Case Study: TEAL at MIT

Eastern SPIN-UP Regional Workshop

Rutgers University
June 5, 2010

Dr. Peter Dourmashkin
MIT

What is TEAL?

Technology-Enabled Active Learning

A merger of presentations, tutorials, and hands-on laboratory experience into a technologically and collaboratively rich environment

TEAL Time Line

Fall 2001-2
Prototype
Off-term E&M 8.02

Models:

RPI's Studio Physics (Jack Wilson)

NCSU's Scale-Up (Bob Beichner)

Harvard Peer Instruction (Mazur)

Spring 2003-Present
Scaled-up
E&M 8.02

Fall 2003-4
Prototype
Mechanics 8.01

Fall 2005-Present
Scaled-up
Mechanics 8.01

MIT First -Year Physics

Fall: Number of students = 910

8.012 Mechanics designed for Physics majors (120 students)

8.01 Mechanics TEAL format (570 students)

8.01L Mechanics for students with weaker mathematical backgrounds (80 students)

8.02 E&M TEAL format (70 students)

8.022 E&M designed for Physics majors (70 students)

Spring: Number of students = 835

8.011 Mechanics (95 students)

8.02 E&M taught in the TEAL format (630 students)

8.022 E&M designed for Physics majors (110 students)

Motivation

Why The TEAL/Studio Format?

Large freshman physics courses have inherent problems

1. Lecture/recitations are passive
2. Low attendance
3. High failure rate
4. Math is abstract, hard to visualize (esp. Electricity and Magnetism)
5. No labs leads to lack of physical intuition

Learning Objectives

Learning Objectives

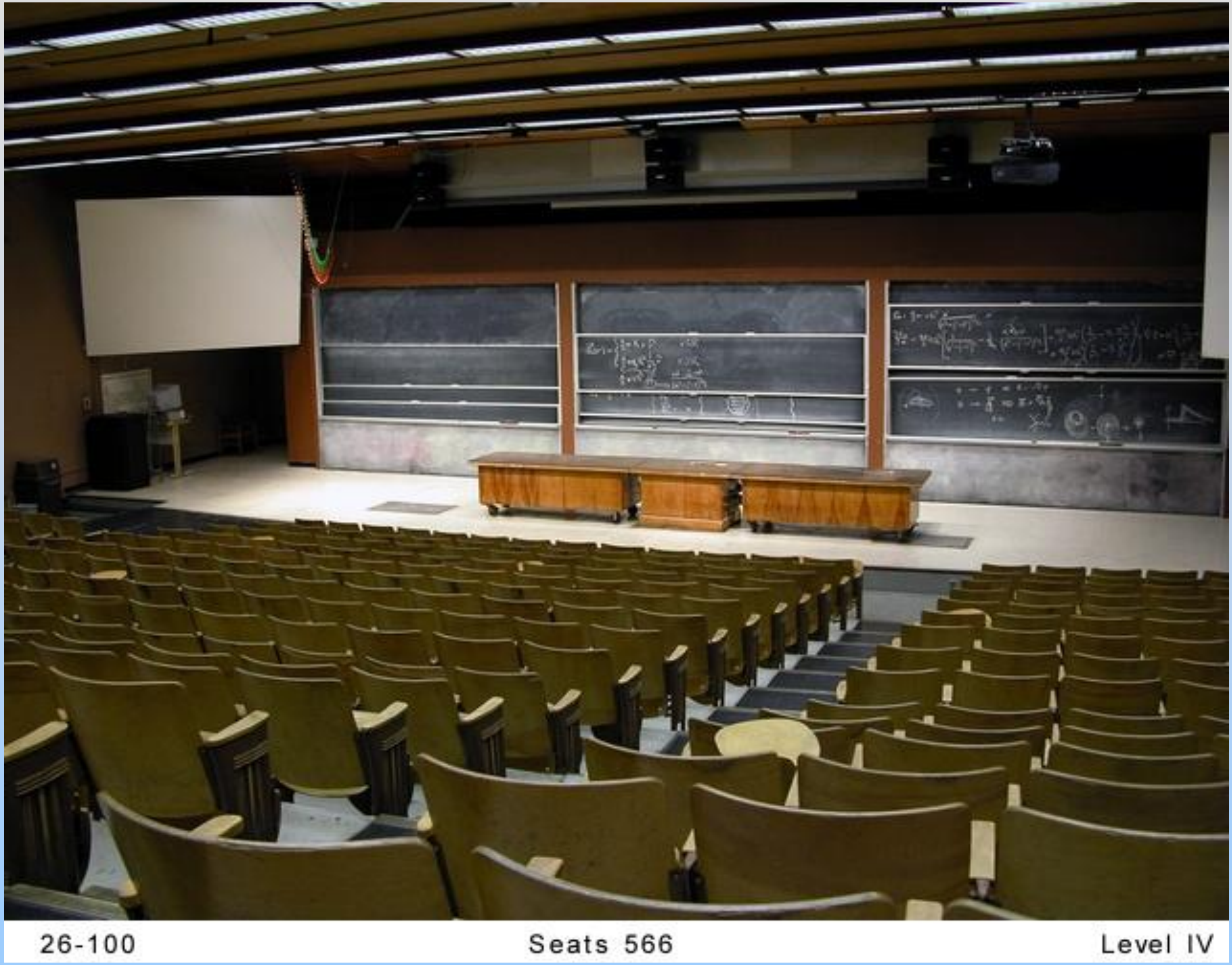
- Move away from passive lecture format to active studio learning environment
- Enhance conceptual understanding
- Enhance problem-solving abilities
- Incorporate hands-on experiments that develop project-based/research lab learning skills

Broader Educational Learning Objectives

- Develop communication skills in core sciences
- Develop collaborative learning
- Reduce gender gap
- Develop new teaching/learning resources based on scientific standards of research

Architectural Learning Space

The starting point
1918



The lecture hall when I was a student. Still there today!

