

Undergraduate Physics at Illinois



Rutgers SPIN-UP Workshop

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Road Map for Talk

- **Service Teaching**
 - Reform of Introductory Physics
- **Physics Majors**
 - Programs and Features
- **Challenges and New Initiatives?**

Reforming Intro Physics Instruction

Important Constraint : SIZE



“Parallel Parking an Aircraft Carrier”

Enrollments	Fall	Spring
Algebra-based	900	850
Calculus-based	2250	2550
TOTALS	3150	3400

What Did We Change?

OLD (Spring 95)



NEW (Spring 01)

Lectures	Blackboard/Transparencies Demonstrations	Powerpoint with Demos "ACTs" (peer instruction) Just-In-Time Teaching
Discussion	TAs work problems on board	Collaborative Learning Common Materials created by PER groups or UIUC Faculty
Labs	Intellectually disconnected Focus on measurement	Predict-Observe-Explain Focus on concepts
Homework	End of Chapter (paper) Except: one course CAI (NovaNET)	WWW-based (TYCHO) Interactive Examples
Exams	Multi-part Problems Free Response Partial Credit	Multiple Choice Created by Faculty Team
TA Instruction	None	Orientation Mentor TAs Observation

Note: Most course materials are available by download from:
<http://research.physics.uiuc.edu/PER/>

I will not go into detail on the nature of these changes here, but will be happy to answer questions later

How Was the Plan Created?

- Physics committee formed to implement changes
 - Lemons to Lemonade !
 - **Improve Teaching Experience** (Eliminate Burnout and need for Heroic efforts)
 - **Improve Learning Experience**
 - Focus on Pedagogy and Course Organization (structural change)

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)
- **Use Interactive Engagement Methods**
 - The learning of physics is NOT a spectator sport; engage the student in ALL aspects of the course!
 - Make use of the products of Physics Education Research (materials and knowledge). There is a research base here and faculty (esp at a research university) should use it!!

Why Did the Change Work and Persist?

- **Strong Departmental Support**
 - Released Time, Choice of Faculty, new Assoc Head position
- **Infrastructure created to Facilitate Faculty Participation**

Guiding 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

• Culture Change

- "My Course" → "Our Course"

• Source of Continual Change: The PER Group

- Now have faculty whose research activity is to assess reform and created new materials/methods
 - **Interactive Examples** (concept-based problem solving web activity)
 - **Multimedia Learning Modules** (web-based "prelecture" activity)

Multimedia Learning Modules

• Multimedia Learning Modules (MLMs)

- Module contains essential content of one lecture (~ 15 minutes)
 - **Module** \approx 10 "slides"
 - "Slide" = Flash movie
 - Narration plus Animations
 - Student controls progress of movie (play, pause, repeat, ff, etc..)
 - **Questions:** occasionally (2-3 times/module) student is presented with a question
 - Student answers correctly: given explanation and can proceed
 - Student answers incorrectly: given feedback and a related question
 - Once related question answered correctly, original question is represented.
- Design of modules guided by principles of multimedia learning
 - Animations coordinated with Narration
 - No extraneous visual/auditory material
 - Minimal text on slide

DEMO

We are making these prelectures available from:
<http://research.physics.uiuc.edu/PER/>

The screenshot shows a software interface for a prelecture titled "ELECTRIC FIELDS". At the top, there are navigation tabs for "PRELECTURES" and "WORKED EXAMPLES", with "Overview" selected. Below the title, the equation $\vec{E} \equiv \frac{\vec{F}}{q}$ is displayed in an orange box. Two diagrams illustrate electric fields: "Point Charge" with the equation $E = k \frac{Q}{r^2}$ and "Infinite Line of Charge" with the equation $E = 2k \frac{\lambda}{r}$. Each diagram shows red arrows representing the electric field lines radiating from a central point or line. A vertical sidebar on the right contains a stack of slide thumbnails. At the bottom, a control bar shows "Slide 1 of 11", navigation buttons, and a progress indicator at "0.00 | 0.50".

Results

- **Clinical Study:**

- Compared student performance after (i) reading textbook to (ii) interacting with MLMs for the first four units (Coulomb to Gauss)

- **RESULT:** Significantly better performance from MLM students: effect size = 0.7

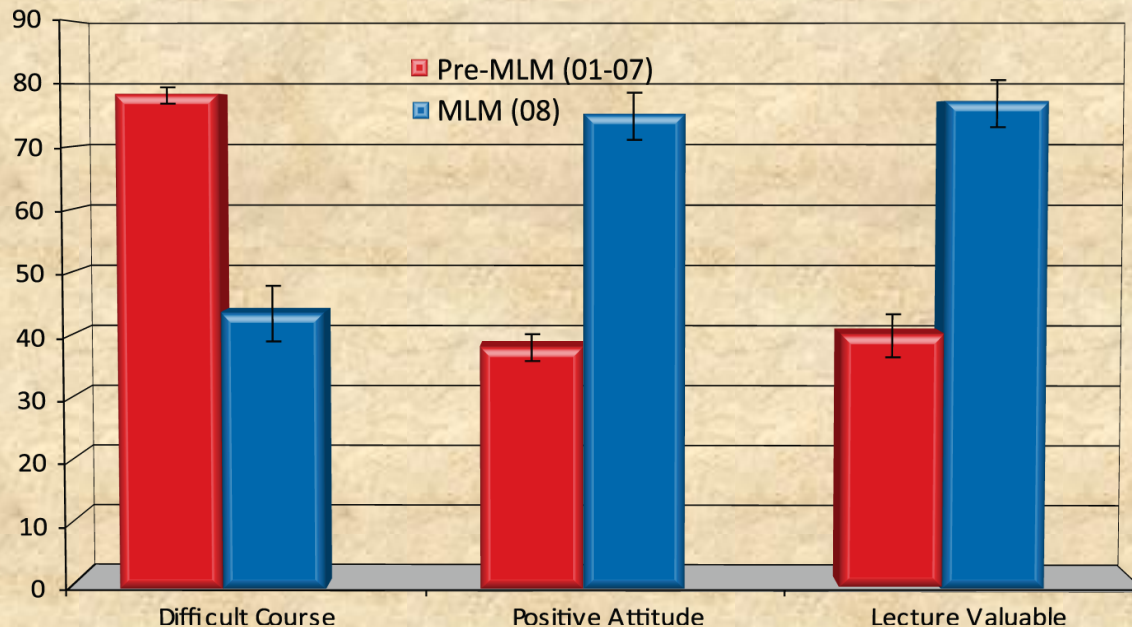
- **Real World Study:**

- Implemented web-based Multimedia Learning Modules as a "Prelectures" in introductory calculus-based E&M course.

- Dramatic improvement in student preparation for lecture

- Small improvement in student performance on exams

- **DRAMATIC** improvement in students' perception of the course.



