- *Basic* Newtonian concepts.
- Research-based

*Hestenes, Wells, Swackhamer, Physics Teacher **20**, 141 1992

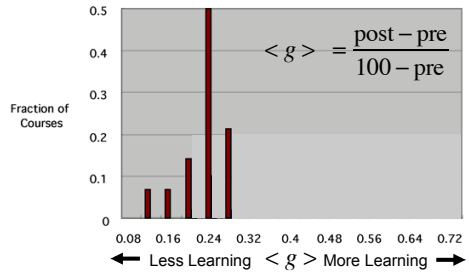
FCI – Sample Question



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

Force Concept Inventory

red = traditional



R. Hake, "…A six-thousand-student survey…" AJP **66**, 64 (1998).

Force Concept Inventory

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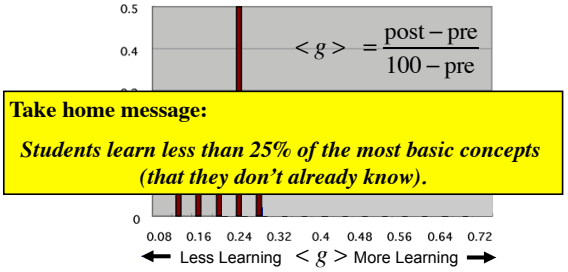


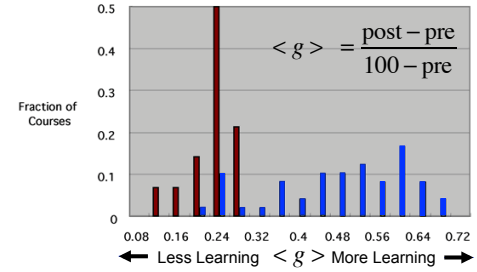
Take home message:

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 (1998).

Force Concept Inventory

red = traditional, blue = interactive engagement



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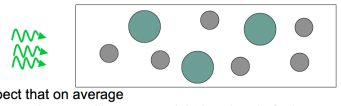
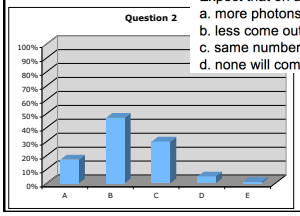
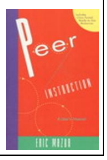
Personal Response Systems

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



Expect that on average
a. more photons will come out right hand end of tube
b. less come out right
c. same number as go in
d. none will come out.





Force Concept Inventory

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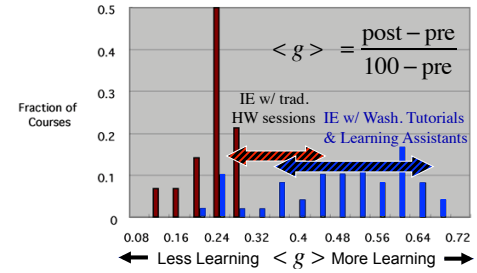
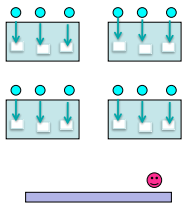


R. Hake, "…A six-thousand-student survey…" AJP **66**, 64 (1998).
S. Pollock and N. Finkelstein, PRST-PER **4**, 010110 (2008)

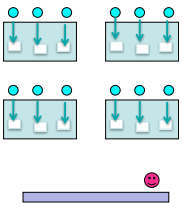
Traditional Classroom



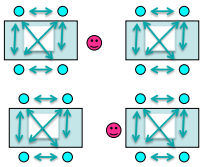
Reconceptualise the learning environment:

- learning materials
- classroom format
- role of instructor

Traditional Classroom

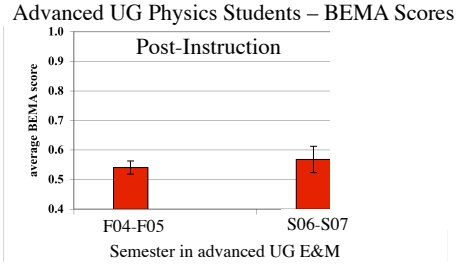


Collaborative Learning



Long Term Impacts

Advanced UG Physics Students – BEMA Scores



Students with no Wash. Tutorials in **introductory** E&M

S. Pollock, PRST-PER **5**, 020101 (2009)

Long Term Impacts

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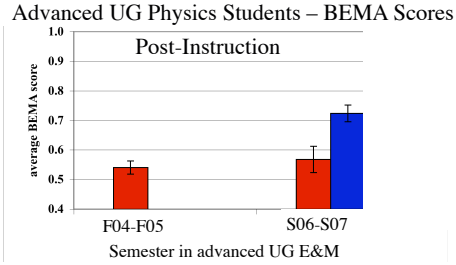