Trying to have it both ways

Transforming the Learning Space: TEAL Classroom

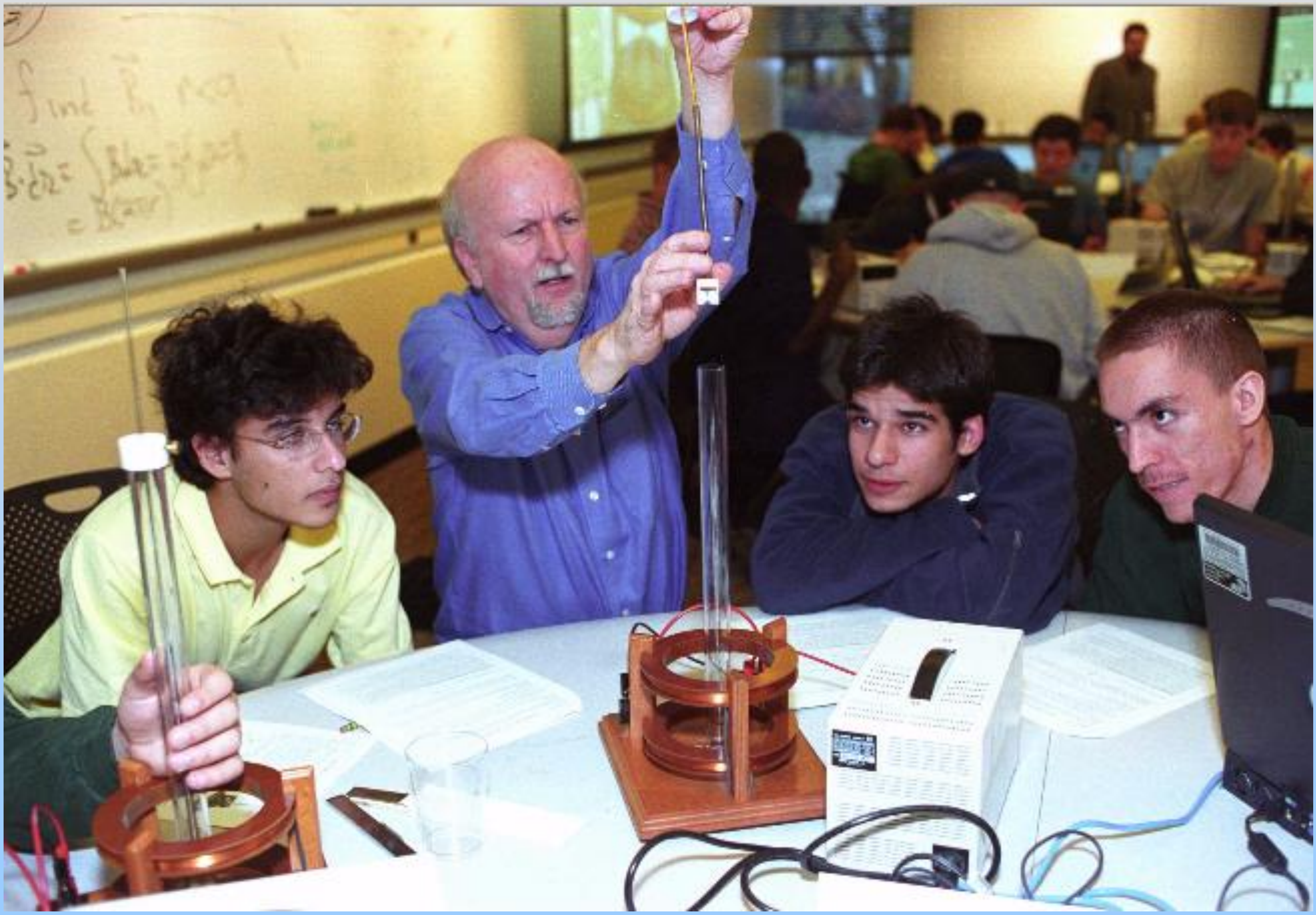
Collaborative learning (Modeled after NCSU's Scale-Up Classroom)

9 Students work together at each table of 9 students each

Form groups of 3 students that work collaboratively

Learning Space

Rethinking Teaching Roles



Rethinking Teaching Roles

Instructor no longer delivers material but focuses on student learning

Measures learning outcomes

Motivates student and instills passion for learning

Rethinking Teaching Roles

Instructor: No longer delivers material

Graduate TA: Learn to teach

Undergraduate TA: Encourages student teaching

Technical Instructor: No longer hidden

Students: Peer Instructors

Teaching Staff Fall Semester

Subject	8.01 TEAL	8.012	8.01L Semi-TEAL	8.02 TEAL (Off-Term)	8.022	Total
Students	570	120	80	70	70	910
Co-Administrator	2	0	0	0	0	1
Faculty	7	4	2	2	3	22
Grad TA	8	2	1	1	0	13
Undergrad TA	30	0	0	2	0	32
Undergrad grader	0	5	2	3	2	12

Weekly Schedule: 5 hours a week

TEAL Sections: M/T 2 hours, W/R 2 hours, F 1 hour

Non TEAL Sections: Lecture MWF 1 hour, Recitation TR 1 hour

TEAL Teaching Constraint:

Same number of faculty teaching staff as in the traditional lecture format

Active Learning

Components of Active Learning Class: TEAL

- Integrated Modular Approach
- On-line Visualizations
- ConcepTests: Peer Instruction with Clickers
- Interactive Presentations with Demos
- Desktop Experiments
- Extensive Problem Solving Opportunities

Integrated Modular Approach

Sun On-Line: Students read textbook, answer questions based on readings.

Mon/Tue In-Class (2 hr): Presentations, ConcepTests, Table Problems.

Tue Night: Math Review

Wed/Thur In-Class (2 hr): Presentation,.. ,Experiments

Thur On-line Mastering Physics: Problem Solving/Tutorials based on M/T and W/R classes.

Fri In-Class (1 hr): Mini Experiments, Group Problem Solving

Sun Physics Tutoring Center: Help Sessions for Problem Set.

Tues: Hand Written Problem Set Due 9 pm

Thur On-line Mastering Physics: Problem Solving for Friday Quiz.

Fri In Class: Short Quiz

Conceptual Understanding

Develop Conceptual Understanding

- Inquiry based on Discovery
- Use of ConcepTests and Peer Instruction
- Hands-on Experiments that Emphasize Concepts
- Multiple Representations of Concepts

ConcepTests / Peer Instruction

Model: Eric Mazur's Peer Instruction based on ConcepTests using "Clicker" Technology

Methodology:

- Concept Test
- Thinking
- Individual Answer
- Feedback: Just in time Teaching
- Peer Discussion
- Revised Group Answer
- Explanation

Visualizations

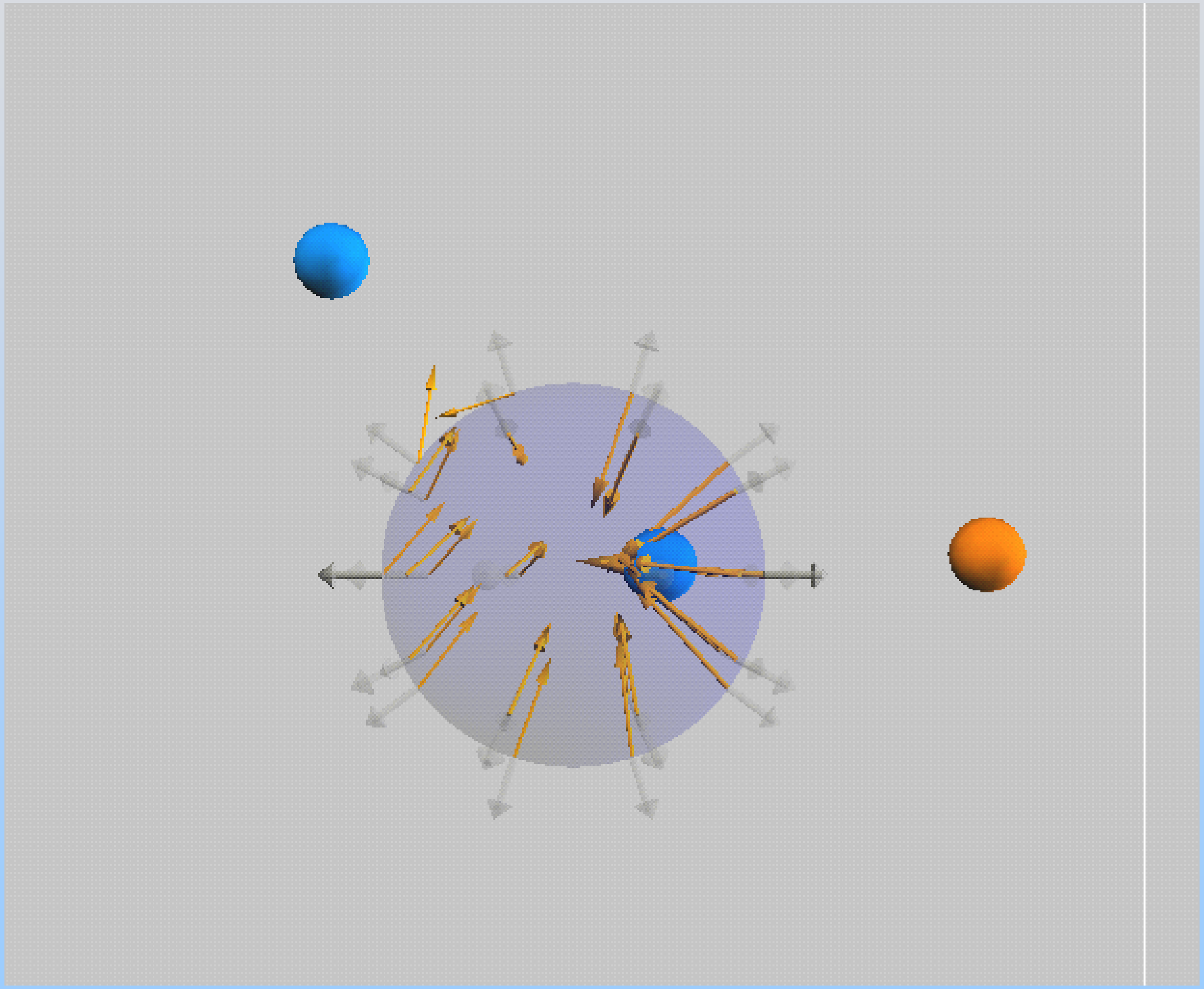
Visualizations and Simulations: Address Core Misconceptions

