MOOCs, Online Education, & Learning for Physics Department Heads, Chairs, …

Opinions, Examples, and Advice
- much from MIT & RELATE

Prof. Dave Pritchard and his RELATE.mit.edu Group

REsearch on **L**earning **A**ssessing and **T**utoring **E**ffectively

http://RELATE.MIT.edu

Understand and Improve Learning:

Research→Develop→Test (Measure)→Recycle

S. Rayyan, R. Teodorescu, A. Pawl, Y. Bergner, A. Barrantes, D. Seaton,
C. Fredericks, J. Champaign, K. Colvin, Z. Chen, Dave Pritchard



Why Reform (Improvement) Is Essential

NRC Report: Adapting to a Changing World

- Internet Age → Expertise>> Knowledge
- Serve the 99% who don't major in physics
- Research: Traditional Instruction Works Poorly
  - Reformed Education gives Greater Learning
- Make Physics More Attractive vs. Other Sciences

GOAL: Increase Learning

- Reduce Cost of Education

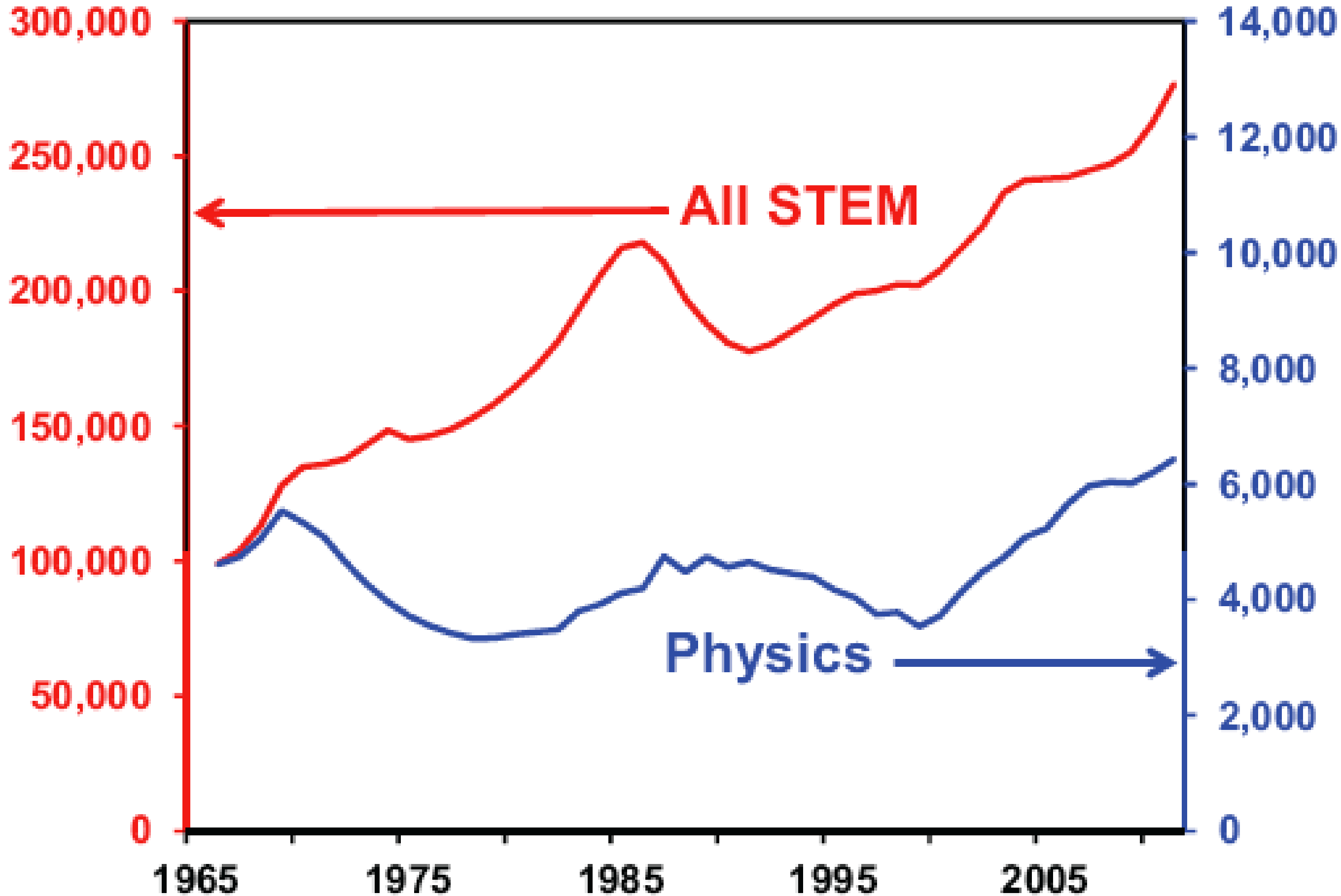
Nat'l Center for Academic Transformation

KEY to Successful Reform:

Evidence/Assessment/Measurement

Must Measure How Well it Works

Physics B.S. degrees vs. STEM



NRC Report 2013: **Adapting to a Changing World** – challenges and opportunities in Undergraduate Physics Education

Sheila Tobias: "I was shocked at my first AAPT meeting. The professors looked at Physics 1 as a *filter,* preferably for HS students who had had AP physics. I didn't have psychology in HS, and *Psychology 1* made me decide to major in psychology."

Your Desires

1. More Student Learning
2. Less cost (especially faculty effort, etc.)

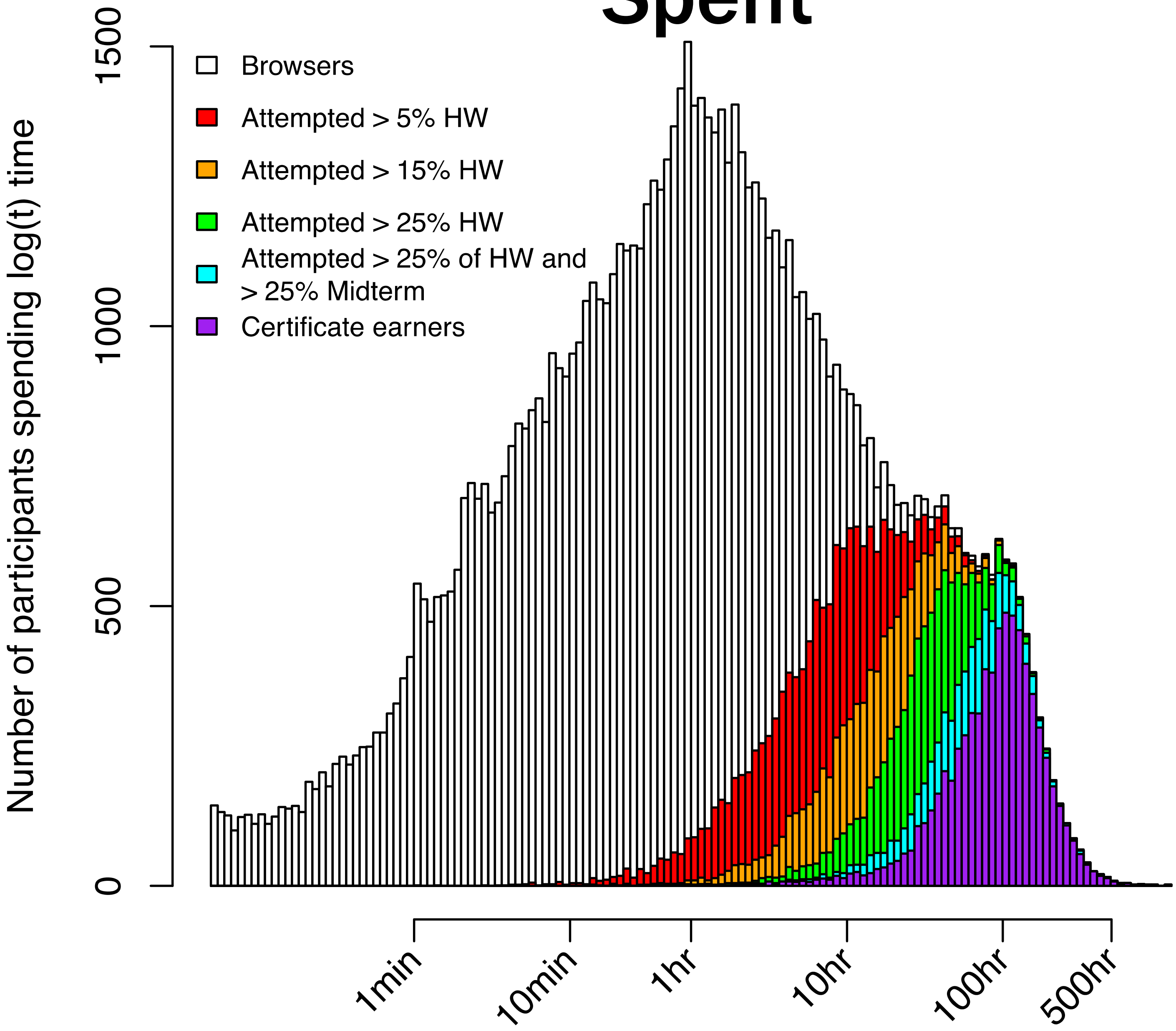
1. Learn about MOOCs
2. Online Homework with Personal Tutoring?
3. Blending (Flipping) using Online Resources
4. Helping Students “Think Like Physicists”
5. Reusing the Department’s Good Resources

MOOCs Often Traditional Course Put Online

Traditional Course	6.002x Online
• Lectures	• Lecture Videos
	• Lecture Questions
• Textbook	• e-Textbook
• Recitation	• TA Tutorials
	• TA-Student Wiki
• Homework	• Homework
• Laboratory	• Circuit Simulator
• Student Discussions	• Discussion Forum
• Office Hours	

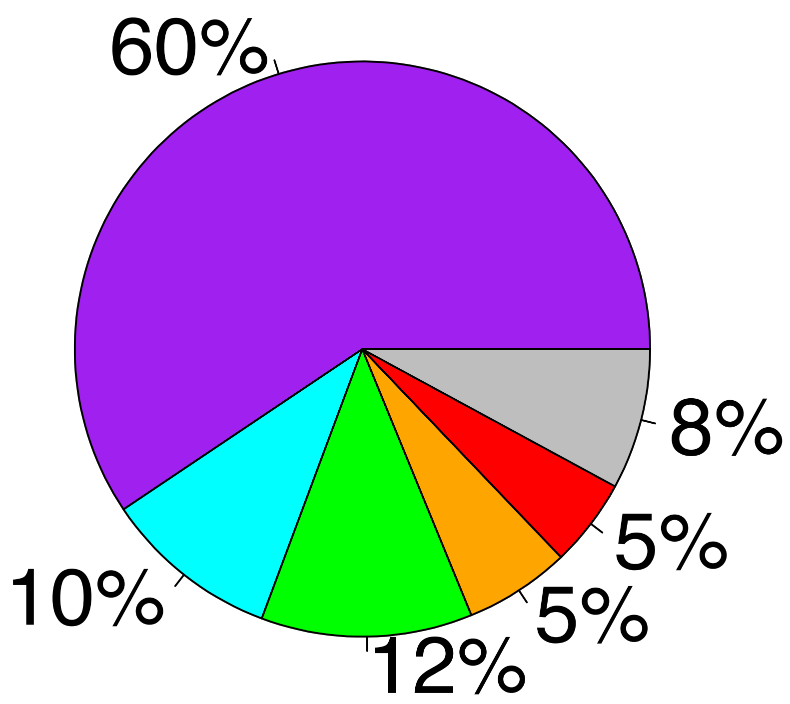
We can observe students in a traditional course structure

