The science of teaching science: lessons from physics education research

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HP Technology for Teaching
Microsoft External Research

The California State University
RISING ABOVE THE GATHERING STORM

Energizing and Employing America for a Brighter Economic Future

NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, AND
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES
“One of the things that I’ve been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and math...

President Barack Obama

3rd Annual White House Science Fair, April 2013
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President Barack Obama
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STEM is our business.

Top 5 U.S. Cities for Young Computer Professionals
You might think computer science is a young person's game dominated by whiz kids in hoodies. Think again. Nationally, a mere six…

How Can We Fill the Empty Seats in STEM AP Classes?
Let's talk about the biggest Advanced Placement (AP) scandal in education. If the media is your guide, you probably think that's the…

Top 5 U.S. Cities for Advanced Manufacturing

@changeequation
RT @Nlglobal: If you want your kid to become an #engineer, this video has some useful tips http://t.co/bmxU6hJcU3

RT @girlscouts: “It's a priority for women to participate in #STEM fields. These are the fastest growing parts of our economy,” Cathy Cough…

RT @exxonmobil: 3 researchers win a Nobel Prize for super-zoom microscopes that help scientists study diseases via @AP http://t.co/I0u3Ul3J

@Rick_Hall Thanks for sharing our blog!
Economic forecasts point to a need for producing, over the next decade, approximately 1 million more college graduates in STEM fields than expected under current assumptions.
Physicists studying

• how people learn the concepts, practices, and ways of thinking of science and engineering;
• the nature and development of expertise in a discipline;
• effectiveness of instructional approaches
• how to make science and engineering education broad and inclusive.
Economic forecasts point to a need for producing, over the next decade, approximately 1 million more college graduates in STEM fields than expected under current assumptions.

**Recommendations**

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.
How physics assumed a leadership role

Presence in physics departments
Prominent champions
Professional society support

**APS Statement 99.2**
RESEARCH IN PHYSICS EDUCATION
(Adopted by the Council, 21 May 1999)
In recent years, physics education research has emerged as a topic of research within physics departments.

... The APS applauds and supports the acceptance in physics departments of research in physics education.
US physics education research programs
Large-scale comparison of science teaching methods sends clear message

Carl E. Wieman

Department of Physics and Graduate School of Education, Stanford University, Stanford, CA 94305

the impact of active learning on educational outcomes is both large & consistent.

... in undergraduate STEM education, we have the curious situation that, although more effective teaching methods have been overwhelmingly demonstrated, most STEM courses are still taught by lectures—the pedagogical equivalent of bloodletting.

failure rate decreased from 34% with traditional lecturing to 22% with active learning (Fig. 1A), whereas performance on identical or comparable tests increased by nearly half the SD of the test mean (on average 0.4 SD).

Wieman, C.E., 2014, PNAS, 111(23), pp. 8319-20

Fig. 1. Comparisons of average results for studies reported in ref. 3. (A) Failure rates for the active learning courses and the lecture courses. (B) Shift in distribution of student scores on concept inventory tests.
If two galaxies collide, what do you think happens to the stars in the galaxies?

A. Many of them will hit each other.
B. Few will hit each other, but many will stop orbiting the center of their own galaxy.
C. Few will hit each other, but many will stop orbiting the center of their own galaxy.
Peer Instruction: Comparing Clickers to Flashcards

N. Lasry, John Abbott College, Montreal, QC

Peer Instruction (PI) is a student-centered instructional approach developed at Harvard by Eric Mazur (1997). The method has been welcomed by the science community and adopted by a large number of colleges and universities, due among other reasons to its common sense approach and its documented effectiveness (Fagen et al., 2002; Crouch & Mazur, 2001, Mazur, 1997). In PI, the progression of any given class depends on the outcome of real-time student feedback to ConcepTests: multiple-choice conceptual questions. In the early 1990s, students responded to ConcepTests using flashcards showing their answer. Instructors would then estimate the proportion of students holding each alternative conception. A few years later Mazur began using wireless handheld devices - colloquially called 'clickers' - to replace the flashcards. Previous users of clickers in university classrooms had reported benefits such as increased rates of attendance and decreased rates of attrition (Owens et al., 2004; Lopez-Herrejon & Schulman, 2004). The purpose of this paper is to determine the specific contribution of 'clickers' to conceptual learning and traditional problem solving skills as compared to low-budget flashcards.