Explain the meaning of

$$\oiint \vec{E} \cdot d\vec{a} = \frac{1}{\varepsilon_0} \iiint \rho \, dV$$

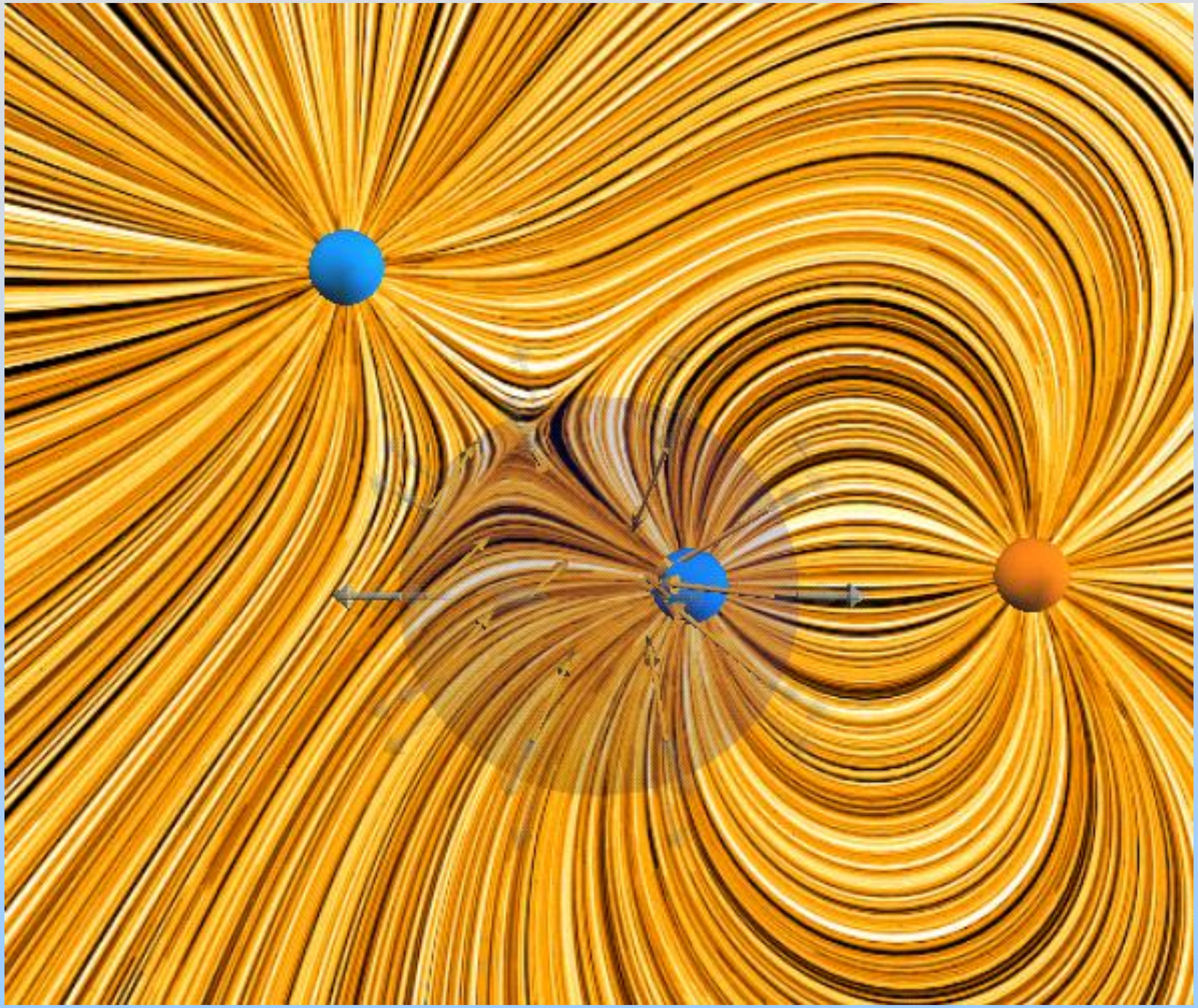
(Gauss's Law)

