Revealing Differences Between Curricula Using the Colorado Upper-Division Electrostatics Diagnostic

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Paradigms in Physics
http://www.physics.oregonstate.edu/portfolioswiki/

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Introduction

- Recently, the University of Colorado at Boulder (CU) developed the Colorado Upper-Division Electrostatics (CUE) Diagnostic to assess student conceptual learning of upper-division electricity and magnetism (E&M) [1–3].
- Using the CUE, we have been documenting students' understanding of E&M at Oregon State University (OSU) over a period of 5 years (from 2009 to 2013).
- Our analysis indicates that the CUE identifies concepts that are generally difficult for students, regardless of the curriculum.
- Using student data from both OSU and CU, we discuss similarities in the overall pattern of scores and possible causes for differences on selected questions, as well as steps that may rectify the situation.

Course Schedule at OSU

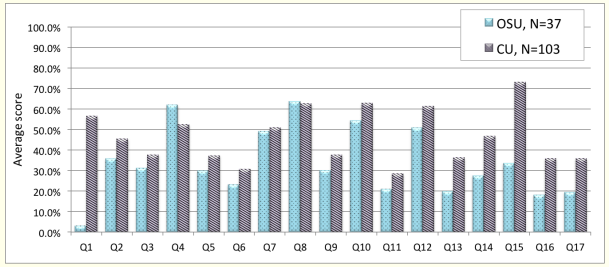
Standard schedule of Paradigms and Fall term Capstones. E&M-related courses, during which the CUE is being administered, are highlighted in bold. Courses in italics are where the method of separation of variables is discussed.

Junior Courses			Senior Courses
Fall	Winter	Spring	Fall
Symmetries **Vector Fields** Oscillations	Preface Spins *1-D Waves* *Central Forces*	Energy and Entropy Periodic Systems Reference Frames Classical Mechanics	*Mathematical Methods* **Electromagnetism**

What are Paradigms?

- Paradigms revolve around concepts underlying different fields of physics: energy, symmetry, forces, wave motion, etc.
- The content is arranged differently:
  - more time spent on direct integration and curvilinear coordinates,
  - less time devoted to separation of variables (SofV),
  - covering potentials before electric fields,
  - covering magnetostatics in vacuum before electrostatics in matter.
- Large variety of active engagement strategies:
  - individual small white board questions,
  - small group problem-solving,
  - computer visualizations, simulations and animations,
  - kinesthetic activities.

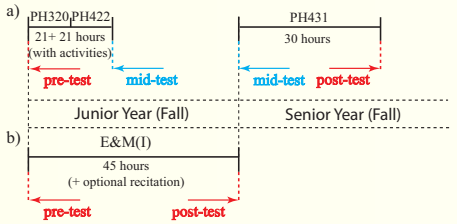
The Average Performance on Each Question at OSU & CU



- The post-test was administered at OSU three times: in the Fall terms of 2010, 2011 and 2013 to a total of $N = 39$ students.
- With the exception of two questions (Q1 and Q15), the averages agree to within 10% on the first 12 questions and to within 20% thereafter.
- Students at OSU scored on average $36.5 \pm 2.4\%$ compared to $47.8 \pm 1.9\%$ at CU.
- For $N = 24$ students who took the pre- and post-tests, we found an average normalized gain of 33% (28% non-normalized), which is similar to gains of 34% (24%) reported in Ref. [2].

CUE Schedule at OSU & CU

Schedule of administering the CUE at (a) OSU (quarter systems) and (b) CU (semester system).



Although OSU students have had more contact hours in E&M at the time they take the post-test than CU students (72 vs. 45 hours), most of the additional hours are on the more advanced content from E&M(II) at CU.

References

[1] Chasteen, S. V. and Pollock, S. J., *Tapping into Juniors' Understanding of E&M: The Colorado Upper-Division Electrostatics (CUE) Diagnostic*, AIP Conf. Proc. **1179**, 109 (2009).

[2] Chasteen, S. V. *et al.*, *Colorado Upper-Division Electrostatics diagnostic: A conceptual assessment for the junior level*, Phys. Rev. ST PER **8**, 020108 (2012).

[3] Pepper, R. E. *et al.*, *Observations on student difficulties with mathematics in upper-division electricity and magnetism*, Phys. Rev. ST PER **8**, 010111 (2012).

Acknowledgments

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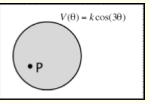
Discrepancy in Scores and Their Causes

OSU students' scores differ by over 50% on question Q1 and by almost 40% on question Q15, which test whether students can set up the solution to a problem involving partial differential equations:

- recognizing SofV as an appropriate problem-solving technique and/or
- defining boundary conditions (BCs).

Q1. An insulating sphere with radius R, with a voltage on its surface $V(\theta) = k\cos(3\theta)$. Find E (or V) inside the sphere at point P.



Q15. Circle **all** of the following boundary conditions that are suitable for solving Laplace's equation for finding V(r,θ) everywhere due to a charge density σ on a spherical surface of radius R.

(I) $V_{in} = V_{out}$ at r=R
(II) $\vec{E}_{in} = \vec{E}_{out}$ at r=R
(III) $E^{\perp}_{in} - E^{\perp}_{out} = -\sigma/\varepsilon_0$ at r=R
(IV) $E^{\parallel}_{in} - E^{\parallel}_{out} = -\sigma/\varepsilon_0$ at r=R

- At OSU students are exposed to the SofV mainly in the context of the Schrödinger equation:
  - 1-D Waves and Central Forces (Junior year),
  - Math Methods (Senior year).
- There is only one day spent on Laplace's equation in the E&M Capstone, followed by 2 or 3 homework problems.
- It was assumed that – once exposed to certain problem-solving technique in one context – students will be able to transfer knowledge of its applicability from one field of physics to another.
- Low scores on two other questions involving SofV and BCs: Q11 (finding BCs in a specific scenario) and Q13 (recognizing the form of solutions that match given BCs) support our suspicion that students are not getting enough exposure to these topics in the context of E&M.

Conclusions

- Due to the significantly restructured curriculum at OSU, our findings provide valuable data for comparison with reported results from CU's more moderately reformed curriculum and from institutions with a more traditional (lecture) format.
- Despite the different sample of students, the difficulty pattern for most questions is preserved, regardless of the curriculum.
- Students at OSU on average scored about 11% lower, yet they showed *learning gains* of 33%, which is similar to students from other institutions taught in PER-based courses and higher than gains observed in standard lecture-based courses.
- Strong differences in scores on a few specific questions revealed gaps in our curriculum.