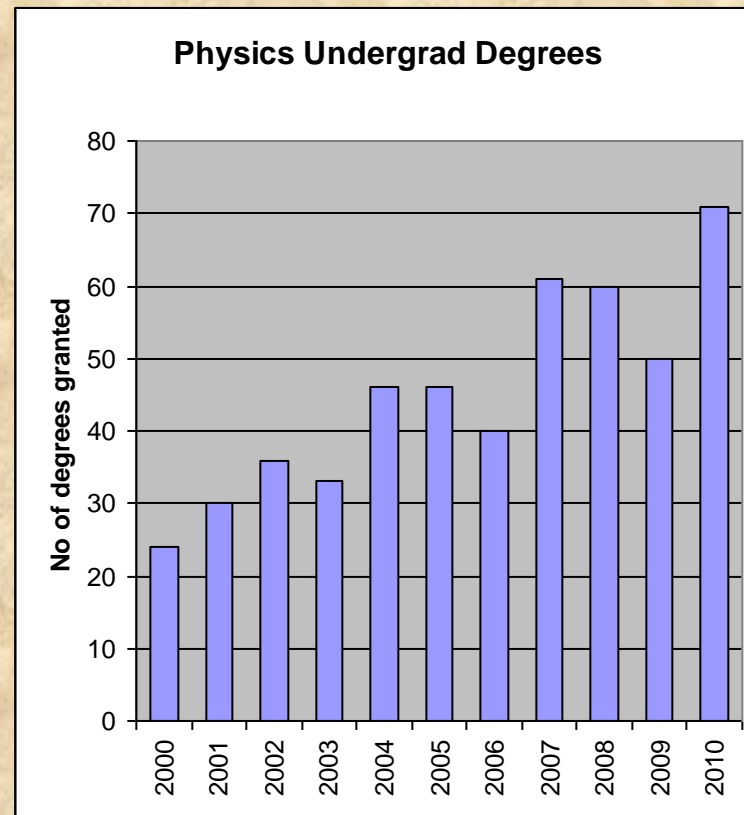
Mechanics course was similarly transformed and offered for the first time Fall09!

PRELIMINARY Results look similar to those for E&M!

Physics Majors

- Curriculum change Fall 2004:
 - Reduced core physics course requirement to 6
 - Added 4 - 6 course "option" that addresses "intellectually coherent body of knowledge"... technical and non-technical options are possible.. 1 option consists of 5 physics courses and one math course designed for preparation for graduate school in physics.
- Current Enrollments
 - Freshmen ~ 100
 - Soph - Seniors ~ 200

Number of Physics Graduates have been increasing over the last 10 years



Modern Experimental Physics Lab

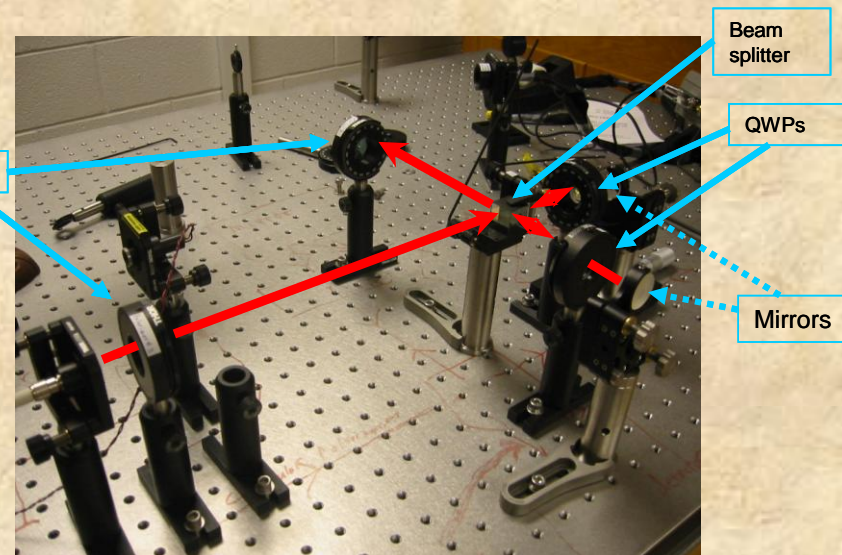
3 Cycles (4.5 weeks each)
Experimental rooms
Content-expert staff

Networked Digital Scopes
Electronic Logbooks
Modern Data Analysis

- Nuclear / Particle (NP)
 - Cosmic ray muons: lifetime, magnetic moment, angular distribution
 - Nuclear gamma-gamma correlation
 - Alpha range in gas

- Atomic / Molecular / Optic (AMO)
 - Optical pumping of rubidium gas
 - QI: Berry's phase, Quantum erasers,
 - Entanglement

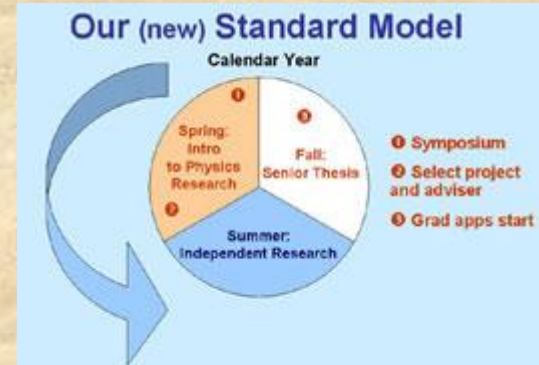
- Condensed Matter (CM)
 - Superconductivity:
 - Fabrication & measurements of metal films
 - 2nd Sound in Helium-4 superfluid state
 - Pulsed NMR
 - STM
 - Polarized optical microscope for ferroelectric expts
 - Videos of phase transitions



Senior Thesis

(<http://physics.illinois.edu/undergrad/seniorthesis.asp>)

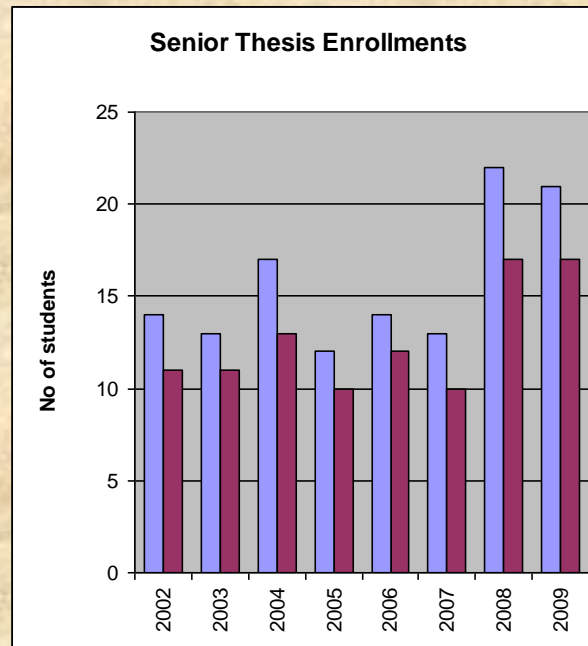
- Three semesters of integrated research & instruction
 - Intro to Physics Research (spring)
 - Literature Reviews, Estimates, Technical Writing, Presentations, Ethics
 - Research Experience (summer)
 - Senior Thesis (fall)
 - Prepare Scientific Poster
 - Grad School Preparation
 - Prepare & Review Research Proposal
 - Write Thesis



- Symposium in January
 - Present results

Enrollments

- Program began 2002
- Increase in 2008



Challenges & New Initiative?