Visualizations and Simulations: Address Core Misconceptions



Enclosed charge is not the source of the electric field

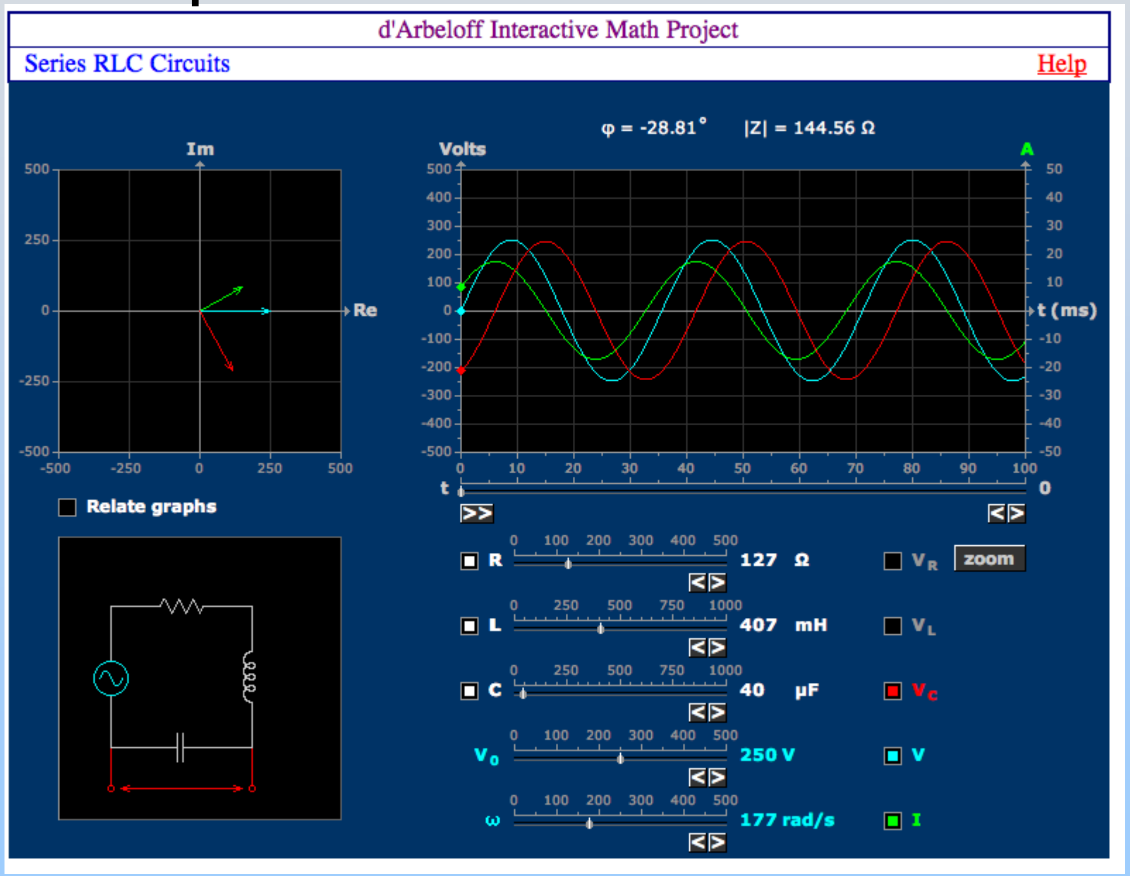
Visualizations and Simulations: Address Core Misconceptions



Enclosed charge is not the source of the electric field

Introduce Difficult Mathematical Concepts: Mathlets

http://math.mit.edu/mathlets/



http://www-math.mit.edu/~jmc/8.02t/SeriesRLCCircuit.html

Developers: Jean-Michel Claus, Prof. Haynes Miller (Math Department), Dr. Peter Dourmashkin

Mini-Presentations

In-Class Presentations

- Peer Instruction: Concept Questions using ‘clickers’
- Short Group/Table Problems with student presentation of work at boards
- Mini-Presentations using whiteboards (or slides)

Problem Solving

Problem Solving

A MIT Education requires solving 10,000 Problems

Measure understanding in technical and scientific courses

Regular practice

Expert Problem Solvers:

Problem solving requires factual and procedural knowledge, knowledge of numerous models, plus skill in overall problem solving.

Problems should not ‘lead students by the nose” but integrate synthetic and analytic understanding

Problem Solving/Exams

On-Line Mastering Physics:

1. One assignment per week with hints and tutorials

2. Review problems for quizzes/exams

In-Class Concept Questions and Table Problems

In-Class Group Problems (Friday)

Weekly Problem Sets

1. Multi-concept analytic problems
2. Pre-class Reading Questions
3. Pre-lab questions and analyze data from experiments

8.01 Mechanics: Nine Quizzes,Two Exams and Final Exam

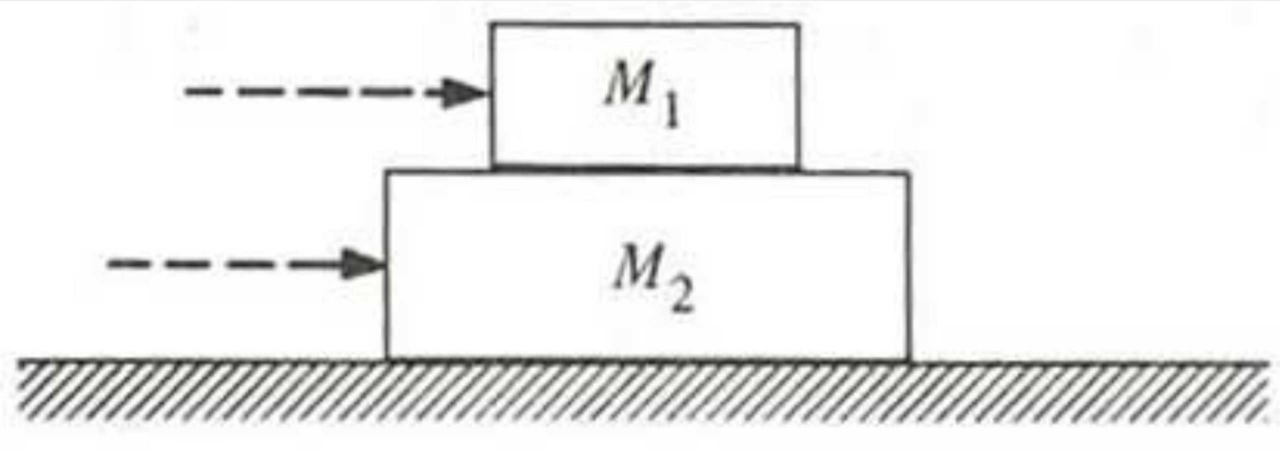
Hands-On Experiment

- Networked laptops with data acquisition links between laptop and experiments

Mini-Experiment:
Two Block Pull

Group Problem: Pushing Books

Consider two textbooks that are resting one on top of the other. The lower book has M_2 and is resting on a nearly frictionless surface. The upper book has mass $M_1 < M_2$. Suppose the coefficient of static friction between the books is μ_s.



a) What is the maximum force with which the upper book can be pushed horizontally so that the two books move together without slipping? Identify all action-reaction pairs of forces in this problem. **Half of class does this part**

b) What is the maximum force with which the lower book can be pushed horizontally so that the two books move together without slipping? Identify all action-reaction pairs of forces in this problem. **The other half of the class does this part.**

Gender Gap

Gender Gap

Gender gap disappears in the active learning environment compared to a traditional lecture format. Possible reasons:

1. Peer instruction
2. Ability to ask questions
3. Many opportunities to practice problem solving
4. Cooperative learning in a non-competitive learning environment

Does TEAL work?

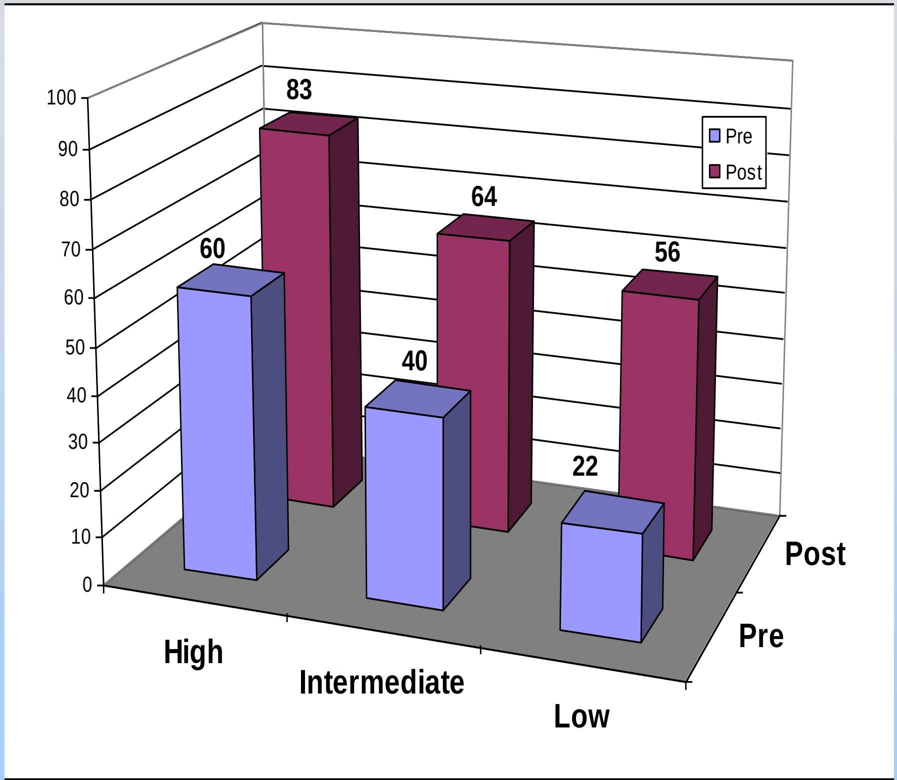
Pre/Post Conceptual Test Scores Relative Improvement Measure