154k→108k Participants -Total Time Spent

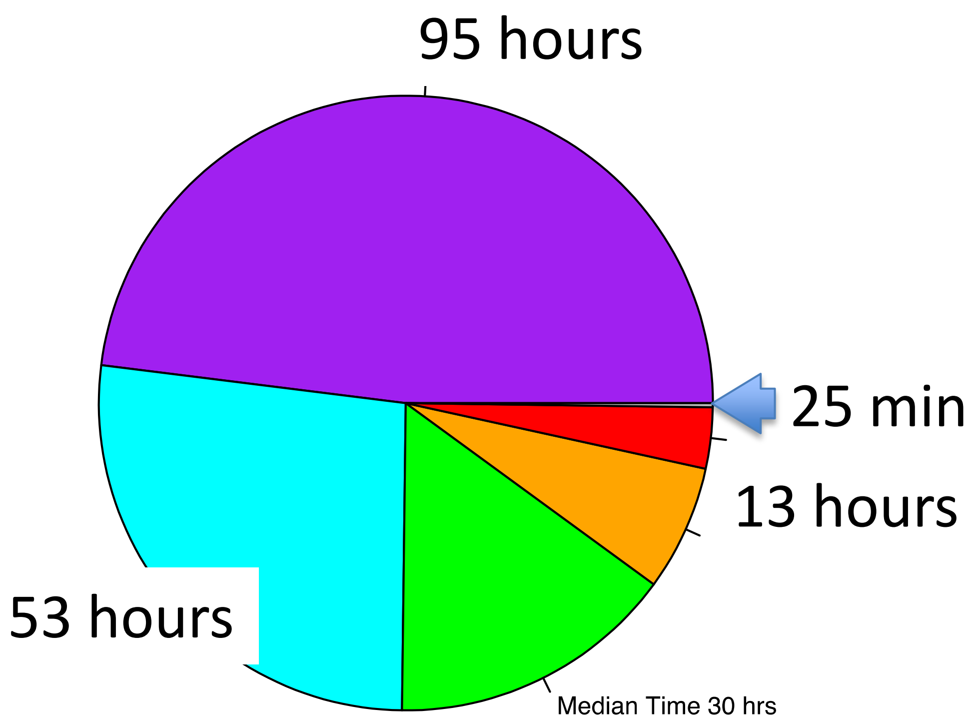


Time for Each Group

Fraction of Total Time in System

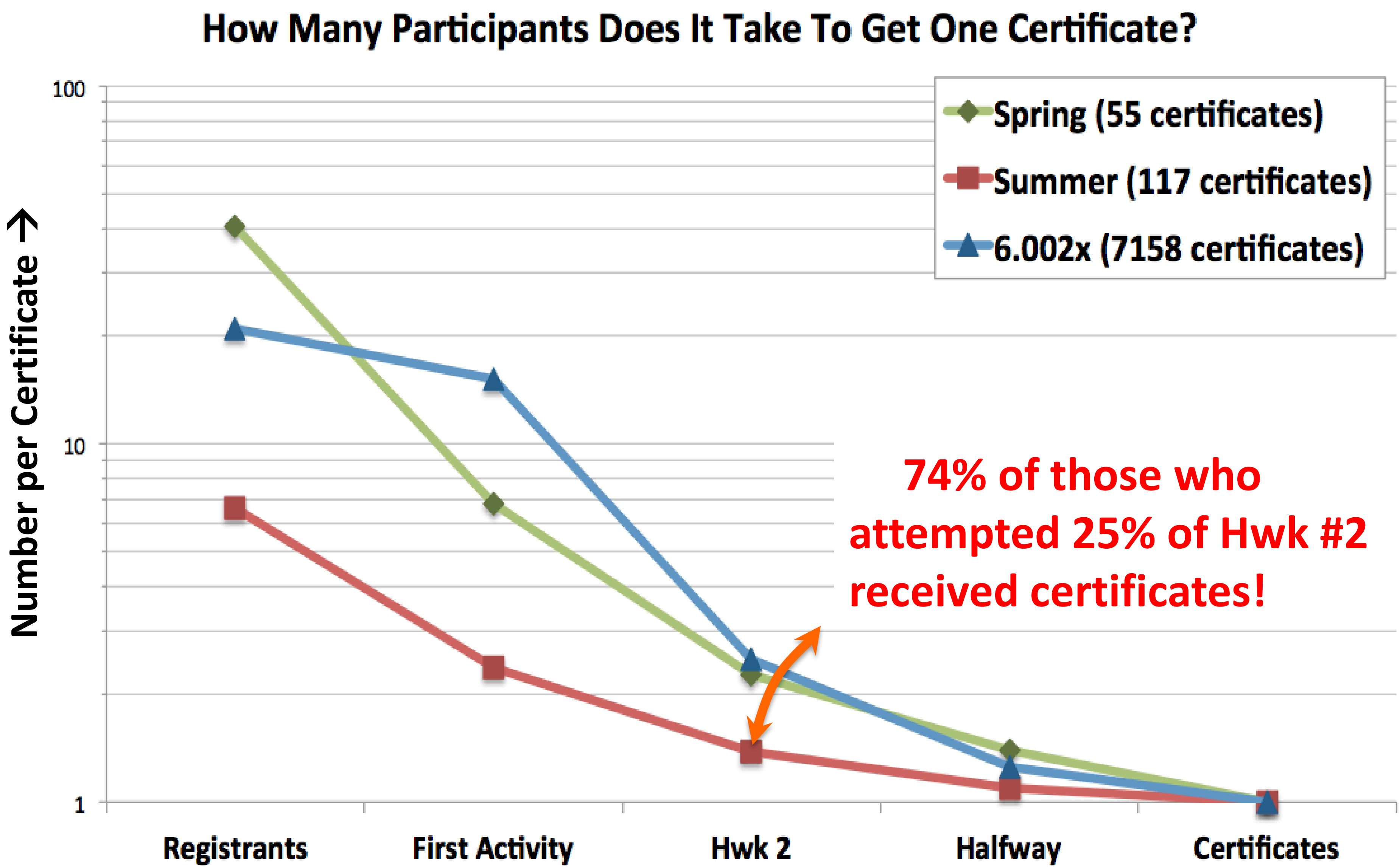


Median Time of Group



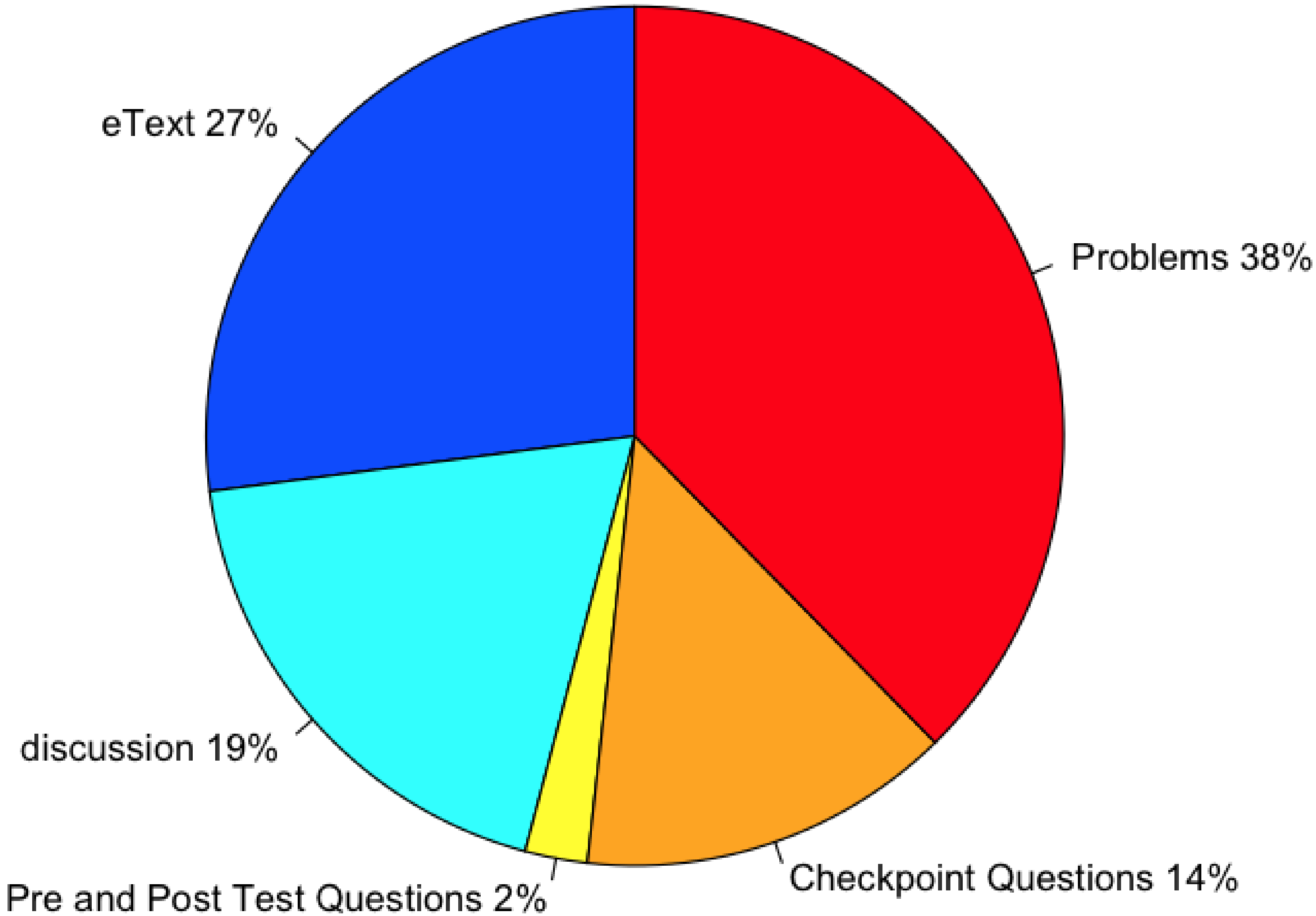
Pritchard http://RELATE.MIT.edu

Attrition/Retention by Key Event



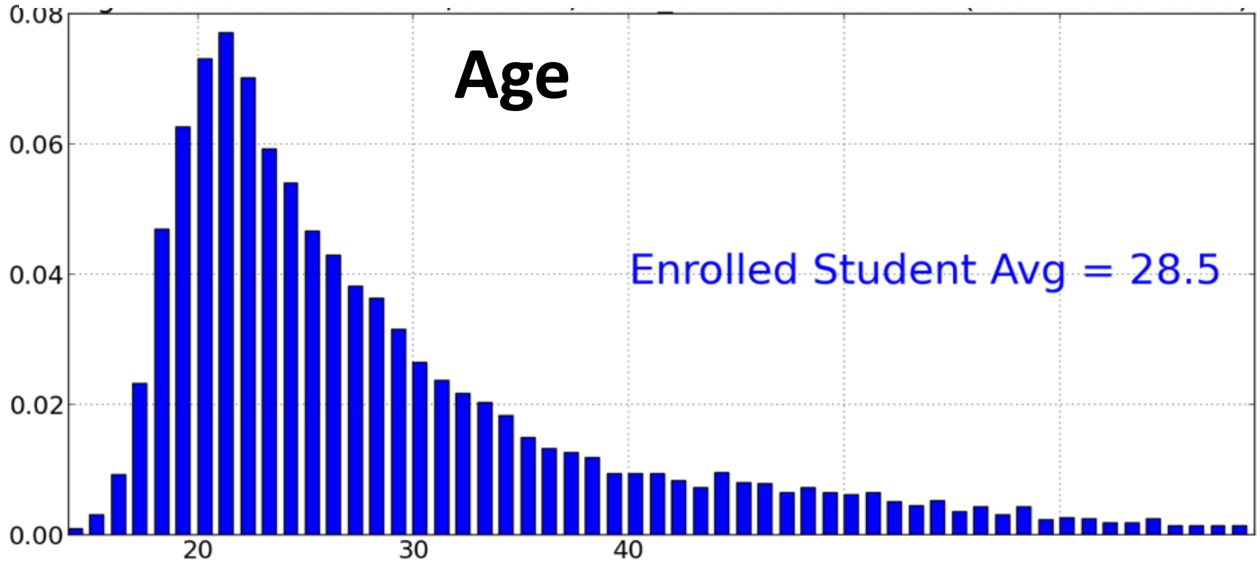
Pritchard http://RELATE.MIT.edu

8.MReV Where Students Spent Time



People who finished the course (n=1080) Note that cool colors indicate instruction and warm colors indicate assessment

Demographics 8.MReV Summer 2013

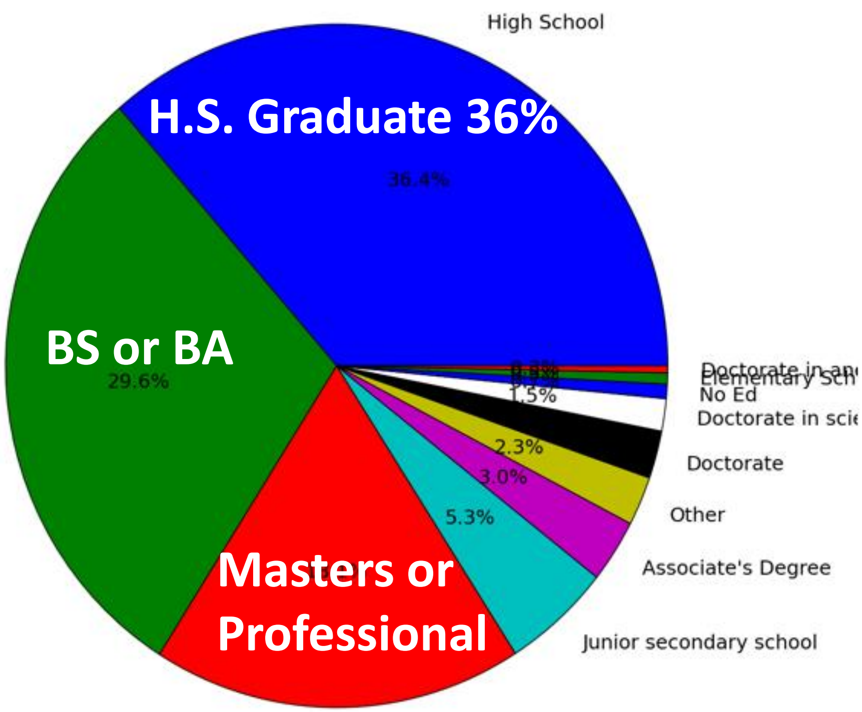


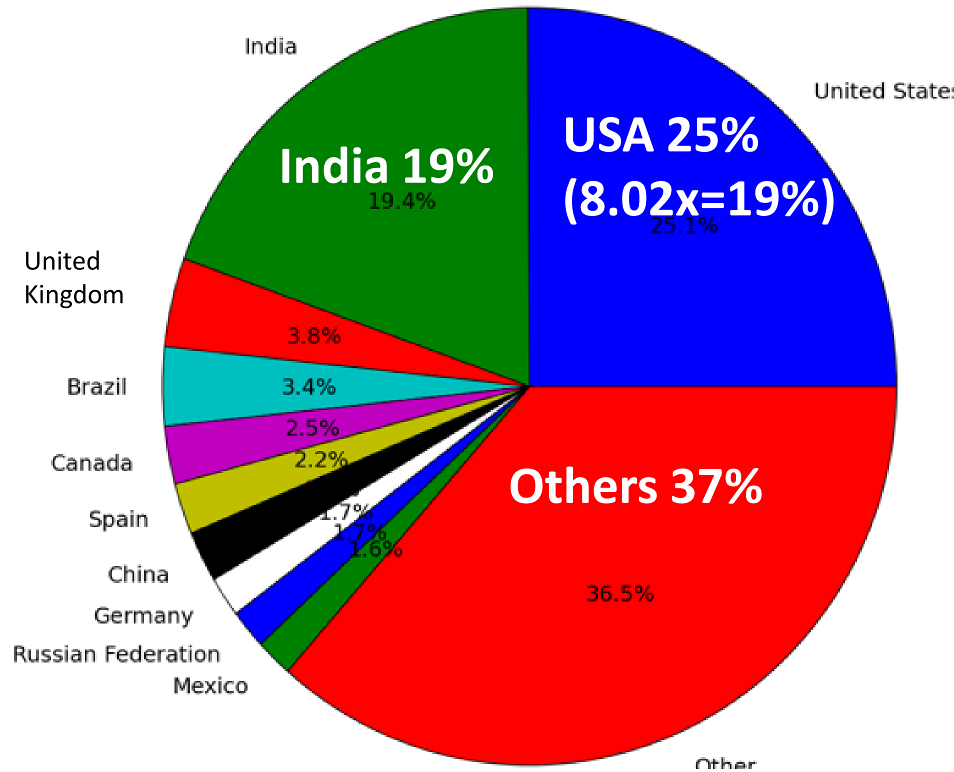
Audience

25% Physics Teachers

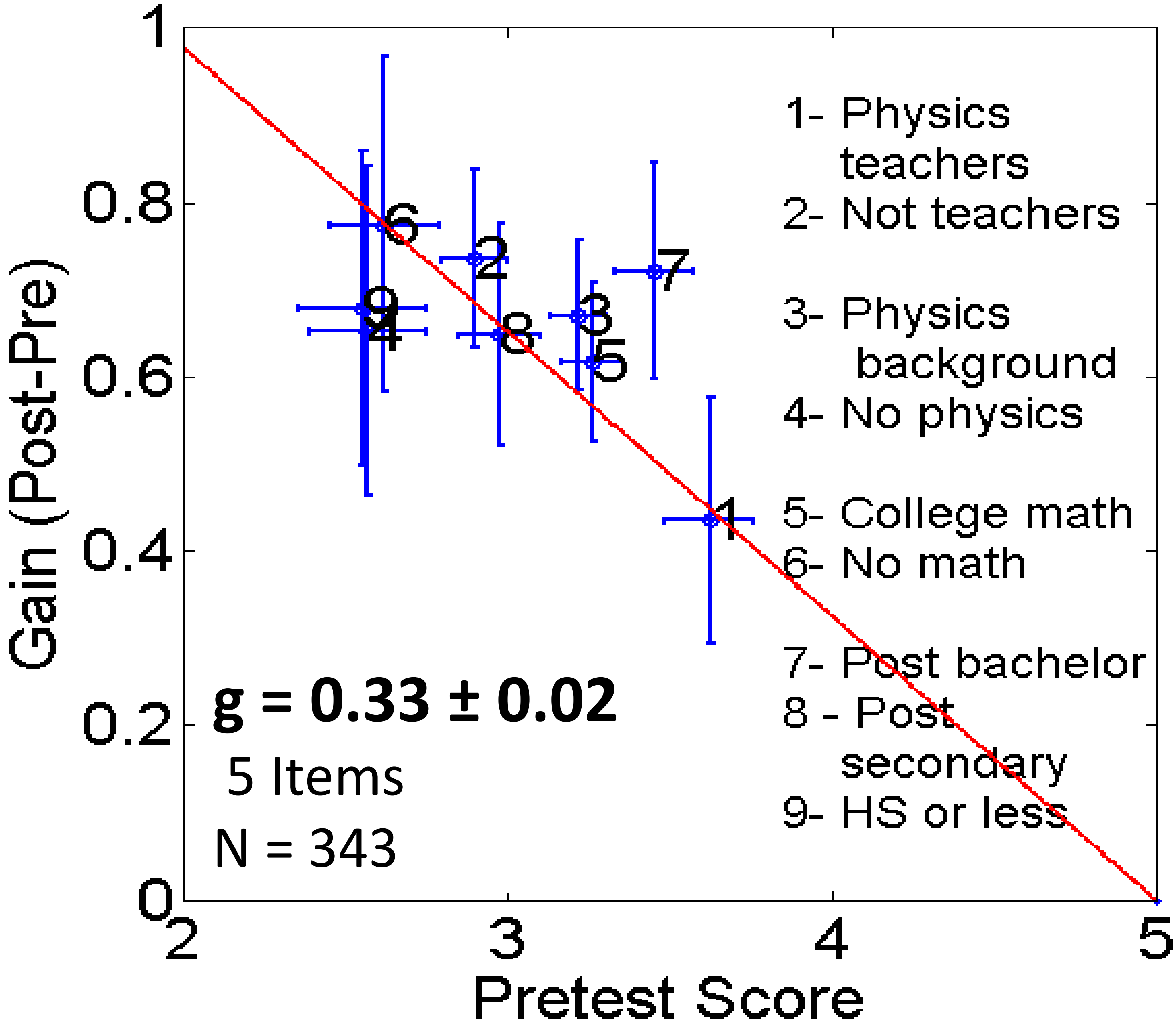
19% Female

Est. ~ 1200 certs





Non-Force Concept Questions 8.MReV



What We Learned About MOOCs at MIT

1. Conceptual Learning > Lectured Classroom
2. Learning same for unskilled as skilled
3. Lots of work
4. Incredible effort checking & rechecking
5. Walter Lewin (~10^6 Google hits) drew only ~2000 certificate earners, mostly professionals → no plans to continue

DO NOT make a MOOC for:
Fame, Glory, or your College President

MOOC: Sprouting Seeds of Self-Destruction

Network TV challenged by Internet

MOOCs trying to invent network education

Digitizing Dinosaur of Lecture-based Education

Should start with Personal Tutor

Typically only 2k get *free* certificates - just over 100k certificates given for first ~30 courses

No emerging business model for financial success

MOOC: Why They're Good

Blending, Research, Reduce Cost of Education

Online Education Now Seriously Considered

Blend with your class → more interaction with students

Can spread good pedagogy, professional development

Enable profs to teach&learn higher level or special classes

Use for Targeted Audiences (e.g. professional ed, students for NY Regents, physics in Swahili)

Education Research: Exptl-control studies w. large N

Research, Develop, and Deploy Researched Resources

Mine MOOC data, recommend best help for individual

Most Importantly, They Force us to Ask:

What are students getting for their $40,000?

