Assessing Student Understanding in Upper-Division Undergraduate Electricity & Magnetism I

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Overview

We adapt research-based techniques known to be effective at the introductory level to an upper-division course.

We investigate student understanding of upper-division Electricity & Magnetism (E&M) through student interviews, homework, exams, and two research-based conceptual assessment tools. We compare student performance in a traditional and a transformed course.

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

What Changed?

Class blended traditional lecture with interactive engagement methods -- not as dramatic a departure from the traditional approach as other transformation efforts[1,2]. Techniques included:

- Explicit course **learning goals**
- **Interactive lecture** style including whiteboards and kinesthetic activities
- **Concept Tests** (with clickers and peer instruction)
- **Homework** assignments that addressed the learning goals, including real-world contexts, sense-making, estimations.
- Weekly optional Socratic-style homework **help sessions**
- Weekly optional guided-inquiry **Tutorials** inspired in part by others[1,2,3]
- Conceptual and calculational **assessment tools**

The Courses

Traditional Course (N=41)

Instructor usually teaches upper-division courses by traditional lecture

Average student ratings of instructor: 90%/75% (upper- and lower- division)

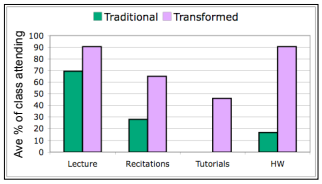
Transformed Course (N=21)

Award-winning instructor usually teaches lower-division courses with PER techniques

Average student ratings of instructor: 97%/94% (upper- and lower- division)

Students in each course were similar in terms of
- Male/female ratio (~75%/25%)
- College of Arts & Sciences/Engineering (~60%/40%)
- Pre-requisite course GPA (3.1)

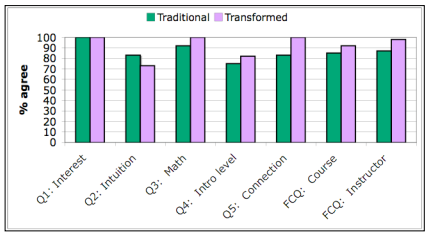
Attendance



Students in Transformed course had more contact hours with the material.

"Lecture" is an average of two class dates. "HW" is the % survey respondents reporting spending more than 6 hours/week on HW.

Student Attitudes



Survey questions: Q1: E&M is interesting subject. Q2: Intuition useful in solving E&M prolems. Q3: I'm generally able to do math calculations in course. Q4: Instructor made connections between intro level and upper-division material. Q5: Connections were made between math and physics. FCQ (Faculty Course Questionnaire): Rate the Course overall and rate the Instructor overall.
Students in Traditional course who completed survey had higher course grades than those who didn't, so students were matched by course grade. N=11 for each course.

Students were very positive about the new course, especially about the instructor and extra help sessions, but differences between courses were small. Most differences in attitudes were with respect to the instructor and extra help sessions.

"*Prof XX is hands down the best prof I've had at CU and pretty much the best physics teacher I've ever had.*"

"These were fantastic homeworks to guide the learning. I also enjoyed the help sessions."

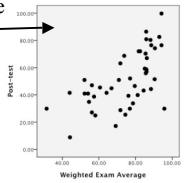
"We absolutely love it."

Conceptual Assessments

CUE Assessment

Colorado Upper-Division E&M Assessment

- New, challenging, upper-division electrostatics assessment, primarily open-ended questions.
- Good discrimination: Items (except one) correlated with overall test score (typical r=0.50)
- Correlated with course score (r=0.53) & exams (r=0.62)

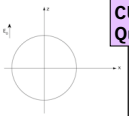


Students in transformed course scored at least 10% higher on 11 out of 14 items.
(only 8 out of 11 differences on items were significant due to low N)

Q9. You are given a non-conducting sphere, centered at the origin. The sphere has a non-uniform, positive and finite volume charge density $\rho(r)$. You notice that another student has set the reference point for V such that V=0 at the center of the sphere: $V(r=0)=0$.
What would V=0 at r=0 imply about the sign of the potential at $r\to\infty$?
(a) V ($r\to\infty$) is positive (+)
(b) V ($r\to\infty$) is negative (-)
(c) V ($r\to\infty$) is zero
(d) It depends
Briefly explain your reasoning.

