Achieving and Sustaining Systemic Change in Physics Teaching at MIT: TEAL (Technology Enabled Active Learning)

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What is TEAL?

Technology-Enabled Active Learning

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

Outline of Presentation

Brief History of Physics Education at MIT

Why Change to TEAL?

Learning Objectives

Teacher/Learner Relationship

Components of TEAL

Assessment

Student Reaction

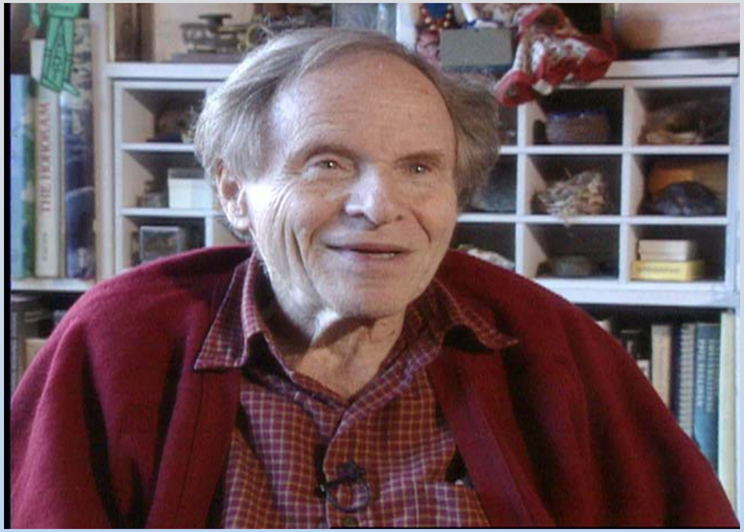
Conclusions

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

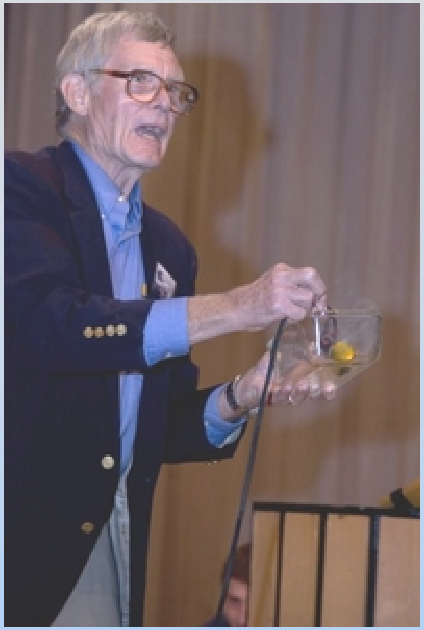
Conceptual: Physics for Poets

Dan Kleppner

Physics for Majors

A.P. French

Introductory Textbooks

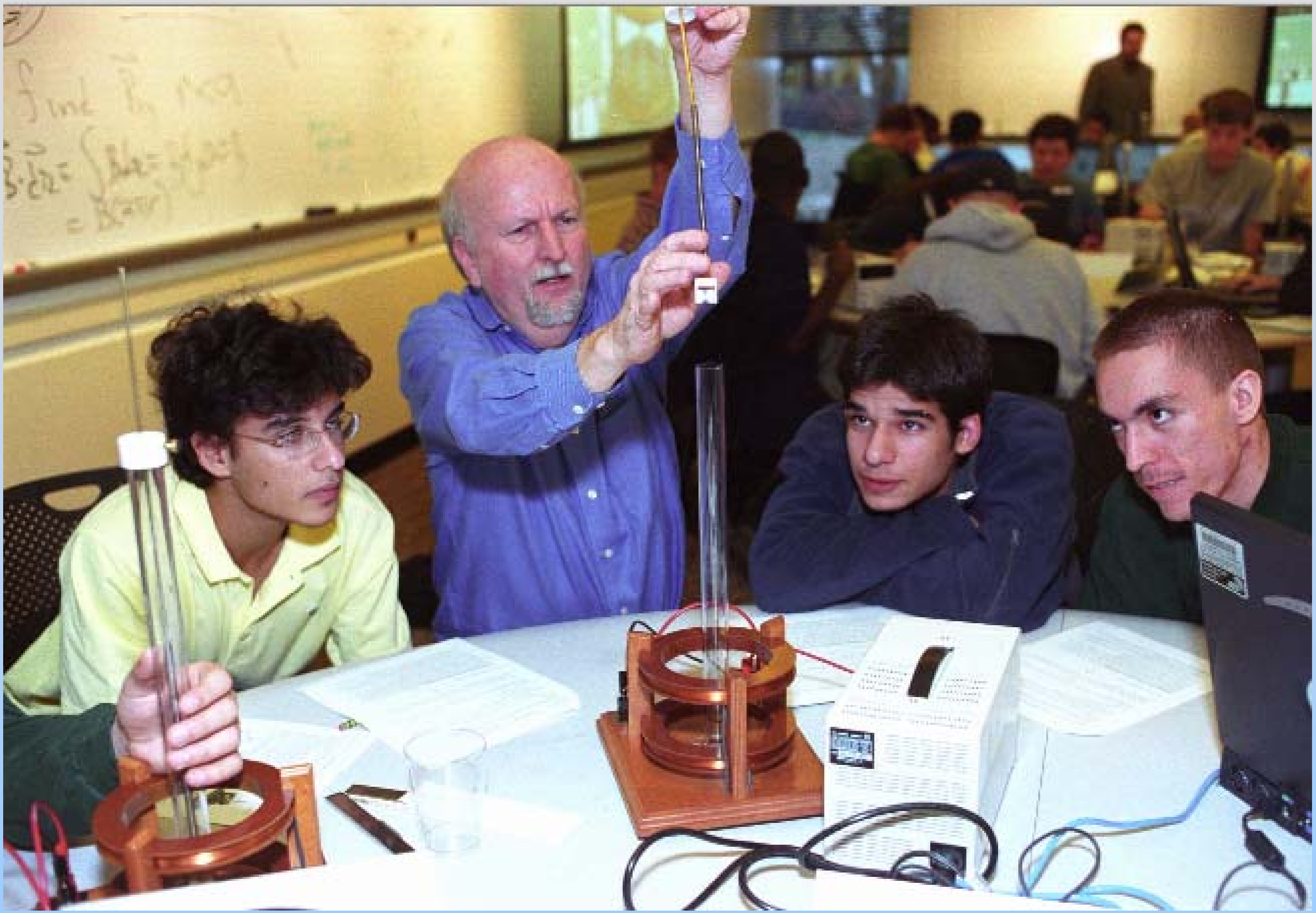


John King

8.01x Hands-on

Take-home

Experiments



John Belcher

Belcher: Motivation

- Lectured the 700 student 8.02 (E&M) from 1991-1994, with some success, as measured by the Student Subject Evaluations (SSE)

- SSE Evaluation 8.02 Spring 1994: [Lecturer] Professor John Belcher is highly praised by most of his 8.02 students. "He was one of the best professors I have had here -- interesting, relevant, and a good teacher. He is funny too!"

- Belcher also receives high marks for his ability to explain concepts clearly, his preparation, his organization of course materials, his clear use of the blackboards, the use of lecture demonstrations, the outlines he uses in lectures, and his reviews of previous lectures. Most class members praise his attitude toward teaching and toward his students: “He definitely knows how to teach,” and “He cares about his students.”

So what’s the problem, why change?

What's Wrong With This Picture?

- The SSE comments above were based on 175 responses to a questionnaire in class in the last week of the term
- There were 700 students in the class; 175/700 = 0.25
- The failure rate was 12%
- What's wrong: low attendance, high failure rate, no laboratories