Online: Increase Learning and Efficiency
USE ONLINE INTERACTIVELY

Blend for More Interactive Classroom

TEAL uses Peer Instruction for Concepts

Make a Socratic Homework Tutor

Teaches Students to do MIT Exam Problems

Data Mining and Specific Learning

Try to Help Students Become Expert

Modeling Applied to Problem Solving

Using Online, especially to reduce costs: http://www.thencat.org
National Center for Academic Transformation

Blending – aka "Flipping the Classroom"

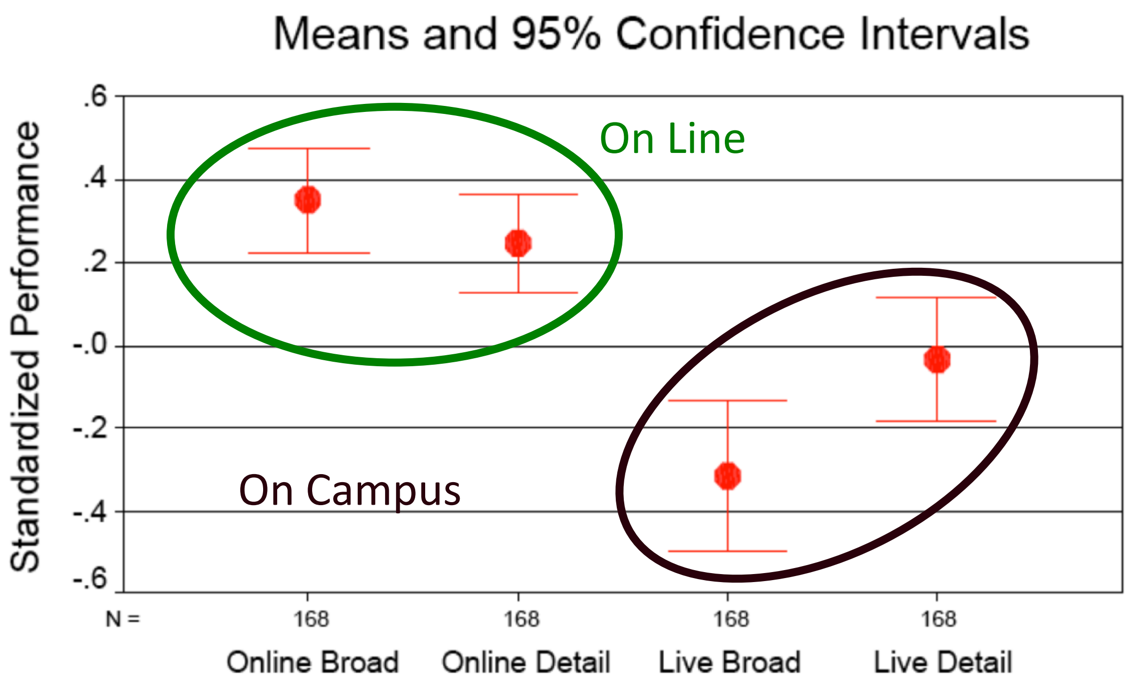
- Information Transmission:
  - Replace Lectures with Video Lectures
  - Or Ensure Students Read Text with Quiz
- Use Class time for Faculty-Student interaction
  - Peer Instruction – "clicker questions"
  - Student Groups doing Problems with Comments
  - Student presentations
- TEAL – Mostly Peer Instruction & Results

Conceptual Learning Only

Lecture Capture > Live Lectures

J. Newman, Tomas Lozano-Perez, and Eric Grimson

Students using Lecture + Transcript + Search OutPerformed students attending Real Lecture



Recent Lecture Capture Incorporates FAQ's to the TA,
some with Lecturer Elaboration, discussion groups

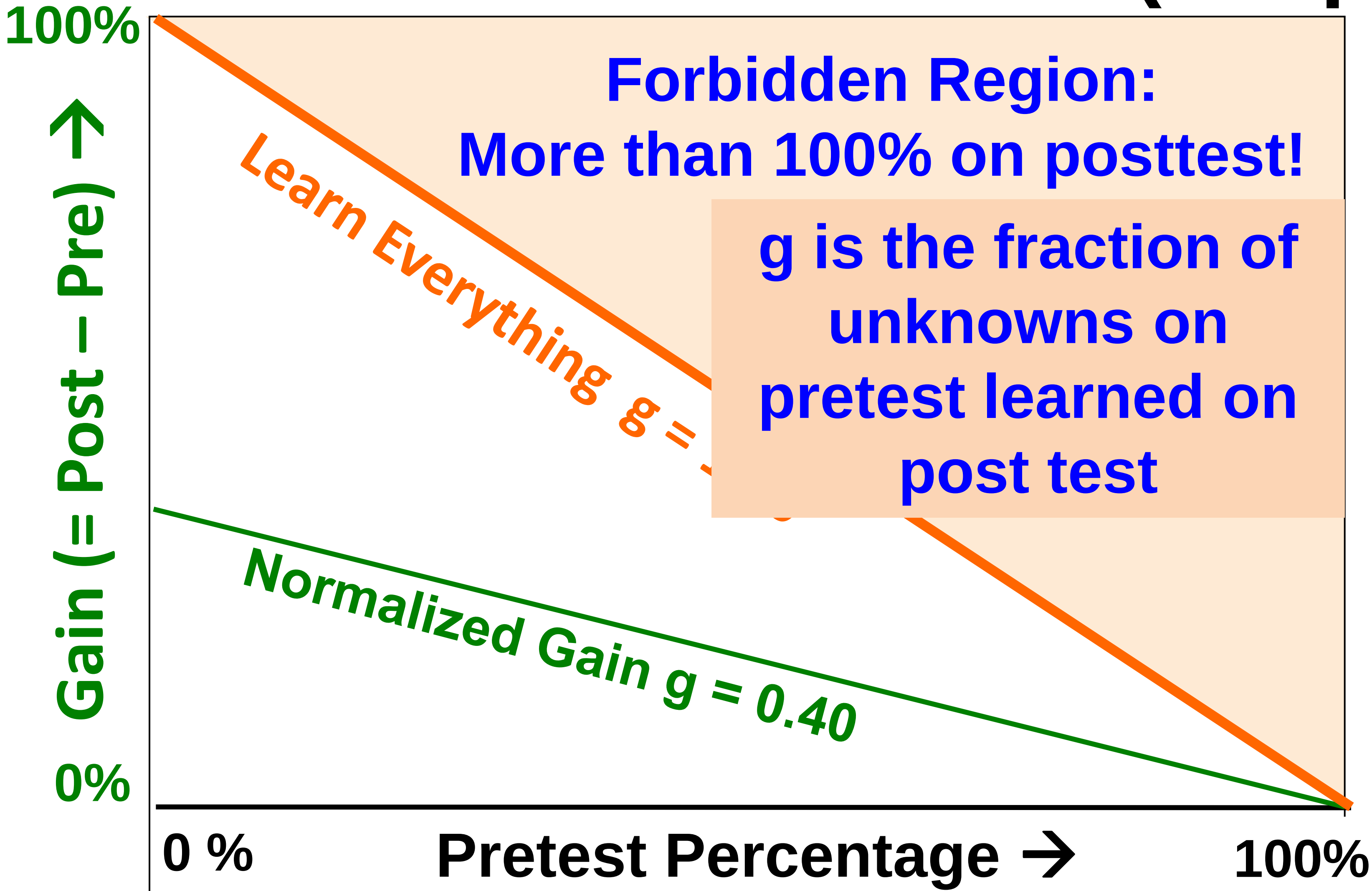
Assess Courses by Measuring Learning (vs. student approval ratings)

Use Same Exam with Same Grading Rubric to Assess this year's changes wrt. Last year

Use Standard Instrument

- Give Same Test *pre- and post- instruction*
- See if there is Improvement, Gain = (post-pre)

Gain and Normalized Gain (-slope)



Normalized Gain $g = \dfrac{\text{Gain (= Post – Pre)}}{\text{100\% - Pre}}$

Research-Based

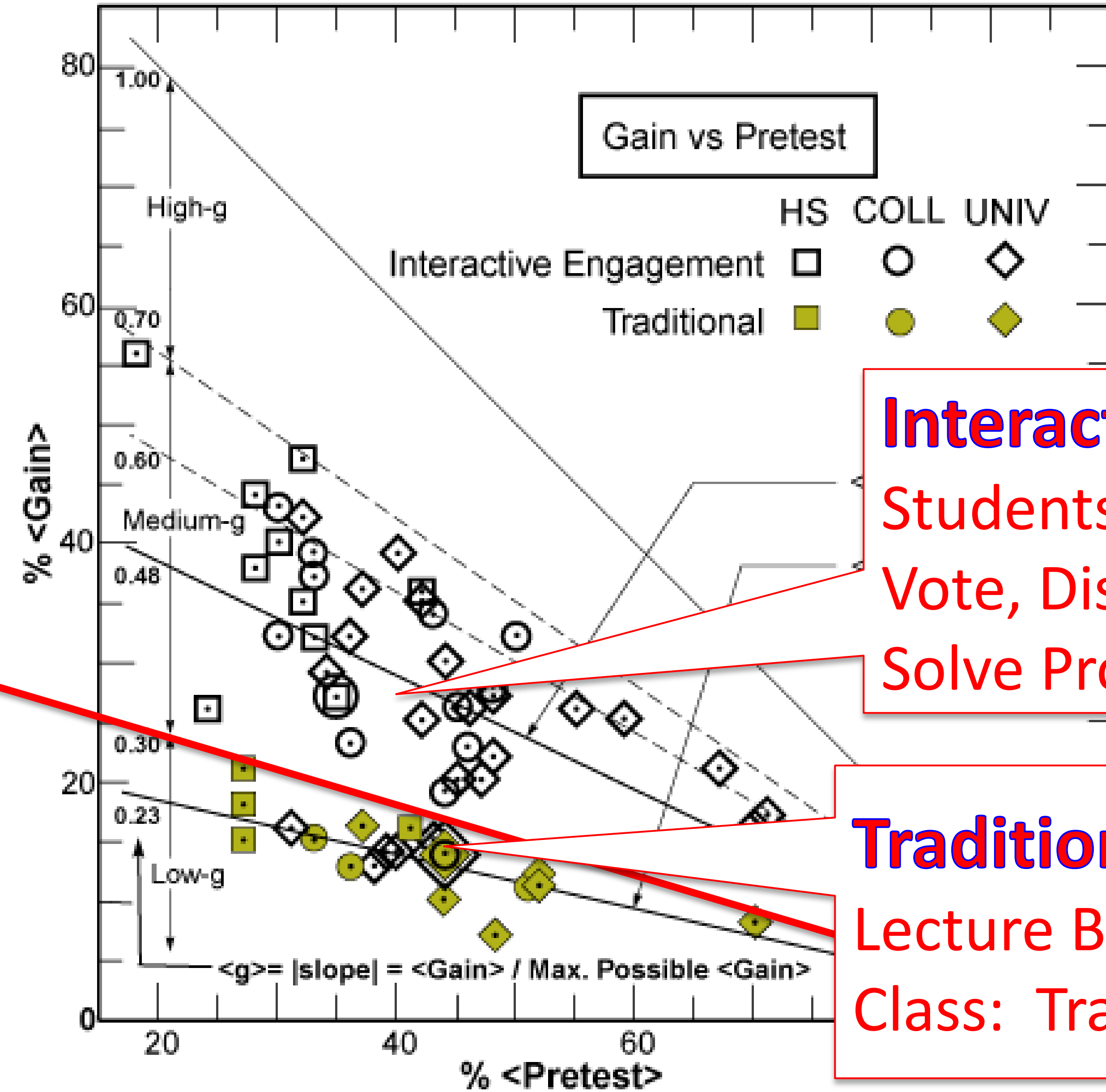


Fig. 1. %<Gain> vs %<Pretest> score on the conceptual Mechanics Diagnostic (MD) or Force Concept

From R. Hake's study of 6545 students in 62 classes. HS→Top College

Interactive Engagement

Students **DO SOMETHING**

Vote, Discuss, Explain, Write, Solve Problems in Groups…

Traditional Instruction

Lecture Based

Class: Transfer Information

Peer Instruction (Thanks, Eric Mazur)

Key technique for Interactive Engagement

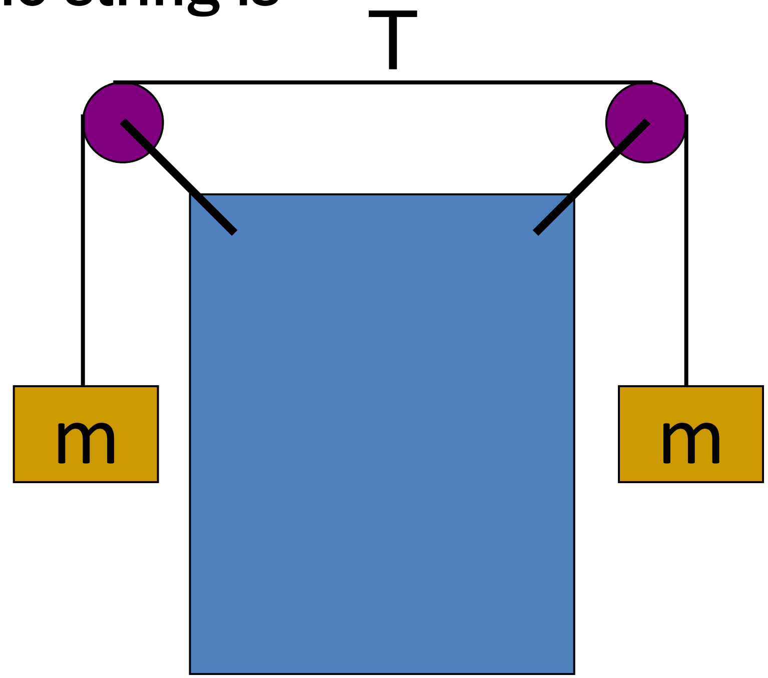
- Pose Concept Question to Class
  - Students vote with Clickers (or Colored Cards)
  - If not 30%-70% correct, dismiss or discuss
- Have Students Discuss with Others (Peers)
  - Revote with Clickers
    - Not enough progress? - prof. comments & Repeat
- Prof. and Class Discuss Key Lessons

Students Discussions at Table

Concept Question: Tension in String

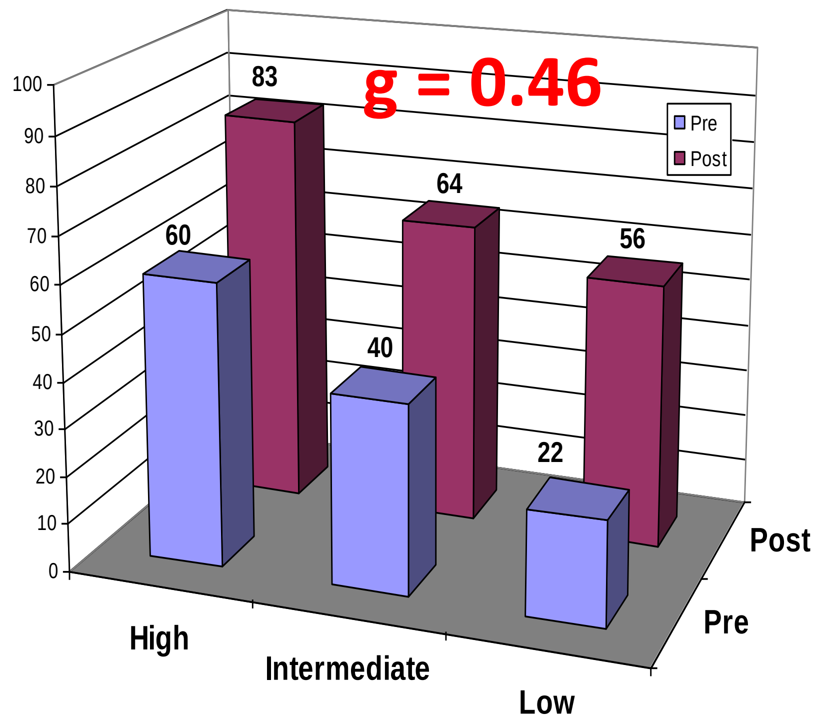
The tension T in the middle of the string is