Had introductory E&M **with** Wash. Tutorials

S. Pollock, PRST-PER **5**, 020101 (2009)

Long Term Impacts

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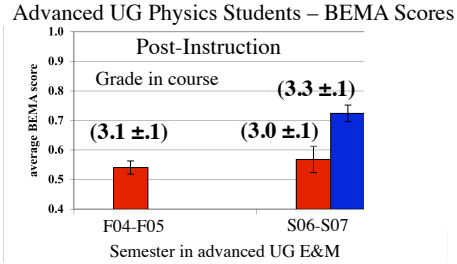
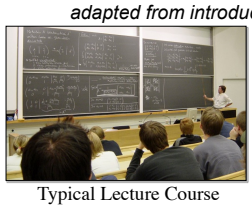


Advanced E&M had no significant impact on BEMA scores

S. Pollock, PRST-PER **5**, 020101 (2009)

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

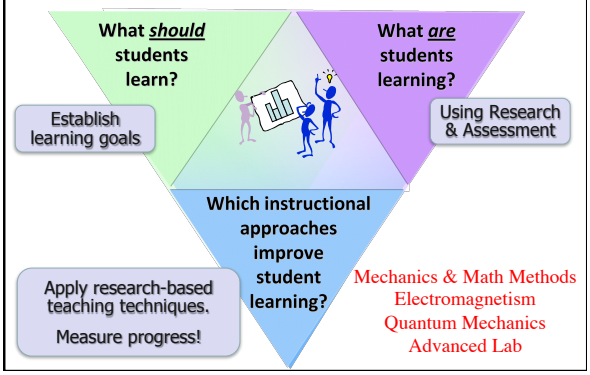


Typical Lecture Course

?

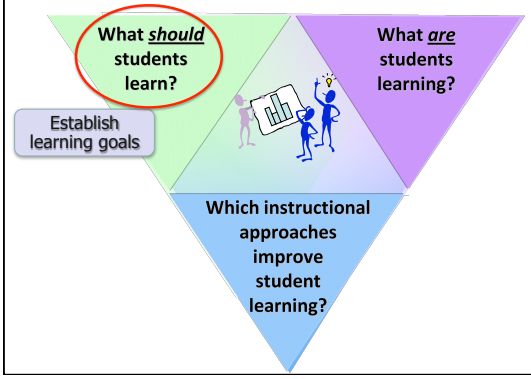
Students debate a concept test

Model for Course Transformation



Mechanics & Math Methods
Electromagnetism
Quantum Mechanics
Advanced Lab

Model for Course Transformation



Course Learning Goals

- From faculty working group
- Framed course transformations
- Made explicit to students

Students should be able to...

...calculate and sketch the direction of the dipole moment of a given charge distribution.

...outline the general steps necessary for solving a problem using separation of variables.

Course Learning Goals

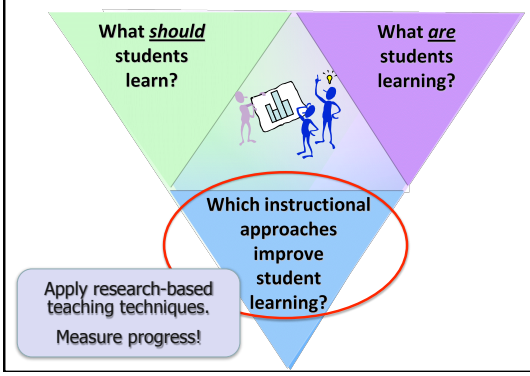
- From faculty working group
- Framed course transformations
- Made explicit to students

Students should be able to...

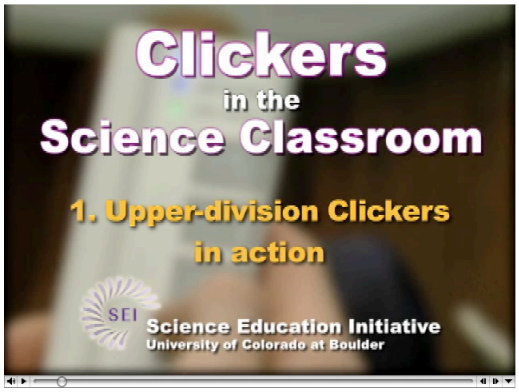
...achieve physical insight through the mathematics of a problem