$$\langle g \rangle = \left(\frac{\%\text{Correct}_{post-test} - \%\text{Correct}_{pre-test}}{100 - \%\text{Correct}_{pre-test}} \right)$$

Group	Trial 2001		Control 2002		Spring 2003	
	N	⟨g⟩	N	⟨g⟩	N	⟨g⟩
Entire population	176	0.46	121	0.27	514	0.52
High	58	0.56	19	0.13	40	0.46
Intermediate	48	0.39	50	0.26	176	0.55
Low	70	0.43	52	0.33	300	0.51

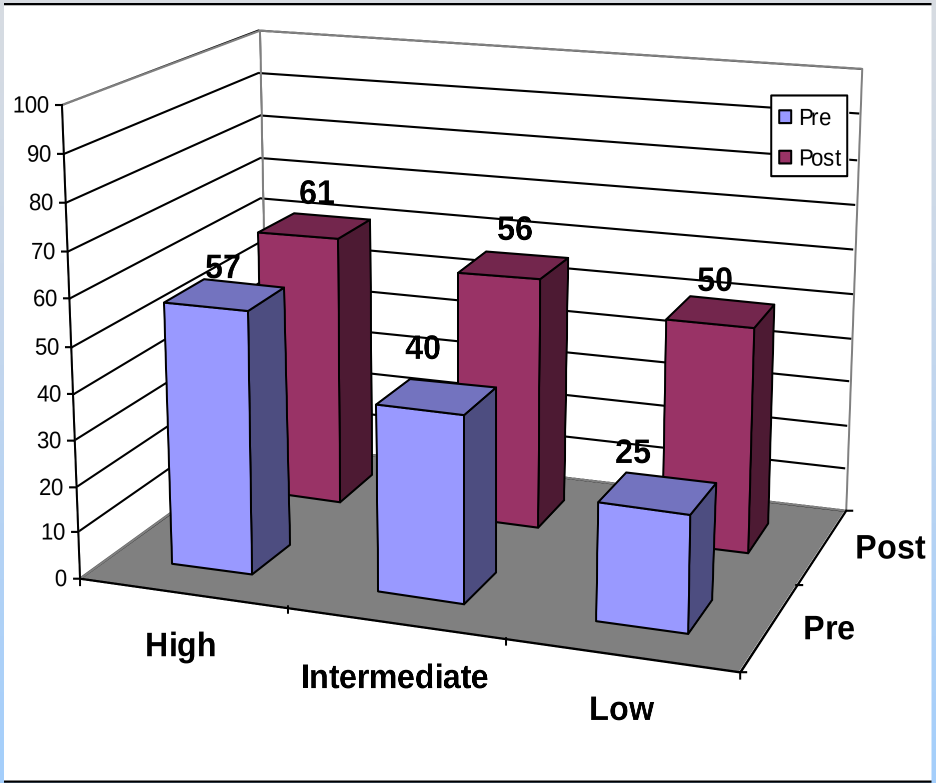
Pre-Post Concept Test Scores

N students = 176



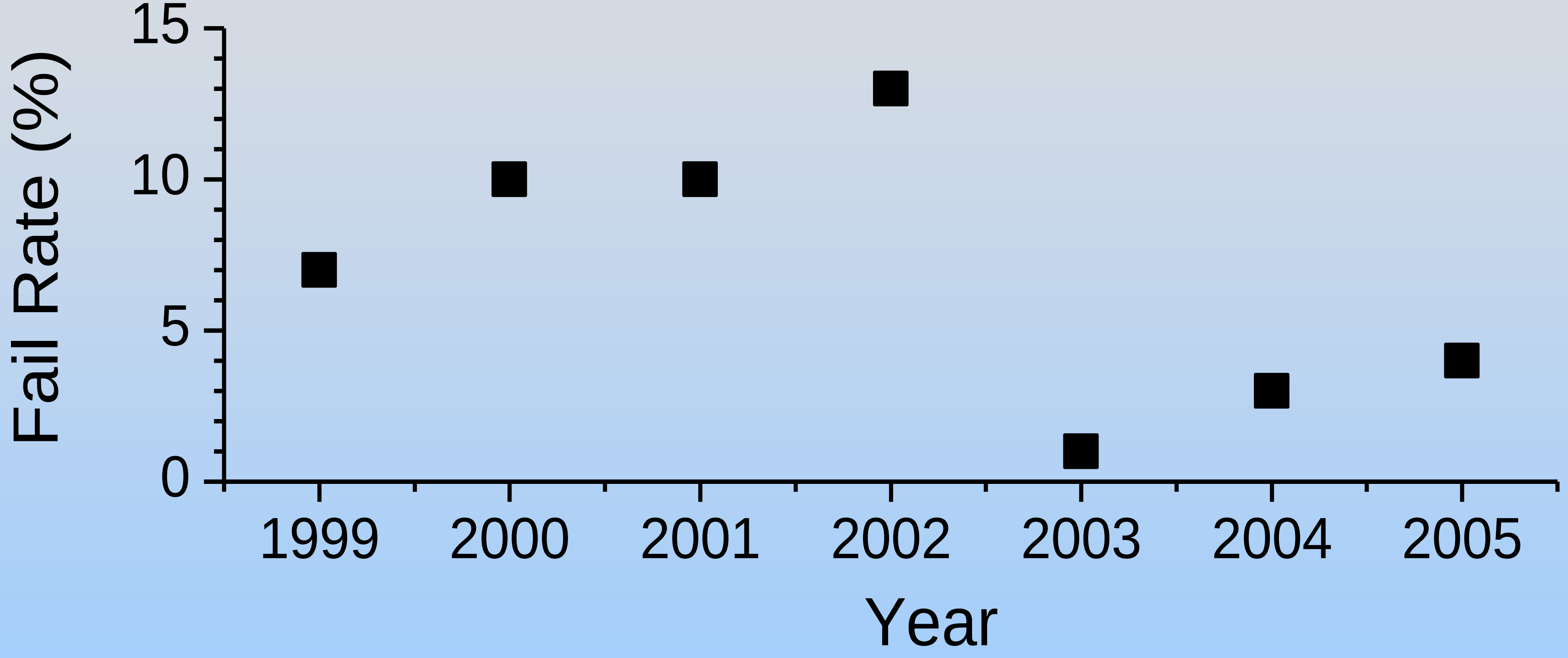
Experimental group - Fall 2001

N students = 121



Control group - Spring 2002

E&M Lower Failure Rate



Changing Teaching/Learning Cultures

Sustainability

Obstacles

- Student evaluations and attitudes: negative to neutral
- Divergent faculty opinions about lecturing and course content
- Student cultural issues: contrast between traditional courses and active learning based courses
- Traditional Learning Issues: Math Background,..