1) m
2) 2 m
3) m/2
4) m g/2
5) m g
6) 2 m g
7) Need to know velocities
8) Not sure



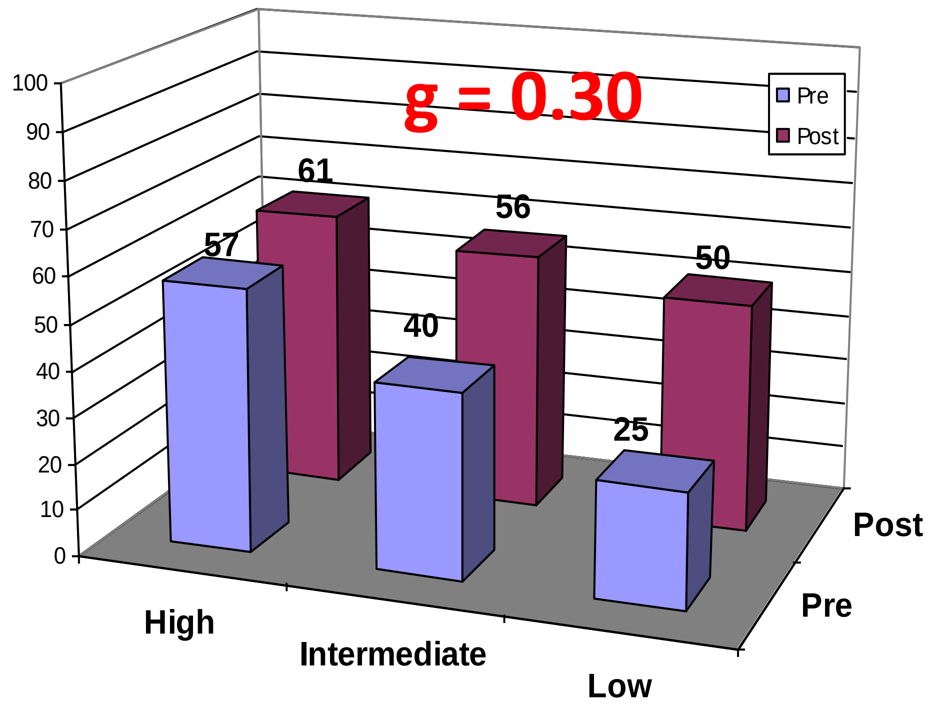
Pre/Post Conceptual Test Scores

N students = 176



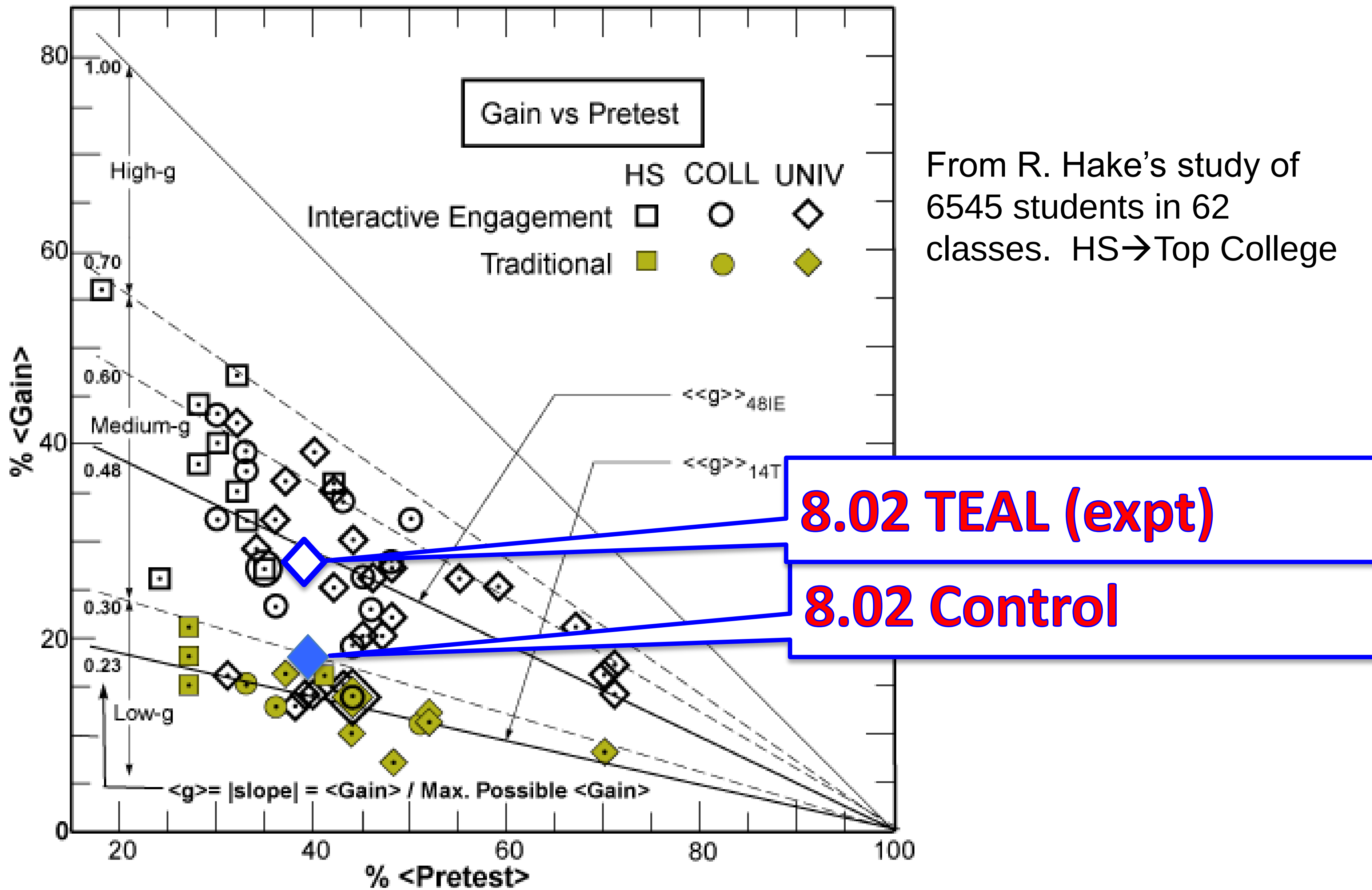
Experimental group - Fall 2001

N students = 121



Control group - Spring 2002

Gain (posttest – pretest) vs Pretest



From R. Hake's study of 6545 students in 62 classes. HS→Top College

Fig. 1. %<Gain> vs %<Pretest> score on the conceptual Mechanics Diagnostic (MD) or Force Concept

Homework Tutor (not Administrator)
MasteringPhysics.com (DEP & son Alex)

A Socratic Personal Tutor for Homework
Used by ~300k students last year in Physics

Improve Learning &
Eliminate Time Grading

Students Have Trouble With Homework

Late at Night (when they do it) there is No Help

→Make Online Tutor to Help Them

MasteringPhysics.com Design Philosophy

Online Socratic Tutor is impersonation of Expert Human Tutor – best educational approach