- Large increase in students: Last year: additional ~ 500 students in both Mech & E&M
 - Less Faculty
 - Reduced TA Budget
 - No New Space
- Management of Undergrad Research Opportunities
 - Summer funding
 - Faculty Participation
 - Matching Faculty/Students
- Masters Degree in Teaching of Physics (??)
 - GOALS
 - Improve preparation of undergrad students taking intro physics
 - Revenue stream?
 - Focus on remote delivery to in-service teachers
 - Improved understanding of pedagogy & fundamental physics

That's All Folks !



That's All Folks!

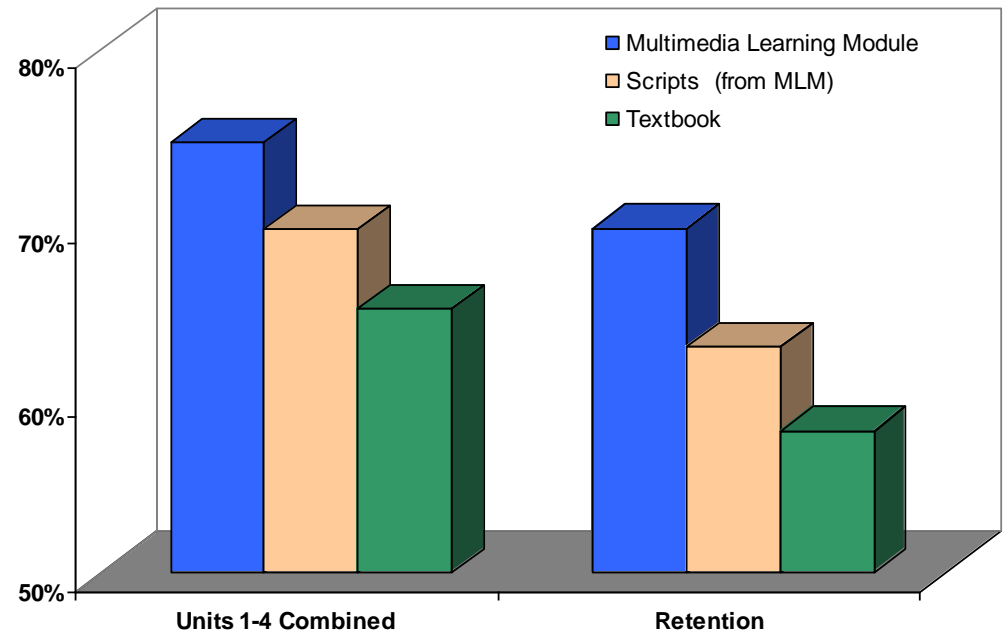
Initial Experiment

- **“Clinical” test** (limited statistics but controlled environment)
 - **Population:**
 - Students near end of semester course in calculus-based mechanics
 - **Content: Four initial units in E&M course**
 - Coulomb's Law
 - Electric Fields
 - Electric Flux
 - Gauss' Law
 - **Treatment Groups: (45 students completed all segments)**
 - Multimedia Learning Module (MLM): 16 students
 - Scripts (from MLM): 13 students
 - Text (standard): 16 students
 - **Protocol:**
 - Students do materials and then take test
 - ~45 minutes per unit (study + ~16 question test)
 - Students return two weeks later to take retention test (37 questions)

Results

Raw Performance Data:

	Combined (Units 1-4)	Retention
MLM (N=16)	74.7 ± 2.6	69.7 ± 4.0
Script (N=13)	71.7 ± 3.0	65.1 ± 3.7
Text (N=16)	63.2 ± 3.1	56.8 ± 4.1

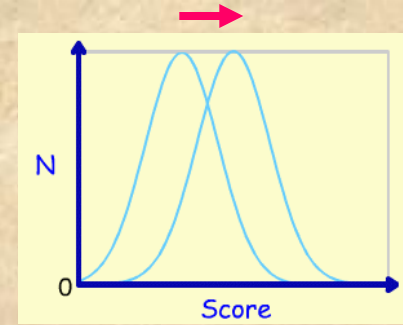


Effect Size Analysis

Effect Size:

$$E.S. = \frac{\langle obey \rangle - \langle violate \rangle}{\sigma}$$

Effect Size ~ 1
is Large!



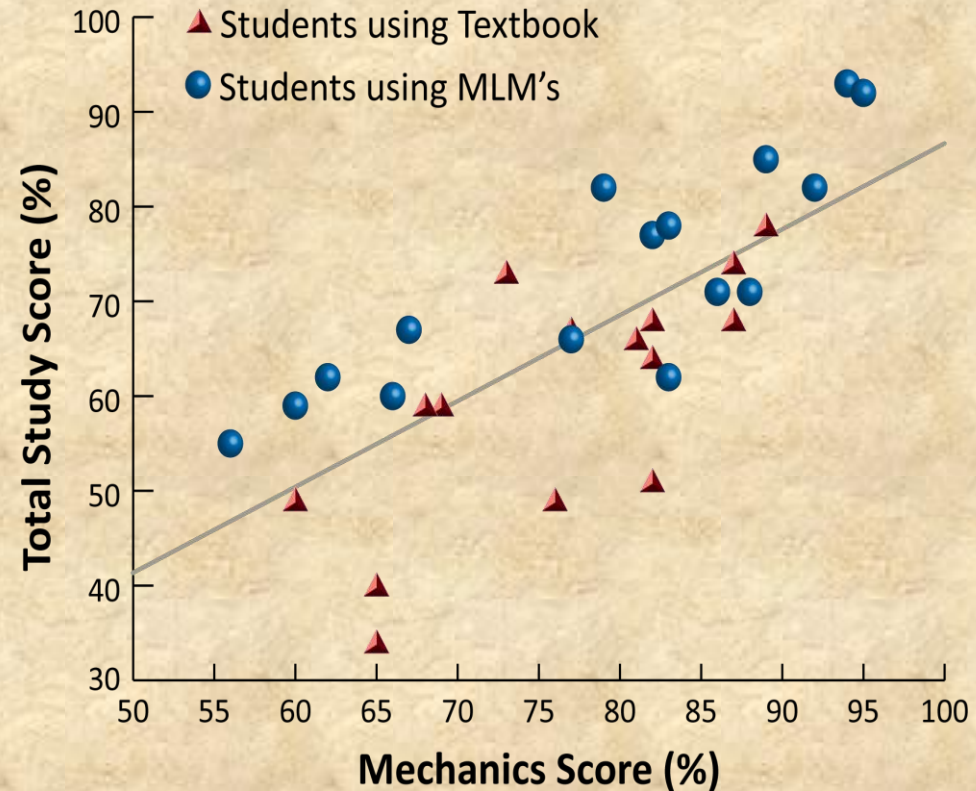
Combined (Units 1 - 4)

	MLM	Script
Text	ES = 0.74 p < 0.01	ES = 0.36 p = 0.06
Script	ES = 0.46 p = 0.03	

Retention

	MLM	Script
Text	ES = 0.67 p < 0.01	ES = 0.31 p = 0.16
Script	ES = 0.45 p = 0.04	

Correlate with Exam Scores from Mechanics Course



The REAL WORLD

Clinical test
looks good!

