Interplay of research and development: A Case Study in Integrating Visualizations into a Reformed Curriculum

Sahana Murthy, Massachusetts Institute of Technology
Carolann Koleci, Worcester Polytechnic Institute
Peter Dourmashkin, Massachusetts Institute of Technology
John Belcher, Massachusetts Institute of Technology

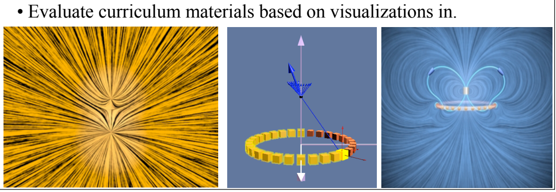
Foundations and Frontiers of Physics Education Research
August -6-10, 2007, Bar Harbor, ME

Motivation for project

We currently have visualizations of electromagnetic fields and phenomena developed as part of an introductory studio-style E&M class at MIT under the TEAL [1] project. However we find a gap between what students learn from the visualizations and what the designers intended to convey. At the same time, TEAL instructors wish to make the electromagnetic fields visible when students work on concepts, experiments and problems involving electromagnetic phenomena. Our project aims to develop materials to address both these issues.

Goals for project

- Create a comprehensive suite of 2D & 3D visualizations of electromagnetic fields and phenomena.
- Design interactive activities incorporating these visually rich representations to help students develop visual, conceptual and analytic models of electromagnetic phenomena.
- Build flexibility in curriculum materials so that they can be used in different settings and contexts.
- Evaluate curriculum materials based on visualizations in.



Process of research, curriculum development and and instruction

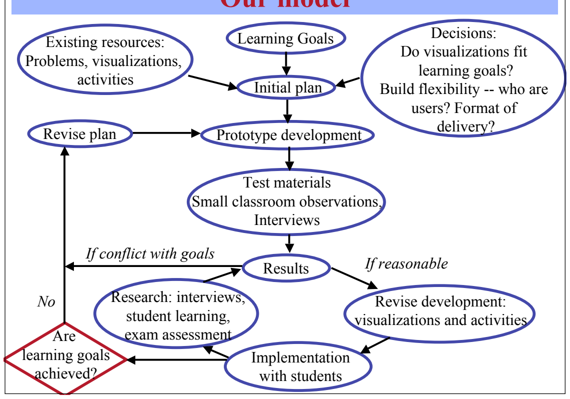
We present **a detailed model of the process** of research, curriculum development and instruction[2,3] that we used in integrating visualizations into a studio-style E&M physics course. We **describe examples** that examine the interplay between parts of this process.

Questions we considered:

- What are our learning objectives for students ? (Conceptual reasoning, problem-solving, multiple representations, models of EM phenomena)
- How can teachers and learners adapt our materials? (Interactive Engagement v. traditional classes, in-class v. homework v. self-study)
- What format should we use for materials? (Paper-pencil, electronic)
- What resources already exist? How do we build on them?
- How do we assess the effectiveness of visualizations?

(What do students learn? Do visualizations work as intended?)

Our model



Building flexibility in curriculum materials

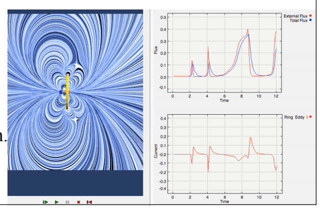
Which aspects of flexibility should we target ?	Determine implications	Make decisions
Institutions MIT, WPI Other university instructors High school teachers 2-year college instructors	Need versatility, satisfy different goals, must be adaptable by different instructors, viz must work on different platforms	Develop paper & pencil activities. Post on webpage, release under Creative Commons License.
Uses • Students in class • Students self-study • Instructors adapt only visualizations • Instructors adopt our curriculum as is	Need activities for formative and summative assessment, for different modes of teaching and learning	Develop questions and activities for in-class work, homework, exams. Test materials in different modes.
Level Introductory E&M Intermediate E&M	Need to choose appropriate content for visualizations	Develop problems of varying levels of complexity

Example : Research ➞ Development ➞ Implementation ➞ Further research

Hypothesis testing activity to go with visualization

Motivation:

- Research shows that students struggle with Faraday's law concepts [4]
- Previous observations of MIT students using Faraday's law visualization showed that there was little interaction between students and the visualization.



