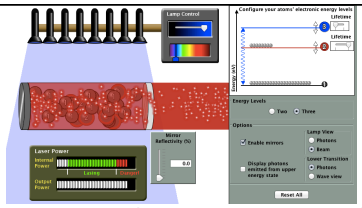


Active Learning & Quantum Simulations in the Classroom

KITP Conference, Santa Barbara
March 2, 2013

Charles Baily
Department of Physics
University of Colorado Boulder
baily@colorado.edu
per.colorado.edu/baily

PER.COLORADO.EDU

Faculty:
Melissa Dancy
Michael Dubson
Noah Finkelstein
Valerie Otero
Kathy Perkins
Steven Pollock
Carl Wieman (on leave)

Postdocs/ Scientists:
Charles Baily
Danny Caballero
Stephanie Chasteen
Julia Chamberlain
Katie Hinko
Kelly Lancaster
Emily Moore
Arief Paul
Rachel Pepper
Noah Podolefsky
Benjamin Zwickl

Grad Students:
Stephanie Barr
Kara Gray
May Lee
Mike Ross
Ben Spike
Ben Van Dusen
Bethany Wilcox

Teachers / Partners / Staff:
Shelly Belleau
Jackie Elser
Trish Loeblein
Susan Nicholson-Dykstra
Sara Severence
Emily Quinty
Mindy Gratny, Kate Kidder
John Blanco, Sam Reid
Chris Malley, Jon Olson
Oliver Nix, Nina Zabolotnaya

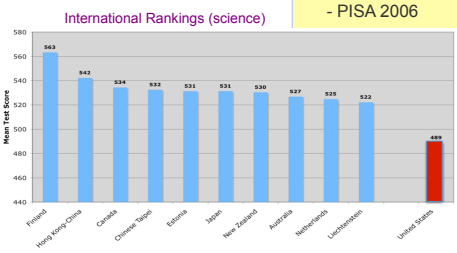
How important is education?

In March 2001, the U.S. Commission on National Security/21st Century …. on which I served warned that the crisis in scientific research and education is the second greatest threat facing American national security. In fact, the 14 bipartisan members unanimously agreed that the 'inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine.' The Commission went on to assert that only a nuclear or biological weapon released in an American city [is] a greater threat

-Newt Gingrich, AEI
Open letter to Congress, May 2005

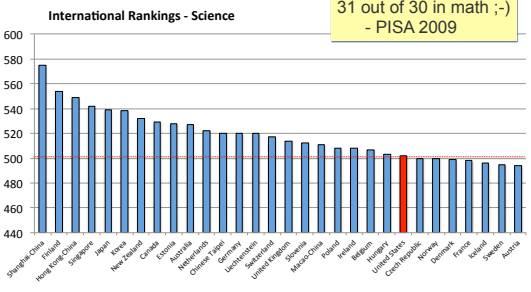
A Crisis in US Education

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



A Crisis in US Education

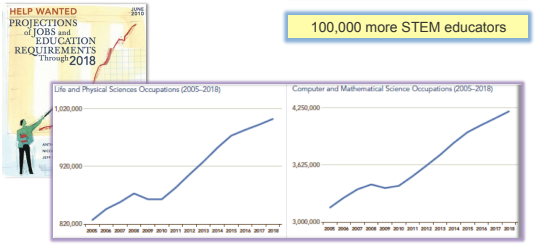
U.S. ranks:
24 out of 30 in science
31 out of 30 in math ;-)
- PISA 2009



Challenges in US Education

1 Million more STEM grads needed over the next decade

100,000 more STEM educators



APS/AAPT Doubling Initiative Mission Statement (2007)

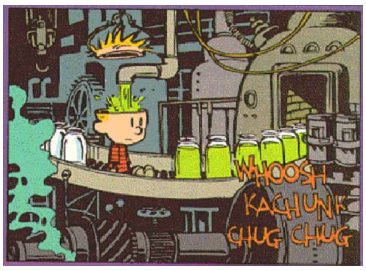
We advocate doubling the number of bachelor degrees in physics to address critical national needs including K-12 education, economic competitiveness, energy, security, and an informed electorate.