- In 1999 there was a unique opportunity at MIT due to the generosity of Alex d'Arbeloff and Bill Gates to change this

Why The TEAL/Studio Format?

Large MIT freshman physics courses had intrinsic problems

1. Lecture/recitations are passive
2. Re-introduced experiments into first year physics which had been missing for 30+ years
3. No labs leads to lack of physical intuition
4. Math is abstract, hard to visualize (esp. E&M)

TEAL/Studio addresses these by

1. Replacing large lectures with interactive, collaborative pedagogy
2. Incorporating desk top experiments
3. Incorporating visualization/simulations

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 2006-7

Fall: Number of students = 948

- 8.012 Mechanics designed for Physics majors (165 students)
- 8.01 Mechanics TEAL format (530 students)
- 8.01L Mechanics for students with weaker mathematical backgrounds (72 students)
- 8.02 E&M TEAL format (109 students)
- 8.022 E&M designed for Physics majors (72 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)

Teaching Staff Fall 2006

Subject	8.01 TEAL	8.012	8.01L Semi-TEAL	8.02 TEAL (Off-Term)	8.022	Total
Students	530	165	72	109	72	948
Administrator	1	0	0	0	0	1
Faculty	7	4	2	2	3	22
Grad TA	8	2	1	1	0	13
Undergrad TA	7	0	0	2	0	7
Undergrad grader	16	5	2	3	2	28

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

Learning Objectives

Learning Objectives of TEAL

Create an engaging and technologically enabled active learning environment

Move away from passive lecture/recitation format

Incorporate hands-on experiments

Enhance conceptual understanding

Enhance problem-solving ability

Broader Educational Learning Objectives

Develop communication skills in core sciences

Develop collaborative learning

Create an environment conducive to learning and teaching

Develop new teaching/learning resources

Components of TEAL

- Classroom/Learning Space
- Weekly Integrated Modules
- Interactive Presentations with Demos
- ConcepTests
- Visualizations
- Desktop Experiments
- Problem Solving Opportunities
- Online Homework (Mastering Physics)