...choose and correctly apply the appropriate problem-solving technique

Model for Course Transformation



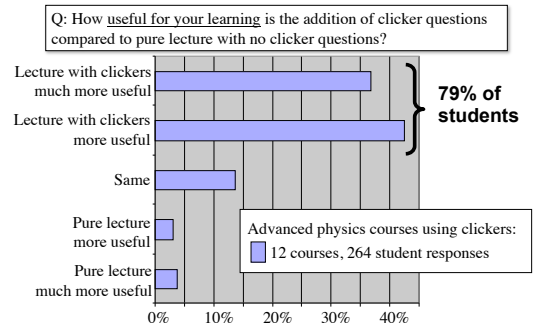
STEMclickers.colorado.edu



Arguments *against* clicker use

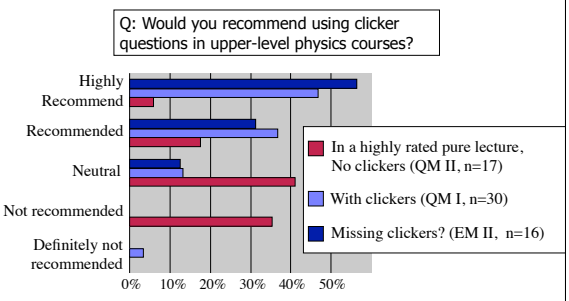
- Eats up time
  Important ideas in lecture, continue learning in HW
- Discussion easy in small classes
  We/they don't always know they need to ask questions
- Students are sophisticated learners
  Clickers can augment traditional learning
- Students may resist
  But perhaps only initially…
- Extra effort for instructors
  Question banks available if you want to try!

Students find clickers useful



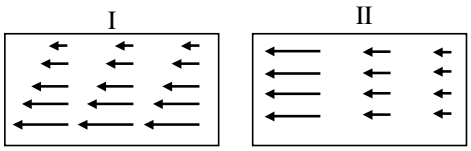
K. K. Perkins and C. Turpen, *PERC Proceedings* (2009)

Students don't predict their usefulness



K. K. Perkins and C. Turpen, *PERC Proceedings* (2009)

Which of the following could represent an electrostatic field in the region shown?



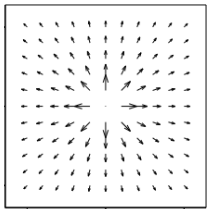
A) Both
B) Only I
C) Only II
D) Neither

Silent voting: about 65% correct

After discussion: over 95% correct

Consider this 3D vector field in spherical coordinates:

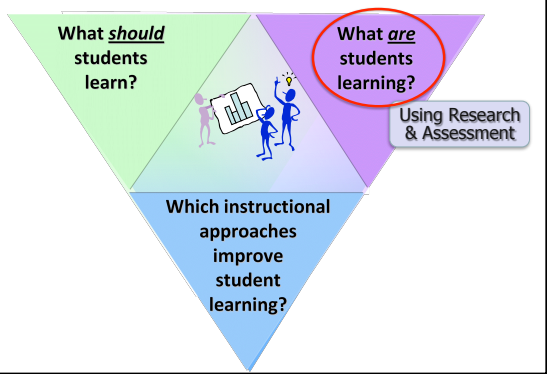
$$\vec{V}(\vec{r}) = c\left(\frac{\hat{r}}{r^2}\right)$$



The divergence of this vector field is:

A) Zero everywhere except at the origin
B) Zero everywhere including the origin
C) Non-zero everywhere, including the origin.
D) Non-zero everywhere, except at origin (zero at origin)
E) Not sure how to get this without computing Div.V

Model for Course Transformation



Data Sources

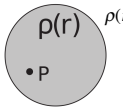
- Classroom observations & student work
- Student interviews
- Attitude surveys
- Traditional exams
- End-of-course conceptual assessments

Research-Validated Assessments

- **Electrostatics:**
  Colorado Upper-division Electrostatics Assessment (CUE)
- **Electrodynamics:**
  Colorado UppeR-division ElectrodyNamics Test (CURrENT)
- **Classical Mechanics:**
  Colorado Classical Mech./Math Methods Instrument (CCMI)
- **Quantum Mechanics:**
  Quantum Mechanics Assessment Tool (QMAT)
- **Advanced Lab:**
  Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS)

CUE Assessment

Do **not** solve, but give "the easiest method you would use to solve the problem" & "why you chose that method".