BUT

What about a
real course??

PHYS 212
Before SPRING 2008

JiTT Preflights
(few read text)

LECTURE
75 minutes
Narrative + Peer Instruction

CHANGES

PHYS 212
SPRING 2008 → present

MLMs implemented as "Prelectures"
(initial exposure to material)

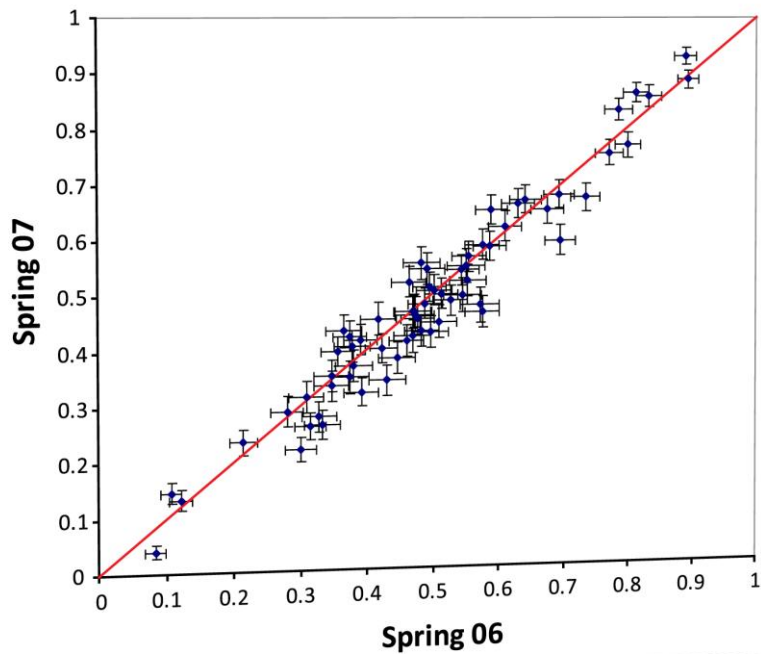
JiTT Preflights
(formative assessment)

LECTURE
50 minutes
Highly Interactive
(8 - 10 clicker questions)