Organizational Structure: Integrated Modular Approach

Framework for integrating in-Class and outside-Class activities

Provides structure for new teachers

Explains approach to students: learning occurs over a two week cycle

Allows for focused improvement of content based on performance data

Integrated Modular Approach

Sun On-Line: Mastering Physics Assignment: Preparation for upcoming week

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

Wed/Thur In-Class: Presentation, ConcepTests, Table Problems, and Experiments

Thurs On-Line: Mastering Physics Assignment: Problem Solving and Tutorials

Fri In-Class: Group Problem Solving Session

Sun Physics Tutoring Center: Help Sessions

Sun On-Line: Mastering Physics Assignment: Problem Solving and Tutorials for previous week

Wed: Hand Written Problem Set Due

Fri In Class: Short Quiz

Teacher/Learner Relationship
Teacher

Motivates: Provides context

Diagnoses: Understands what students do and do not know

Guides Active Learning:

(a) provides timely specific interaction

(b) poses the right level of questions

(c) never “tells” answer

(d) praises the process by which students arrive at correct answers

(e) let’s students make mistakes, encourages a discovery process

Develops Reflective Learners:

- “Do I understand my thinking process?”

(a) “Do I understand how to constructive check my results?”

(b) “Can I explain my answer to my peers?”

(c) “Do I understand how a given problem fits into the larger picture?”

Teacher/Learner Relationship Student

Subject Content:

Expert Goal: Develop coherent structure of concepts

Novice Content Contrast: Memorize isolated fragments that are handed down by authority

Problem Solving:

Expert Goal: Develop systematic concept based strategies that are widely applicable

Novice Contrast: Pattern matching memorized recipes.

Role of Technology

Pre-Class: Preparation

Encourages students to be prepared and ready to learn

In-Class: Enhancing Interaction

Interactive presentations using “clickers” encourage Peer Instruction

Interactive simulations and experiments immediately apply concepts; “put lecture demos in students hands”

Post-Class: Guiding Learning

On-line and traditional homework becomes “effective practice” that encourage expert problem solving skills with authentic problems that engage students interest

Classroom/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

Integrated Modular Approach

Mini Presentations

In-Class Presentations

Students are expected to complete weekly reading assignment before the first class of the week.

Active Participation mixed with ‘traditional lecture-style’ including lecture demos

Concept Questions using Personal Response System (PRS)

Short Group/Table Problems with student presentation of work at boards

Presentation of material using boards (or slides)

ConcepTests / Peer Instruction

Model: Eric Mazur's Peer Instruction based on ConcepTests

Types of Questions

- Based on Confused Points in Pre-Class Reading (Just-in Time Teaching)
- Breakdown Complicated Problems into Individual ConcepTests
- Conceptual / Analytical / Estimation
- Experiment Questions
- Student Background / Evaluation

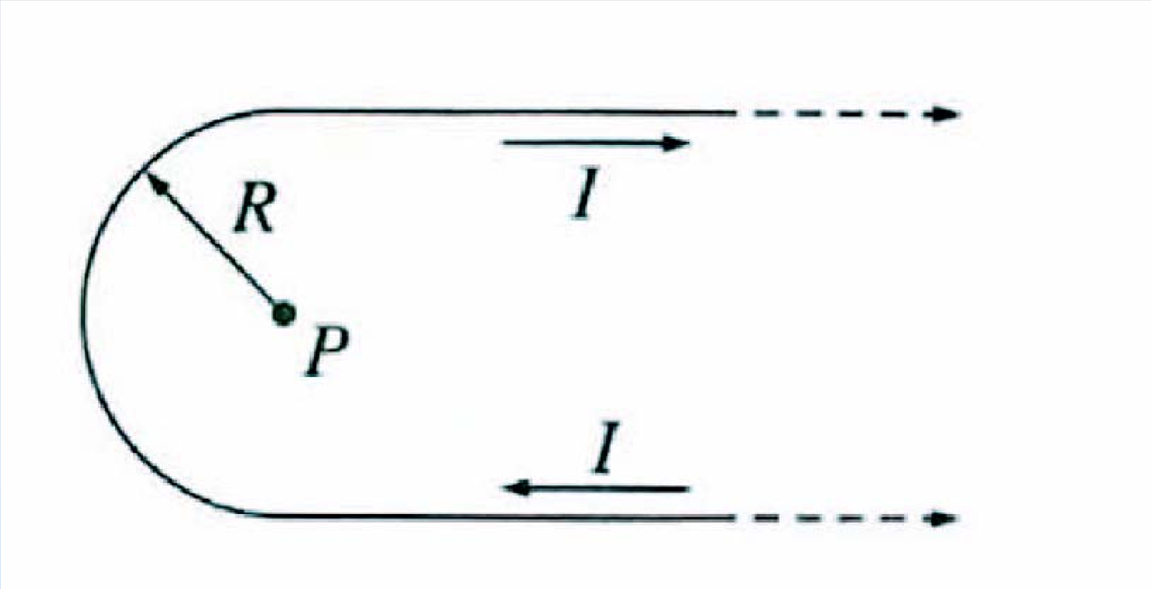
Methodology

- Individual Response
- Group Discussion
- Second Individual Response
- Closure Discussion

