Developing Tutorials for Advanced Physics Students: Processes & Lessons Learned

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All course materials available at
http://per.colorado.edu/Electrodynamics

Course Description

2nd semester upper-division electrodynamics (EM2)

15-week semester — Three 50-minute lectures/week

30-50 students — Primarily junior physics majors

Topics: Time-dependent Maxwell eqns, Potentials and fields, Radiation, Conservation principles, EM waves, Special relativity

Standard textbook: D. J. Griffiths, *Introduction to Electrodynamics, 3rd Ed.*

Background

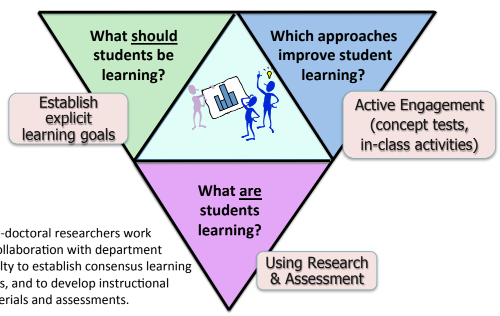
Several long-term upper-division course transformation projects at CU Boulder

Classical Mechanics/Math Methods, Quantum Mechanics, Electrostatics (EM1)

NSF funding awarded in Summer 2011, sufficient for a two-year project

We could arrange for ourselves to teach EM2 in the FA11 and SP12 semesters

SEI† Transformation Process



Post-doctoral researchers work in collaboration with department faculty to establish consensus learning goals, and to develop instructional materials and assessments.

† *Science Education Initiative*

Initial Challenges

Funding, Institutional & Other Constraints

Two year timeframe to develop and refine tutorials.

Not every student can attend optional tutorial sessions outside of class.

Unable to add a recitation section because required hours for physics majors already at the maximum allowed by CU.

Identifying Student Difficulties Within a Short Time Period

Limited pre-existing research base on student difficulties in advanced EM2.

Fewer advanced students available for interviews than in introductory courses.

Interviews with students who have already completed EM sequence won't provide insight into challenges faced when first exposed to new topics.

Completion Times and Student Feedback

How to design activities that are meaningful for advanced students, but still take less than 50 minutes to complete?

Need feedback regarding clarity of problem statements and diagrams from students who are new to the topics.

Identifying Student Difficulties

– Listen to experienced EM2 instructors

Conducted six individual interviews with faculty members at CU

Invited outside faculty with experience in PER and curriculum development for a two-day meeting in Boulder

– Individual student interviews

Recruited five students who had recently completed the full EM sequence

Useful for confirming anecdotal reports from instructors

– Classroom observations and artifacts

Concept test responses and student questions/discussions

Reflections from Learning Assistants

Homework problem-solving sessions

Weekly pre-flight submissions

LIFT PAGE FOR EXAMPLES

Focus-Group Interviews

Decided to create tutorials on a weekly basis and validate during FA11

Recruited 3 students for 12 sessions throughout semester

Meetings took place at end of week, before students began HW assignment

Format mimicked a typical tutorial environment (collaborative small-group work, Socratic questioning)

Received immediate feedback on clarity, utility and timing of tutorials

Unanticipated difficulties led us to change focus of several activities

Design strategies developed through these interviews:

(1) **Focus on concepts.** Students slowed by complicated calculations. Have them determine signs of quantities, or whether they are *zero* or *non-zero*.

(2) **Scaffold problems:** Initial problem statements should be very explicit, with successive ones less so – build on information acquired just prior.

(3) **Don't underestimate completion times:** Easy to convince ourselves students would quickly finish "simple" tasks – they generally required 10 minutes/page when adequate space was provided for written work.

Initial Implementations

<u>Spring 2012</u>

About 40% of lectures partly or fully replaced by small-group work

Oriented students to upcoming activity with clicker questions/discussion

Average completion times ranged anywhere from 10-45 minutes

<u>Fall 2012</u>

Non-PER instructor used smaller subset of tutorials and clicker questions, with post-doc support

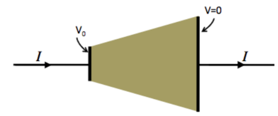
Implementation strategies resulting from these experiences:

(1) **Sell students on group work.** Even if they liked using tutorials in introductory courses, students may still be skeptical of group work in an upper-division course.

