

Reforming Large Courses at a Research University: A Case Study from Physics at Illinois



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Learning Conference

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Overview

- **WHAT:**
 - How to create and sustain educational change in a research university environment?
- **HOW:**
 - Case Study: Introductory Physics at the University of Illinois
- **THEME:**
 - Engagement with Evidence: always present from design to assessment

QUESTIONS WELCOME AT ANY TIME !!!

The Problems Confronting Reform at Research Universities

- **Size**

- e.g., at Illinois a total of ~3000 students are taught in courses ranging in size from 300 - 1000 students.
 - "Parallel Parking an Aircraft Carrier"
 - "Educating in Bulk"

- **Research First**

- Primary Responsibility: New Knowledge
- Important Teaching Responsibility: Graduate Students

- **Organizational Change**

- An Unnatural Act
- Obstacles arising from personality and cultural issues

The Story

- **Overview**
 - the OLD (all courses prior to Fall 96)
 - The NEW (all courses after Fall 99)
- **The Reform**
 - Faculty Participation
 - The Pieces
- **How to Sustain the Reform?**
 - Infrastructure and Culture
- **Reflections on Difficulties of Implementing Change**

The OLD

- Introductory Physics at Illinois prior to Fall 1996

- We do "Educate in Bulk"

	FALL	SPRING
• Calculus-based sequence		
- Physics 106 (Mechanics)	500	1000
- Physics 107 (E&M)	800	450
- Physics 108 (Waves)	400	750
• Algebra-based sequence		
- Physics 101 (Mechanics, thermo)	600	400
- Physics 102 (E&M, modern)	<u>300</u>	<u>400</u>
	2600	2900

- Tradition, Tradition, Tradition

- Large (200-300) Lectures with Small (24) Sections for Discussions and Labs (6-7 hrs/week)
- Lecturers free to "reinvent the flat tire" , Discussion TAs pretty much on their own, Labs intellectually disconnected from rest of course.
- Exams: Quantitative Problems
- RESULTS: NOBODY IS HAPPY !!

The NEW

- Introductory Physics at Illinois as of Spring 2000

ALL COURSES TOTALLY REVISED !

The Big Idea: Integrate all aspects of a course using interactive engagement methods based on physics education research in a team teaching environment

- **ONE COURSE !!**
 - All pieces of the course (lecture, discussion, labs, homework) must be made of the same cloth.
 - The student should see a coherent plan at work.
- **Emphasize Concepts**
 - Traditionally, there is a large gap between what we think we are teaching (physics) and what is being learned (equation manipulation)
 - Introduce explicit instruction on concepts (and test for it!)
- **Use Interactive Engagement Methods**
 - The learning of physics is NOT a spectator sport
 - Engage the student in all aspects of the course (including lecture)
 - Make use of the products of Physics Education Research (materials and knowledge). There is a research base here and faculty (especially at a research university) should use it!!

Faculty Participation

- Overriding Rule:



NO HEROES!

- **Key Ideas**

- Sustainability cannot be built on heroism.
- Faculty assignment must be seen as an ordinary assignment
- Infrastructure lowers the bar for participation

- **How to Do It?**

- 16-17 Faculty assigned for these courses (2800 students)
- **Responsibilities:** Lecturer, Discussion Coordinator, Lab Coordinator
- Faculty team meets weekly to keep course on track.
- Faculty team creates exams
- Support Infrastructure developed (computing, secretarial, ...)

Over 60 Faculty have taught in these new courses!

The Pieces

- Lectures, Discussions, Labs, Homework, Exams
 - IMPORTANT RULE:



STEAL FIRST!

Well, maybe **ADAPT** is a better word?

- Local conditions often dictate some modifications
- Don't invent anything until you discover a real problem that has not yet been solved.

Lectures

- **ALL Lectures "the same"**
 - If need multiple lecturers, they use same slides
- **ACTs** (see "Peer Instruction", E. Mazur)
 - Punctuate lectures with interactive segments
 - Ask Questions, Students Discuss, Students Vote, Resolution

Lectures



Stairmaster

i-clicker vote

Preflight 6.1

0:30 72

Calculate the current through resistor I_1

20% 63% 17%

1) $I_1 = 0.5 \text{ A}$ 2) $I_1 = 1.0 \text{ A}$ 3) $I_1 = 1.5 \text{ A}$

$-\mathcal{E}_1 + I_1 R = 0 \Rightarrow I_1 = \mathcal{E}_1 / R = 1 \text{ A}$

ACT: Voltage Law

How would I_1 change if the switch was opened?