Tested on Exams

ConcepTest: Bent Wire

The magnetic field at P is equal to the field of:



1. a semicircle
2. a semicircle plus the field of a long straight wire
3. a semicircle minus the field of a long straight wire
4. none of the above

Desktop Experiments

Networked laptops with data acquisition links between laptop and experiments

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Visualizations

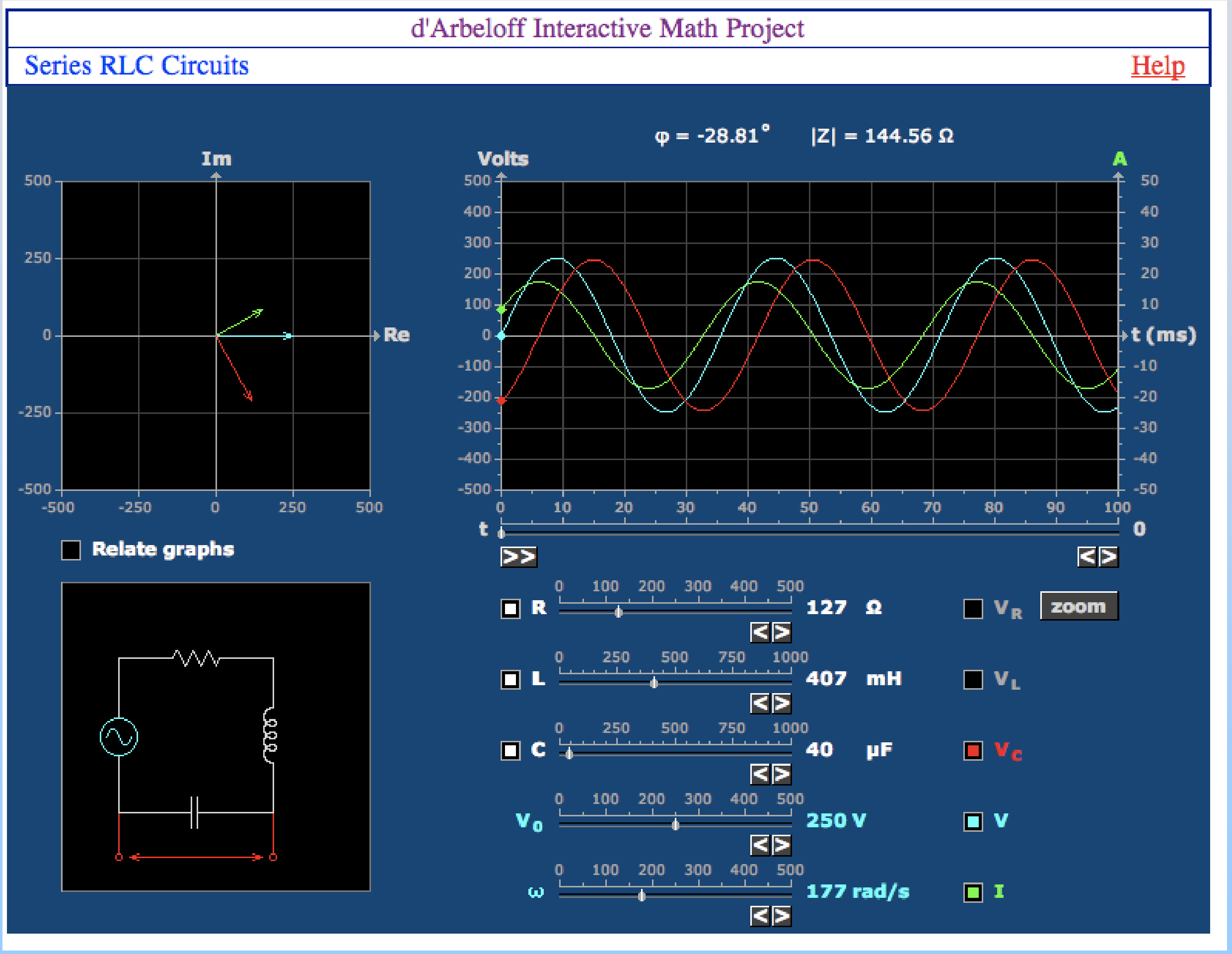
Visualizations

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

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

Mathlet

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



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

Problem Solving

An MIT Education is solving 10,000 Problems

Measure understanding in technical and scientific courses

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

Regular Practice

Problem Solving Opportunities

On-Line Mastering Physics:

1. Problem Solving
2. Tutorials
3. Reading Assignments
4. Pre-Lab Questions

In-Class Concept Questions and Table Problems

In-Class Group Problems (Friday)

Weekly Problem Sets

1. Multi-concept analytic problems
2. Pre-lab questions
3. Analyze data from experiments

Six Quizzes and Three Exams

Polya: How to Solve it!