Assess Appropriate Response

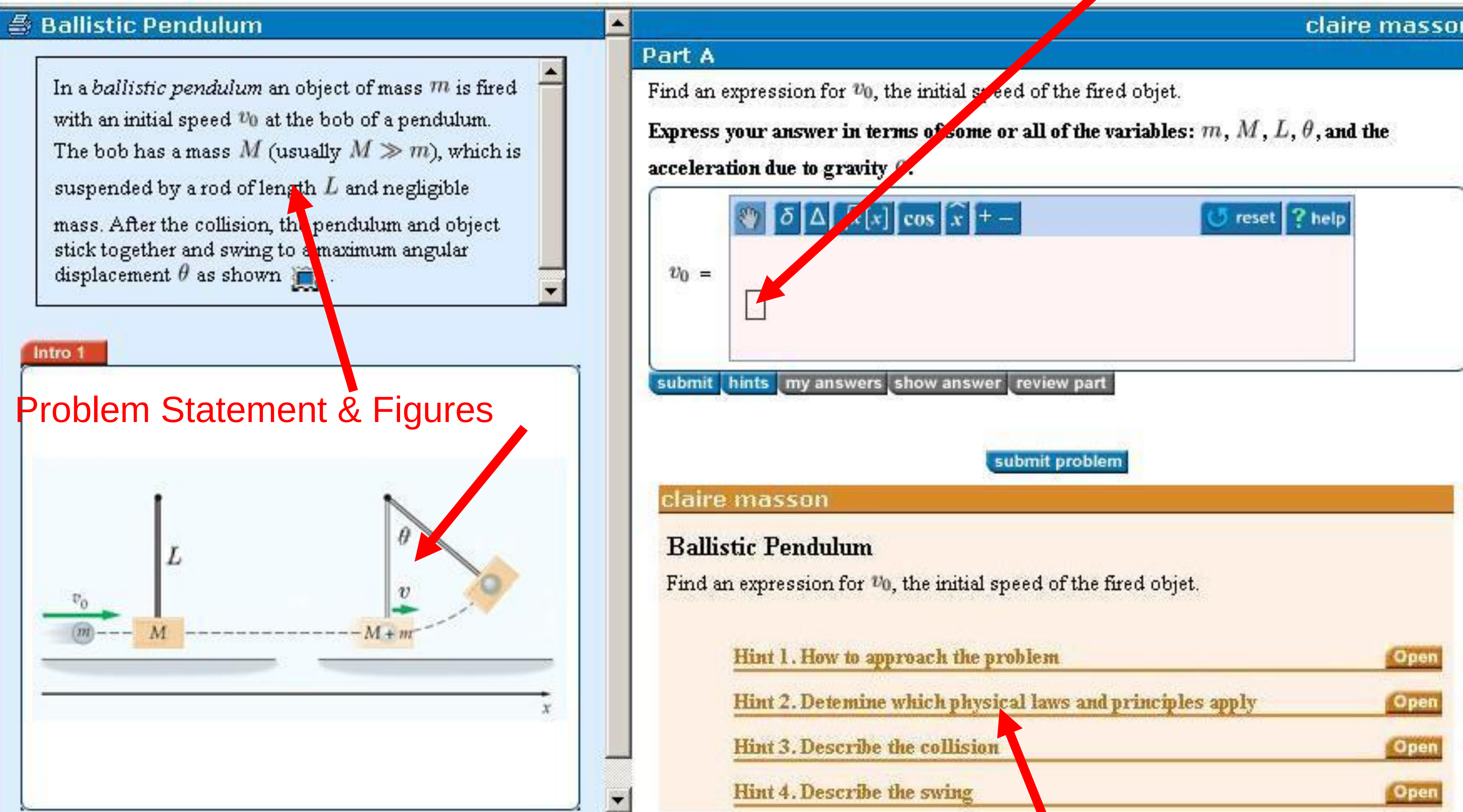
Part of Grade

The tutor provides detailed assessment

Data Mining and Analysis Improves the Tutoring

Online Tutor with Socratic Pedagogy

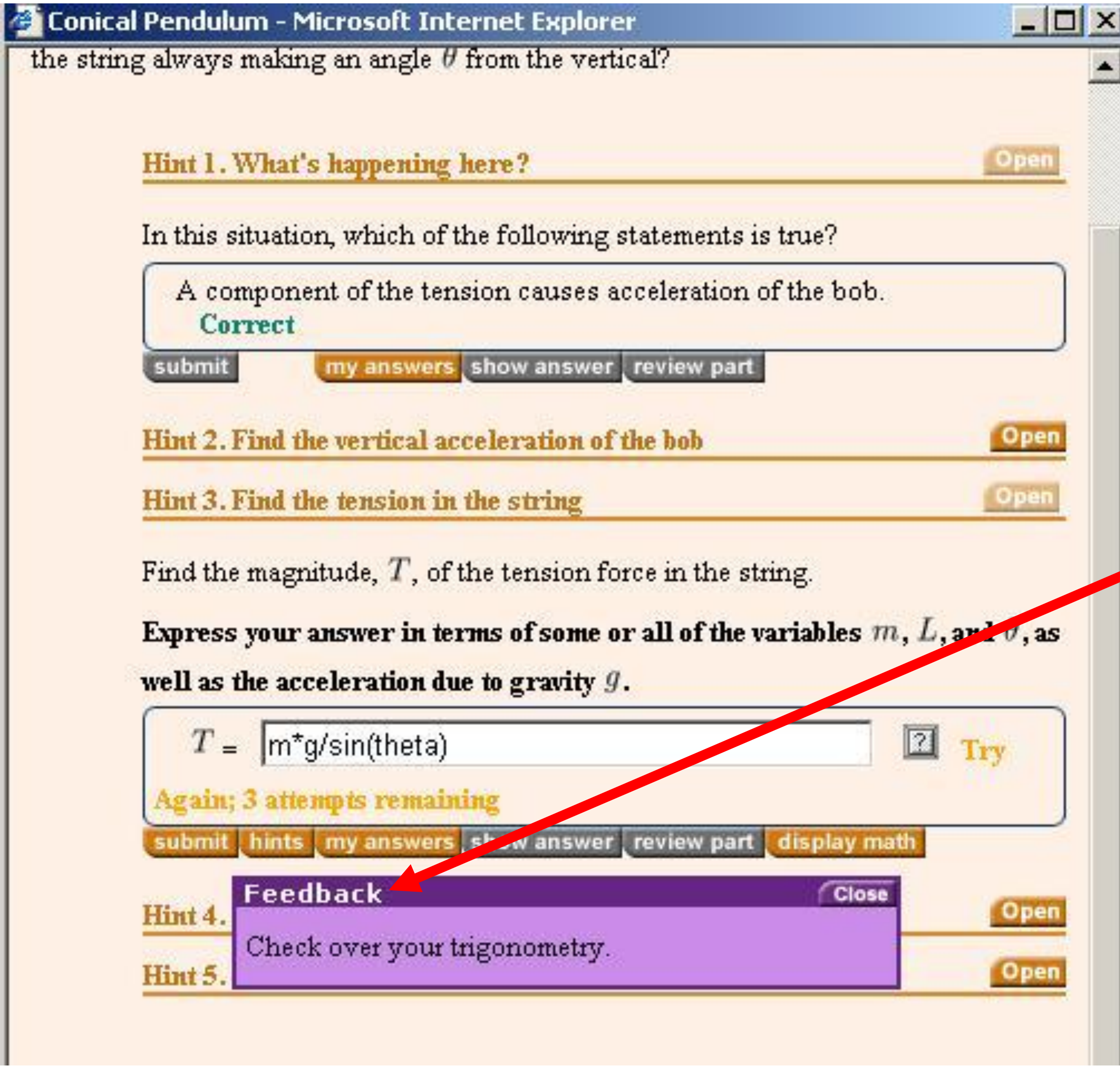
Demand Appropriate Response



Problem Statement & Figures

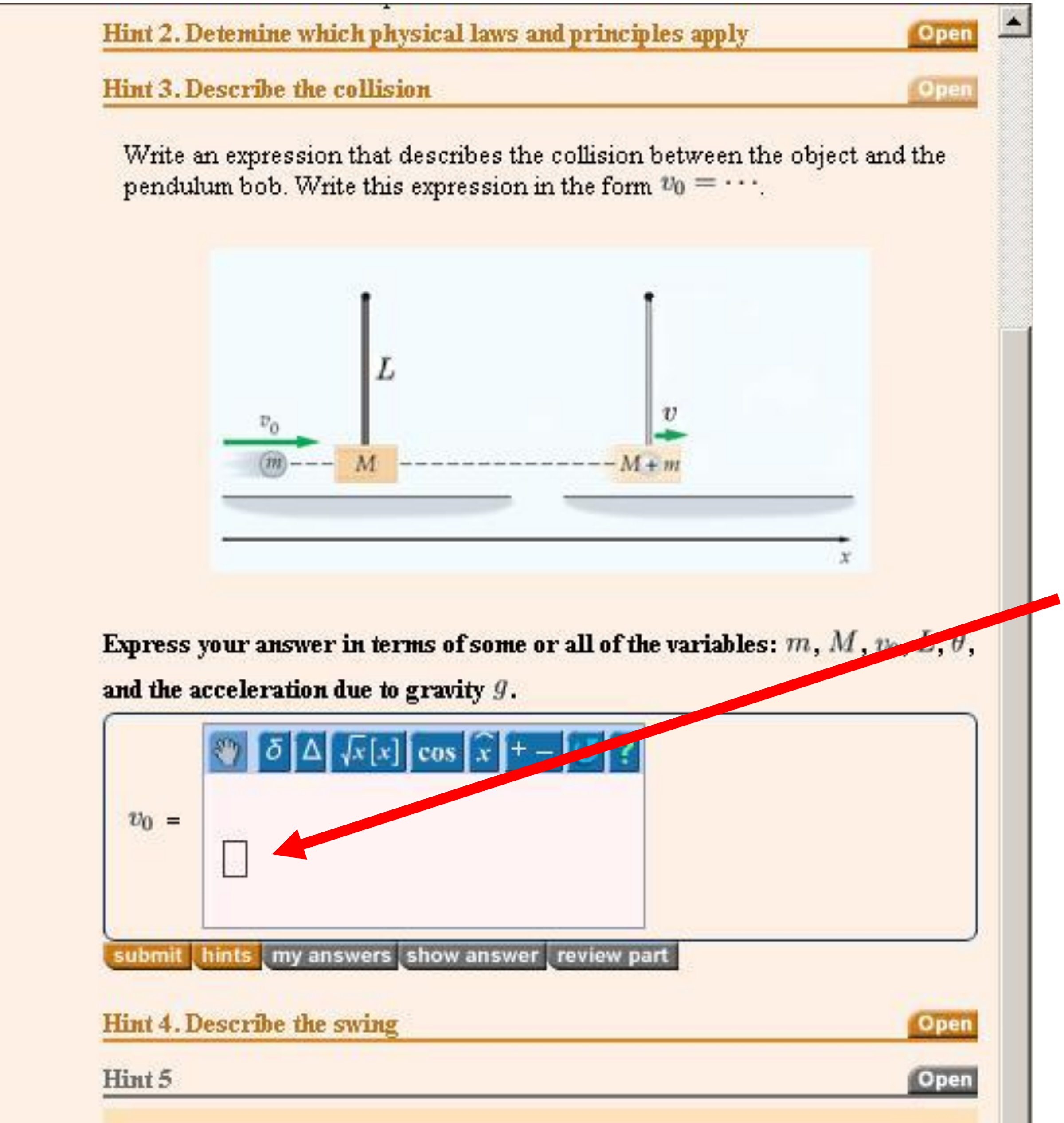
Requestable List of Hints (plan of attack)

Specific Wrong Answer Feedback



Feedback Addresses Particular Error(s) in Student's Response with advice or challenge

Students can Request Hints



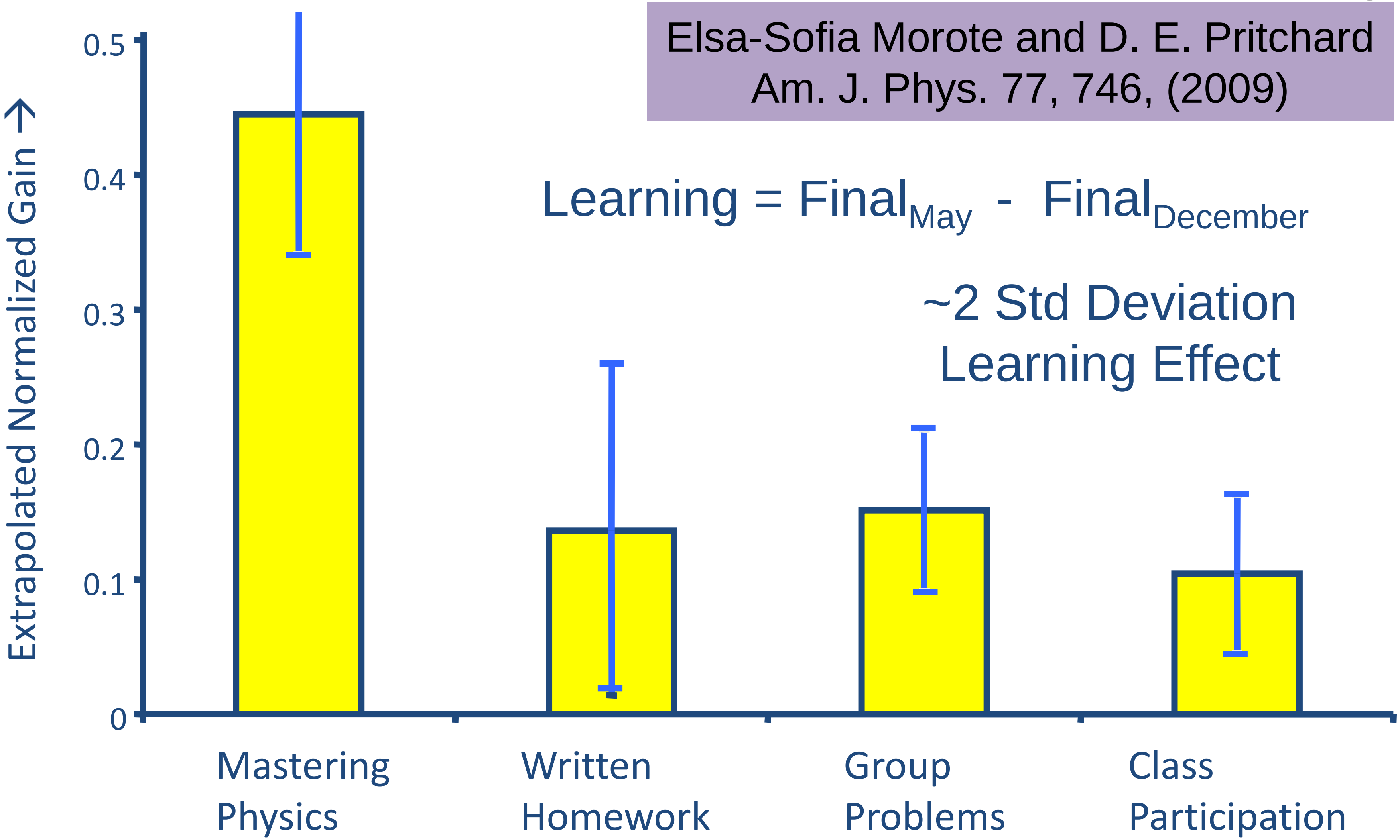
This hint is a SubTask

It Requests a Response that helps answer the main question.

Responding is optional, although informative.

What Course Elements Correlate with Learning?

Elsa-Sofia Morote and D. E. Pritchard
Am. J. Phys. 77, 746, (2009)



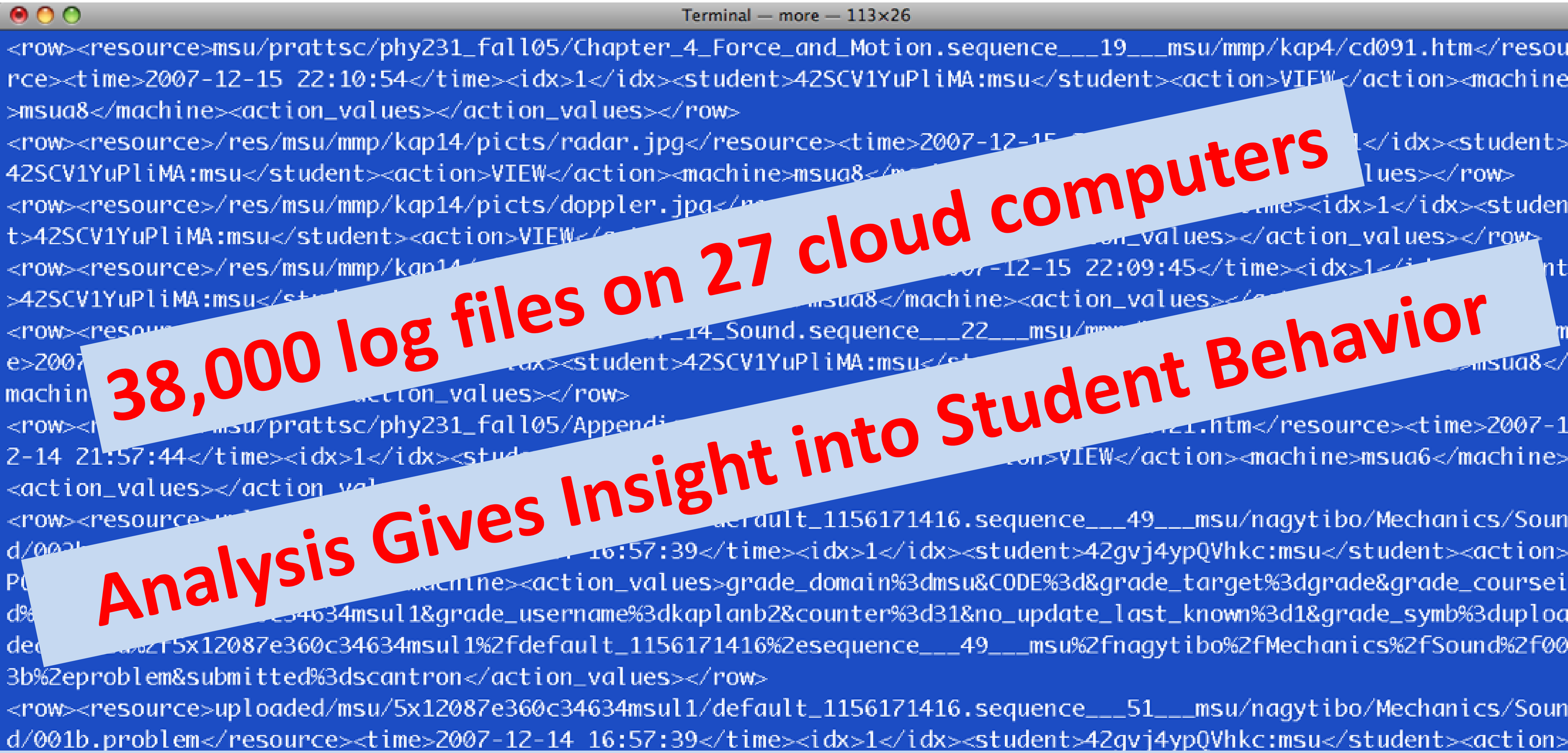
Improvement on the final exam for Spring Mechanics course relative to the Fall final exam score correlates strongly with online homework

(The spring course is largely for students who didn't pass the Fall Course.)