1) Increase 2) No change 3) Decrease

Question 2

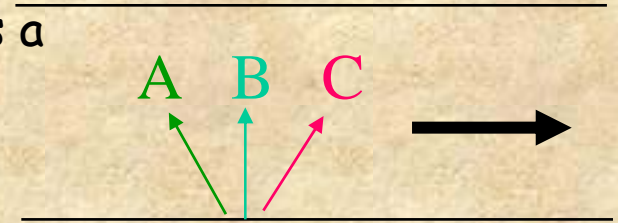
Option	Percentage
A	20%
B	63%
C	17%
D	0%
E	0%

Lectures

- **ALL Lectures "the same"**
 - If need multiple lecturers, they use same slides
- **ACTs** (see "Peer Instruction", E. Mazur)
 - Punctuate lectures with interactive segments
 - Ask Questions, Students Discuss, Students Vote, Resolution
- **Just-In-Time Teaching** (see "JiTT", Novak, Patterson, Gavrin, Christian)
 - Students complete Web-based "preflights" (questions based on readings) **BEFORE** coming to lecture.
 - Lecturer reads the responses of students and prepares "Lecture" informed by these responses.
 - Lecture consists of explanations and ACTs that are designed to address the student difficulties seen in the preflights.

Sample Preflight from Physics 101

Three swimmers can swim equally fast relative to the water. They have a race to see who can swim across a river in the least time. Relative to the water, Beth (B) swims perpendicular to the flow, Ann (A) swims upstream, and Carly (C) swims downstream. Which swimmer wins the race?



16% A) Ann

The shortest distance across is a straight line. Beth starts off straight but the current is taking her to the right so she has to swim longer to get across. Carly is already going to the right and plus the current so she would have to travel the farthest. Ann is swimming to the left and because the current is going to the right it would push her into a straight line. So Ann would get there the fastest.

30% B) Beth

Beth will reach the shore first because the vertical component of her velocity is greater than that of the other swimmers.

53% C) Carly

While Carly is moving forward she will also be moving along with the current. two positive(+) direction motions = faster velocity.

Discussion Sections



- Key Idea: Collaborative Learning
 - Students work in groups of 4 on problems prepared by the senior staff. TAs act as facilitators, not lecturers.
 - TA preparation very important (credit to Tim Stelzer)
 - Orientation, Weekly Meetings, Mentor TAs, Observation
 - Content of prepared materials very important (Tutorials (Washington), Context-Rich (Minnesota), and our own)

Labs

- PREDICT
- OBSERVE
- EXPLAIN

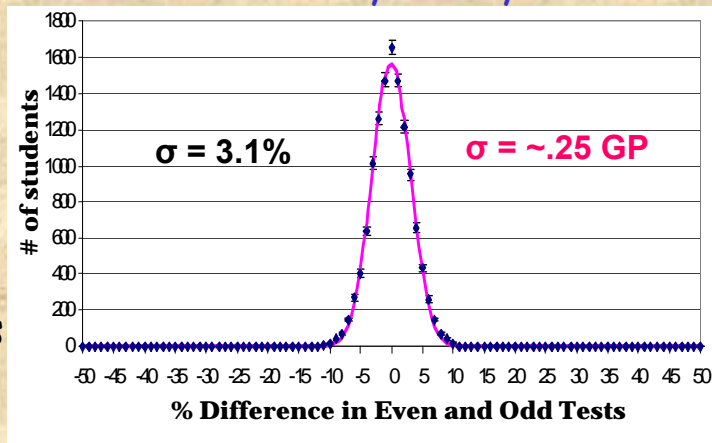
- Adopt the approach of Thornton & Sokoloff to actively engage the students in the learning process and to promote mastery of concepts by manipulation of experimental apparatus.
- Prelab assignments; Lab reports finished within class period.