1. Understand the statement of the problem – 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?

Interactive On-Line Homework (Mastering Physics)

On-Line homework with hints and tutorials

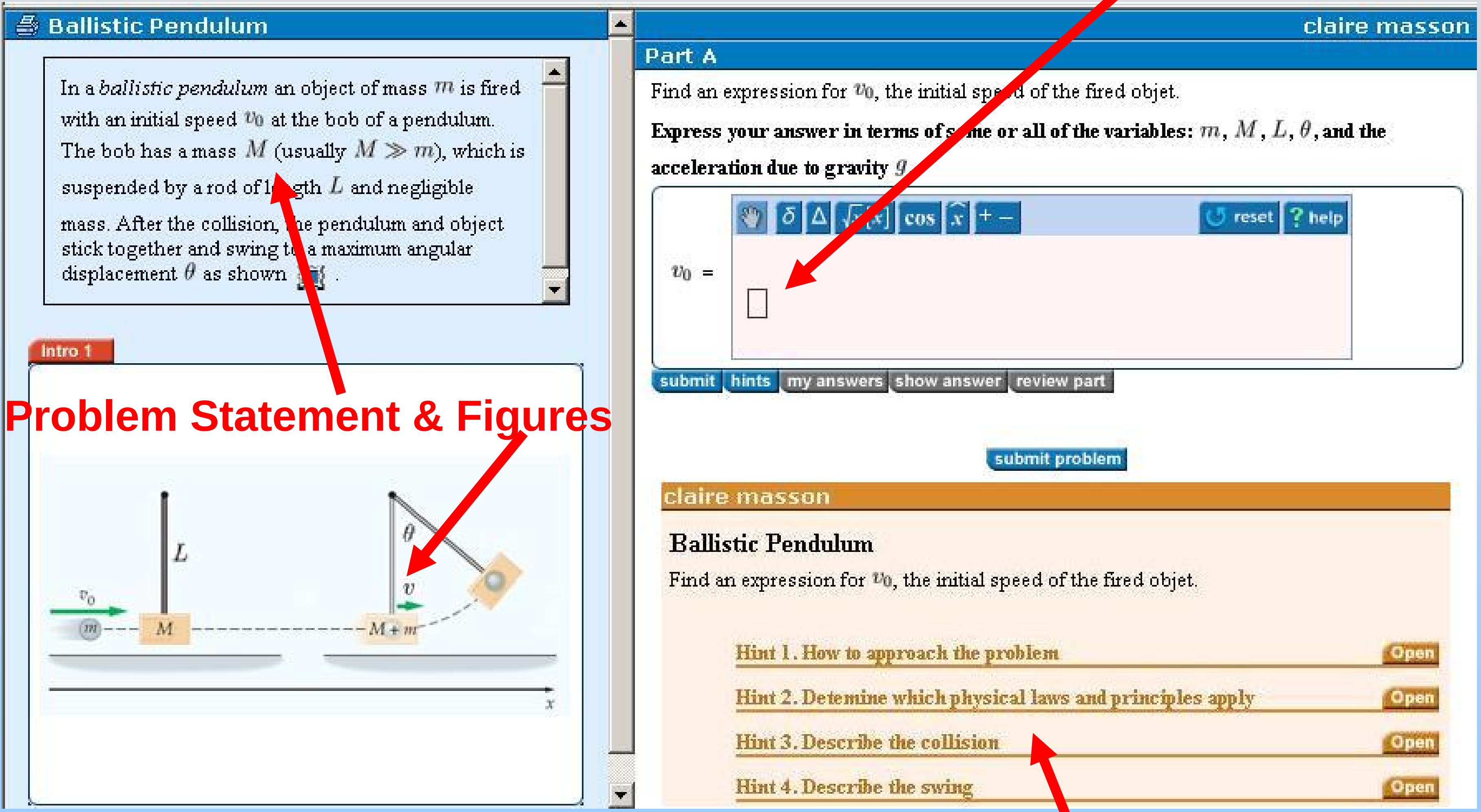
Sunday assignment focuses on the weekly reading assignment

Thursday assignment focuses on the material covered that week.

