

New Ways of Teaching Junior E&M

DESCRIPTION & RESULTS

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SCIENCE EDUCATION INITIATIVE



Also see our
other poster on
best practices in
clicker use
PST2C01

*See our talk Weds
10:30 am, HE06*

References & Acknowledgements

This work is funded by the SEI, CU-Boulder and NSF-CCLI grant #0737118.

We are grateful to the faculty at CU-Boulder who participated in the course transformations, and/or assisted in development of course learning goals and the CUE.

ALL COURSE MATERIALS ONLINE AT
<http://www.colorado.edu/sei/departments/physics.htm>

1. S. V. Chasteen, K.K. Perkins, P. D. Beale, S. J. Pollock, C.E. Wieman, *J. Coll. Sci. Teach.* (in press).
2. S. V. Chasteen and S. J. Pollock, “Tapping into Juniors’ Understanding of E&M: The Colorado Upper-Division Electrostatics (CUE) Diagnostic” and S. V. Chasteen and S. J. Pollock, “A Research-Based Approach to Assessing Student Learning Issues in Upper-Division Electricity & Magnetism” both in *PERC Proceedings 2009*; S. V. Chasteen and S. J. Pollock, “Transforming Upper-Division E&M” in *PERC Proceedings 2008*.
3. S. Tobias. *Revitalizing Undergraduate Science: Why some things work and most don't*. Series editor, W.W. Bacon. Tucson: Research Corporation, 1992.

Introduction & Claims

Created research-based course materials for junior E&M.

Material use sustained over 5 semesters.

Use of materials **improved student learning** on conceptual assessment.

Variability in student learning gains possibly related to:

- Degree of implementation fidelity
- Attention to upper-level student difficulties
- Connection between lecture and assessments

Key things that helped sustain material use:

- Positive **departmental culture** & support
- **Staff** dedicated to developing and disseminating materials
- Institutionalized **co-seminar tutorial**
- Instructors' **positive experiences** with course
- Easily modified materials in organized **course archive**

Use of the new materials still takes instructor time, but they report more “bang for the buck” for their effort.



Look for the two examples of less effective transfer that suggest some necessary features in successful course transformation

Methods



- Transformed first-semester of junior-level E&M with department faculty
- Developed research-based materials with staff support and co-teaching [1,2]
 - ▶ Learning Goals
 - ▶ Concept Tests / Clicker Questions
 - ▶ Tutorials
 - ▶ Modified Homework
 - ▶ Student Difficulties
- Developed conceptual diagnostic, the CUE* [2]

WHAT CHANGED?

We added learning goals



- Faculty agreed on what students should be able to do at end of course
- Used to design course & assessments

“...” should read “students should be able to”

1. **Math/physics connection:** ...translate a physical description to a mathematical equation, and conversely, explain the physical meaning of the mathematics.
2. **Visualize the problem:** ...represent key aspects of physics through sketches.
3. **Organized knowledge:** ...articulate the big ideas from each chapter, section, and/or lecture.
4. **Communication.** ...justify and explain their thinking and/or approaches, both in writing and orally.
5. **Problem-solving techniques:** ...choose, apply, and justify appropriate problem-solving techniques in novel contexts, including (a) approximations and series expansions, (b) symmetries, (c) multivariable integration and PDE setup, (d) superposition.
6. **Problem-solving strategy:** ...organize and carry out long, complex physics problems.
7. **Expecting and checking solution:**...articulate expectations for, and justify reasonableness of solutions

We changed the classroom

- Traditional lecture blended with interactive techniques
- Handheld whiteboards
- Concept tests (“clickers”)



Allowed students to discuss & debate challenging 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

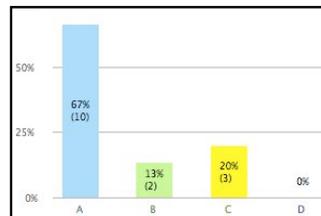
ii) near the bound charges on the dielectric surface

+ Q

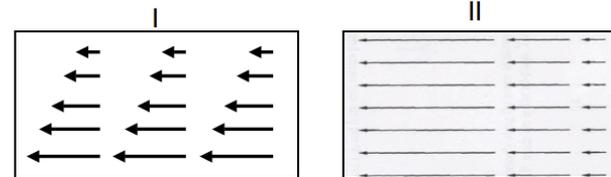


- Q

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?