Sample CUE Questions

Q10. You are given an infinite solid conducting cylinder whose vertical axis runs along the y direction, that is placed in an external electric field, $E_0\hat{z}$. The cylinder extends infinitely in the +y and −y directions.
(a) Sketch the induced charge, σ.
(b) Sketch the electric field everywhere.

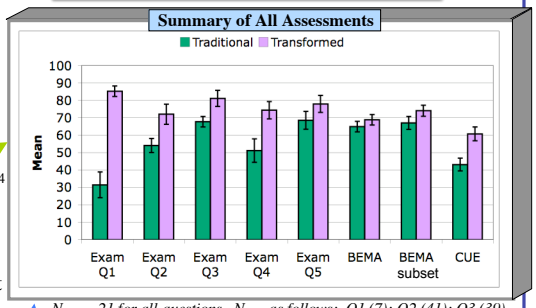


BEMA

Brief E&M Assessment

- An intro-level conceptual test developed by others[4]
- **No significant differences between students in Traditional** (67%) **and Transformed** (69%)
- Students in Transformed course score (nonsignificantly) better on E&M I-related content
- These conceptual difficulties are very stable over time[5] unless explicitly addressed.

Summary of All Assessments



N_{Trans}=21 for all questions. N_{Trad} as follows: Q1 (7); Q2 (41); Q3 (39) Q4 (9); Q5 (39); BEMA (33); CUE (26). All significant at p<0.05 except Q5 and BEMA. BEMA subset is only E&M I-related questions.

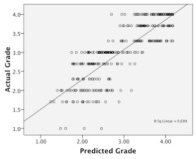
Traditional Assessments

Five exam problems were given in both courses and graded on a common rubric.
Students in the Transformed course performed significantly better than those in the Traditional course on all exam questions except Q5.

Q1: Conceptual Gauss' Law
Q2: Direct integration (final exam)
Q3: Separation of Variables
Q4: Ampere's Law
Q5: Direct integration (midterm)

Effect of Help Session Attendance

To investigate the effects of attendance at optional help sessions, while accounting for self-selection bias, we created a linear regression (r^2 = 0.48) to predict course grade from previous grades (see plot)[6].



Students who went to many help sessions did not get higher grades than predicted by the model
(data not shown)

Results & Conclusions

- An upper-division E&M course was transformed using principles of active engagement and learning theory.
- **Students in the transformed course performed better on both traditional and conceptual assessments**.
- We cannot yet differentiate between the effects of pedagogy and increased student contact with the material (through higher attendance and additional help sessions). This is an ongoing research project, including further development of course materials and assessment instruments.

References

[1] C. Manogue et al, Paradigms in Physics: A New Upper Division Curriculum, *Am.J.Phys.* **69,** 978-990 (2001). Curricular materials online at www.physics.oregonstate.edu/portfolioswiki.
[2] B. Patton, Jackson by Inquiry, APS Forum on Education Newsletter, Summer 1996, and B. Patton and C. Crouch, Griffiths by Inquiry, Personal Communication.
[3] L. McDermott, P. Shaffer, and the PEG *"Tutorials in Introductory Physics,"* Prentice Hall, 2002.
[4] L. Ding et al, *Phys Rev ST: PER,* **2**, 010105, 2006. We supplement the BEMA with three questions from the ECCE instrument of Thornton and Sokoloff, see physics.dickinson.edu
[5] S. Pollock, *PERC* 951, AIP, Syracuse, NY, 2007, p. 172.
[6] Predicted = 0.05+0.23*MathGPA + 0.72*PhysGPA (+0.36 if E&M grade > 3.0) or (-0.41 if E&M grade < 3.0)

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