Review problems for exams are available with hints

Socratic Pedagogy

Demand Appropriate Response



Problem Statement & Figures

Requestable List of Hints (plan of attack)

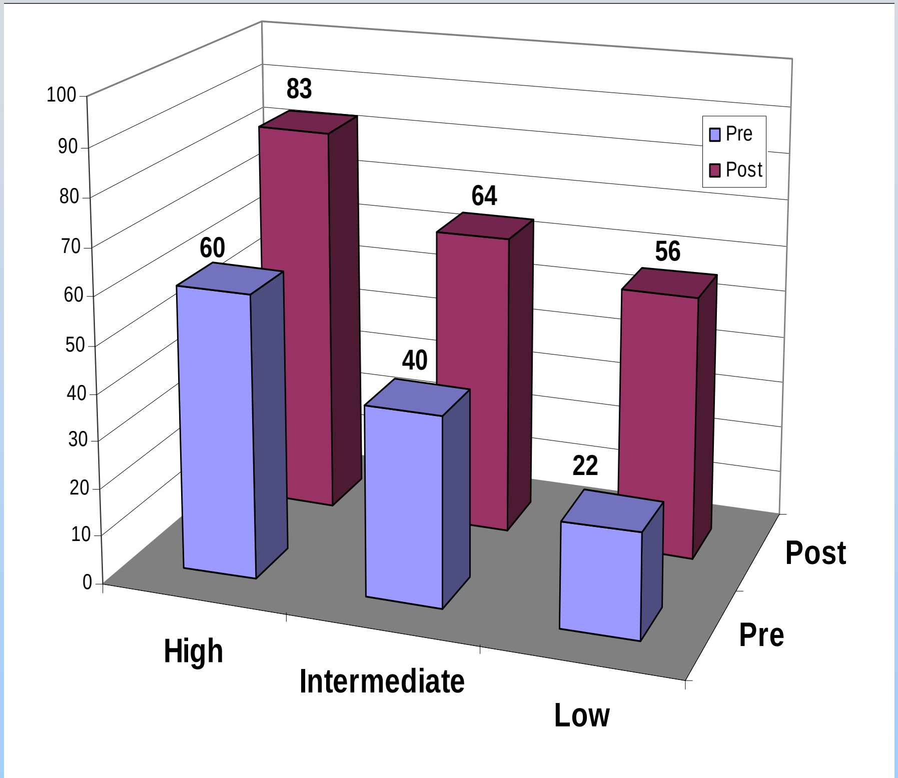
Does TEAL work?

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

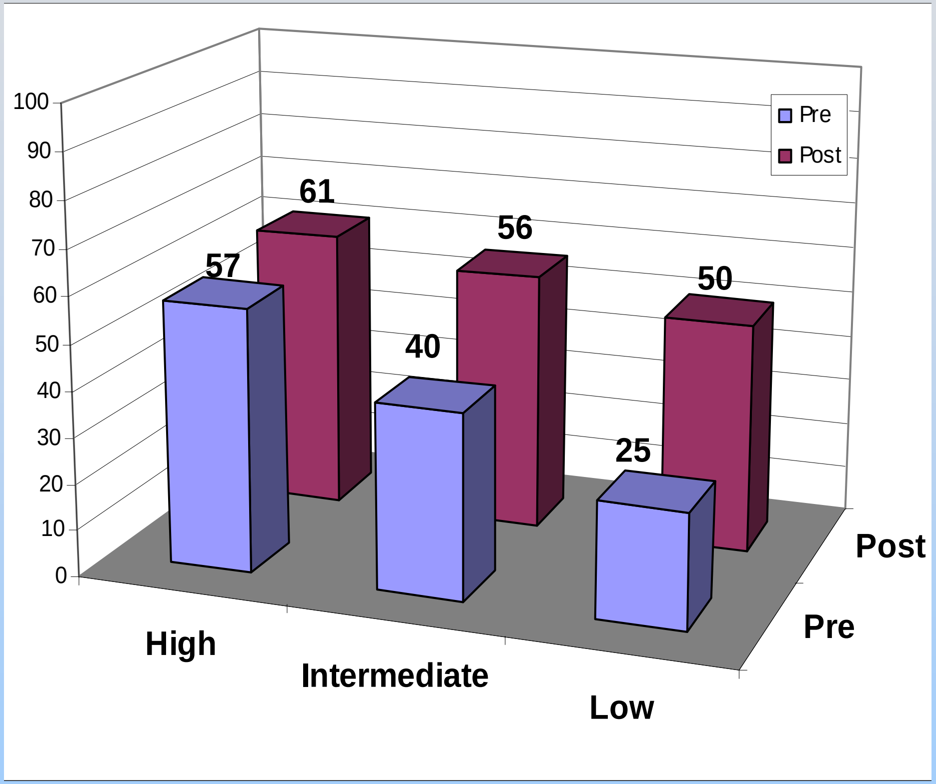
Pre-Post Concept Test Scores

N students = 176



Experimental group - Fall 2001

N students = 121



Control group - Spring 2002

Relative Improvement Measure Fall 2001

$$\langle g \rangle = \left(\frac{\#\mathrm{Correct}_{post-test} - \#\ \mathrm{Correct}_{pre-test}}{\#\ Questions - \#\ \mathrm{Correct}_{pre-test}} \right)$$