Exams

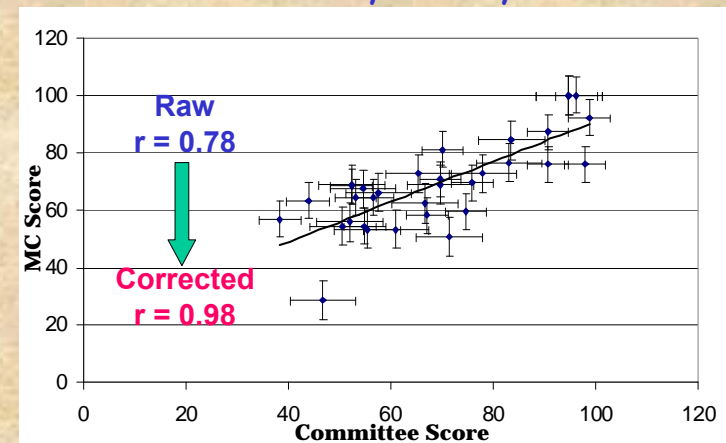
- What we used to do:
 - Exam composed of 4 multi-part calculational problems.
 - Exam graded by faculty + TAs immediately afterward. Subjective partial credit given based on student's approach.
 - Problems?
 - Students can learn to do these problems without understanding what they are doing.
 - Whining, cheating on regrades, questionable application of partial credit.
- What we do now:
 - Exam composed of Multiple Choice questions, both qualitative and quantitative, often using the same physical situation. We have always believed in the importance of conceptual understanding, but students didn't believe us because we never explicitly asked these questions before!
 - Partial credit scheme for quantitative (5 possible answers) questions. Students can choose to get reduced credit if they can successfully eliminate unphysical answers.

4 courses
32 course-sem
51 profs
128 exams
>4000 questions
>12000 students

Reliability Study



Validity Study

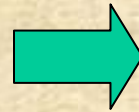


Did It Work?



- How do students rate their TAs?
- University-wide ranking of "excellent" \equiv top 30% of peers

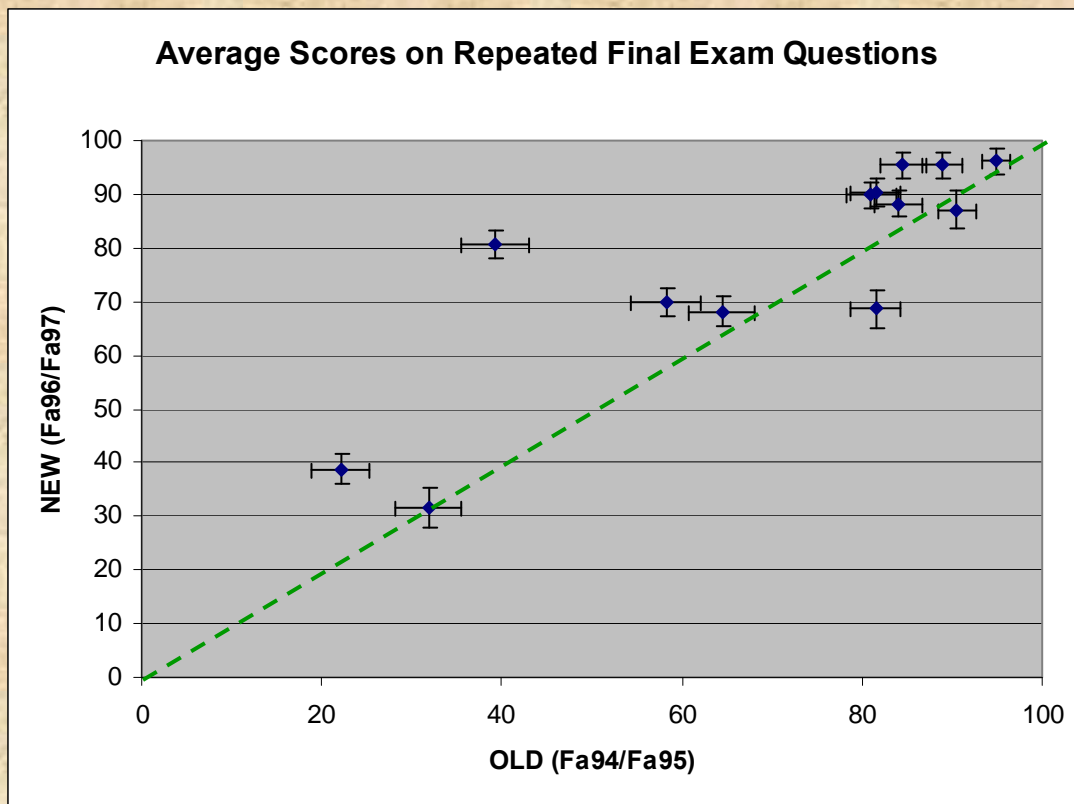
THE OLD
Spring 95
Total Physics TAs = 77
"Excellent" = 15
19 \pm 5 %



THE NEW
Spring 01
Total Physics TAs = 75
"Excellent" = 58
77 \pm 6 %

Did Student Performance Improve?

