A research-validated approach to transforming upper-division E&M: issues and measures

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Outline

• Overview, and some background
• Building on a research base:
  – Why transform E&M?
  – What changed?
  – Assessment and data
  – Outcomes and research questions
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+recent grads (4 PhD)
+ many participating faculty and LAs
Background at CU Boulder

Physics Department
55 faculty
350 undergrad majors
230 graduate students
Background at CU Boulder

- Clickers & Peer Instruction
- Tutorials in Introductory Physics
- Pre/post assessments
Longitudinal

Upper division majors’ BEMA scores

After upper div. E&M. (Only students who took intro without Tutorials)


Upper-Level Course Transformation
Upper-Level Course Transformation

Longitudinal

BLUE: students who took freshman E&M with Tutorials

Why transform junior E&M I?

Lecture with clickers

Washington Tutorials

Can our majors learn better from interactive techniques adapted from introductory physics?
Establish learning goals

What *should* students learn?

Apply research-based teaching techniques & measure progress

Faculty & Staff

Which instructional approaches improve student learning?

What *are* students learning?

Using Research & Assessment

- E&M 1 & II
- QM I
- Class Mech/Math Methods
- Upper-div labs

Chasteen, Perkins, Beale, Pollock, & Wieman, JCST *40* (4), 70, 2011
Chasteen et al., AJP *80*, 923, 2012, PRSTPER *8* 020108, 2012
What Changed?

- Faculty collaboration
- Explicit learning goals
- Collect student data!
- Interactive techniques
- Concept Tests
- Modified Homework
- Homework Help Sessions
- Tutorials

Pepper et al, Chasteen et al, Pollock et al. PERC 2010

Upper-Level Course Transformation
Did it Work? Assessments

- Compared **Traditional** (9 courses) & **Transformed** (9 courses) at CU and elsewhere (N=515).

- Common **traditional exam questions** (5)

- Developed **Colorado Upper-Division Electrostatics Assessment (CUE)**

  and for E&M II, the **Colorado UppeR-division ElectrodyNamics Test (CURrENT)**


Upper-Level Course Transformation
CUE results: Trad courses

CUE Total Post-test Score

Post: Standard

Average (Across Courses)

Common CUE Score (%)

S1  S2  S3  S4  S5  S6  S7  S8  S9

Post: Standard

Non-CU

Standard Lecture-Based Courses

CU


Course Transformation
CUE results

CUE Total Post-test Score

- Post-test: Standard
- Post-test: Research-based

Average (Across Courses)

Common CUE Score (%)

STND 1  STND 2  STND 3  STND 4  STND 5  STND 6  STND 7  STND 8  STND 9

PER 1  PER 2  PER 3  PER 4  PER 5  PER 6  PER 7  PER 8  PER 9  PER 10

Non-CU  Standard Lecture-Based Courses (STND)  Physics Education Research-Based Courses (PER)  Non-CU
CUE results

CUE Total Post-test Score

- Red: Post-test: Standard
- Blue: Post-test: Research-based
- Purple: Post-test: Graduate Students

Average (Across Courses)

Common CUE Score (%)

Standard Lecture-Based Courses (STND)

Physics Education Research-Based Courses (PER)

Course Transformation
CUE score distribution

traditional lecture

interactive engagement

Score (as %)

Fraction of classes

\[ N_{\text{tot}} = 540 \]
Traditional exam questions

Chasteen et al, PERC 2011, AJP 80 (#10) 2012
Upper-Level Course Transformation
Traditional exam questions

Exam Results by Learning Goal

- **STND**
- **PER-C**
- **PER-D**

5 exam questions

Chasteen et al, PERC 2011, AJP 80 (#10) 2012

Upper-Level Course Transformation
Topical Pre-post shifts (effect size)

Effect size

Delta Function math
Delta function interp
Vector potential fully correct
Vector Potential direction only
Bound Current location

Early term
Topical Pre-post shifts (effect size)

Delta Function
- Math
- interp

Vector potential
- fully correct

Vector Potential
- direction only

Bound Current
- location

Effect size

Early term

Modified
Classroom Techniques

• Traditional lecture, *blended with* interactive engagement (e.g. concept tests)
• Simulations & demos
• Small handheld whiteboards
• Tutorials (in or out of class)


Upper-Level Course Transformation
Resources

per.colorado.edu/sei/

Phys 2210: Classical Mechanics / Math Methods

Phys 3220: Quantum I

Phys 2130: Modern Physics

Phys 3310: Electricity & Magnetism I (statics)

Phys 3320: Electricity & Magnetism II (dynamics)

Phys 3340, 4430, 5430: Advanced Lab
Course transformations

Research-based
• Tutorials
• Clicker Questions
• Class activities
• Homeworks

Research-validated
• Consensus learning goals
• Valid/reliable instruments
• Interviews, observations
• Pre/post assessments (intermediate or course scale)

reflective development
Parting thoughts

Course transformation (and broader questions) focusing on upper-div are still at an early stage

- What is the nature of UD student difficulties?
- Do the means to address these differ in substantial ways from lower division?
Parting thoughts

Course transformation (and broader questions) focusing on upper-div are still at an early stage

- What is the nature of UD student difficulties?
- Do the means to address these differ in substantial ways from lower division?
- Can we improve student performance in “the canon”?
- What forms of data support faculty buy-in, & how far and how fast can/should we push?
We are transforming upper division classes:
- Impact on content learning

Included faculty (buy-in?)

Developing materials and resources

Developing assessment instruments
Summary

We are transforming upper division classes:
- Impact on content learning

Included faculty (buy-in?)

Developing materials and resources

Developing assessment instruments

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

Upper division: per.colorado.edu/sei

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Upper-Level Course Transformation