How might this happen?

- Better preparation
- Retention

Traditional Model of Education

Content → Instruction via transmission → Individual



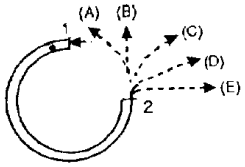
A Wakeup Call

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

A necessary (not sufficient) indicator of conceptual understanding.

* Hestenes, Wells, Swackhamer, Physics Teacher 20, (92) 141, 1992

Sample question

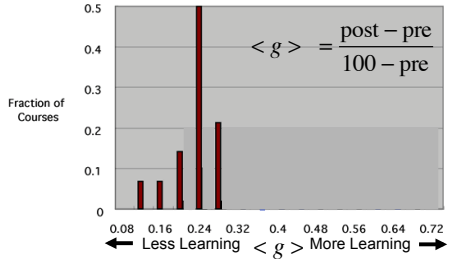


Looking down at a track (flat on table), a ball enters at point 1 and exits at point 2. Which path does it follow as it exits (neglect all friction)?

R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 (1998).

Force Concept Inventory

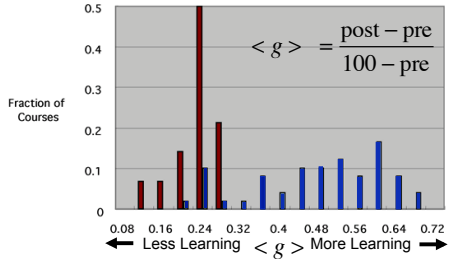
red = traditional



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

Force Concept Inventory

red = traditional, blue = interactive engagement



R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 (1998).

Force Concept Inventory

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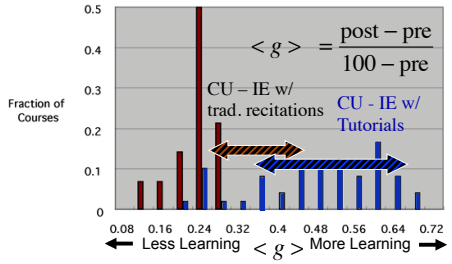


R. Hake, ″…A six-thousand-student survey…″ AJP **66**, 64-74 (1998).
S. Pollock and N. Finkelstein, PRST-PER **4**, 010110 (2008)

Typical Classroom (?)

Can high school students learn more from interactive techniques adapted from university physics courses?

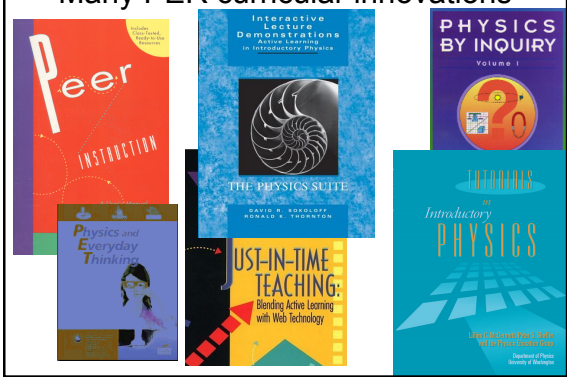
?

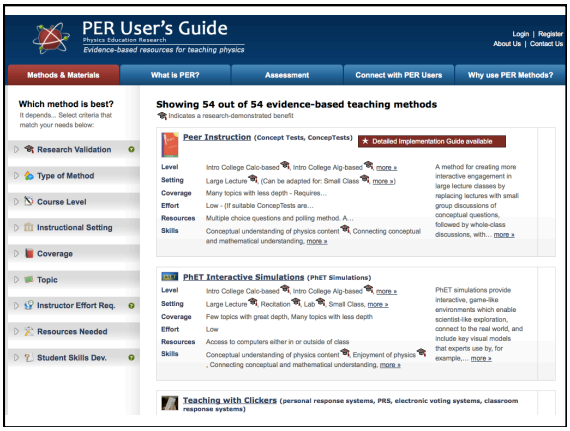
Students debate a concept test

Overview

- Transforming the classroom
  - Concept tests/Peer instruction
  - In-class activities/tutorials
- Quantum Simulations
  - Lasers (!!)
  - Matter waves
- Quantum Interpretations

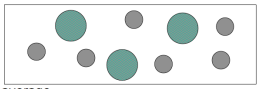
Many PER curricular innovations



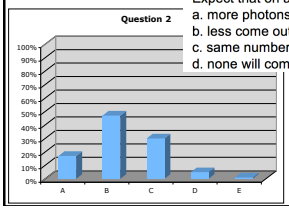


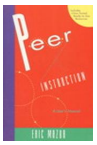
Concept Tests

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.