- Difficult Question
 - "Just Do It" works against assessment: need benchmarks
- Reuse final exam questions from pre-reform
 - Two Problems
 - No conceptual questions (what did they know?)
 - Free response → Multiple choice (reduce m.c. score using flat bkgnd)



RESULTS

Sum 13 questions

OLD = 69.5 ± 0.8

NEW = 77.0 ± 0.8

How to Sustain Reform?

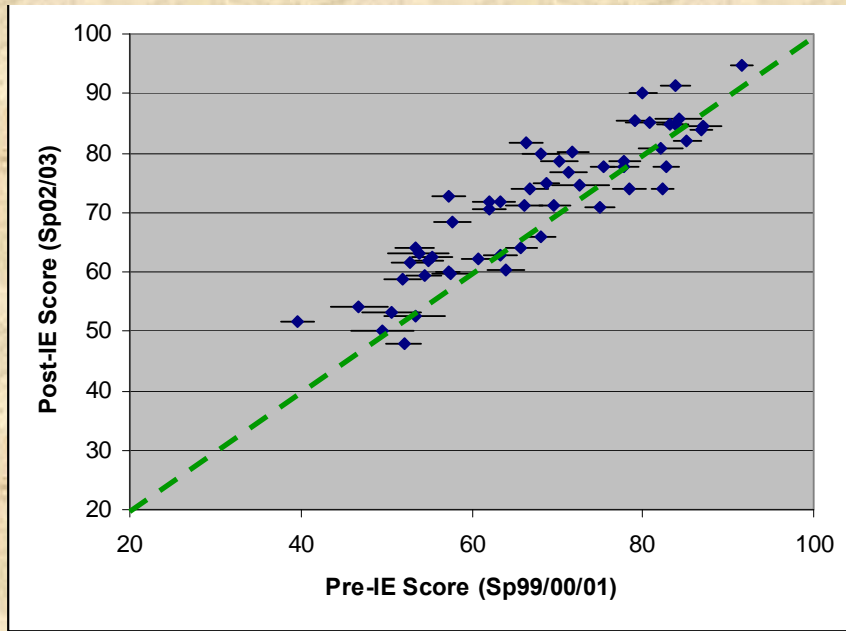
- Very Important Question
 - People who create the reform are usually not the same kind of people who enjoy making the trains run on time.
- Two Keys for Us
 - Establish Infrastructure (and change the culture)
 - People (veteran faculty, computing help, lecture, lab & secretarial support, new Assoc Head position)
 - Computing (all materials on central server, easily accessed by all)
 - Culture Change (Welcome to THE COURSE, here's how we do things....)
 - Made easier by Team teaching
 - Establish Physics Education Research Group
 - Basis for continuing interest (not based on making trains run on time)
 - Assessment of reforms
 - Allows for "continuous change"
 - On to specific example:
 - Creation and Assessment of Interactive Examples

Why Interactive Examples?

- In all other aspects of our revision, we have “borrowed freely” from the work of others!
- We created Interactive Examples (IEs) to address a specific problem for which we could find no existing solution.
 - **The Problem:**
 - It's been our experience that too many students see “**concepts**” and “**calculations**” as two totally separate and unrelated activities.
 - When given a quantitative question, most students will **NOT** think about the **CONCEPTS** that are involved.
 - When given a qualitative question, most students will never consider writing down an appropriate equation... math is **NOT** seen as a **TOOL**
 - **Our Solution:**
 - Create web-based exercises that engage the student in the solution of difficult quantitative problems using a “concept-based” method.

Note: now that we are in “research-mode”, we can (and must!) measure carefully the effect of this “intervention”.