$\rho(r) = \rho_0 e^{-r^2/a^2}$

33% of students did not recognize Gauss' law as the easiest way to solve. (N=325)

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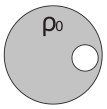
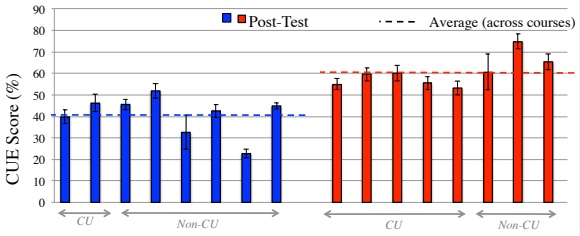
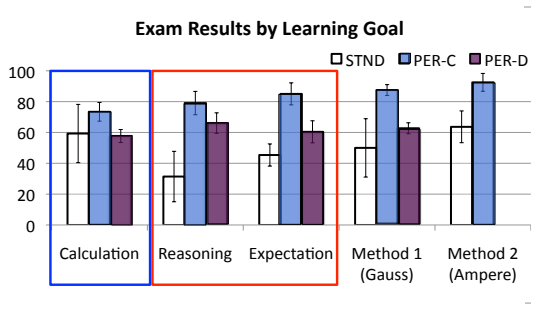


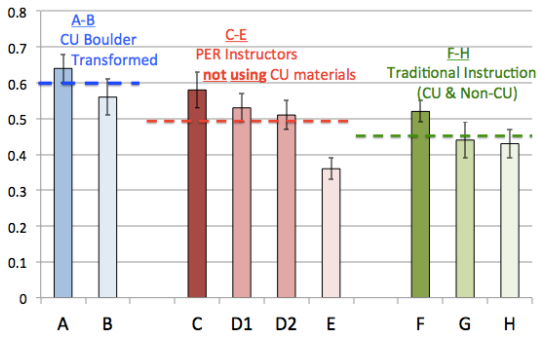
24% of students incorrectly chose Gauss' law as the easiest way to solve. (N=325)

CUE Assessment



S. Chasteen, JCST **40**, 70 (2011)





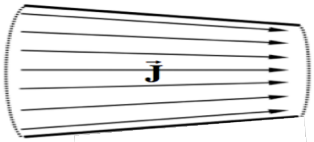
3. Suppose there are two vector fields $\vec{\mathbf{X}}$ & $\vec{\mathbf{Y}}$, where $\vec{\mathbf{X}}$ is equal to the curl of $\vec{\mathbf{Y}}$. Show using Stokes' theorem that the following equation is true:

$$\oint \vec{\mathbf{Y}} \cdot d\vec{\ell} = \iint \vec{\mathbf{X}} \cdot d\vec{\mathbf{a}}$$

$$\vec{\mathbf{X}} = \nabla \times \vec{\mathbf{Y}}$$

$$\rightarrow \quad \iint \vec{\mathbf{X}} \cdot d\vec{\mathbf{a}} = \iint (\nabla \times \vec{\mathbf{Y}}) \cdot d\vec{\mathbf{a}} = \oint \vec{\mathbf{Y}} \cdot d\vec{\ell}$$

62% completely correct, overall average = 71%

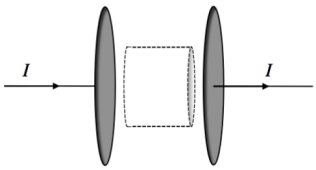


4. A steady current flows in a wire. The diagram depicts the current density $\vec{\mathbf{J}}$ inside a section where the diameter of the wire is gradually decreasing.

Inside this section of wire, is the divergence of the current density $\nabla \cdot \vec{\mathbf{J}}$ *zero* or *non-zero*? Briefly explain your reasoning.

$$\nabla \cdot \vec{\mathbf{J}} = -\frac{\partial \rho}{\partial t}$$

34% correct answer, 29% correct reasoning



5. Is the electromagnetic energy density *increasing*, *decreasing* or *remaining constant*?

~ 2/3 correct

Is the total flux of the Poynting vector $\vec{\mathbf{S}}$ *positive*, *negative* or *zero*? (the area vector points outwards)

~ 1/3 correct

www.colorado.edu/sei/physics/

- **Materials** for instruction and evaluation
  - Clicker Questions
  - Tutorial-style Activities
  - Homework and Exam questions
  - End-of-course assessments
- **Resources** for instructors
  - User's guides
  - Documentation of observed student difficulties

Modern Physics, Classical Mechanics/Math Methods
Electromagnetism, Quantum Mechanics, Advanced Lab

Questions?

http://per.colorado.edu

www.colorado.edu/sei/physics/

Clicker videos at
STEMclickers.colorado.edu