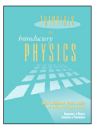
Arguments *against* using concept tests

- Eats up time
  Important ideas can be complex
- Discussion easy in small classes
  We/they don't always know they need to ask questions
- Students may resist
  But perhaps only initially…
- Extra effort for teachers
  Question banks available if you want to try!

Tutorials in Introductory Physics

Reconceptualize Classroom Learning

- Materials
- Classroom format / interaction
- Instructional Role

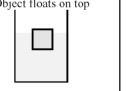
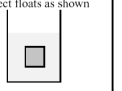
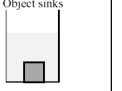


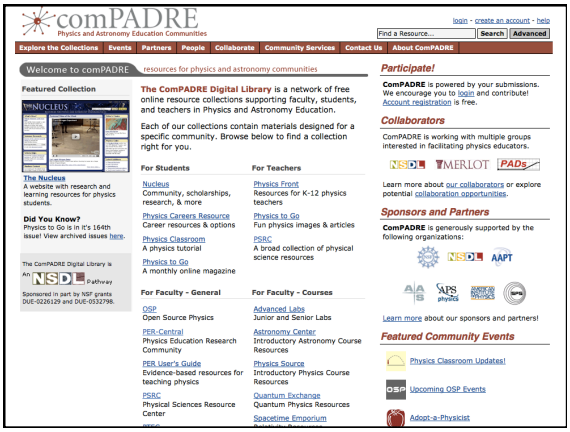
Tutorial Materials

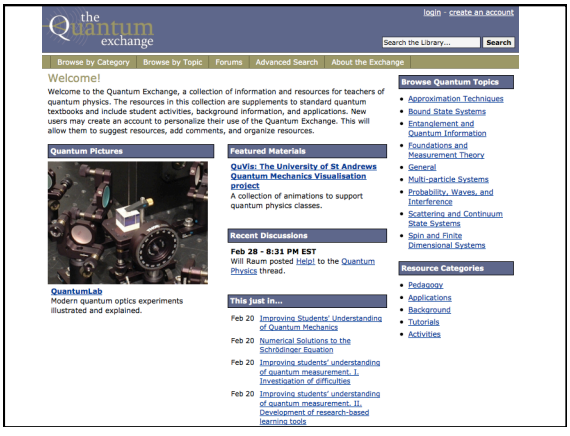
Hands-on, Inquiry-based, Guided, Research-based

Assignment 11M: Name _____
Buoyancy Tutorial section_____

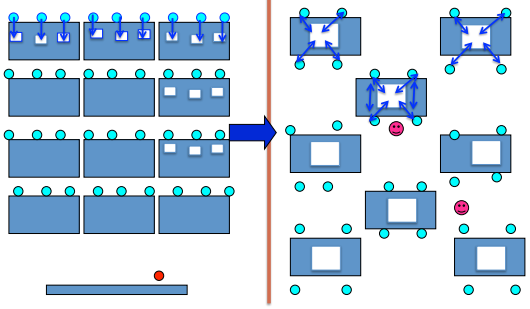
1. Three objects are at rest in three beakers of water as shown.
   a. Compare the mass, volume, and density of the objects to the mass, volume, and density of the displaced water. Explain your reasoning in each case.