A) Both B) Only I C) Only II D) Neither



We changed the homework

- Modified traditional HW problems to better fit learning goals
- Added sense-making, real-world, estimations, etc.
- Offered group problem-solving sessions instead of office hours

Q2. DIVERGENCE AND CURL

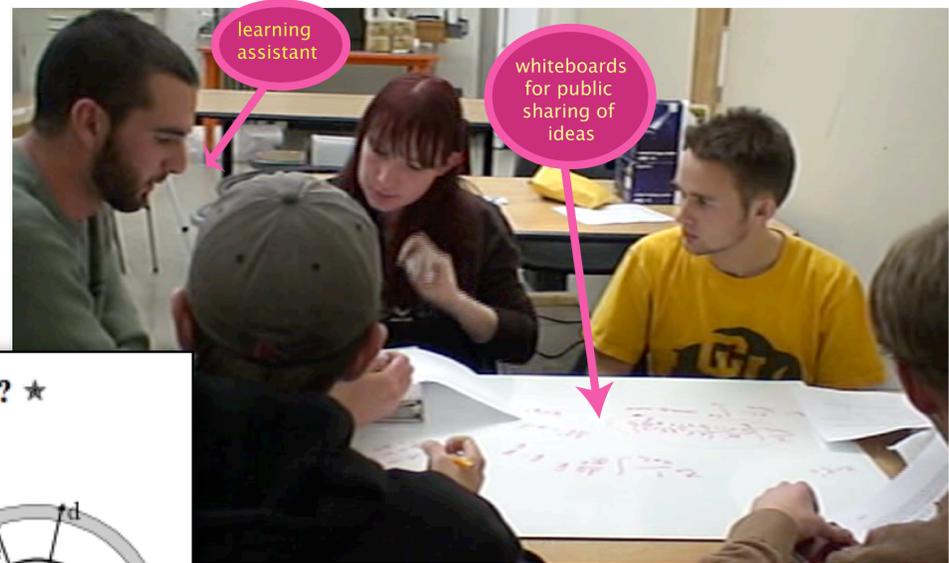
Consider a field $\mathbf{E} = c \frac{\vec{\mathbf{r}}}{r^2}$ (which is NOT the field from a point charge at the origin, right?!) (???)

- a) **Sketch it.** Calculate the divergence *and* the curl of this \mathbf{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 \mathbf{E} field like this? Describe it in words as well as formulas. (Is it physically realizable?)**

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

We added tutorials

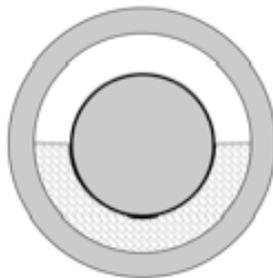
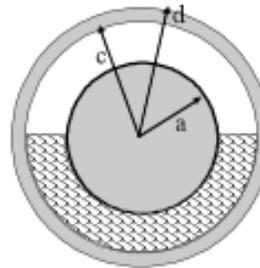
- Optional once/week tutorials
- 1-credit co-seminar



★ TUTORIAL 8: Is the sphere half full or half empty? ★ *Spherical linear dielectric*

Part 1 – Symmetry and boundary conditions

Consider a conducting spherical shell of radii a that is concentric with a conducting sphere of radius c as shown in the figure. The space between them is filled with a liquid having an electric susceptibility χ_e . A total charge of “+Q” is placed in the inner conducting shell and “-Q” in the outer shell.