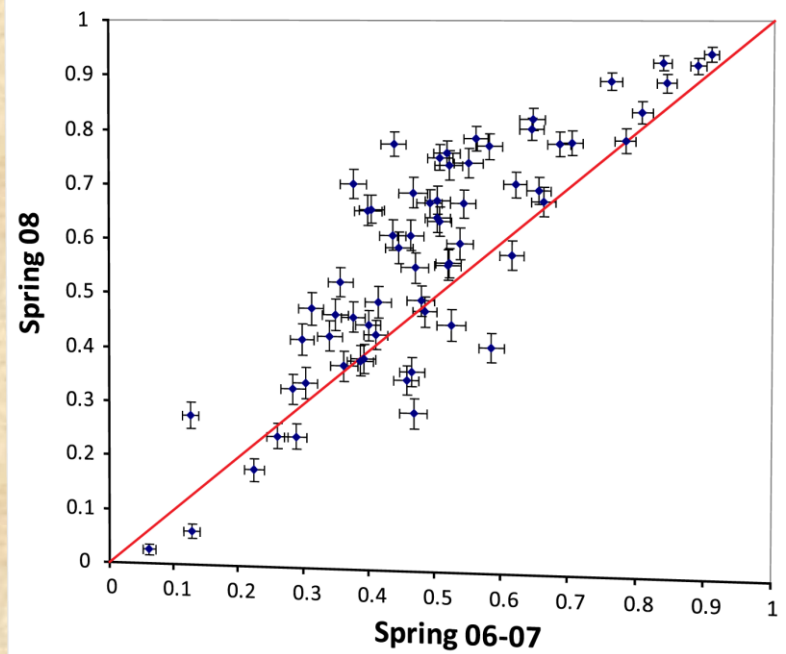
Preflight Assessment

- Repeated Preflight Questions allow for assessment

Before MLM

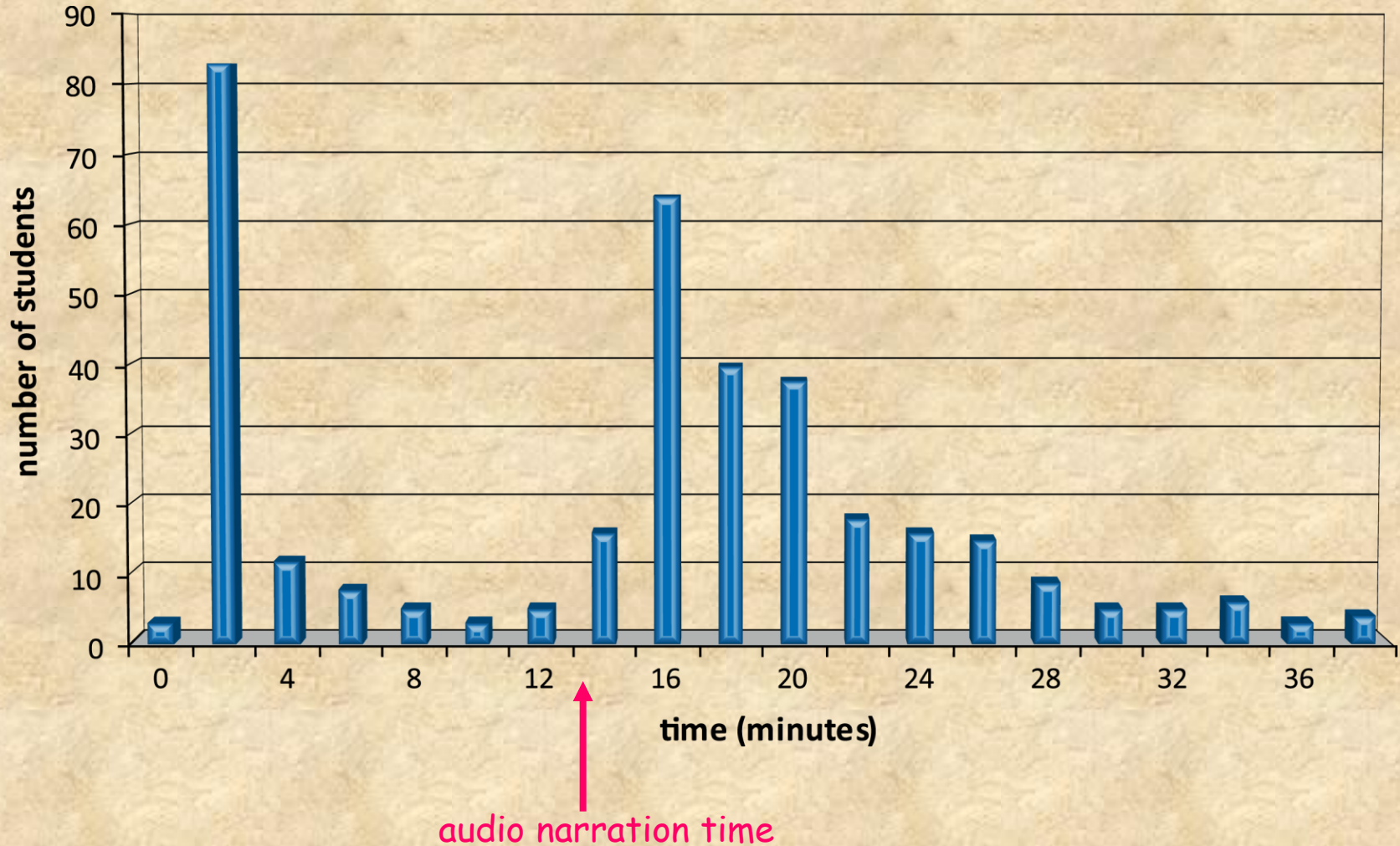


After MLM

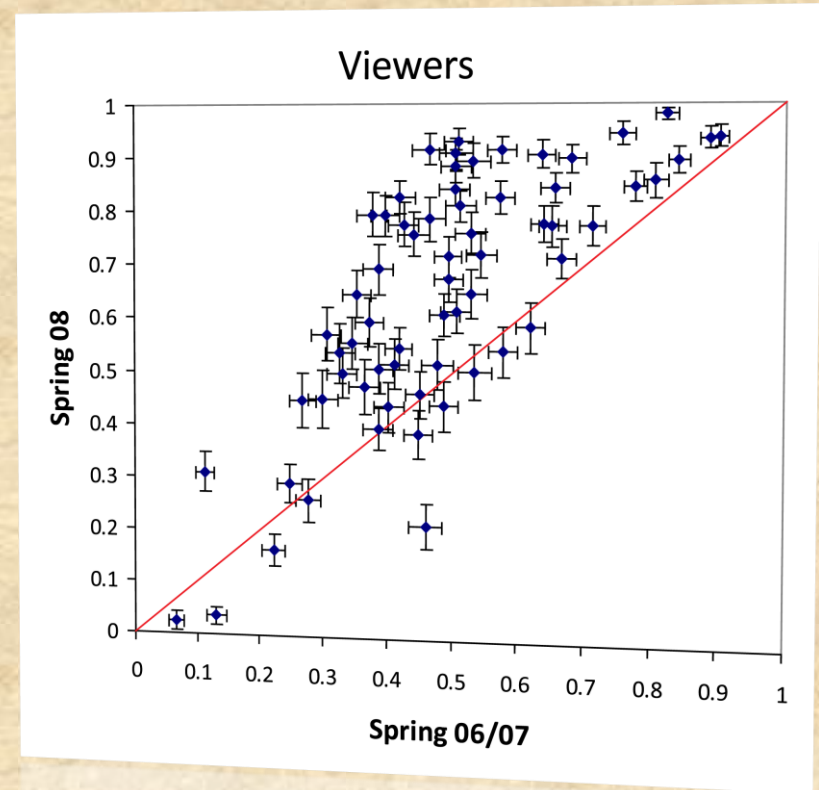
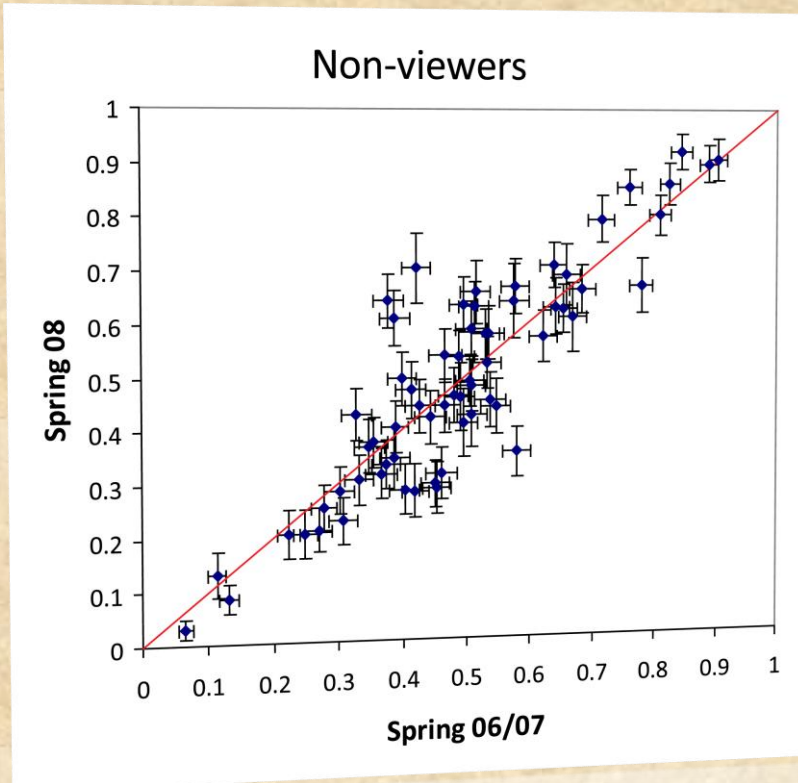