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

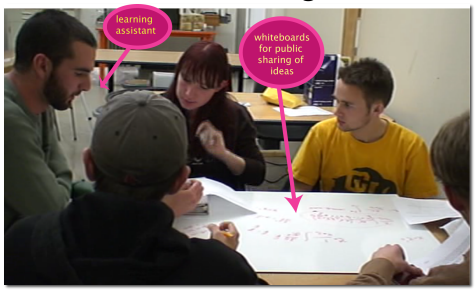




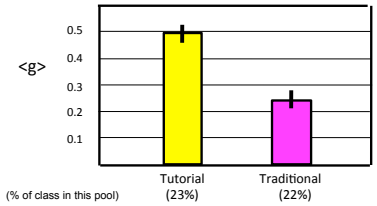
Trad'l Classroom vs. Tutorials



Socratic Dialogue

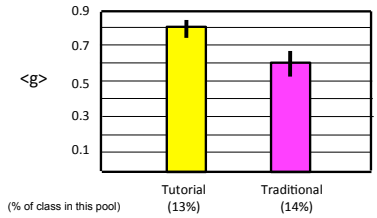


Impact on different pretest populations: "low starters" pretest <=12.5%



S. Pollock, 2005 *PERC proceedings*

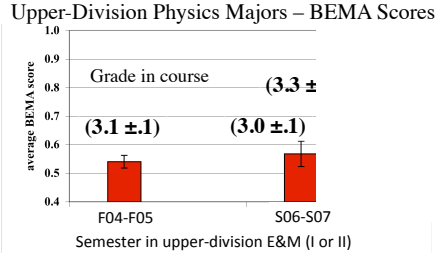
Impact on different pretest populations: "high starters" 50<pre<93%



S. Pollock, 2005 *PERC proceedings*

Long Term Impacts

Upper-Division Physics Majors – BEMA Scores

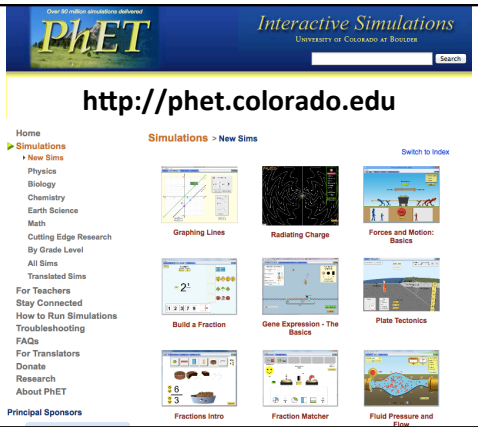


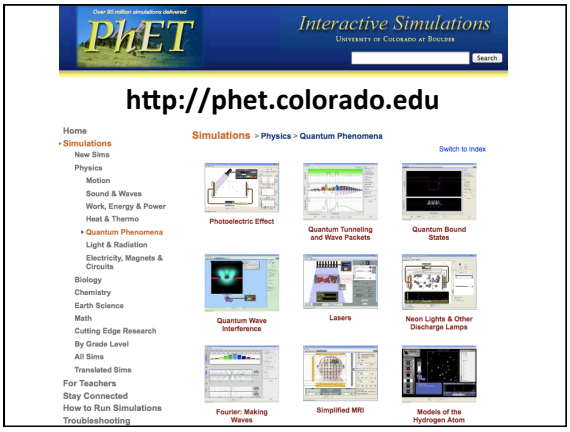
No Tutorials

Had intro E&M **with** Tutorials

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

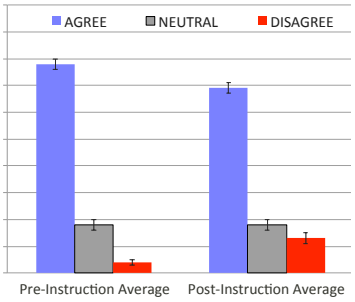
It's not about our teaching, it's about creating environments that support student learning





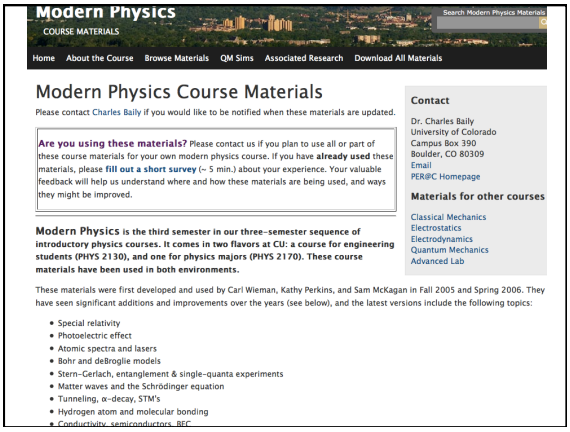
Modern Physics for Engineers

"I think quantum mechanics is an interesting subject."



