A research-based approach to transforming upper-division physics

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Edward Kinney
Oliver DeWolfe
+ working groups
Why transform upper division?

Lecture with clickers

Washington Tutorials

Can our majors learn better from interactive techniques adapted from introductory physics?
# Upper-div Clickers 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>
</tr>
<tr>
<td>Mech &amp; Math II</td>
<td>★</td>
<td>★★</td>
</tr>
<tr>
<td>EM I</td>
<td>★★</td>
<td>★★</td>
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<tr>
<td>EM II</td>
<td>★★</td>
<td>★★</td>
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<tr>
<td>QM I</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>QM II</td>
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<td>★★★</td>
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<tr>
<td>Solid State</td>
<td>★★★</td>
<td>★★★</td>
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<td>Stat Mech</td>
<td>★★</td>
<td>★★★</td>
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<tr>
<td>Optics</td>
<td>★★★</td>
<td>★★★</td>
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<tr>
<td>Grad AMO</td>
<td>★★★</td>
<td>★★</td>
</tr>
</tbody>
</table>

- 12 non-PER ★★ and 2 PER★★ faculty
What Changed?

- Faculty collaboration
- Explicit learning goals
- Interactive classroom techniques
- Concept Tests
- Modified Homework
- Homework Help Sessions
- Tutorials

Students debate a concept test
What’s special about upper-div?

• Intellectually more sophisticated students
• Faculty and student investment & identity
• Complex physics
Learning Goals

• From faculty working group
• Framed course transformations

Students should

… be able to choose and apply the appropriate problem-solving technique

… be able to achieve physical insight through the mathematics of a problem

… demonstrate intellectual maturity
Did it Work? Assessments

- **Traditional** (3 courses) & **Transformed** (5 courses) 
  CU and elsewhere (N=289).

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

- **Colorado Upper-Division Electrostatics Assessment (CUE)**
  - High internal statistical consistency, 
    high inter-rater reliability
Results: CUE and Trad’l Exams

CUE Scores Across Courses

N=289

Pre-test Post-test

TRAD RES1 RES2 RES3 RES4 RES5 Non-CU TRAD Non-CU RES

N=289

Upper-Level Course Transformation

Univ. of Colorado
Results: CUE and Trad’l Exams

Trad'l exam Scores (CU, 2 terms only)

N=289
Concept Tests

- Allowed students to **discuss & debate challenging, high-level ideas**

**An ideal (large) capacitor has charge Q. A neutral linear dielectric is inserted into the gap (with given dielectric constant).**

- **Where is D discontinuous?**
  - i) near the free charges on the plates
  - ii) near the bound charges on the dielectric surface

**A)** i only  
**B)** ii only  
**C)** i and ii ONLY  
**D)** i and ii but also other places  
**E)** none of these/other

**Which of the following could be a static physical E-field in a small region?**

- **I**
  - ![Diagram of E-field I]

- **II**
  - ![Diagram of E-field II]

**A)** Both  
**B)** Only I  
**C)** Only II  
**D)** Neither
Students Find Clickers Useful

Q: How useful for your learning is the addition of clicker questions compared to pure lecture with no clicker questions?

- Lecture with clickers: much more useful - 79% of students
- Lecture with clickers: more useful
- Same
- Pure lecture: more useful
- Pure lecture: much more useful

Upper-div courses using clickers:

12 courses, 264 student responses
Q: Would you recommend using clicker questions in upper-level physics courses?

- **Highly Recommend**
  - In highly rated pure lecture, No clickers (QM II, n=17)
  - Add Clickers (QM I, n=30)
  - Missing clickers? (EM II, n=16)

- **Recommended**
- **Neutral**
- **Not recommended**
- **Definitely not recommended**
Research on student difficulties

Research-based
• Tutorials
• Clicker Questions
• Homeworks
• Class activities
• Consensus learning goals

reflective development

Research-validated
• CUE instrument
• Interviews and class observations
Research on student difficulties

**Research-based**
- Tutorials
- Clicker Questions
- Homeworks
- Class activities
- Consensus learning goals

*reflective development*

**Research-validated**
- CUE instrument
- Interviews and class observations

*and now:*
- pre/post Tutorial assessments
Summary

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

Included faculty (buy-in?) (EM*6, QM*5)

Developing materials and resources

Developing assessment instruments
Questions?

http://per.colorado.edu
http://per.colorado.edu /cts

- Clicker videos at STEMclickers.colorado.edu

- PER course materials for Quantum and E&M http://www.colorado.edu/sei/departments/physics.htm