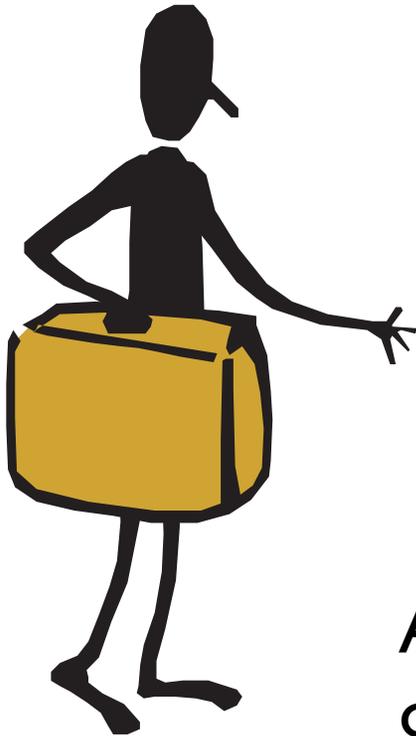


i. Predict where there would be free and bound charge on all surfaces. Sketch your predictions on the diagram to the left.

Predict what the total E-field would look like everywhere. Sketch your predictions on the diagram below. Don't worry too much about getting this exactly right, it is just your intuitive guess for now.

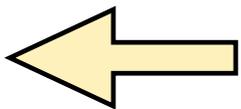
DID IT WORK?

Instructors used materials



Implementation varied, but only whiteboards and learning goal use changed significantly in later semesters.

At least 8 other universities used some of our materials: Three used most of our course approach



Pull out to see data



Data: Material Use

Tracked use of course materials since development.

✓+ exemplary

✓- minimal

✓ simply documented (when no data justify a +/-)

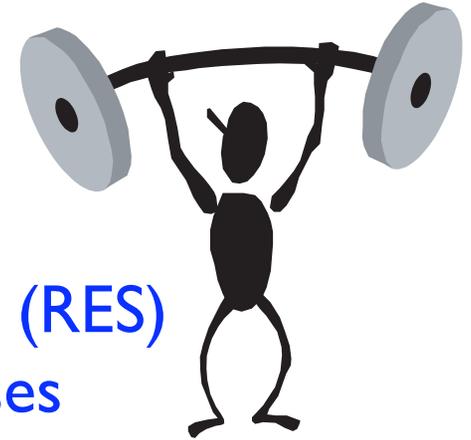
TABLE 1. Sustainability of Course Structure

Semester	RES1	RES2	RES3	RES4	RES5
Instructor →	Developers PER1+STF	PER2 + Non-PER1	Non-PER1 (tenured)	Non-PER2 (junior)	Non-PER3 (junior)
Learning Goals [Used in course prep?]	✓+	✓	✓+	✓	0
Clickers [Used, and used ideally? ⁸] (<i>daily ave</i>)	✓+ (3.5)	✓ (4.2)	✓+ (3.1)	✓+ (3.3)	✓- (2.5)
Tutorials [Offered?] (<i>ave attendance</i>)	✓ (44%)	✓ (30%)	✓ (42%)	✓ (36%)	✓ (35%)
Lectures [Interactive?] (<i>ave attendance</i>)	✓+ (94%)	✓+ (86%)	✓+ (77%)	✓+ (77%)	✓ (74%)
Group homework sessions [Offered?]	✓	✓	✓	✓	✓
Whiteboards [Used often?]	✓+	✓-	✓	✓	0
Modified homework [Used?]	✓	✓	✓	✓	✓
Documented student difficulties [Referred to?]	Not avail.	✓	✓+	✓+	✓-
Implementation Fidelity (sum of ✓; +/- count ½)	10	8	10	9.5	5