Responses

1. Developed explicit learning objectives that form backbone of course
2. More extensive teacher training with a focus on faculty teaching for the first-time
3. Influence and possibly change student culture
    - Communicate objectives and rationale explicitly and frequently to students
    - Improve group interactions
    - hardest: get students to prepare for class
4. Integrate experiments into Modular Activities
5. Gradually improve course materials
6. Establish institutional continuity independent of individual creators

Sustainability

1. Guarantee institutional support

1. Committed Faculty Leader to guide development

2. Adapt teaching to local institutional / faculty / student cultures

3. Address faculty concerns regarding active based learning

4. Develop student support by clear exposition of learning goals

TEAL in Action

Web Pages

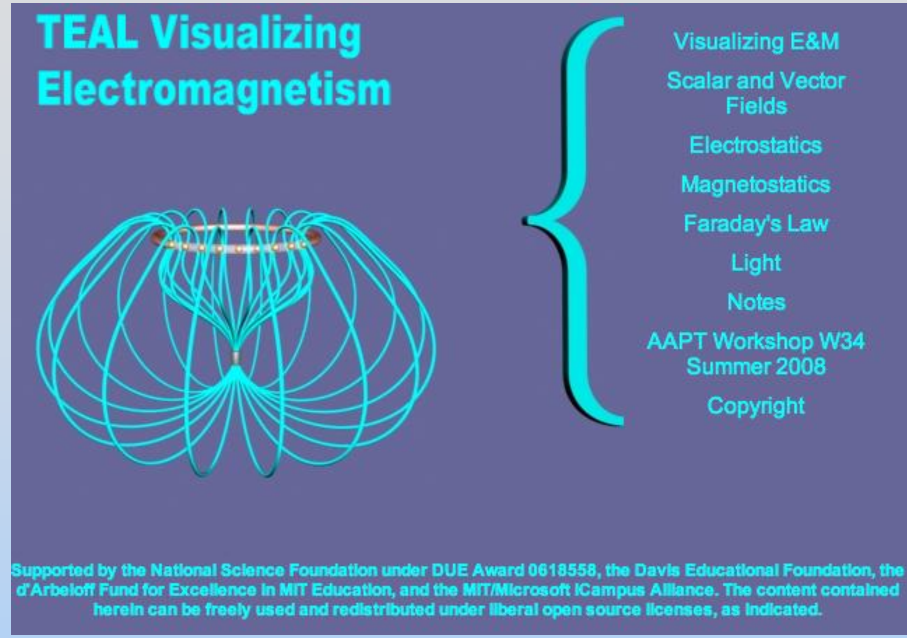
http://web.mit.edu/8.01t/www

http://web.mit.edu/8.02t/www

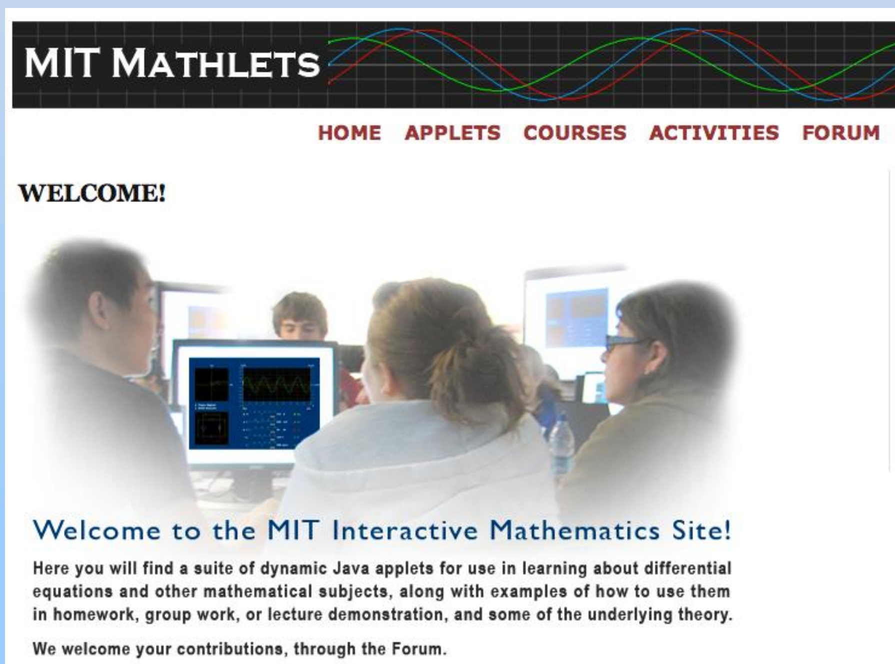
http://web.mit.edu/8.02t/www/802TEAL3D/

http://web.mit.edu/viz/EM/index.html

Visualizations and Mathlets



http://math.mit.edu/mathlets/



http://web.mit.edu/viz/EM/

Appendix

Student Reactions

Not in the Beginning

Students Petition Against TEAL

By Lauren E. LeBon

ASSOCIATE NEWS EDITOR

MIT has been quick to sing the praises of the Technology Enabled Active Learning version of 8.02, but more than 150 students are humming a different tune.

A petition submitted to the physics department Wednesday asks MIT to halt the proposed expansion of the program, questioning its efficacy.

Juliana D. Olmstead '06 started the petition. "I got fed up and thought 'why isn't anyone doing something about it?' so I decided that I might as well," Olmstead said.

The statement reads: "8.02 TEAL does not provide us with the intellectual challenge and stimulation that can be expected from a course at MIT.

"We feel that the quality of our education has been compromised for the sake of 'trying something different.' We strongly advise that the traditional 8.02 course be reinstated as soon as possible. 8.02 TEAL could remain as an option, which will give TEAL an opportunity to evolve. However, it should not be forced upon the majority of the student body."

Petitioners seek other options

The petition suggests that the TEAL version of 8.02 remain as an option, but that it not be imposed on the freshman class. In addition, the petition advises the physics department not to expand the TEAL program to 8.01, as has been planned.

Olmstead explained that the final version of the petition did not list specific grievances since different students may have different complaints. Olmstead wanted to write something that "everyone would agree with."

"I started to list things, but I realized if I tried to list everything, it'd be a five-page-long essay," Olmstead said. "Basically, it's just saying, 'wake up, physics department.'"

Lewin supports old 8.02 format

Student Reaction

1. Reaction to first two prototype E & M courses with 180 students each was favorable

2. Reaction to first on-term E & M course in Spring 2003 was mixed to very negative—start up problems in going from 180 to 500 students

3. Reaction gradually improved as start-up bugs were fixed, and more faculty experience in teaching in this format.

4. Student resistance still persists

Obstacles We Faced

Student evaluations and attitudes: negative to neutral

“I think the format could be more effective, but for a required course it’s okay I guess.”

Faculty misunderstandings and lack of trained faculty

“I've been working as hard as I can to prepare coherent lectures in the meager time that I'm allotted.”