Educational Data Mining

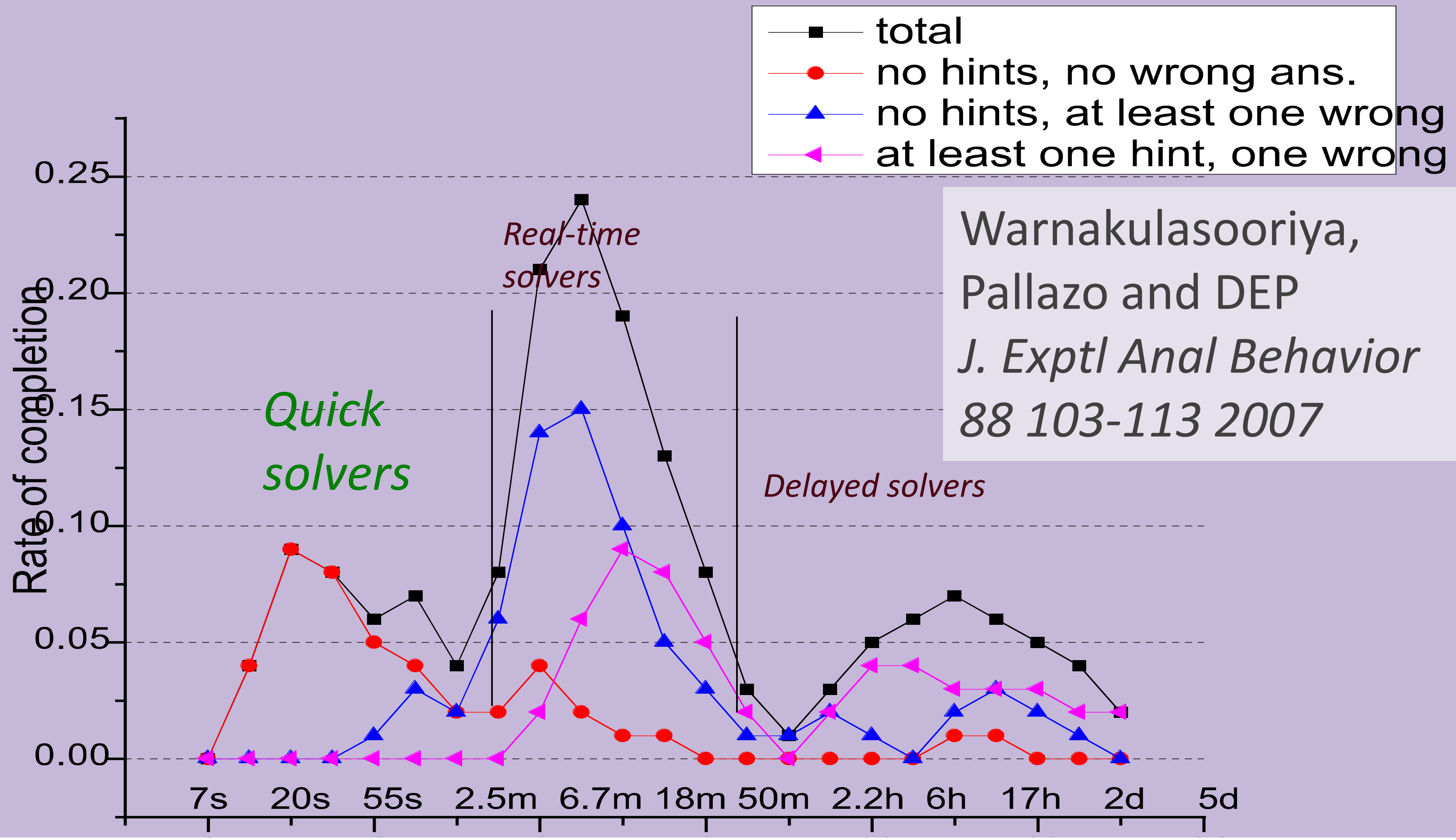
A new window on student behavior

A powerful tool for studying learning



Daniel Seaton could give whole seminar on this

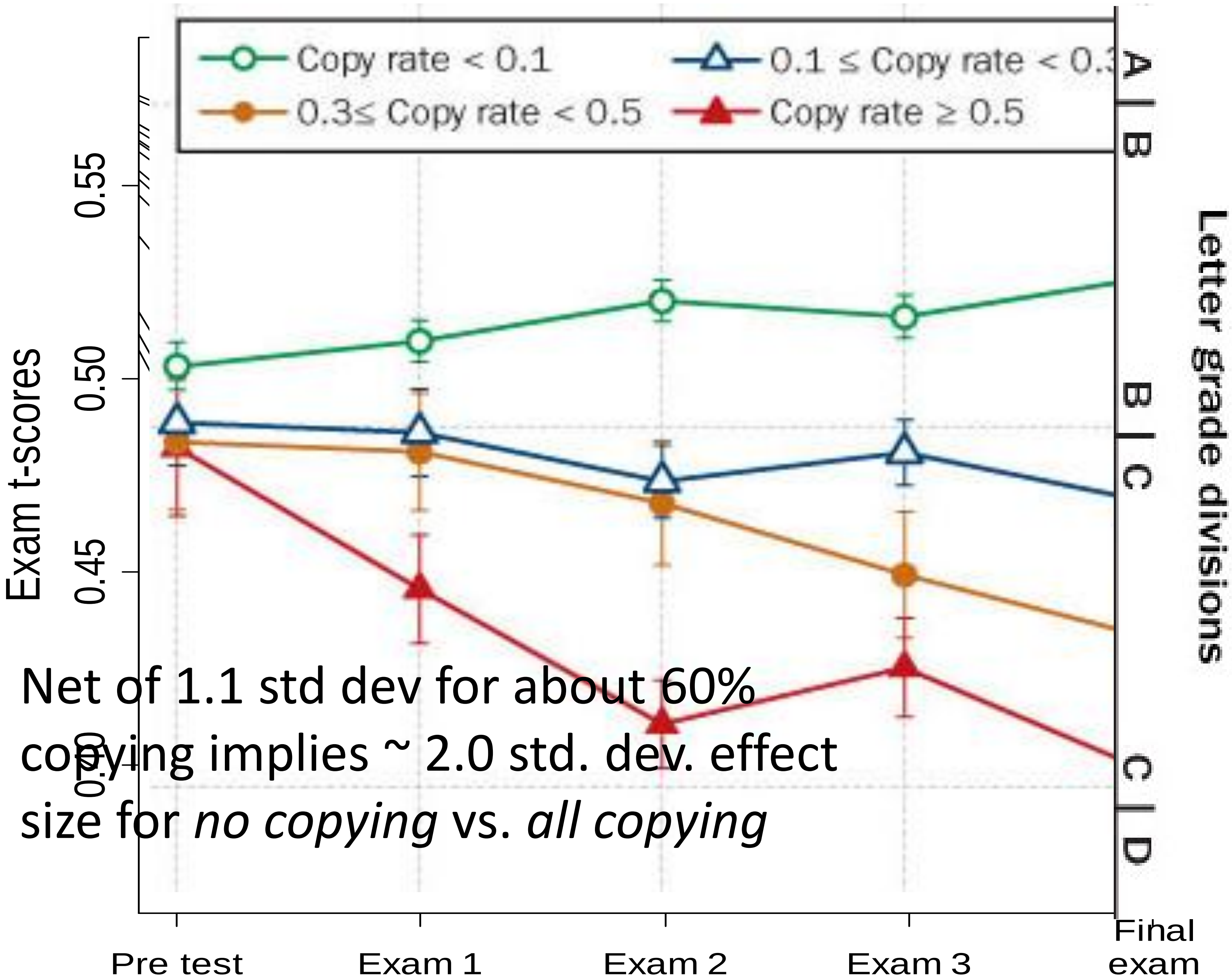
Detect Copying ← Quick, Correct Answer



Warnakulasooriya, Pallazo and DEP
J. Exptl Anal Behavior 88 103-113 2007

1. Respond in <1 min – insufficient to read and answer
2. Correct on first try vs. 90% of remaining students

Final Exam Scores of Copying Groups

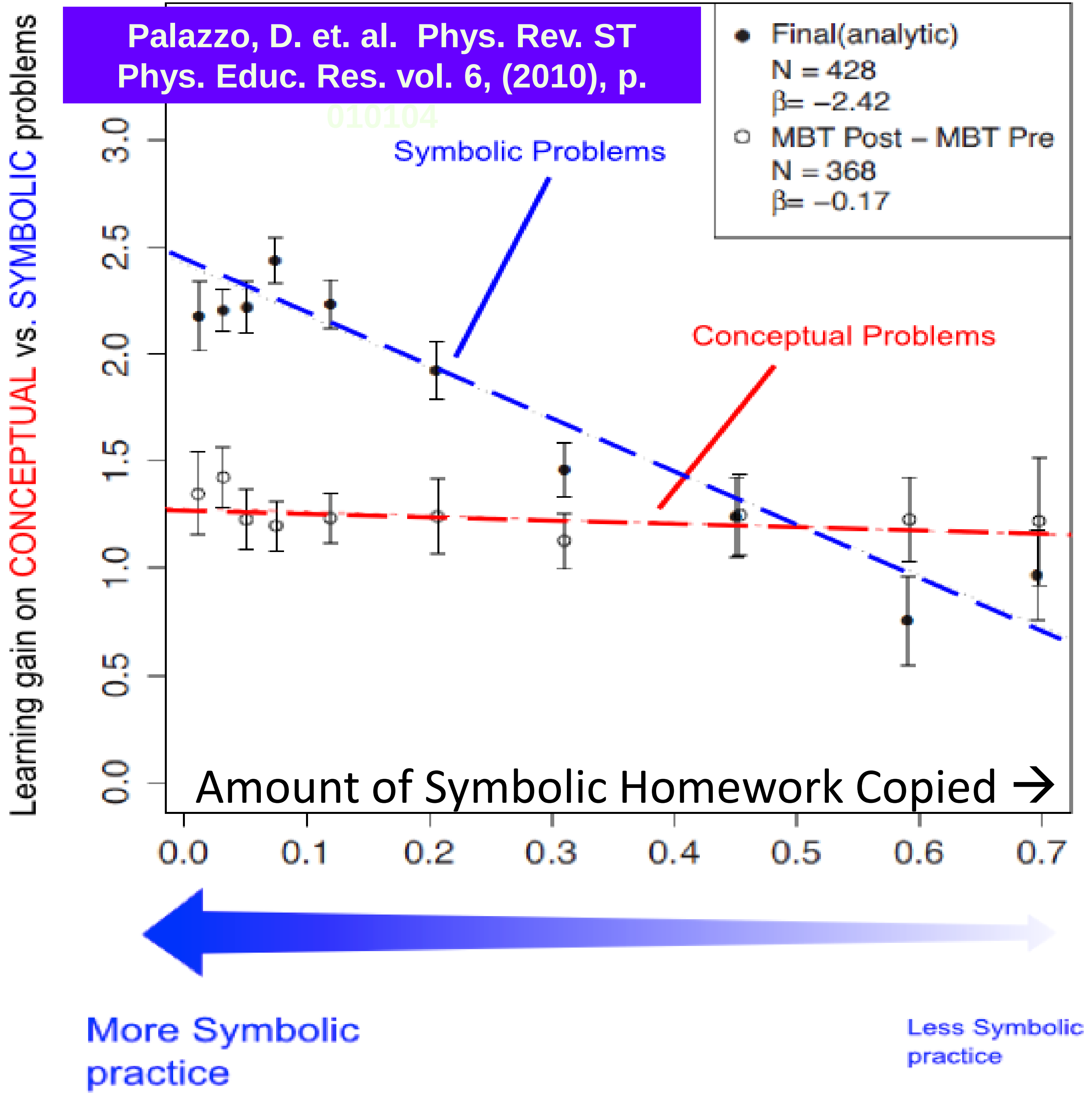


Net of 1.1 std dev for about 60% copying implies ~ 2.0 std. dev. effect size for *no copying* vs. *all copying*

Closer Look At Homework Copying

Symbolic answer:
2.4 Sigma
Learning!

But no help on conceptual



Symbolic vs. Conceptual Difference! ??

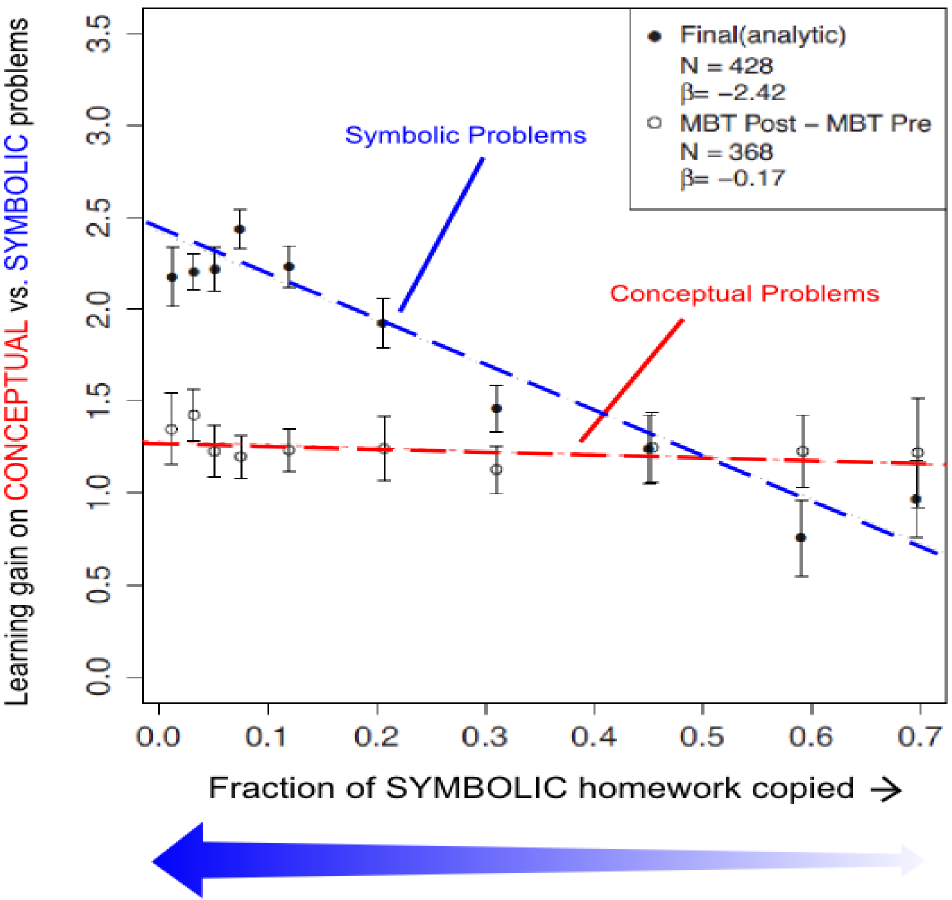
Physics Teacher Expectation

- **Students Start Symbolic Problems from Conceptual Analysis**
- **Answer Numerical Questions by Plugging in Symbolic answer**

- The problems cover the same material, so

This result is **Unexpected**

→ Students are not like **Experts**



Homework Copying

Symbolic answer: 2.4 Sigma Learning!

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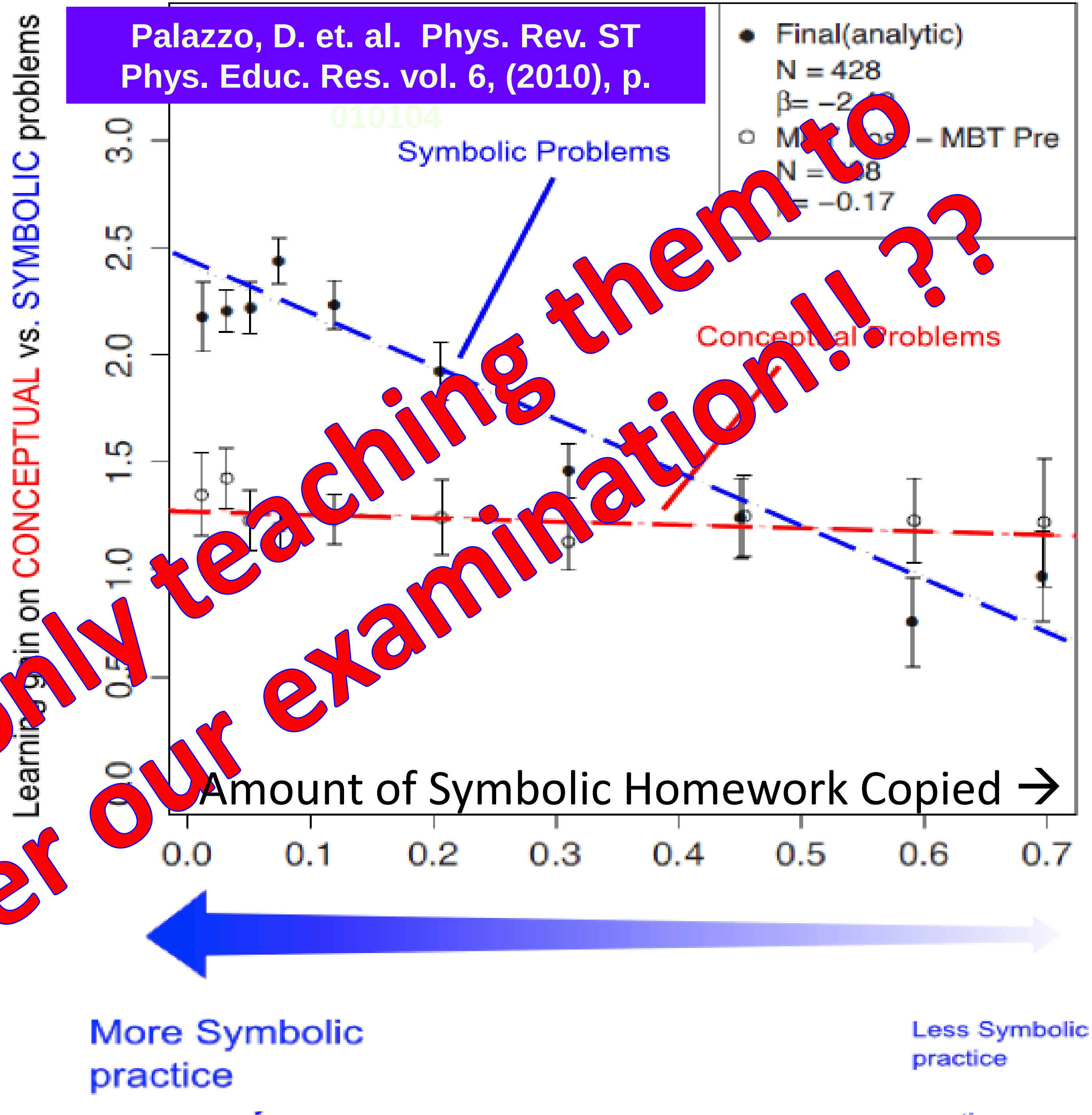


We are only teaching them to answer our examination!! ??

Helping Students to Become Experts

To begin to think like a physicist

To **organize** their mechanics knowledge

- Arrange core knowledge into models
- Understand conditions of applicability of each

To **solve** problems, not get the **answer**

- Have a systematic approach to starting
- Be able to plan solution
- Check that their answer makes sense
- These are expert skills – some transfer!

Elegance of Physics: Few laws + math = physics

MAPS – Modeling Applied to Problem Solving

We Had to Coach Students in Class

- → Students need some skills before class
- Online offers assessment with right/wrong
- Also can inform about student difficulties
- → Make complete online text + problems

~ 80% of Class Time: students working problems in groups of 2 or 3
10% is intro to what's really important
10% is comments on common mistakes
Teacher + TA can handle ~ 10 groups

MOOC to Prepare Students for Class

- Students learn facts & procedures
- Class Time involves students interacting instead of recording:
  - With each other (constructivist learning)
  - With the Teaching Staff (expert feedback)

2.5 week ReView for D’s in Fall Phys 1

Students worked in groups of 2:

- Individual and On-Board Problem Solving.