New Modern Physics Curriculum

- Expose students to ideas regarding interpretive themes from the historical development of QM.
  - Complementarity/wave-particle duality
  - Wave function collapse
  - Entanglement/non-locality
- Present canonical experiments on foundations of QM.
  - Single-quanta experiments
  - Distant, correlated measurements
- Introduce contemporary topics in quantum information theory.
  - Computing, cryptography, etc…



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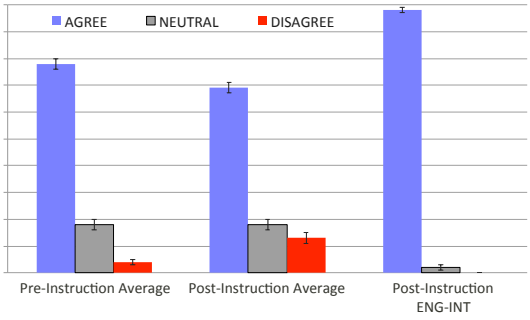
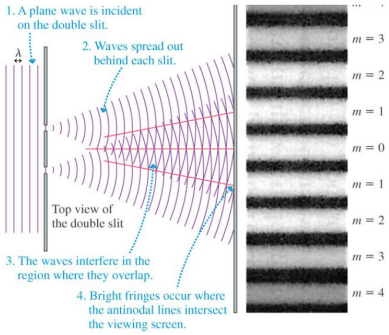
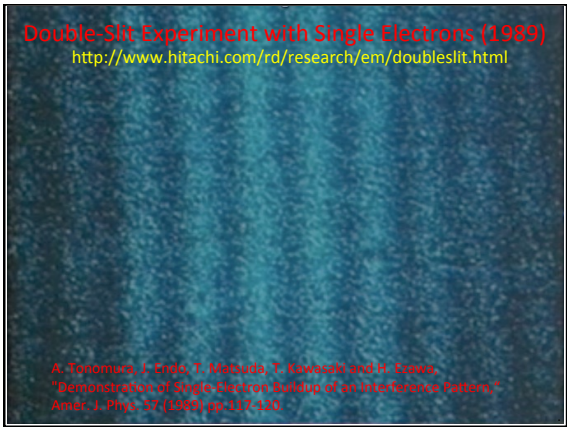
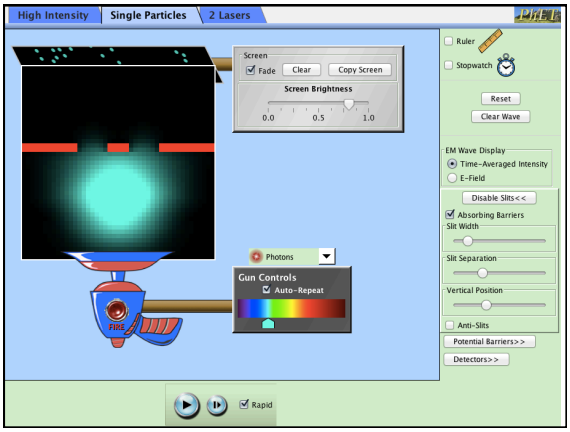
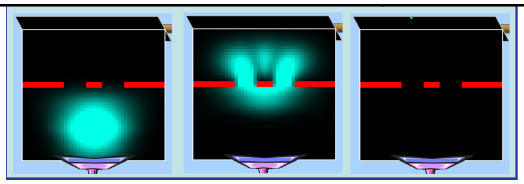


Double-Slit Experiment (photons or electrons)



