Thinking like a Physicist: Transforming Junior E&M

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Overview

We adapt research-based techniques known to be effective at the introductory level as proof-of-concept in how an upper-division course may be transformed in order to improve student learning. Multiple assessments were used to evaluate effectiveness. The transformations have been used for 3 semesters at CU.

All course materials are available online at www.colorado.edu/sei/departments/physics_3310.htm

Why Upper-Division E&M?

Electricity & Magnetism:
- Is a core course valued by faculty
- Requires sophisticated problem-solving
- Is often taught using traditional lecture and abstract formalism
- Has canonical content

E&M defines what it means to learn physics as a major.

Faculty Input

This project combined the skills of two typically non-overlapping groups:
- Faculty teaching introductory courses using methods of active engagement
- Faculty teaching upper-division courses using traditional lecture

Working group of ~10 faculty met biweekly

Faculty involvement should increase sustainability of changes and alignment with faculty values.

Learning Goals

Content is canonical: Griffiths® Chapter 1-6. Ten broad learning goals were developed by 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.

Learning goals drove the course transformations and assessments

The Transformations

Classroom Techniques

- Interactive lecture style
- Clicker questions and peer discussion
- Illustrative simulations and demonstrations
- Kinesthetic activities
- Student work on small whiteboards.

Concept Tests (clickers)

- 2-3 challenging questions in each 50-min class
- Allowed us to gauge student understanding
- Asked student to expand or apply lecture topics
- Kept students engaged and following lecture
- Prepared students to learn from lecture

The SEI has compiled a guide to best practices in clickers®

In order to more explicitly target learning goals, we modified traditional homework.

For example, we added:
- Real-world contexts
- Articulating expected answer
- Making sense of final answer
- Approximations, expansions, estimations...

1. Use divergence and curl

2. Sketch C(div E) = curl E (which is not the field from a point charge at the origin, right?!) Use divergence and curl for the divergence theorem and Stokes’s theorem. In either case, the result is a vector field. The line integral of this vector field is not the same as the field of a point charge. That’s why there’s a point charge field, isn’t it? What’s the area of a circle? What would the field distribution look like if this vector field was a point charge? Describe it in words as well as formula. (Is it physically realistic?)

Sample HW aligned with learning goals. Non-traditional portions in bold.

Homework

- Tutorials
  - 10 weekly tutorials w/ 3 semesters of development*
  - Optional co-seminar (50-60% attendance)
  - Socratic guided inquiry
  - Run with assistance of undergrad Learning Assis®
  - In addition to twice weekly HW help sessions
  - Prepared students for next homework by helping them conceptually interpret the mathematics

- Assessments
  - CONCEPTUAL ASSESSMENT
    - The CUE® was developed to measure students’ progress on learning goals. 17 short-answer questions.
    - Developed to be valid and reliable using student interviews, faculty review, inter-rater reliability, and statistical evaluation of results (Cronbach α = 0.82).
    - The CUE was given to 226 students at CU and elsewhere. All courses using the transformed materials scored higher on the CUE than other courses.

- TRADITIONAL ASSESSMENTS
  - Students in a transformed course (IE1) performed better on 5 traditional exam problems given in common with a lecture based course (Trad).

Results & Conclusions

- We have transformed junior-level E&M to be more closely aligned with principles of how people learn, using the results of student observations and faculty input
- Compared to a traditional lecture, students scored higher on traditional and conceptual assessments and were very enthusiastic about the course.
- Students appreciate upper division clicker use, according to surveys in multiple courses

Pedagogical techniques that improve learning in introductory classes can have similar benefits in upper-division, resulting in improved learning for future physicists, teachers and engineers.

References & Acknowledgements


We acknowledge the generous contributions of the faculty working group at CU, as well as the contributions of two undergraduate Learning Assistants, Ward Hardley and Darren Tarshis, and the entire PER group at CU. We are grateful to the instructors at four outside institutions who administered the CUE in their courses.

This work is funded by The CU Science Education Initiative and NSF-CCLI Grant #0737118.