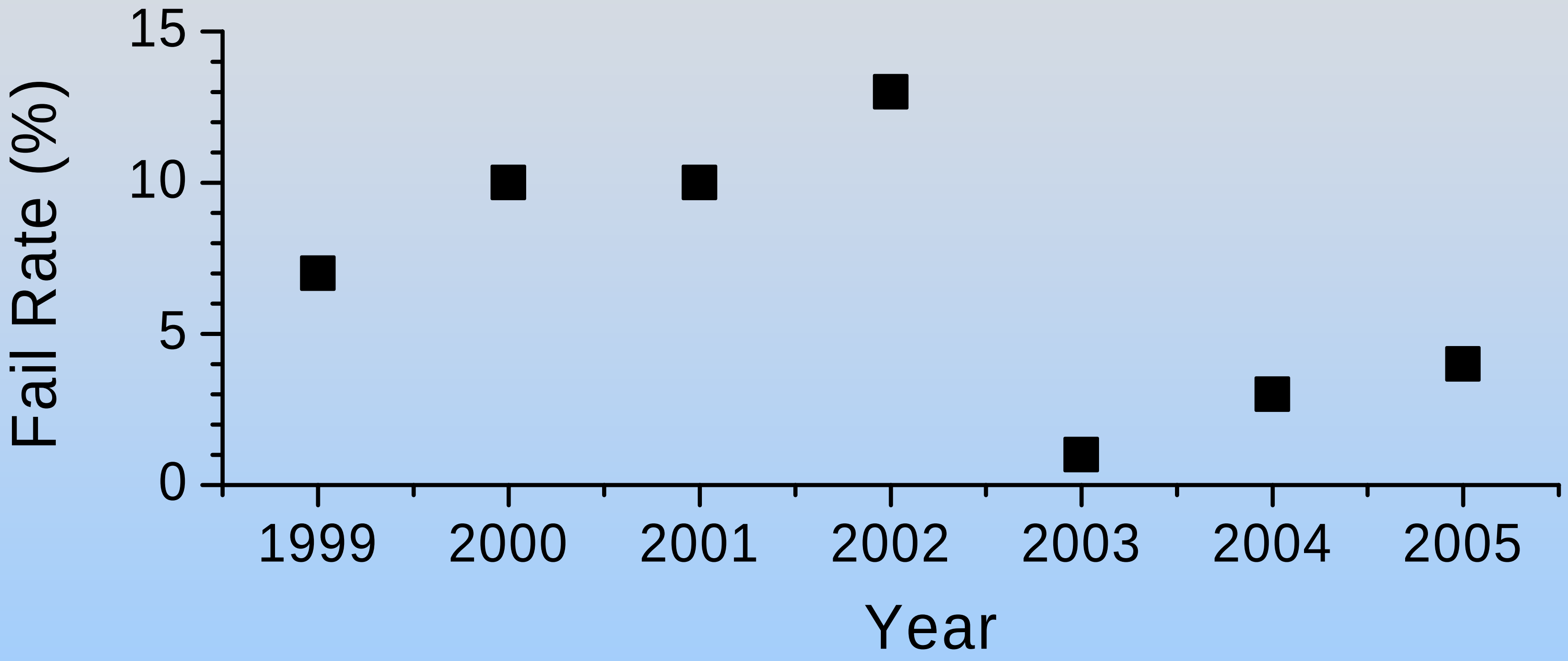
Group	Experimental 2001		Control 2002	
	N	⟨g⟩	N	⟨g⟩
Entire population	176	0.46	121	0.27
High	58	0.56	19	0.13
Intermediate	48	0.39	50	0.26
Low	70	0.43	52	0.33

Scale Up - Relative Improvement Measure Spring 2003

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

TEAL **E & M Spring 2003**	N	⟨g⟩
Entire class	514	0.52
High	40	0.46
Middle	176	0.55
Low	300	0.51