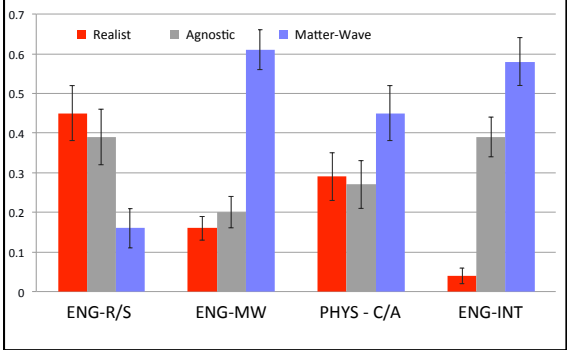


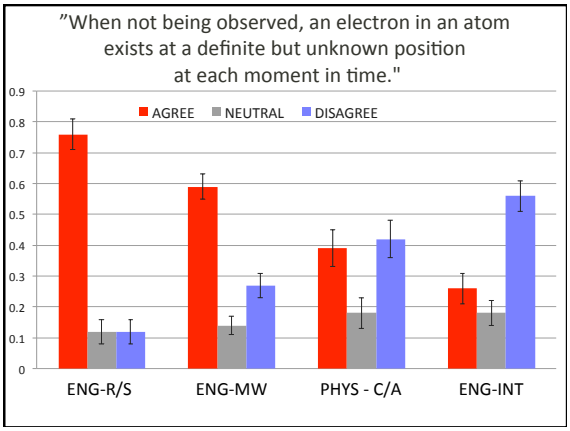


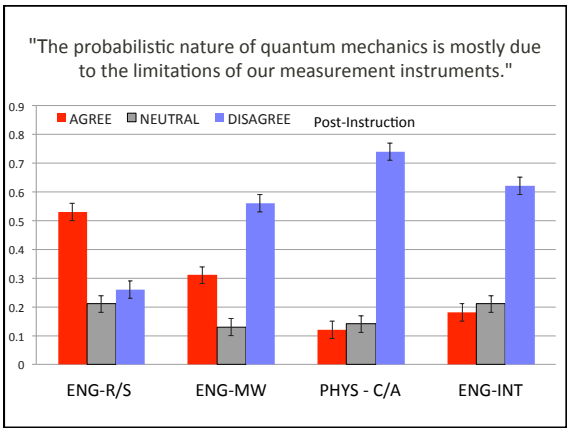


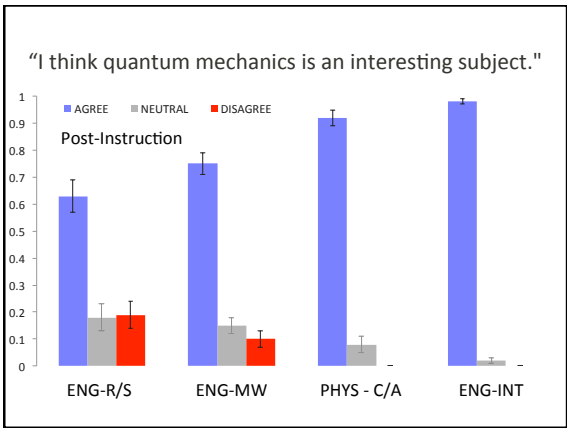
- **[Realist]** Each electron is a tiny particle that went through one slit or the other.
- **[Matter-Wave]** Each electron went through both slits and interfered with itself.
- **[Agnostic]** We can't say what the electron is doing between being emitted and detected.

Double-Slit Interpretation









Student Reflections

"I entered Physics 3 with a bitter taste in my mouth. Yet, some fragment of my mangled ego compelled me to continue down the path I was on. I have always found physics to be the most intriguing subject, and I was not about to let one class ruin it. I approached Physics 3 as the deal breaker: if this class was like its predecessor, then maybe mechanical engineering was a more apt major. […] Throughout the course, the almost magical results quantum mechanics attained reassured me that I am in the correct major. The teaching style in conjunction with the material made quantum physics attainable. I am not sure if it was the teaching that rejuvenated my passion or the material itself; either way I welcomed back my old friend, physics, with open arms and anticipation."

Questions?

Much more at:

per.colorado.edu/cts

per.colorado.edu/ModernPhysics

stemclickers.colorado.edu

phet.colorado.edu

perusersguide.org

www.compadre.org/quantum

www.falstad.com/mathphysics.html