(2) **Pass out worksheets just prior to beginning.** Some students wanted to start working problems right away – discouraged collaborative work later on.

(3) **Create challenge problems.** Working at their own pace, some groups finished before others. Maintain productivity by including one or two challenge questions at the end of each activity.

Sample Tutorial Activity



(a) When a steady current is flowing, is the time derivative of the charge density $\partial\rho/\partial t$ *inside* the resistor *zero* or *non-zero?*

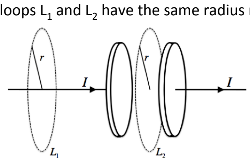
(b) Considering the continuity equation: $\nabla\cdot\mathbf{J} = -\partial\rho/\partial t$, is the divergence of the current density *inside* the resistor *zero* or *non-zero*?

(c) Considering Ohm's Law: $\mathbf{J} = \sigma\mathbf{E}$, is the divergence of the electric field *inside* the resistor *zero* or *non-zero*?

(d) Considering Gauss' Law: $\nabla\cdot\mathbf{E} = \rho/\varepsilon_0$, is the volume charge density *inside* the resistor *zero* or *non-zero*?

Sample Tutorial Activity

A capacitor is in the process of charging up, as shown in the diagram below. The two imaginary loops L_1 and L_2 have the same radius r.



Compare the values of two line integrals of the magnetic field:

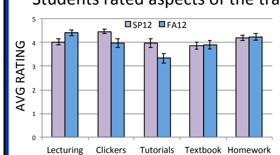
$$\oint_{L1} \vec{\mathbf{B}}\cdot d\vec{\ell} \qquad \oint_{L2} \vec{\mathbf{B}}\cdot d\vec{\ell}$$

Is one larger than the other, or are they equal in value?

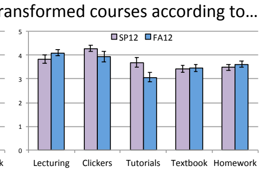
Explain your answer using the formulas you derived previously.

Student Perceptions

Students rated aspects of the transformed courses according to…



…how useful they were for their learning.
5 = "very useful"; 1 = "not at all useful"



…how much they enjoyed using them.
5 = "strongly like"; 1 = "strongly dislike"

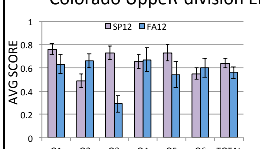
– Results suggest dominant instructional modes received highest ratings
   SP12: less lecturing, more clickers and tutorials
   FA12: more lecturing, fewer clickers and tutorials

– "Utility" rates higher than "enjoyment" in every category.

– Strong correlation in each category between "utility" and "enjoyment".

Learning Outcomes

Colorado UppeR-division ElectrodyNamics Test (CURrENT)



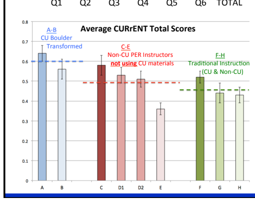
<u>Comparison Between CU SP12 & FA12</u>

– Significant differences in Q2 & Q3

– Differences in Q1 & Q5 marginally significant

– Validation of assessment still ongoing

Results suggest more interactivity in the classroom promotes student learning.



<u>Comparison across institutions</u>

Average total CURrENT scores for the two CU transformed courses, compared with similar classes at other institutions with PER instructors, and also traditional instruction at CU & elsewhere.

Results suggest small-group tutorial activities improve student learning.

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Summary

Designing tutorials for advanced physics students presents challenges that differ from tutorial development for introductory courses:

– Institutional and funding (time) constraints
– Smaller class sizes
– Pre-existing research base on student difficulties is sparse
– Student attitudes about advanced physics courses (tutorials are more suited for "introductory learning")

Difficulties can be overcome by leveraging:

– Faculty experience
– Student feedback
– Classroom observations
– Ongoing interviews

Implementation and instructional styles may affect:

– Student perceptions of "utility" and "enjoyment" of tutorials
– Overall learning outcomes