Implication:

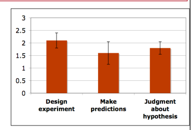
Need for guided inquiry activity to go with visualization.

Development: We developed an in-class activity based on the ISLE [5] cycle.

Observation experiment
Play with the visualization; find as many ways as possible to induce current in the coil.
Proposing a hypothesis.
Propose a qualitative relationship between flux (seen in top graph) and current that flows in the ring (seen in bottom graph).
Testing the hypothesis.
Group A came up with the hypothesis that current through the ring is proportional to flux. Group B, thought that current through the ring is proportional to the *change* in flux. Design and perform a virtual experiment using the visualization to rule out at least one of the hypotheses.

Research and assessment:

1) We analyzed students' write-ups using scientific abilities rubrics [6].
Result: Graph shows students' rubrics scores on designing experiments, making predictions & judgment.



2) We observed students working in groups in the classroom.
Result: Analysis of observations showed that students were engaged in productive group discussions, with a high frequency of sense-making.

Example: Implementation ➞ Research ➞ Revise plan

Research Question: Do electronic homework modules with integrated visualizations help students better understand fundamental physical phenomena in electricity and magnetism?

Study Details:

- Spring 2007 at WPI; Sophomore/Junior Level Electromagnetism
- Text: Griffiths, *Electrodynamics*
- Homework: Both paper-pencil and electronic homework. One-third of HW assignments are electronic.
- MasteringPhysics with integrated visualizations in electrostatics & magnetostatics.
- N = 30.

Preliminary Results:

- Electronic HW with integrated visualizations does not strongly correlate with exam performance.
- Survey responses reveal that students find the visualizations useful but are frustrated with the electronic homework interface.

Correlation Matrix

Variables	(1)	(2)	(3)	(4)
(1) MasteringPhysics Assignment 1	1.00	0.40	0.55	0.47
(2) Traditional Homework Assignment	0.40	1.00	0.66	0.64
(3) Exam Two	0.55	0.66	1.00	0.87
(4) Exam Two, Question One	0.47	0.64	0.87	1.00

Decision:

Change format from electronic homework. Develop paper-pencil curricular materials that can be posted on webpage with link to visualizations.

References

1) http://web.mit.edu/8.02t/www/802TEAL3D/index.html

2 Based on the cycle by the University of Washington physics education group. http://www.phys.washington.edu/groups/peg/curric.html

3) PhET: Interactive Simulations for Teaching and Learning Physics, Katherine Perkins, Wendy Adams, Michael Dubson, Noah Finkelstein, Sam Reid, Carl Wieman, Ron LeMaster, The Physics Teacher, 44(1), 18 , (2006); L. C. McDermott, "Research and computer-based instruction: Opportunity for interaction." Am. J. Phys. 58, 452 (1990);

4) David P. Maloney, Thomas L. O'Kuma, Curtis J. Hieggelke, and Alan Van Heuvelen. "Surveying students' conceptual knowledge of electricity and magnetism." Am. J. Phys. 69, S12 (2001) ; Y. J. Dori, J. W. Belcher, Learning Electromagnetism with Visualizations and Active Learning, Springer Netherlands, Part Section C, pp. 187-216 (2005).

5) E. Etkina, A. Van Heuvelen, D. T. Brookes, and D. Mills, *Physics Teacher* **40**, 351 (2002).

6) E. Etkina, A. Van Heuvelen, S. White-Brahmia, D. Brookes, M. Gentile, S. Murthy, D. Rosengrant, and A. Warren. "Scientific abilities and their assessment." *Phys. Rev. ST Phys. Educ. Res*. **2 (2)**, 020103 (2006).