The Viewing Habits of Students

- Plot the time spent by each student on a prelecture



Preflight Assessment

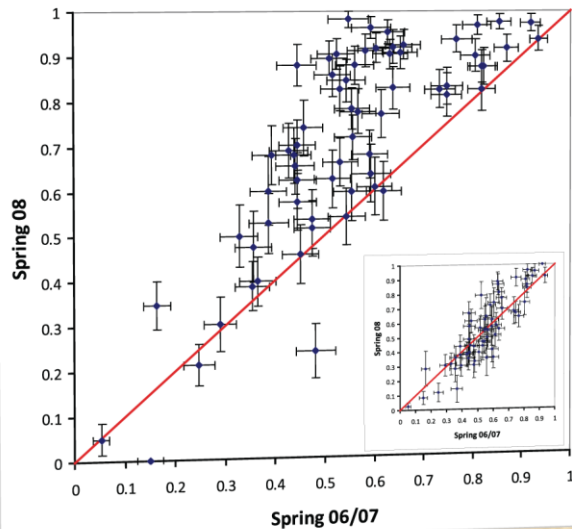


Results for Non-Viewers Look Like Those from Pre-MLM

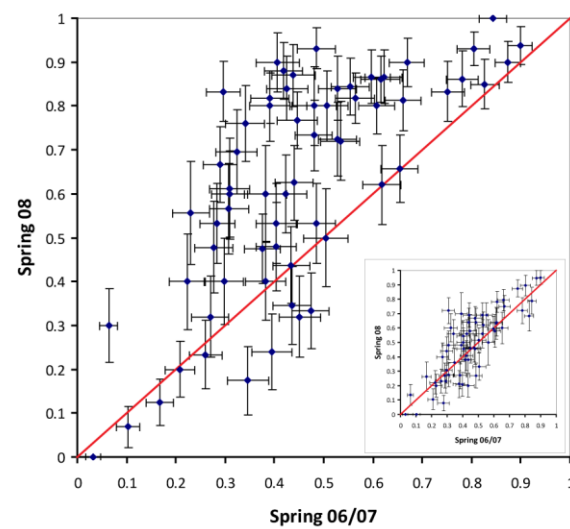
Preflight Assessment

MLMs Benefit Students of All Abilities

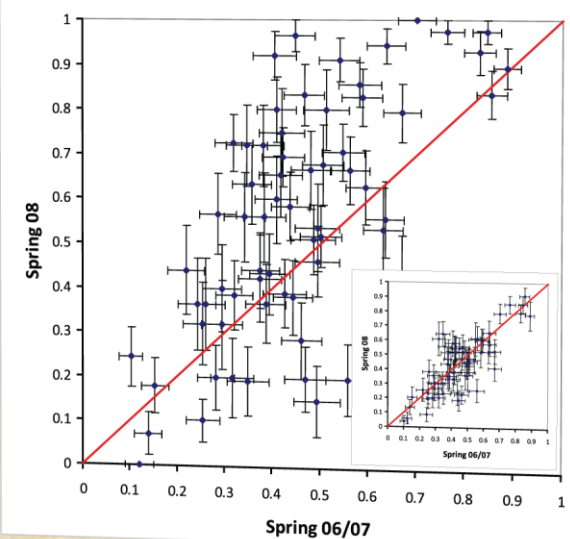
A level: 886-1000



B level: 821-885



C level: 690-820



Main Plots: Viewers
Inserts: Non-Viewers

Lectures: The PAYOFF

- Lectures are qualitatively different now !
 - **Better prepared students means more engaged students !**
- Current lecture plan
 - First half
 - **Mini-lectures and ACTs based on student difficulties observed in preflights**
 - Second half
 - **ACTs based on solution to quantitative problem**
- More Interaction
 - **The OLD: ~ 3 ACTs in 75 minutes**
 - **The NEW: ~ 8 ACTs in 50 minutes**

Lecture Slides Available from:
<http://online.physics.uiuc.edu/courses/phys212/fall09/lectures.html>

Exam Analysis

We have modified the lecture experience

No changes have been made to highly valued homework & discussion components

Do we see any improvement in exam performance??

Low expectations:

Time (Prelecture+Lecture) ~ 30% Time (Homework+Discussion)

Hour Exam 1:

Repeat exam from Fall 1998

<Fall 98> = $72.1 \pm 0.5\%$

<Fall 08> = $76.5 \pm 0.5\%$

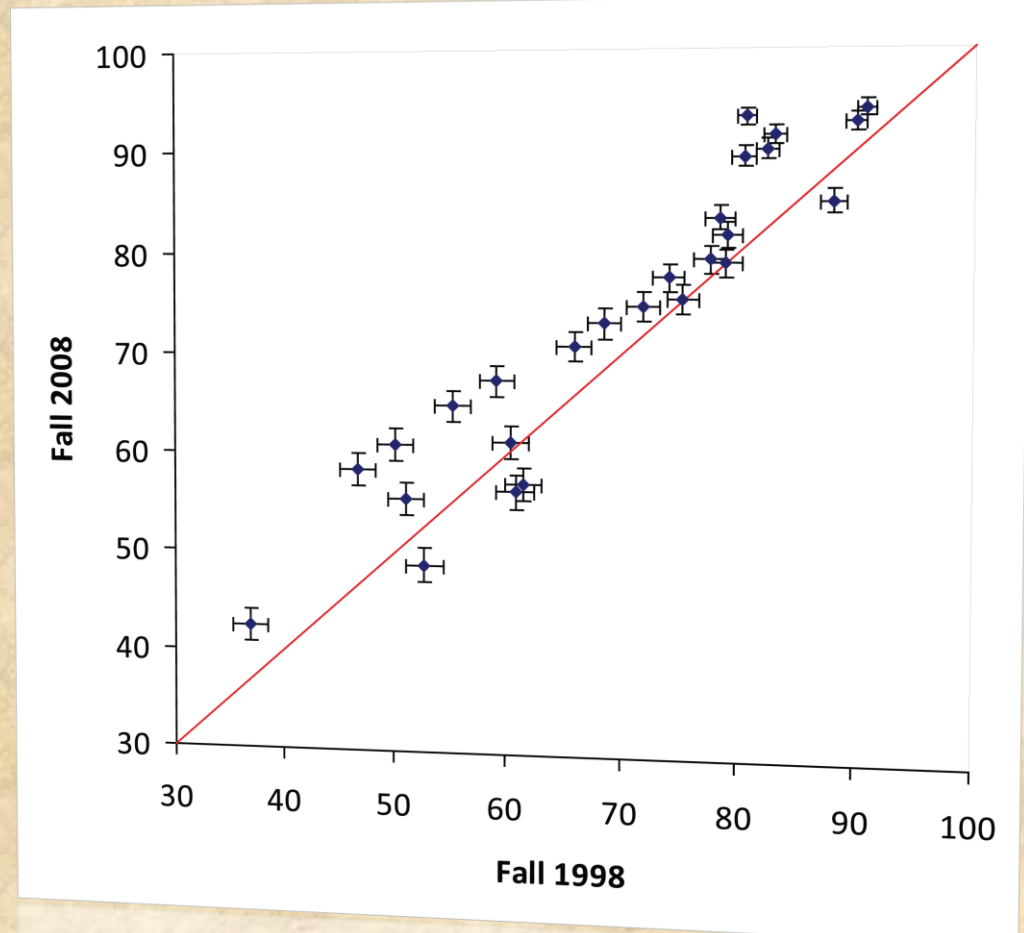
Effect Size = 0.30
 $p < .01$

Similar results for all three
midterms (Spring08)

