Upper-Division Transformations in Physics

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Overview

Adapting research-based teaching approaches to upper-division courses.

Junior-level *Electricity & Magnetism* (E&M) and *Quantum Mechanics*

Why Upper Division?

Sophisticated **problem-solving** courses usually taught with **traditional lecture** and **abstract formalism**.

Highly valued by faculty.

These courses define what it means to learn physics as a major. Can we do better?

Departmental History

Using clickers with peer instruction and interactive tutorials at the freshman level.

Using clickers in 10 upper-division & graduate courses.

Some departmental culture of using interactivity in teaching.

Learning Goals

Ten broad learning goals were developed by a working group of faculty, such as

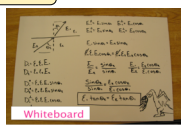
Students should be able to
... achieve physical insight through the mathematics of a problem
... choose and apply the appropriate problem-solving technique
... justify and explain their thinking and approach to a problem.

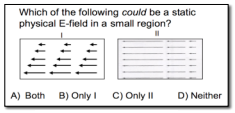
Topic-specific goals were developed for each course.
Learning goals drove course instruction & assessment.

Classroom Techniques

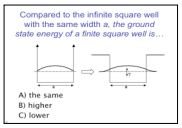
- ✓ **Interactive** lecture
- ✓ **Kinesthetic activities** (E&M only)
- ✓ Small **whiteboards**
- ✓ **Clicker questions** and **peer discussion**

2-3 challenging questions per lecture: Examples below.





Sample E&M clicker question



Sample Quantum clicker question

Tutorials

- ➢ Added optional weekly co-seminar (~50% attendance)
- ➢ Socratic guided inquiry[1]
- ➢ Run with assistance of undergrad Learning Assistant[2]
- ➢ In addition to twice weekly HW help sessions

Prepared students for next homework by helping them conceptually interpret the mathematics

Homework

Modified traditional homework to match learning goals.

For example, we added:
- ✓ Real-world contexts
- ✓ Making sense of answer
- ✓ Approximations, expansions, estimations…

Sample HW: Non-traditional portions in bold.

Q2. DIVERGENCE AND CURL

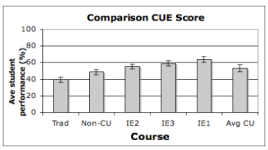
Consider a field $\mathbf{E} = c\frac{\hat{\mathbf{r}}}{r^2}$ (which is NOT the field from a point charge at the origin, right?!)

a) **Sketch it.** Calculate the divergence *and* the curl of this **E** field. Test your answers by using the divergence theorem and Stoke's theorem. **Is there a delta function at the origin like there was for a point charge field, or not?**
b) What are the units of c? **What charge distribution would you need to produce an E field like this? Describe it in words as well as formulas. (Is it physically realizable?)**

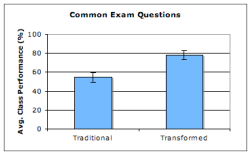
Assessments

E&M: The CUE (Colorado Upper-Div. Electrostatics)[3]

- ➢17-question open-ended conceptual diagnostic; correlates with grades
- ➢Developed from student interviews and faculty



Data on the CUE (*left: N=226*), & 5 common exam problems (*right: N=61;* IE1 vs Trad), after instruction. "Trad" and "Non-CU" are primarily taught by traditional lecture. IE1, IE2, and IE3 are 3 semesters of courses using transformed materials.



Quantum: The QMAT (Quantum Mech. Assessment Tool)[4]

- ➢14-question mostly open-ended conceptual diagnostic
- ➢Developed from student interviews, faculty learning goals and prior research[5]
- ➢Probes student learning in time evolution, wave functions, the Schrödinger eq., measurement, and probability
- ➢Results indicate significant student learning difficulties in areas of measurement and time development.

Students in E&M courses using the transformed materials scored higher on the CUE & traditional exams.

Results & Conclusions

- •We have transformed junior-level Quantum and E&M to be more closely aligned with principles of how people learn
- •Compared to a traditional lecture, **students scored higher on traditional and conceptual assessments** in E&M (Quantum assessments ongoing).
- •**Students' reactions were positive** about course changes.

Pedagogical techniques that improve learning in introductory classes can have similar benefits in upper-division, enhancing the education of future physicists, teachers and engineers.[6]

References & Acknowledgements

[1] Inspired and borrowed from: C. Manogue et al, Paradigms in Physics: A New Upper Division Curriculum, *Am.J.Phys.* **69,** 978-990 (2001). Curricular materials at www.physics.oregonstate.edu/portfolioswiki. B. Patton, Jackson by Inquiry, APS Forum on Education Newsletter, Summer 1996, and B. Patton and C. Crouch, Griffiths by Inquiry, Personal Communication.
[2] http://stem.colorado.edu/la-program
[3]] S V. Chasteen and S.J. Pollock *PERC Proc. 1064*, AIP, Syracuse, NY, 2008, p 91-94 and S. V. Chasteen and S. J. Pollock, *PERC Proceedings 2009*, in press.
[4] M. Dubson, S. Goldhaber, S. Pollock, and K. Perkins, *Transforming Upper-Division Quantum Mechanics: Learning Goals and Assessment* in *2009 PERC Proc*, AIP, 2009.
[5] A. D. Crouse, Ph.D. thesis, Univ. of Washington (2007), C. Singh, *Am. J. Phys.* **76**, 277--287 (2008), E. Gire, and C. Manogue, *2008 PERC Proc*, AIP, **1064**, NY, pp. 115--118 (2008).
[6] All materials at www.colorado.edu/sei/departments/physics.htm

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