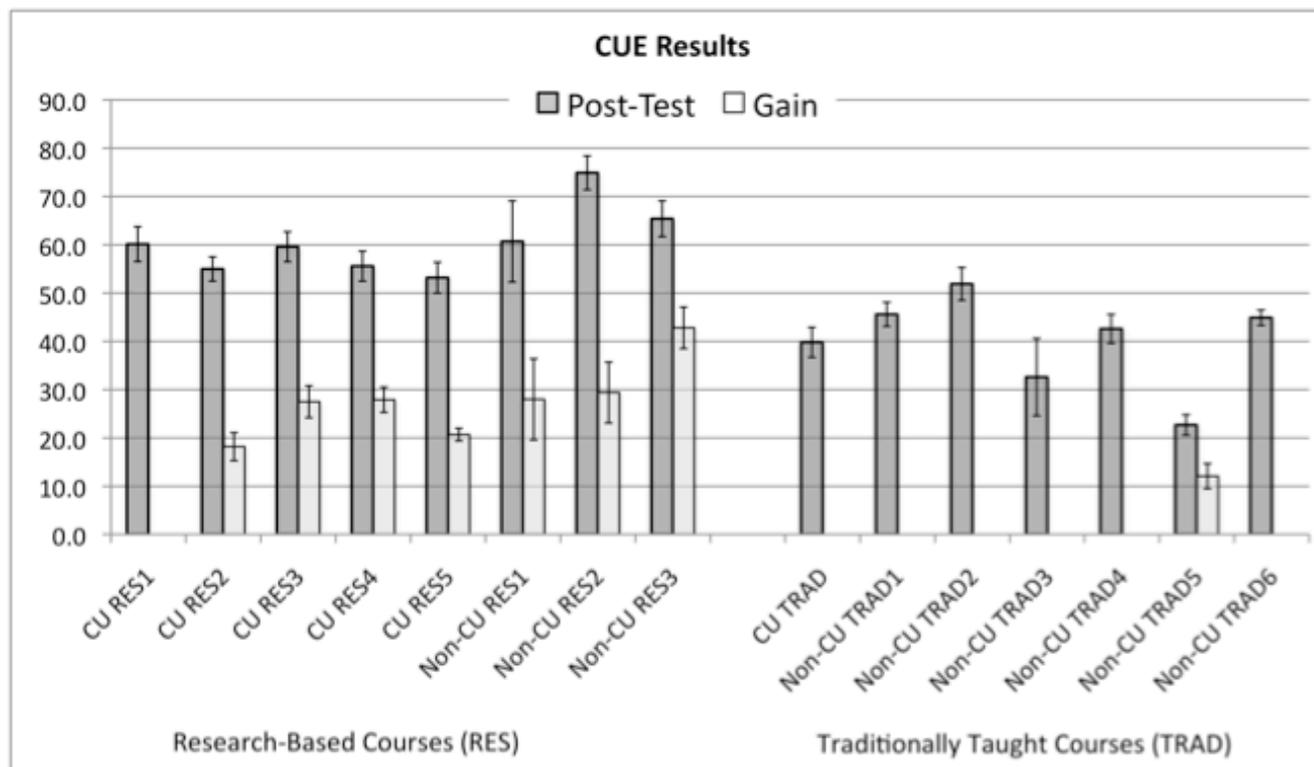
★ RES5 has lower “implementation fidelity”. Does this affect student learning?

“Ideal” clicker use as defined by best practices in the Instructor’s Guide at <http://STEMclickers.colorado.edu>

Students learned more



Student learning gains higher in all research-based (RES) courses than in traditionally-taught (TRAD) courses



Not related to student prep or class size



But why are gains lower in RES2 and RES5?

Error bar represent ± 1 SE of mean. "Gain" represents student absolute gains on the 7-questions on the Post-test which match the 7-question Pre-test; Gain (and SE) estimated for TRAD and RES1 (based on consistent Pre-test data in later semesters). Non-CU TRAD is an average of three courses at another large research university. Non-CU RES is the average of three courses at three institutions that used our research-based materials. Post-test N's are as follows: CU TRAD(27), RES1-5 (20, 42, 27, 35, 59), Non-CU TRAD (221), Non-CU RES (31).