Physics 112 Spring Results



clear effect

Plot Post-IE (Spring02/03) vs Pre-IE (Spring99/00/01)

Define:
$$\delta \equiv \frac{\langle S_i \rangle_{sem1} - \langle S_i \rangle_{sem2}}{\sigma}$$

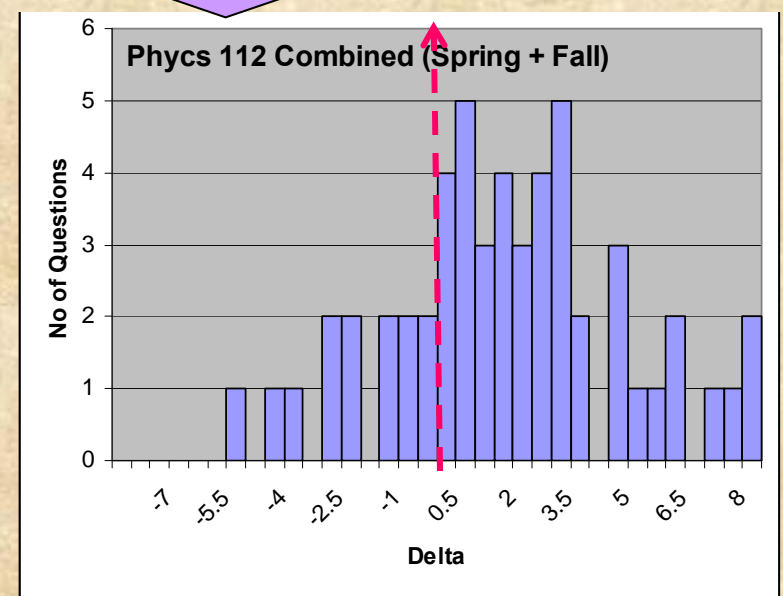
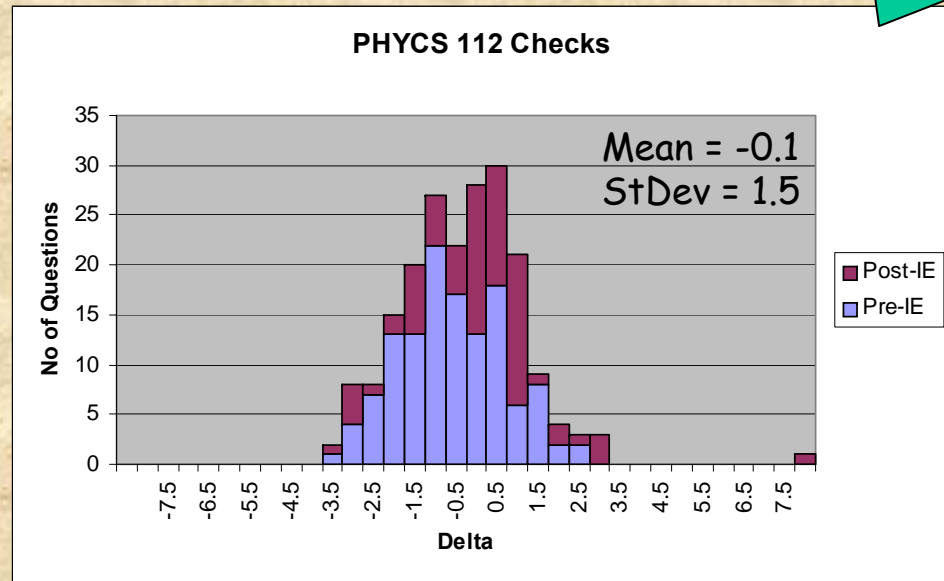
Compare PRE-PRE and POST-POST

Compare PRE-POST

clear effect

54 Questions
28% have $\delta > 3\sigma$

no effect



Conclusions and Reflections

- We have successfully reformed all of our introductory physics courses.
 - **The Big Idea:** Integrate all aspects of a course using interactive engagement methods based on physics education research in a team teaching environment.
- We have effected organizational change to sustain this reform.
 - **Establish Infrastructure (and change the culture)**
 - People, Computing (Welcome to Phys 1XX, here's how we do things..)
 - **Establish Physics Education Research Group**
 - Allows for "continuous change"
- What are the main difficulties in implementing this change at other research universities?
 - The key is to realize organizational change is needed!
 - What is main obstacle to this change?

PROVOCATIVE SUGGESTION TO FOLLOW.....

Final Thoughts

What is the main obstacle to Change specific to Physics Departments?

ALL?

Main Obstacle to Change is the Faculty !!

- **Personality issue:** The Arrogance of Physicists
 - What makes effective instruction is largely an empirical question.
 - Listen to students and Learn from others
- **Cultural issue:** "My" Course
 - Course is NOT just lectures
 - Progress comes from contributions of many to an ongoing effort: The Course.



The Good News: This obstacle can be overcome!

- Accepting an open attitude toward student learning
- Deriving satisfaction from contributing to The Course effort