Study Description

First-semester students in a two-year Canadian public community college were randomly assigned by the registrar to one of two sections of an algebra-based mechanics course. Instruction in the first section consisted of PI with clickers (n=41) while the other followed PI with flashcards (n=42) to respond to in-class ConcepTests. Both sections were taught by the author, followed the same course structure and content (using 3-4 ConcepTests with peer discussion in each class) and had the same laboratory component.

A schematic description of the PI method used in this study is shown below (Fig.1).

Figure 1: Peer Instruction Implementation Algorithm

- **Brief lecture (~10min)**
- **ConcepTest Students Vote**
  - **correct ans <35%**
    - Revisit Concept
  - **correct ans: 35%-80%**
    - Peer discussion (2-3min) students try to convince each other
    - Students revote
  - **correct ans >80%**
    - Remaining misconception explained
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**Figure 1  A Peer Instruction Implementation Algorithm**

ConcepTest

Students Vote

correct ans <35%

Revisit Concept

correct ans: 35%-80%

Peer discussion (2-3min) students try to convince each other

Students revote

Remaining misconception explained

A copper cylinder is machined to have the following shape. The ends are connected to a battery so that a current flows through the copper.

Which region has the greatest magnitude electric field $E$?

A  
B  
C  
D: All are the same  
E: No idea!

A:  
B:  
C:  
D:  
E:  

Brief lecture (≈10min)

A copper cylinder is machined to have the following shape. The ends are connected to a battery so that a current flows through the copper.

Which region has the greatest magnitude electric field $E$?

A  
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C  
D: All are the same  
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Correct ans <35%

Revisit Concept

Correct ans: 35%-80%

Peer discussion (2-3min) students try to convince each other

Students revote

Remaining misconception explained

A:  
B:  
C:  
D:  
E:  

34.4% 34.4% 25.0%

A:  
B:  
C:  
D:  
E:  

76.7% 20.0%
Establish learning goals

What should students learn?

Apply research-based teaching techniques.

Using Research & Assessment

What are students learning?

Which instructional approaches improve student learning?

Faculty & Staff

Measure progress!
I. INTRODUCTION

Lab courses require instructors to have a clear understanding of the learning features of each lab activity. What equipment should students use? How many hours should group work be permitted for grading? When creating individual activities, many finer details arise: What kinds of prompts should be in the lab guide? How much of the experiment should be set up?

We start by laying out a clear teaching philosophy for upper-division labs because it helps us make decisions about how to implement them. We begin by taking a big-picture look at a common optics lab as a concrete case study of a broadly applicable approach, we highlight many aspects of the development of activities.

Implementing a laboratory activity involves a complex interplay among learning goals, available resources, feedback about the existing course, best practices for teaching, and an overall philosophy of teaching. We focus on building a laboratory activity as a means to teach many finer details about modeling, and technical lab skills (e.g., data analysis, measurement in experimental physics).

The lab course is a many-to-one student-to-instructor environment, the course should focus on content and assessment, model construction, predictions, comparison, and model validation. We highlight many aspects of the development of activities.

Incorporating learning goals about modeling into an upper-division physics laboratory experiment

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Resources

Advanced Laboratory Physics Association

BFY II
Conference on Laboratory Instruction
Beyond the First Year of College II
University of Maryland
July 22 - 24, 2015

ALPhA’s Laboratory Immersions

PhysPort beta
Supporting physics teaching with research-based resources

ComPADRE
Resources and Services for Physics Education
A collaboration of the AAPT, AAS, AIP, APS, & SPS

AAPT Advanced Labs
Summary

• Physics has a leadership position in DBER; response to calls for more/better STEM ed
• Active engagement
• Thriving physics advanced lab community, synergy with PER
• Via research-based development and testing, we can increase opportunities for students to engage in hands-on experimentation