$\delta \sim 3\%$ $ES \sim 0.2$

Somewhat smaller
results for Final Exams

$\delta \sim 1 - 3\%$ $ES < 0.2$



Student Perceptions

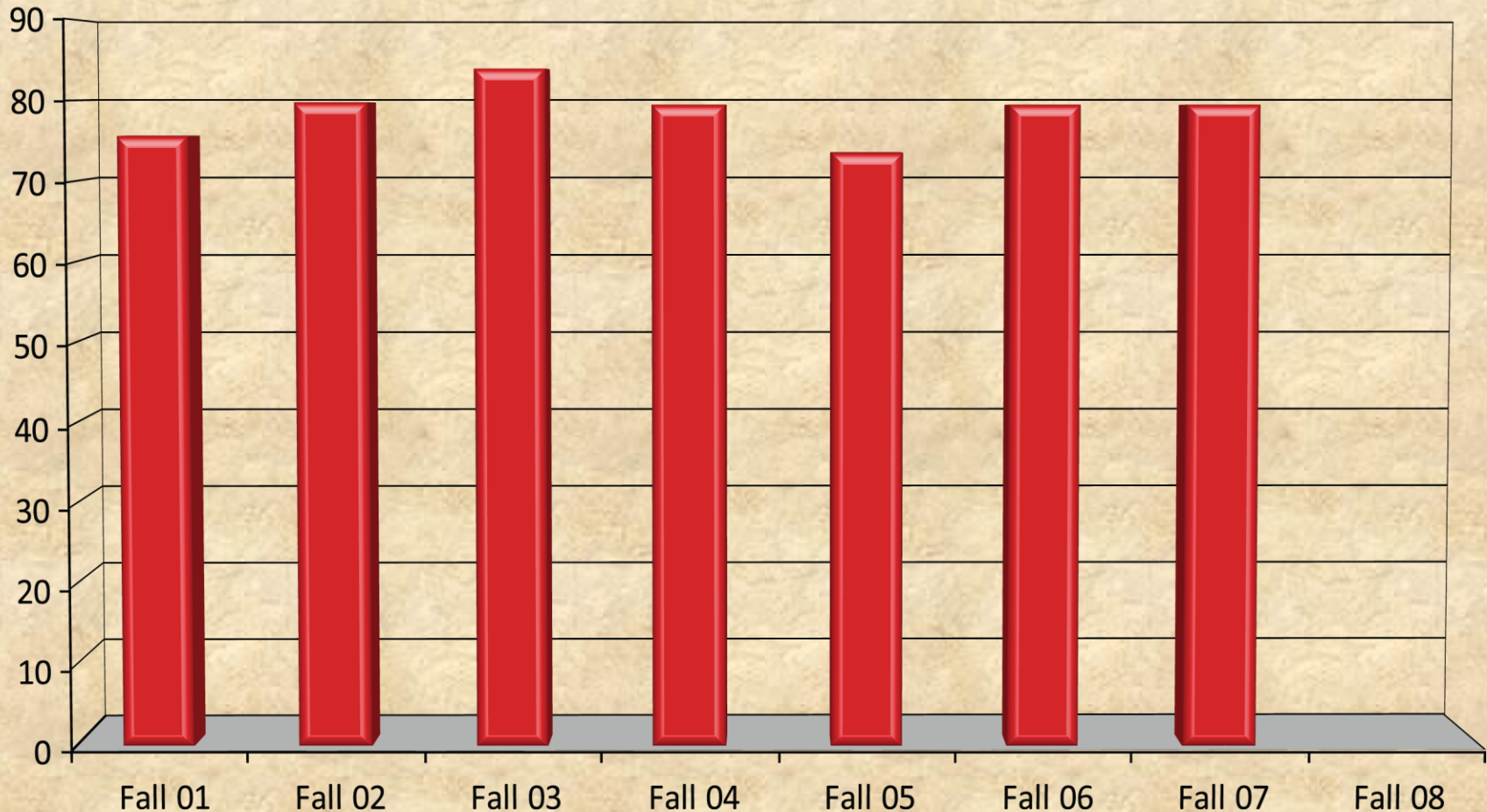
End of Term Survey: Students asked to rate items on a 5 point scale

Example: Rate this course in terms of difficulty

(1: one of easiest, 3: average, 5: one of most difficult)

Plot fraction of students who responded with 4 or 5

Course Difficulty



Student Perceptions

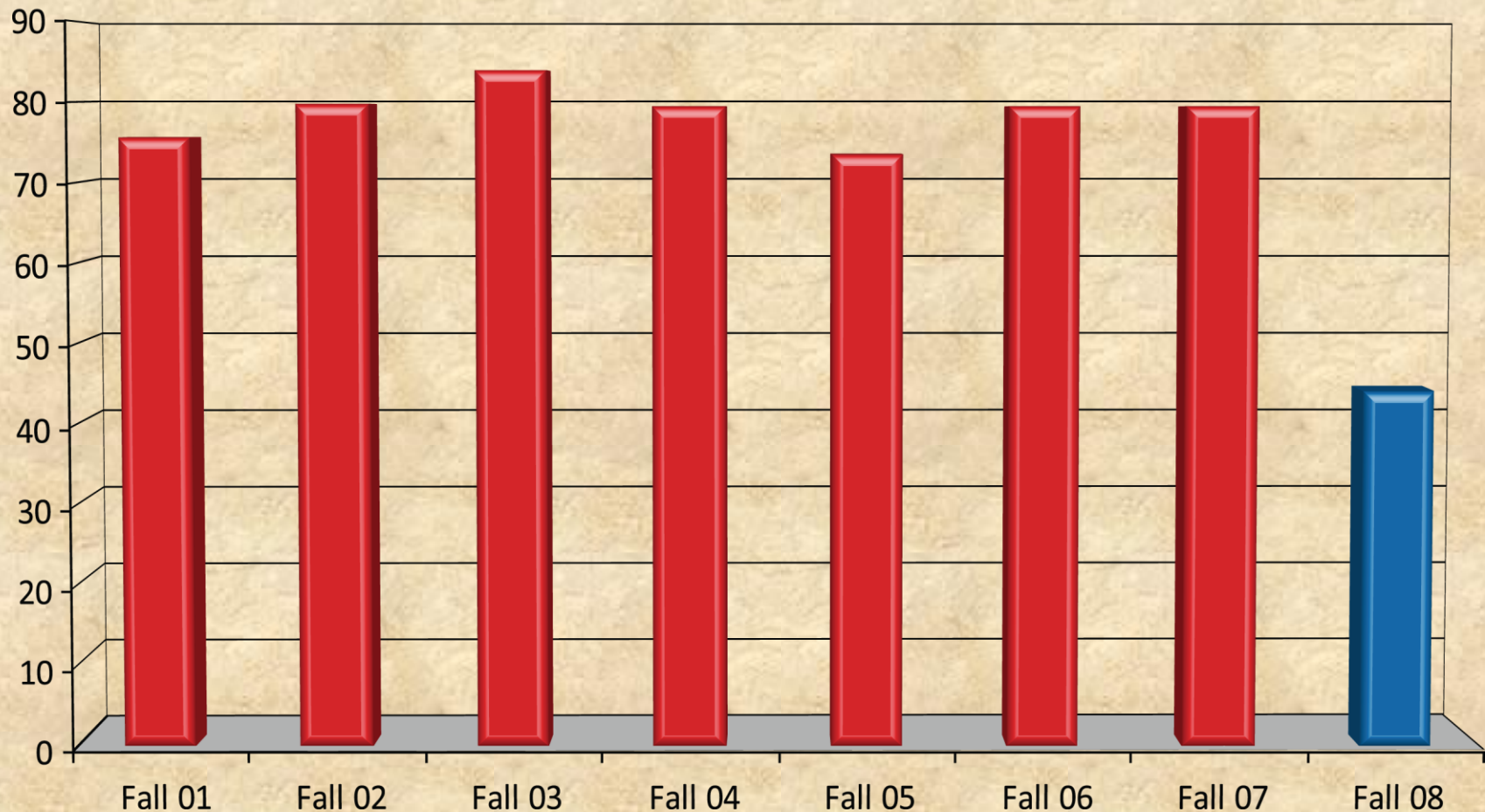
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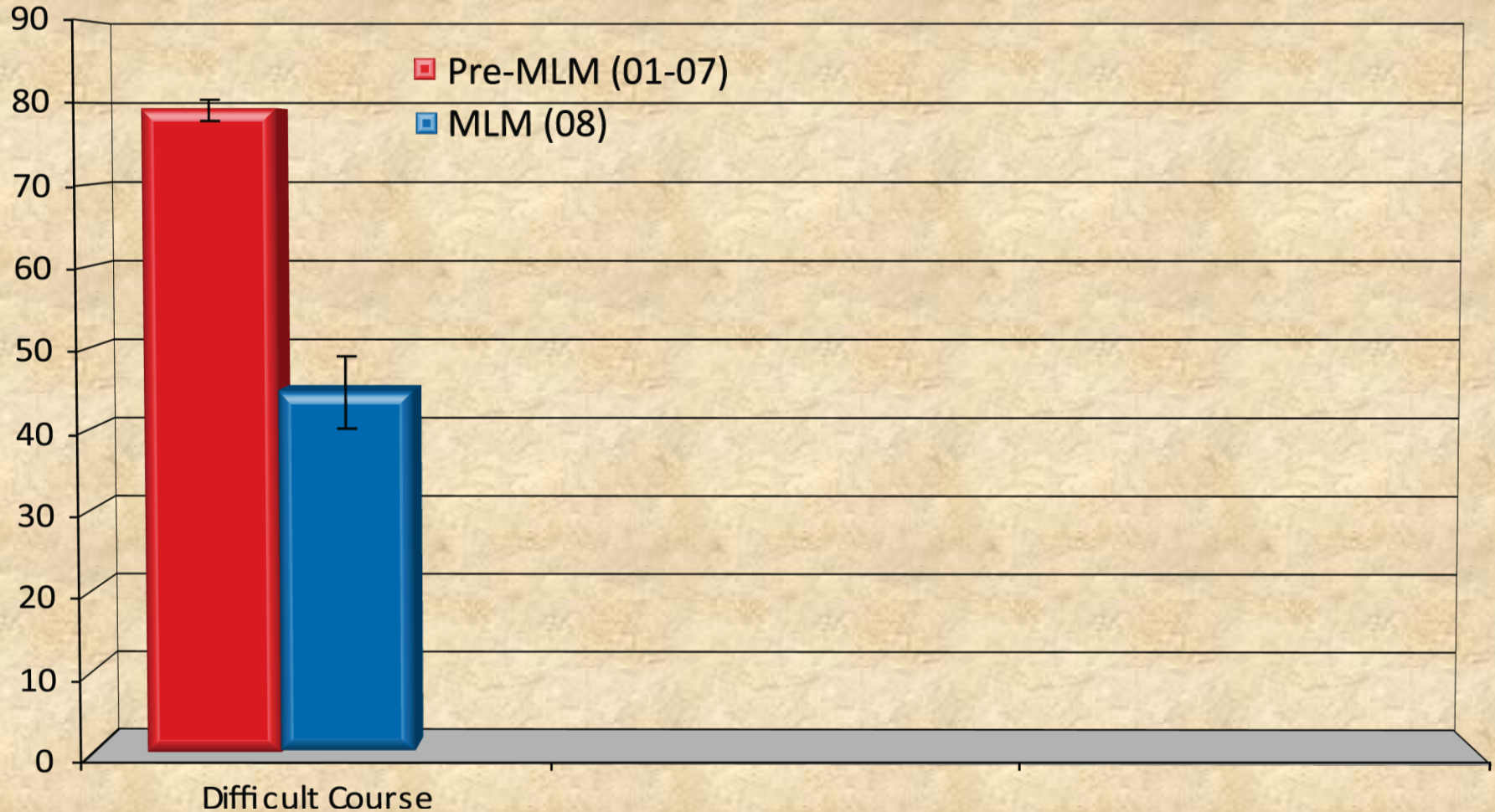
Plot fraction of students who responded with 4 or 5