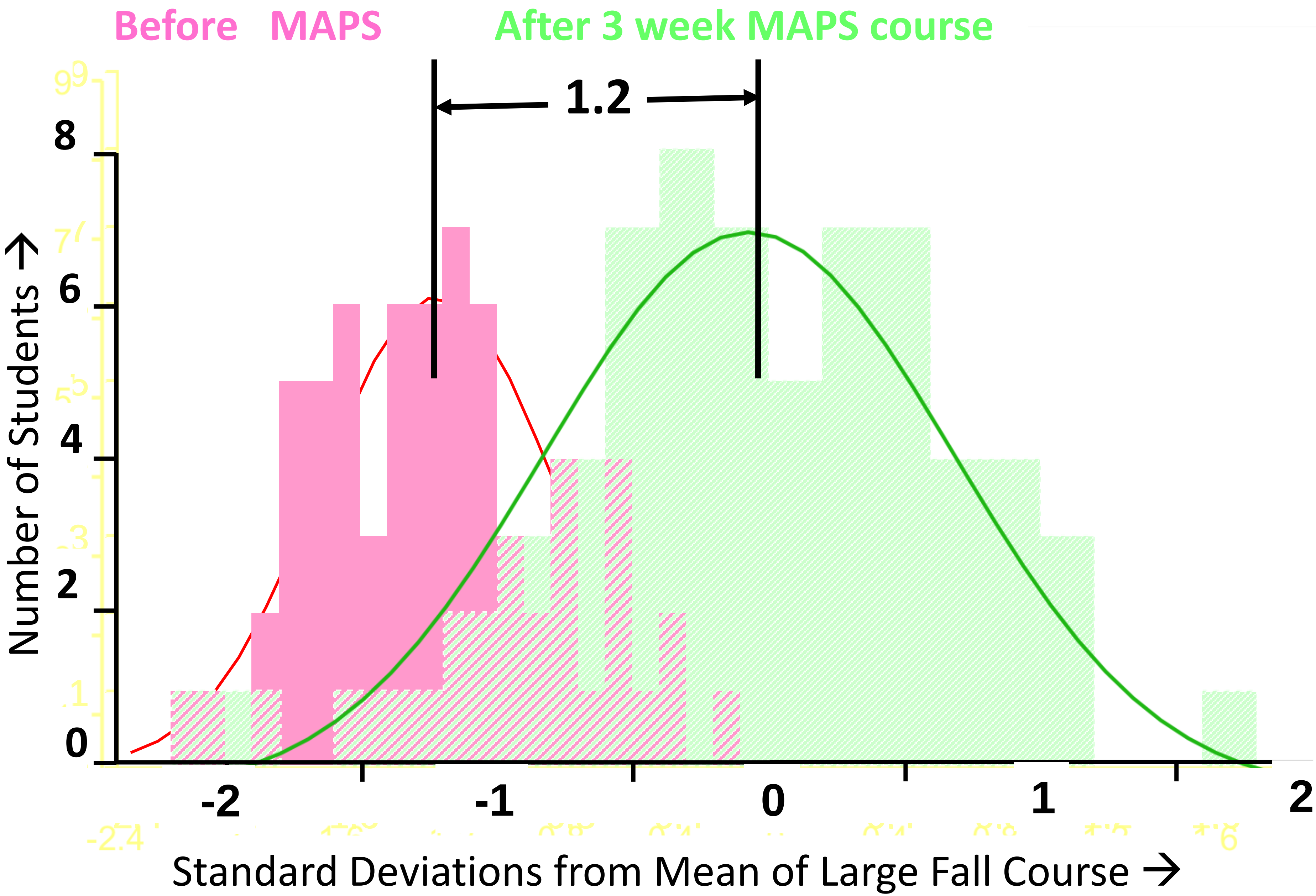
-Table activities (4 students per table).

EVIDENCE (for Success of MAPS)

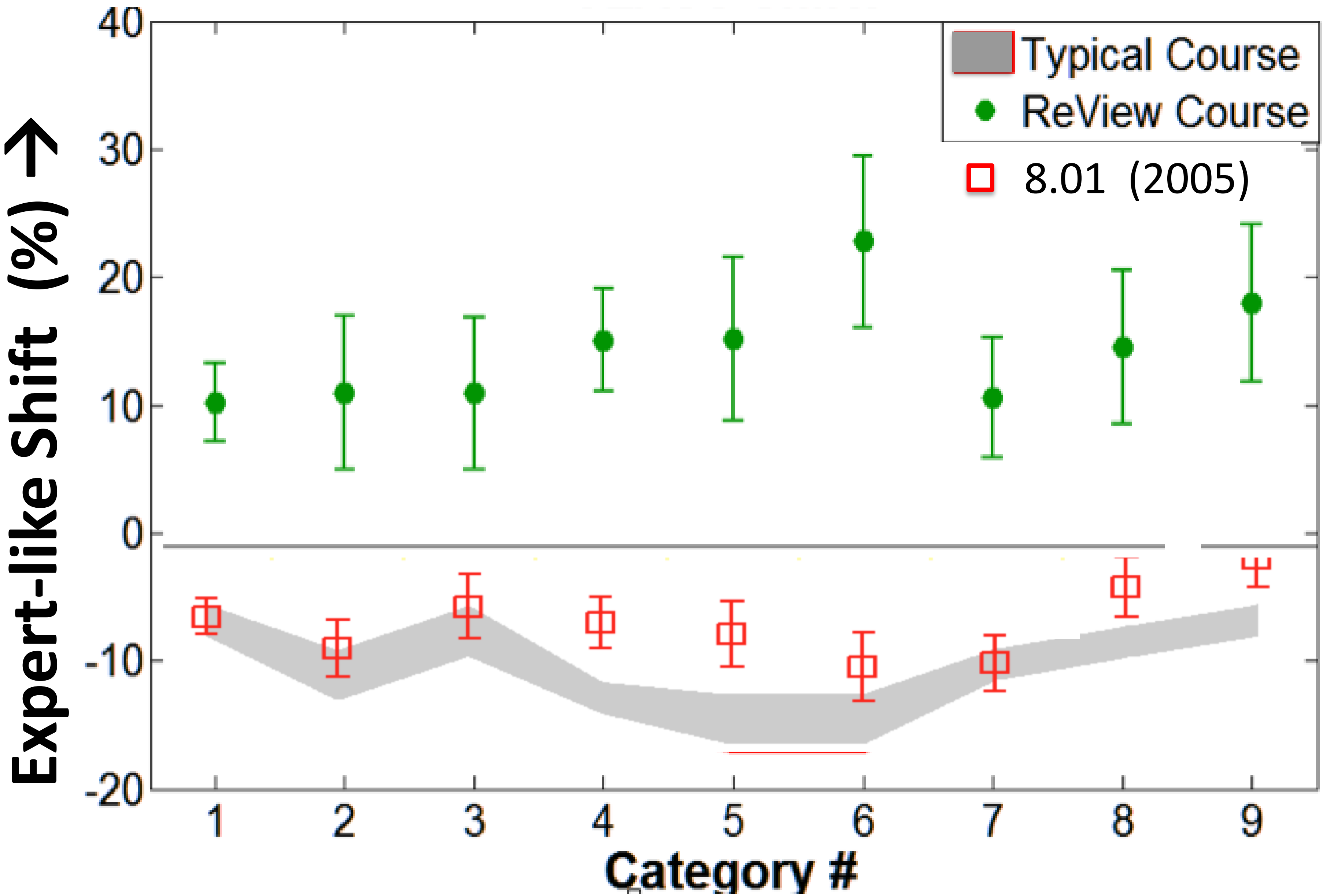
MAPS Helps Students Learn to Solve Problems

1. Measurably better
2. With Transfer to future E&M course
3. With more expert learning attitudes
4. Improvement: Mechanics Reasoning Inventory

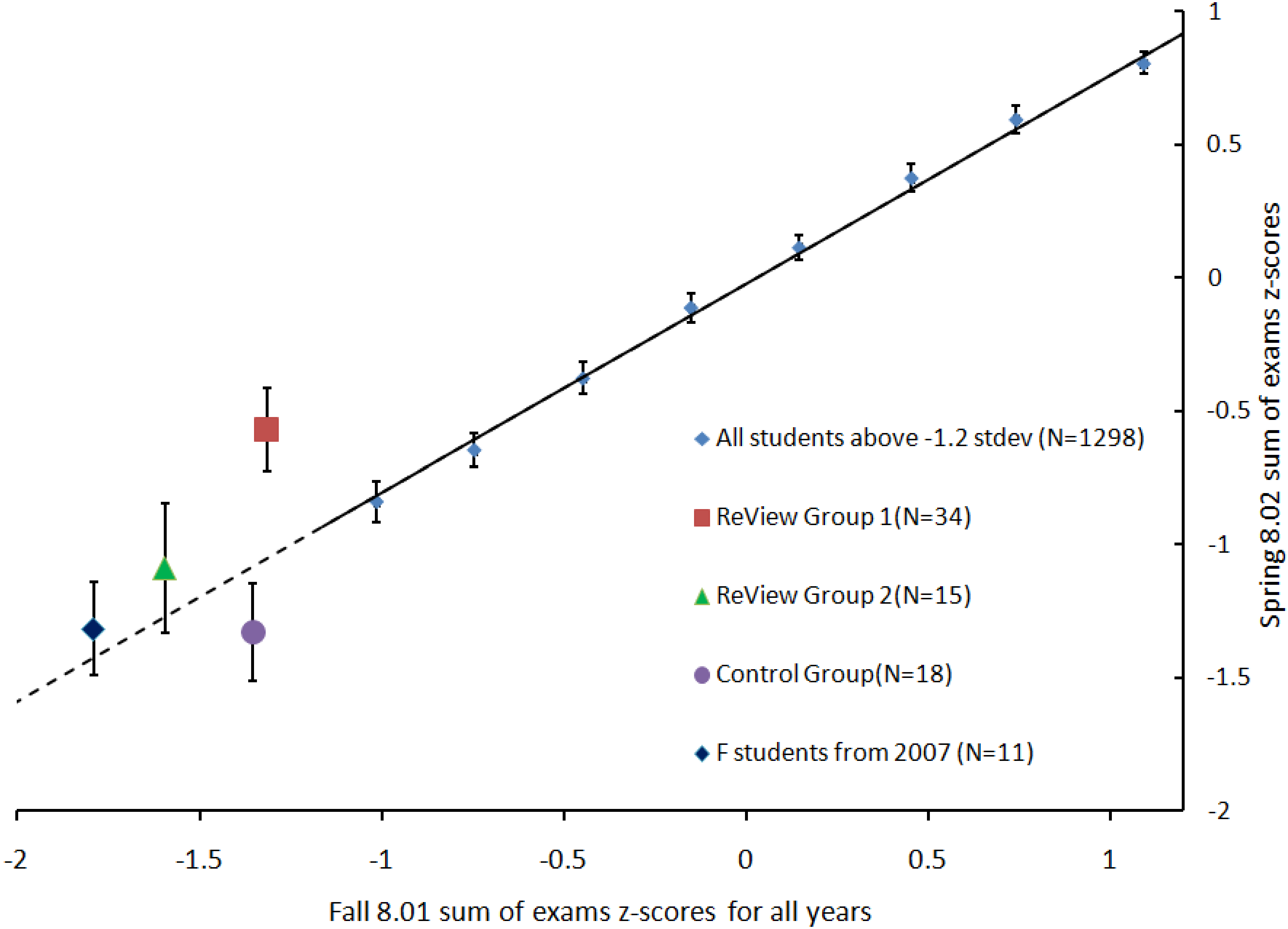
Improved Performance – MIT Final



More Expert on CLASS: + vs Fall Course



E&M score vs Mechanics score



Summary

- Conceptual Learning in 8.MReV equal or greater that traditionally taught on-campus course
- All of the major cohorts (HS students, poor math or physics background, and physics teachers) have the same normalized gain
- Contrary to concerns, there is no evidence that students with low initial skill learn less than more experienced students

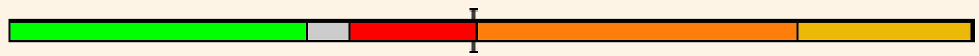
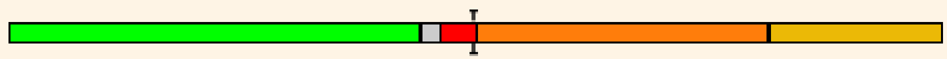
Course Management vs. Learning Management

- Course Management Systems post pdf’s, announcements, calendar, list registrants, facilitate communications with students, have gradebook, scheudle office hours, etc.
- Learning Management Systems control instruction, have libraries of materials, eTexts, assignments, auto-grading, …
- LMS’s should allow organized access and editing for all instruction-related activities

Wrong Answer Responses

Typically, wrong answer responses guide about 2/3 of the initially incorrect students to the correct solution

Author can replace standard with custom response

Answer Stats:	Students	% Correct	% Unfinished	% Req'd Solution	Wrong/student	Hints/student
Overall	17092	64.5%	8.7%	26.9%	2.3	0.6
						
MIT8011SPRING2011	29	89.7%	3.4%	6.9%	1.7	0.6
						

Wrong Answers for MIT8011SPRING2011		
% Wrong	**Answer**	**Response**
42%	$v\cos(\phi)$	Your answer either contains an incorrect numerical multiplier or is missing one.
12%	$-v\cos(\phi)$	Your answer either contains an incorrect numerical multiplier or is missing one.
8%	$2v\cos(\phi)$	Your answer either contains an incorrect numerical multiplier or is missing one.
6%	$mv\cos(\phi)$	The correct answer does not depend on the variable: m.
4%	$v\cos(\phi)$	The correct answer does not depend on the variable: θ.

Library view: select items for quiz/assignment

- Easy to use search,
- Appropriate information for decision

Book/Source: Young/Freedman, University Physics with Modern Physics, 12e
Chapter: 5. Applying Newton's Laws

Publisher Items
☑ Tutorial ☐ End-of-Chapter ☐ Test Bank

My Items
☑ My Items

44 items found (To sort, click any column heading)

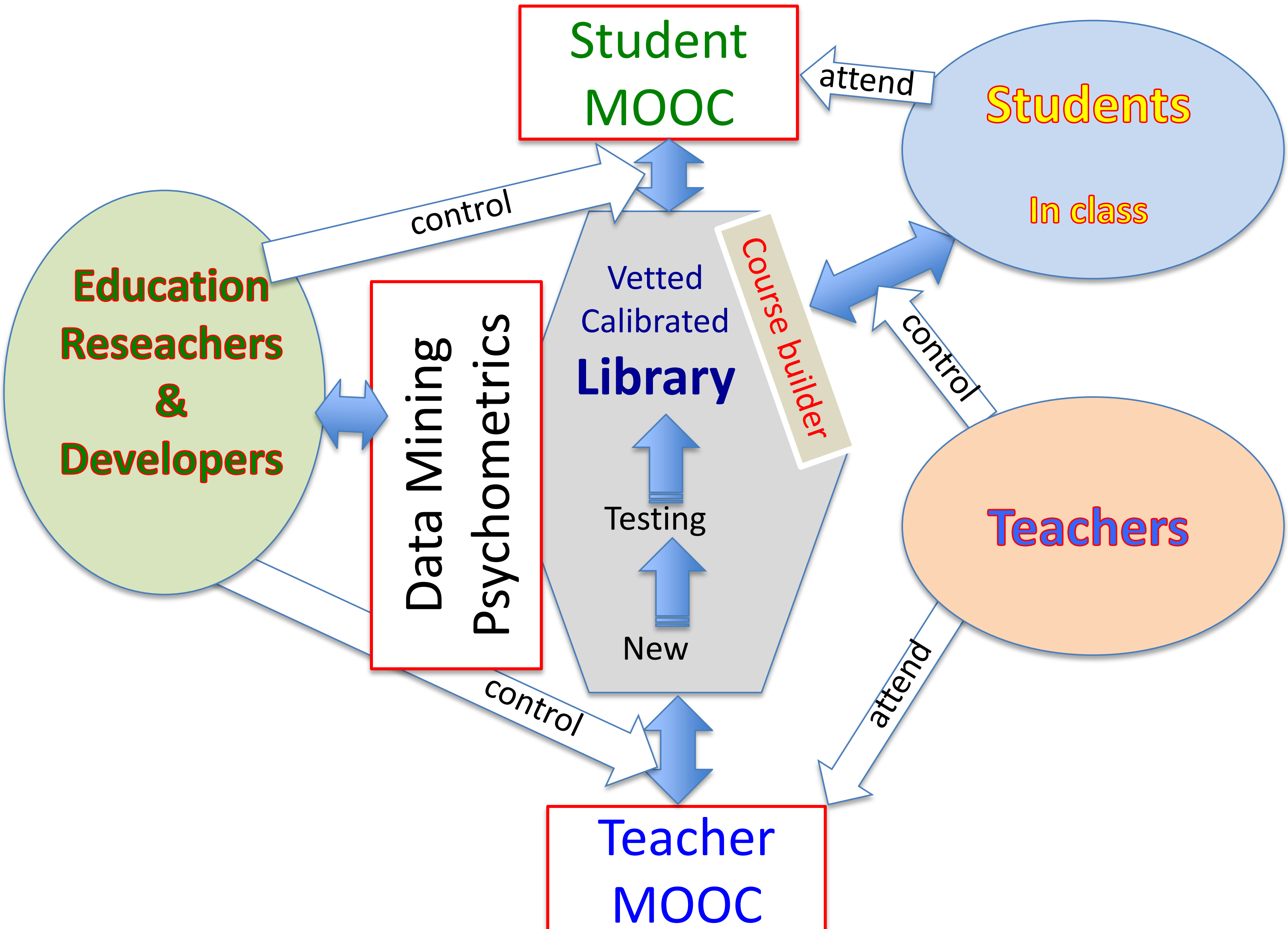
ASSIGN	ITEM TYPE	TITLE [Hide Descriptions]	TIME	DIFFICULTY (5=hardest)	▲ USAGE STATISTICS (Roll over any colored segment)
5. Applying Newton's Laws					
☐	Tutorial STP	Static Friction and Frictional Force Ranking Task Rank the frictional force on boxes of different masses and various friction coefficients. (ranking task)	7m	5	
☐	Tutorial STP	Pushing a Lawnmower A lawnmower is pushed via a handle which makes an angle theta with the horizontal. Find the force needed to push the lawnmower at constant speed, with friction. Find the critical angle at which the lawnmower becomes impossible to push.	17m	5	
☐	Tutorial STP	Hanging Chandelier Given a chandelier hanging from two nonsymmetric cables, find the tension in one cable.	13m	5	
☐	Tutorial STP	Centripetal Force Ranking Task Conceptual question on determining the force needed by various satellites to maintain a circular orbit around a space station. (ranking task)	10m	5	
☐	Tutorial STP	Two Masses, a Pulley, and an Inclined Plane One block on incline (with friction) connected to another hanging over the edge. Given acceleration, angle of inclination, and coefficient of friction, find the ratio of the masses of the blocks.	12m	5	
☐	Tutorial STP	Kinetic Friction in a Block-and-Pulley System Two blocks, one on a table and one hanging, are connected by a pulley. Find the kinetic friction for the block on the table knowing that both blocks are moving at a constant speed. Find the magnitude of	18m	4	

My Vision For Future of College Ed

- Real Learning
  - → Research-Based Resources and Assessment
  - →Teachers organize/advise & optimize learning
- Assignable Library of researched resources
  - →Less Teacher time preparing lectures & assessments
  - →Less TA and Prof. time spent grading
  - →Increase Teacher & TA *interactions* with Students

→Need Real-Time Assessment with Actionable Results

Library of Research-Based Resources



END – rest is leftovers

MOOC: Massive Open Online Course

Made from Online for Modeling Applied to Problem Solving Class!