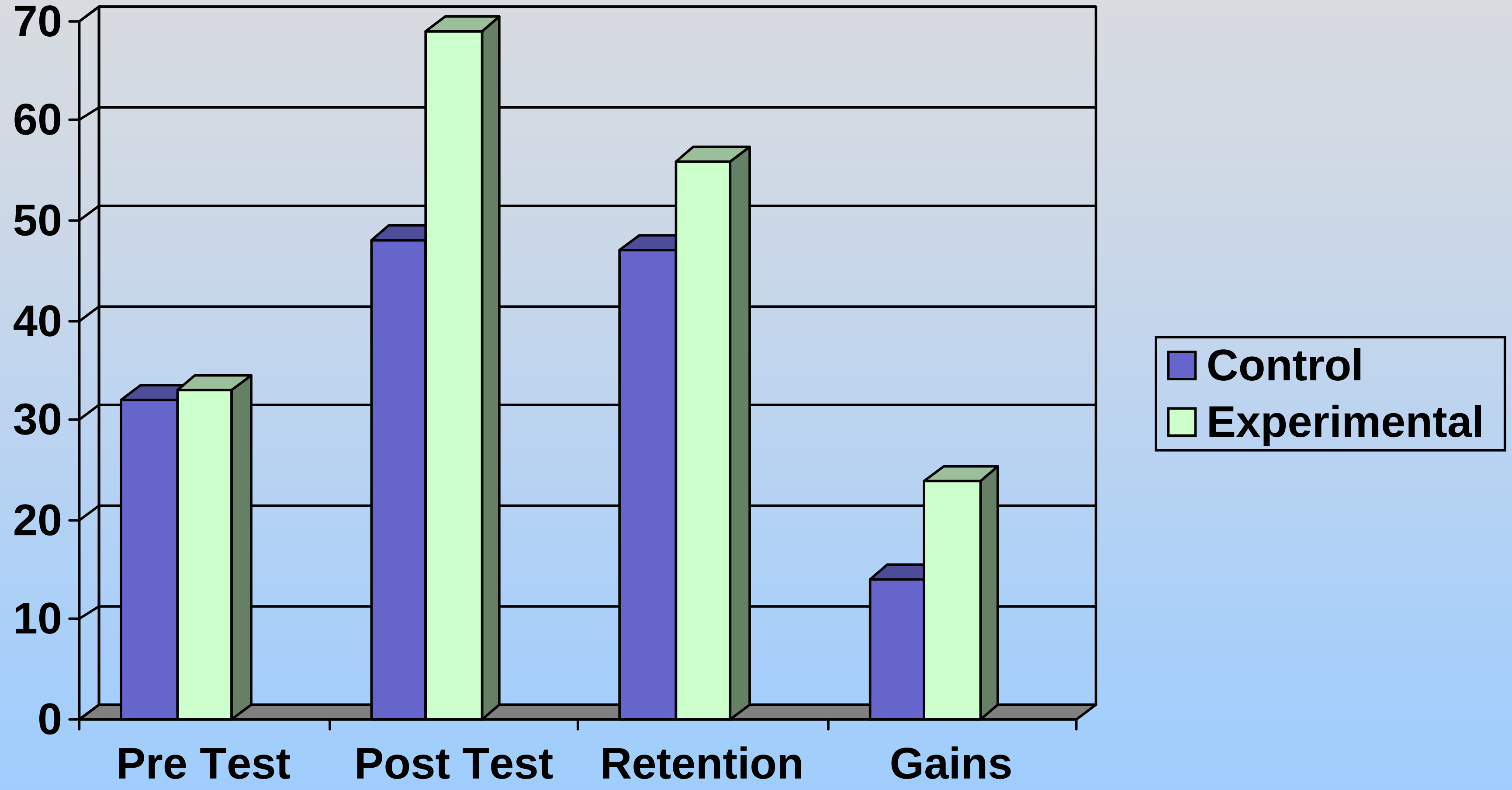
E&M Lower Failure Rate



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

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.

Student Reactions

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

Not in the Beginning

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."

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
4. Manage student learning
5. Integrate experiments into Modular Activities
6. Gradually improve course materials
7. Establish institutional continuity independent of individual creators

Invariants

- “Required” attendance as measured by graded ConcepTests, Experiments, and Friday Problem Solving

  Most number of complaints BUT activities form core of group learning

- Heterogeneous Grouping

  Not many complaints, Important!

- “Too many assignments”

  Keeps students thinking physics, using multiple approaches

Sustainability

1. Develop subject content that matches learning objectives
2. Demonstrate learning gains through objective measures based on data
3. Support a robust teacher training program
4. Develop institutional continuity
5. Adapt teaching to local institutional / faculty / student cultures:

- Guarantee institutional support
- Address faculty concerns regarding active based learning
- Develop student support by clear exposition of learning goals

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

Professor Hudson,I just wanted to thank you for all you did. **I really enjoyed your class,definitely my favorite one last semester!** I'm not just saying that either…I loved my table. I mean, we got so close we created our own email list! I looked forward to coming to class everyday, knowing I was guaranteed to laugh at least once. 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 kind of 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.** Pretty much, they're as excited to hear about it as I am to tell them about it - which is saying a lot. I'm really glad I got to know you. I definitely will consider being a TA myself (not next semester, but maybe next fall, definitely if it fits into my schedule). **I really appreciate all you did for us - review sessions, email updates regarding testing material and results, cool demos, the list goes on. I can tell you cared about my success (and everyone else too).**Thank you.

Webpage

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

Thank you