Student cultural issues: contrast between traditional courses and TEAL

“I learn best if I listen to a well organized lecture like chemistry… in TEAL, there isn’t any lecture… ’’

‘‘Mandatory class attendance is contrary to MIT philosophy’’

“Of course I had heard how terrible TEAL was. I will tell [future] freshmen to avoid it if possible.”

Work in Progress

Improve Mechanics Version of TEAL

Develop Teacher Training program

Develop Expert Problem Solving Strategies

Integrate Student Pre-class Preparation Work with Learning Objectives

The Light at the End of the Tunnel (Fall 2007)

Professor Hudson, **I really enjoyed your class, definitely my favorite one last semester!** I came from a real small high school. So, I was pleasantly surprised to feel like, even in a class about four times the size of my largest high school class, I was able to get to know you and the TA's so well. Now that I'm back home, people of course are asking me how school and classes were. I tell them that math and chemistry were good, interesting, not much more than that. **I leave physics for last, it's a completely different story! I go into detail about how the room was set up, the computers, projectors, tables/chairs/PRS, everything. They all think it's so cool, totally MIT.**

Interactive On-Line Homework (Mastering Physics)

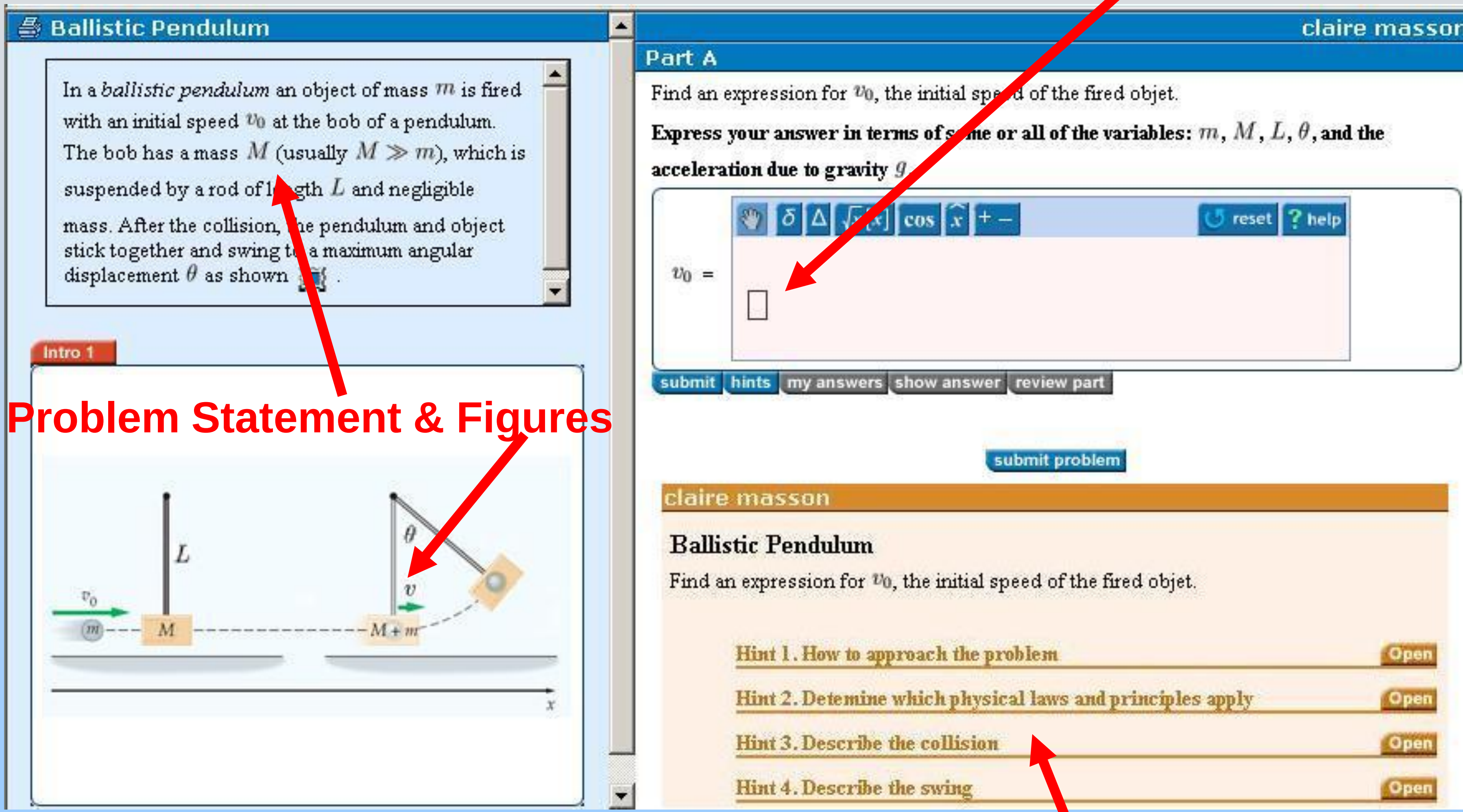
One assignment per week

On-Line homework with hints and tutorials

Review problems for exams are available with hints

Socratic Pedagogy

Demand Appropriate Response



Problem Statement & Figures

Requestable List of Hints (plan of attack)

Beginner Problem Solvers

- Unable to represent quantify physical concepts
- Unable to combine multiple ideas
- Unable to apply mathematical reasoning
- Engage in symbol manipulation
- Unable to estimate and make ‘back of the envelope’ calculations

Polya Model for High School Problem Solving: How to Solve It!

1. Getting Started – identify assumptions and givens

2. Plan the Approach – articulate a strategy that may involve multiple concepts and problem solving methodologies

3. Execute the plan – does it work?

4. Review - does the answer make sense?

(Some) Goals of Science Education

Develop next generation of scientists and science teachers

Develop scientific literacy so that the next generation is capable of making informed decisions on issues arising from complex systems, for example environmental change, management of finite resources, development of renewable energy sources

Develop expert problem solvers to tackle complex problems that face society

Develop intellectual curiosity about scientific thought

Why Change?

Introductory physics courses have inherent problems

"Our physics courses are actually teaching many students that physics knowledge is just the claim of an arbitrary authority, that physics does not apply to anything outside the classroom, and that physics problem solving is just about memorizing answers to irrelevant problems."

Carl Wieman, American Physical Society News, Nov. 2007 (Vol 16,No. 10)

Research Based Teaching

- Develop specific learning objectives
- Create rigorous means to measure the actual objectives.
- The methods and instruments for assessing the objectives must satisfy the same criteria, as is done in scientific research

Research Based Teaching

‘…the most effective first step will be to provide sufficient carrots and sticks to convince the faculty members within each department or program to come to a consensus as to their desired learning outcomes at each level (course, program, etc.) and to create rigorous means to measure the actual outcomes. These learning outcomes cannot be vague generalities but rather should be the specific things they want students to be able to do that demonstrate the desired capabilities and mastery and hence can be measured in a relatively straightforward fashion. The methods and instruments for assessing the outcomes must meet certain objective standards of rigor and also be collectively agreed upon and used in a consistent manner, as is done in scientific research.’

Carl Wieman, Change. Magazine 39, 5 (September/October 2007). 183

Assessment

Professor Judy Yehudit Dori of the Department of Education in Technology and Science at the Technion.