Students liked it

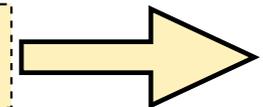
Students found all aspects of course enjoyable and useful, and well-connected to one another.



- “Homework” received highest ratings
- “Tutorials” varied, but overall positive
- “Whiteboards” generally seen as less useful
- Students in RES courses spend more time on homework (7-9 hours) than in TRAD (3-4 hours)



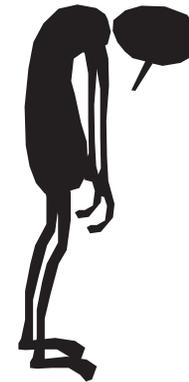
With one exception. Why?



Poor student ratings

One course (RES2) had consistently lower student ratings:

- Less connection between in-class time, homework, and exams
- Lower usefulness of tutorials
- Lower enjoyment of pure lecture & tutorials
- Less comfort asking questions during class
- Less satisfaction and learning in the course overall



Course also had:

- Lower CUE gains
- More clicker questions
- Lower course implementation fidelity

But this was an award-winning instructor. What happened?

- Students complained that lectures were “too easy” for exams
- Instructor unusually busy and less invested in course

Instructor may have been following lower-division beliefs and practices too much, and course may have suffered from instructor inattention.



**WHAT HELPED INSTRUCTORS
USE MATERIALS?**

Department Support

Department provided both tangible supports and a generally receptive culture

- Faculty contributed to discussions
- Chair & associate chair buy-in



Instructor experiences



Instructors very positive about experience, student learning, student feedback, and bigger impact for the same preparation time.

- Could lead to word-of-mouth spread of materials

Staff Support

Dedicated staff reduced work burden on instructors.
Crucial in creation and documentation of course.

- Developed transformations
- Created and sustained course archives
- Documented impact of transformations
- Undergraduate learning assistants assisted with tutorials

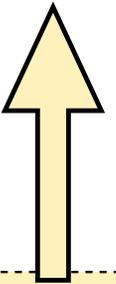


Course Archives

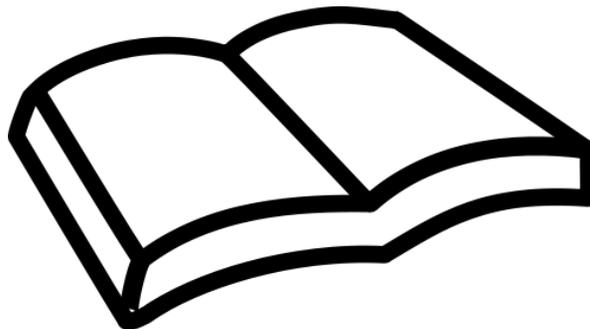
Materials organized by topic and type of material. All modifiable. Instructors can pick and choose.



What do instructors say?



- Most instructors found archive takes time to use but is well organized.
- Most discussed the course with developers in addition to viewing the archive



Instructor Quotes

“Just taking those materials and reading them isn’t the same thing [as talking to developers about the approach]”

– Instructor for RES2

Can using course materials give illusion of fully transformed course?

What might take the place of developer discussions?

“[These materials] allow the interested person to start teaching a transformed course without the huge time investment that it might otherwise have required”

– Instructor for RES5



Note: RES5 mentored in interactive techniques, but had lower course fidelity, lower learning gains, and did not feel the need to discuss the course with developers.

What do you think?



- Would you use these materials? Why or why not?

*Write on this post-it and
attach here or in
appropriate spot on poster*

- Share your related experiences as an instructor or curriculum developer

*Write on this post-it and
attach here or in
appropriate spot on poster*