Course Difficulty



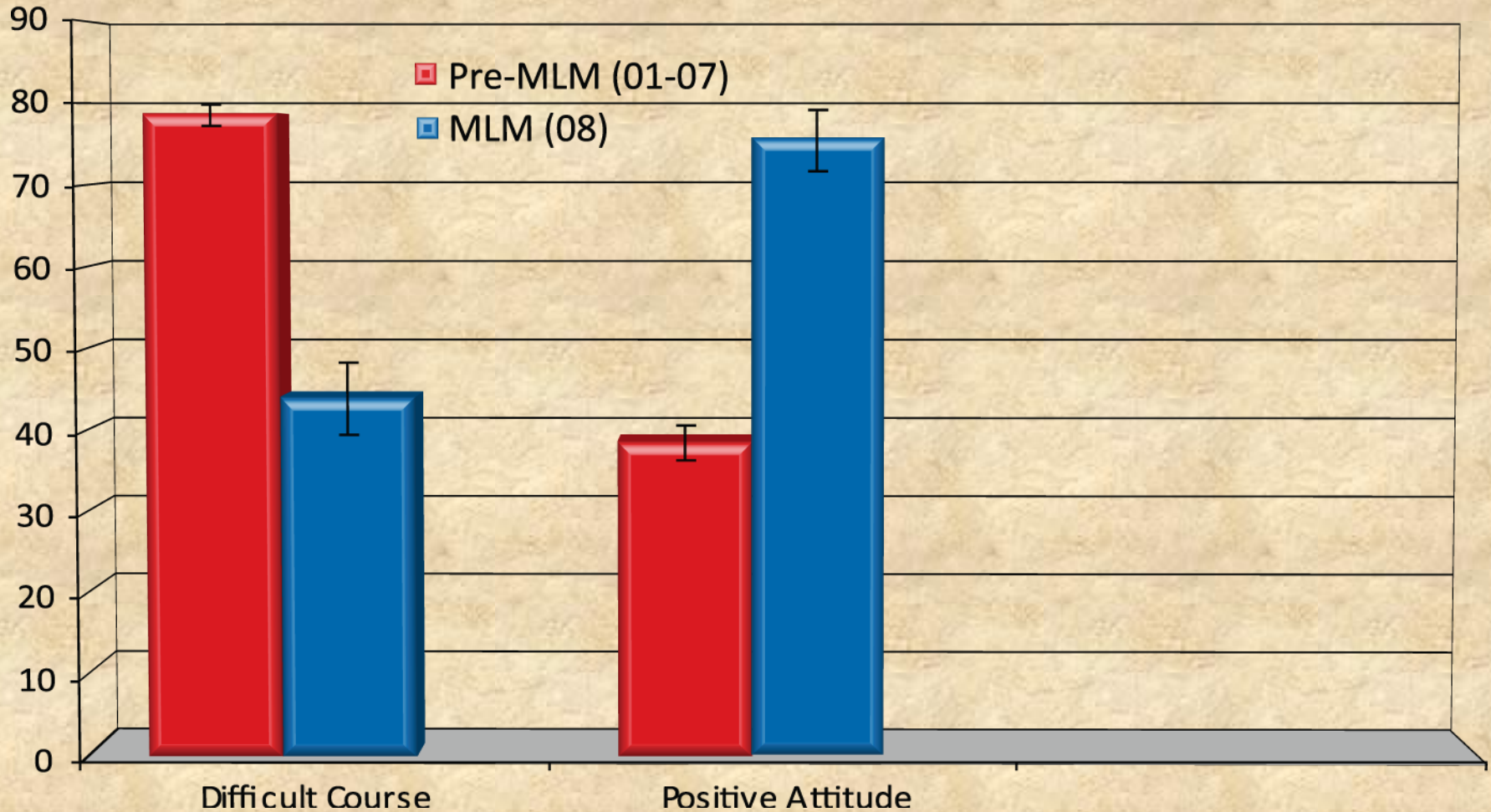
Student Perceptions

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