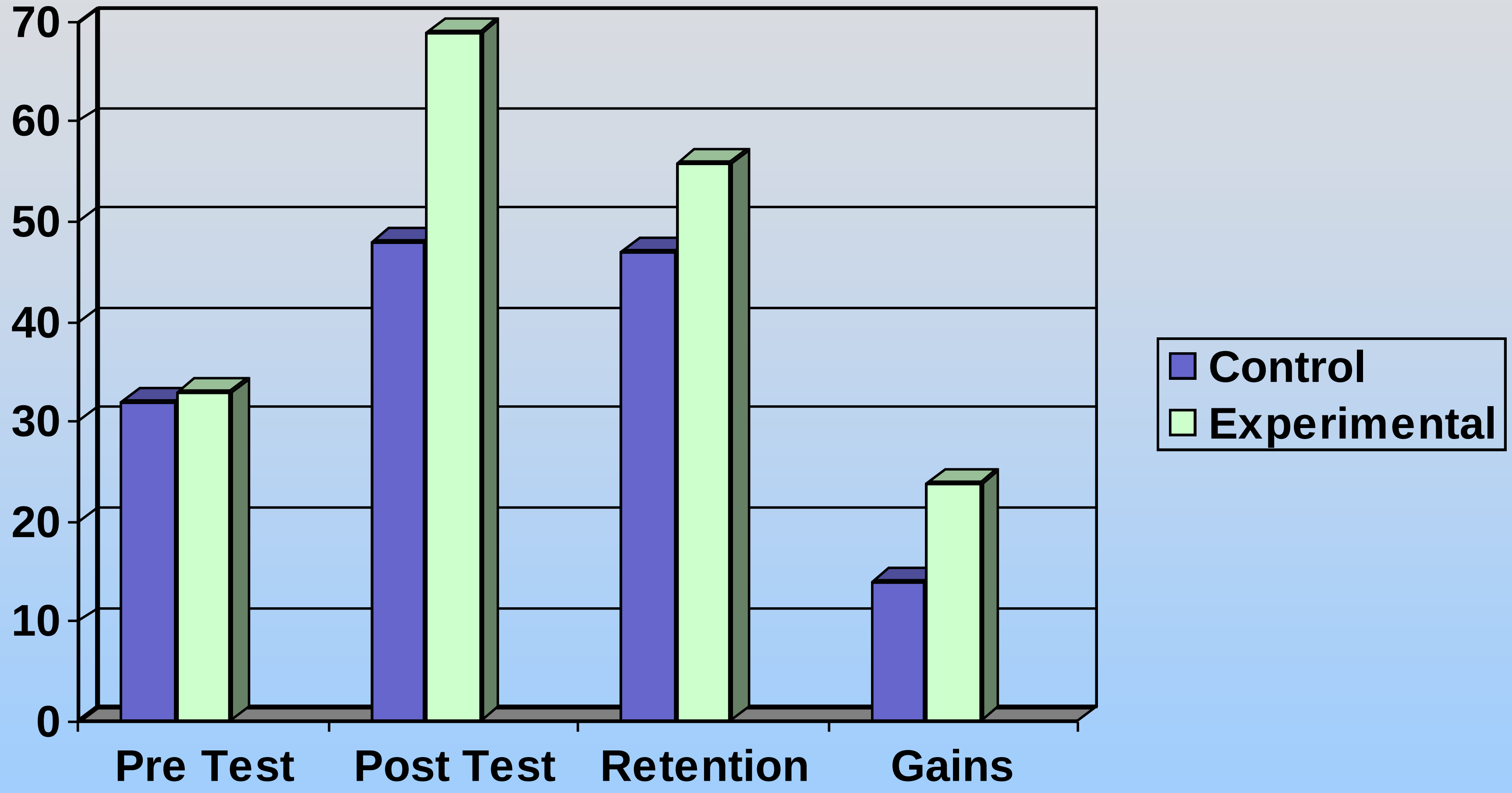
Dr. Sahana Murthy Experimental Study Group MIT

We use a variety of assessment techniques, including the traditional in-class exams, focus groups, questionnaires (in addition to MIT's CEG questionnaire), and pre and post testing.

Research Instruments

Assessing Variables	Instruments
Problem Solving	Tests with quantitative problems
Conceptual Understanding	1. Pre-tests and post-tests 2. Spatial tests
Attitudes	1. Mid-term & post-term questionnaires 2. Focus discussion group

Increases Seen Long Term



- Source: Dori, Y.J., E. Hult, L. Breslow, & J. W. Belcher (2005). "The Retention of Concepts from a Freshmen Electromagnetism Course by MIT Upperclass Students," paper delivered at the NARST annual conference.

Study Limitations

1. Attendance monitored In Experimental Group, not in Control Group. At end of term, 50% in Control, 80% in Experimental.
2. Demographics of Control and Experimental Groups different (not true in Spring 2003 comparison)
3. Experimental Group used a mix of both analytic and conceptual problems in class, Control primarily analytic.
4. Control Group pre- and post-tests volunteer basis; Experimental Group tests counted toward course grade.
5. “Teach To Test” in Experimental Group? Hawthorne Effect.

Fall 2007: Mechanics Baseline Test and Student Evaluations

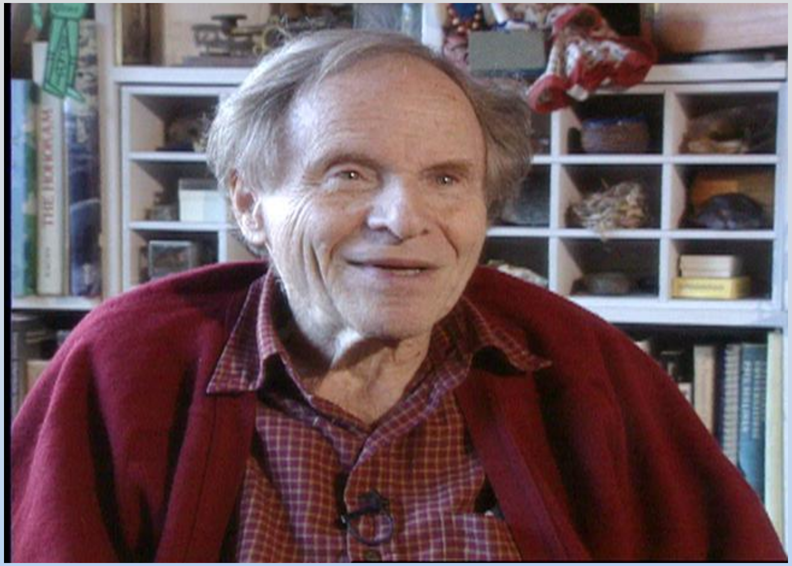
Group	N	⟨g⟩	Absolute score	N	Course Evaluation 7 max	Instructor Evaluation 7 max
Entire population	496	**0.47**	76.3%	348	4.63	5.25
L01	112	0.49	76.5	79	5.41	6.31
L02	38	0.56	82.0	34	4.62	5.48
L03	85	0.46	74.7	57	3.47	3.94
L04	60	0.41	74.3	33	4.06	3.85
L05	89	0.47	76.5	59	4.97	6.05
L06	29	0.52	79.7	24	5.13	4.50
L07	83	0.44	75.0	62	4.49	5.15

MIT Physics Education Innovation

Ned Franck (left)
Introduction to Mechanics of Heat
John Slater Department Head

Jerrold Zacharias (left) and Francis Friedman
Physical Science Study Committee PSSC

MIT Physics Education Innovation



Phil Morrison
Conceptual: Physics for Poets

A.P. French
Series of Introductory Textbooks

John King
8.01x Hands-on
Take-home
Experiments