Centered on short e-text w. videos, PhET's, etc.

- Embedded checkpoint questions

Homework

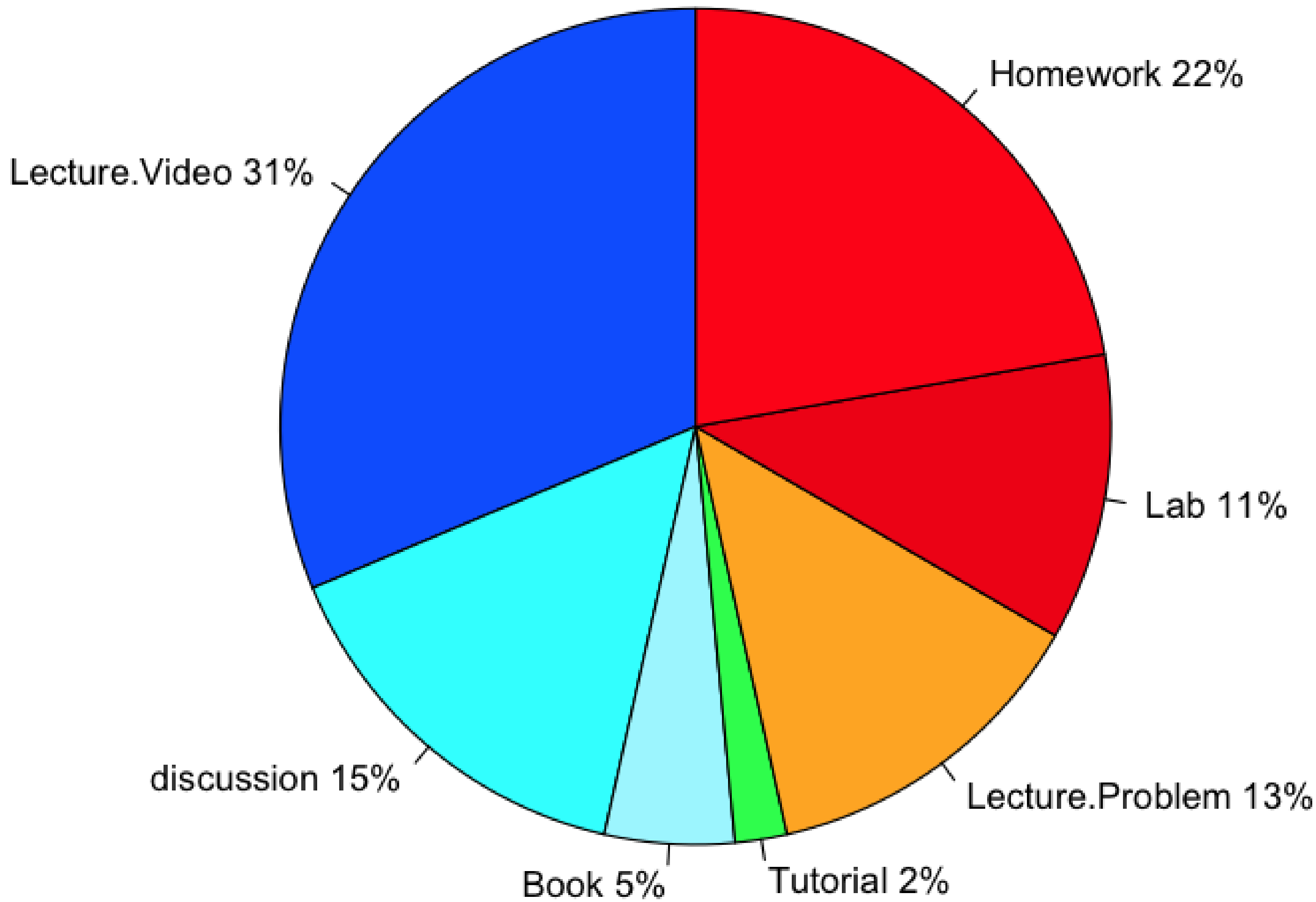
- 3 levels: med, hard, MIT

Discussion Boards after each page

Weekly Tests

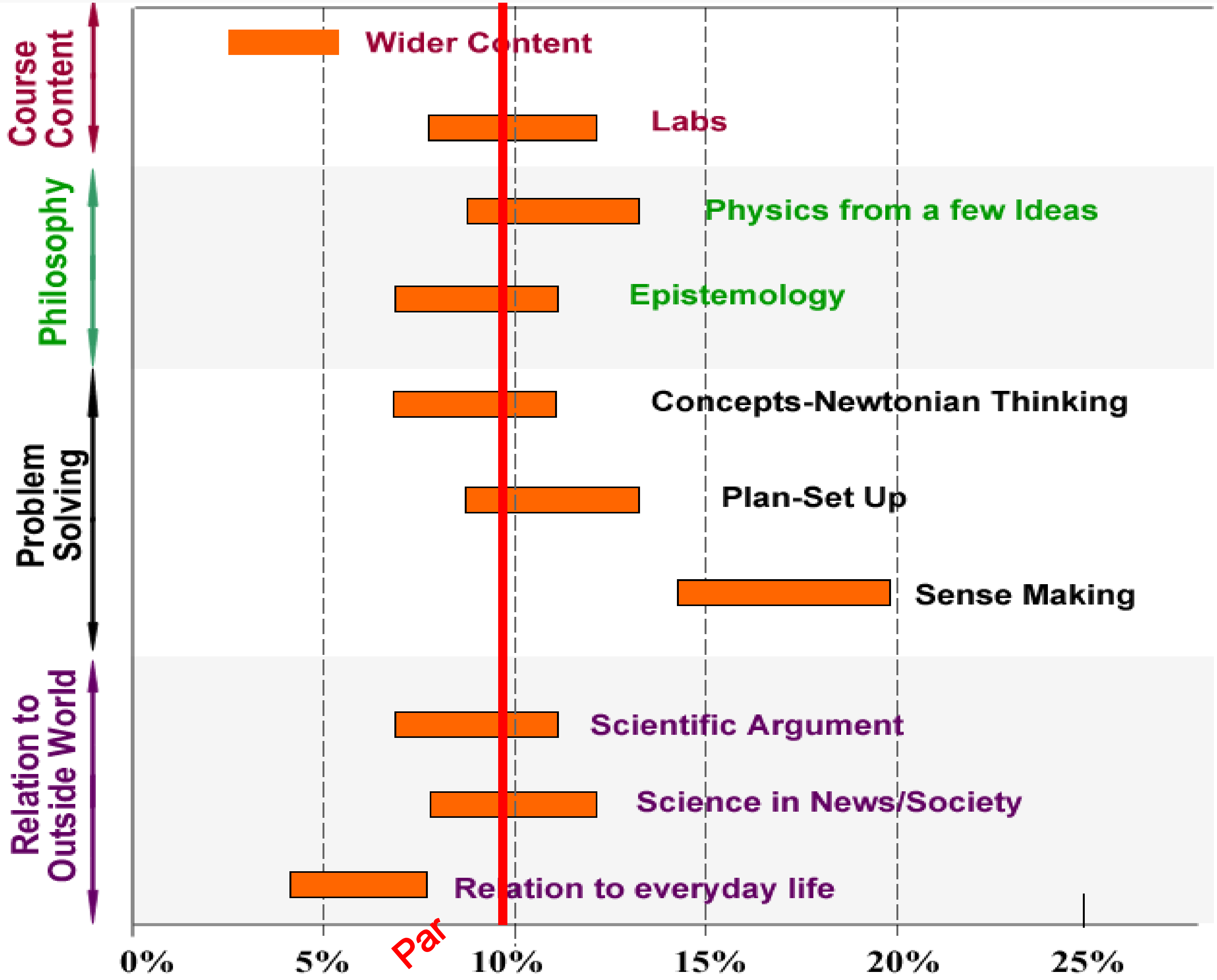
"Second mechanics course" – aims at imparting strategic knowledge on problem-solving

The fractional division of time among the various resources of 6.002x



Data are for 1080 certificate earners who spent an average of 95 hours on the entire course. Note that cool colors indicate instruction and warm colors indicate assessment

~700 Instructor Votes



21st century learning skills www.p21.org

- Being a life-long learner
  - Interest and skills to learn new things
- Thinking Habits and Abilities
  - Critical Thinking, Problem-solving, Creativity
- Communication and Collaboration
- Life Skills
  - Citizenship, career skills, self-management

What To Teach in Introductory Physics

David E. Pritchard, Analia Barrantes, Brian Belland

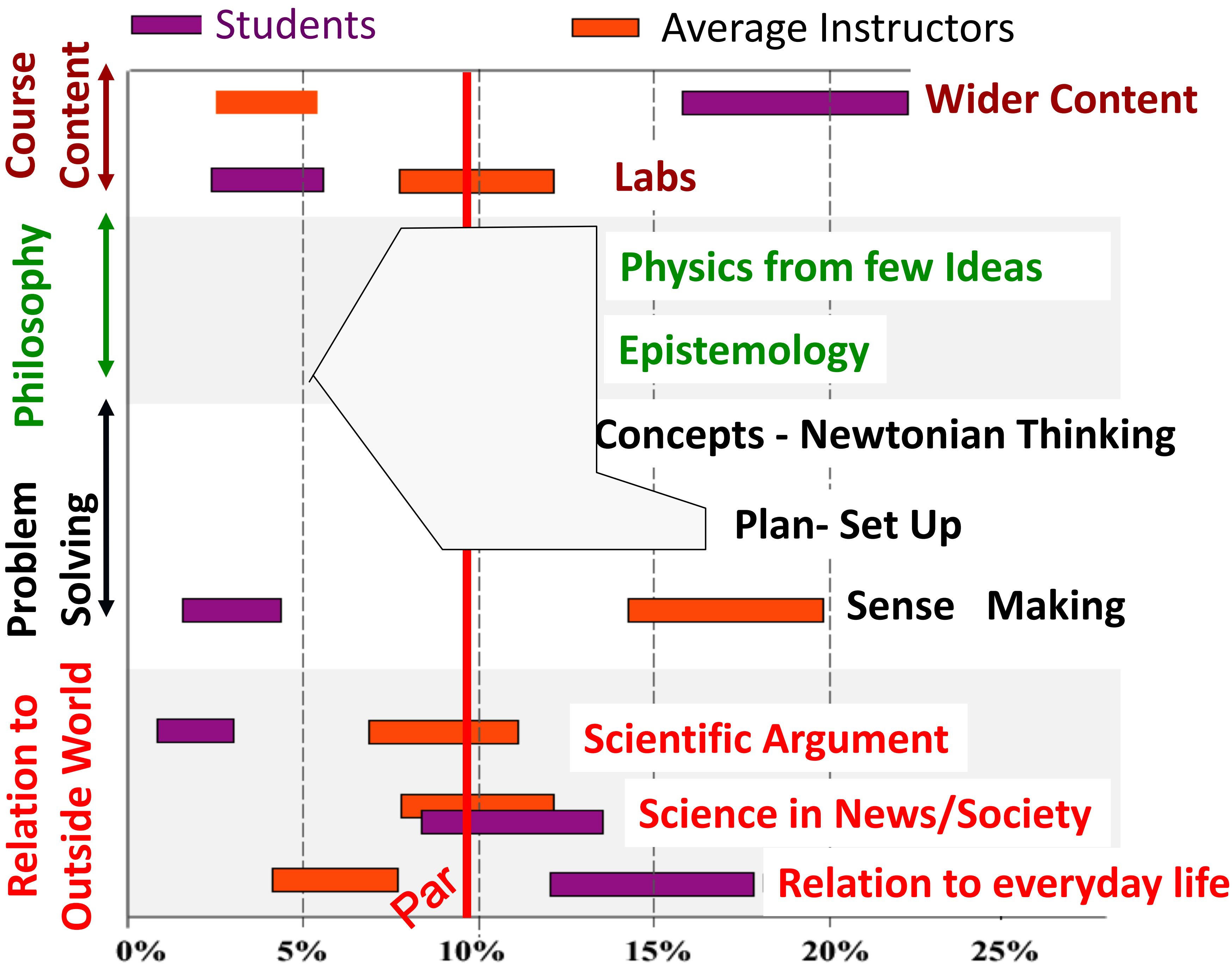
WHAT SHOULD WE BE TRYING TO TEACH?
SOME POSSIBILITIES

Teach our Students (our conception of) Physics
Prepare them for their lives
Prepare the 95% non-physics majors for their majors
Teach Useful Learning Habits

Survey of Teachers

David E. Pritchard, Analia Barrantes, Brian Belland

MY QUESTION: Due to a change in the academic calendar, you have 20% more time to teach the calculus-based introductory physics course to non-physics majors, and the syllabus has not been expanded. What learning will you seek to add or emphasize with this extra time?



Students
Average Instructors
Course Content
Wider Content
Labs
Philosophy
Physics from few Ideas
Epistemology
Problem Solving
Concepts - Newtonian Thinking
Plan- Set Up
Sense Making
Relation to Outside World
Scientific Argument
Science in News/Society
Relation to everyday life
Par
0%
5%
10%
15%
20%
25%

r = -0.4 Professors vs Students?

- Catalog says College will turn students into lifelong Problem Solvers
- Professors "Welcome to college where we're going to turn you into expert professionals and problem solvers"

- **Catalog says freshman year is for exploration after which students are able to pick any major**
- **Students "I'm looking for a major, show me why physics is relevant to my interests and life. Then I might invest 10+ years to become an expert!"**

- → RECOMMENDATION: more attention to why intro physics is relevant to their current and future life

Core Models Map

Translation ← (Change of Position) — **Motion** — (Change in Orientation) → Rotation about axis *a*

Motion Variable

Velocity	Momentum	Mechanical Energy	Angular Velocity	Angular Momentum
$\vec{\mathbf{v}}(t) = \frac{d\vec{\mathbf{r}}(t)}{dt}$	$\vec{p}(t) \equiv \sum_{i=1}^{masses} m_i \vec{\mathbf{v}}_i$	$E = \sum_{i}^{bodies} [K_i + U_i]$	$\omega(t) \equiv \frac{d\theta(t)}{dt}$	$\vec{\mathbf{L}}_S^{total} = \sum_{i}^{bodies} [\vec{\mathbf{L}}_{S,i}^{orbit} + \vec{\mathbf{L}}_{cm,i}^{spin}]$

System

Single-Particle System	Multi-Particle System	Multi-Rigid-Body System	Single-Rigid-Body System	Multi-Rigid-Body System

Interactions

External Forces ← **Interactions** → External Torques about axis *a*

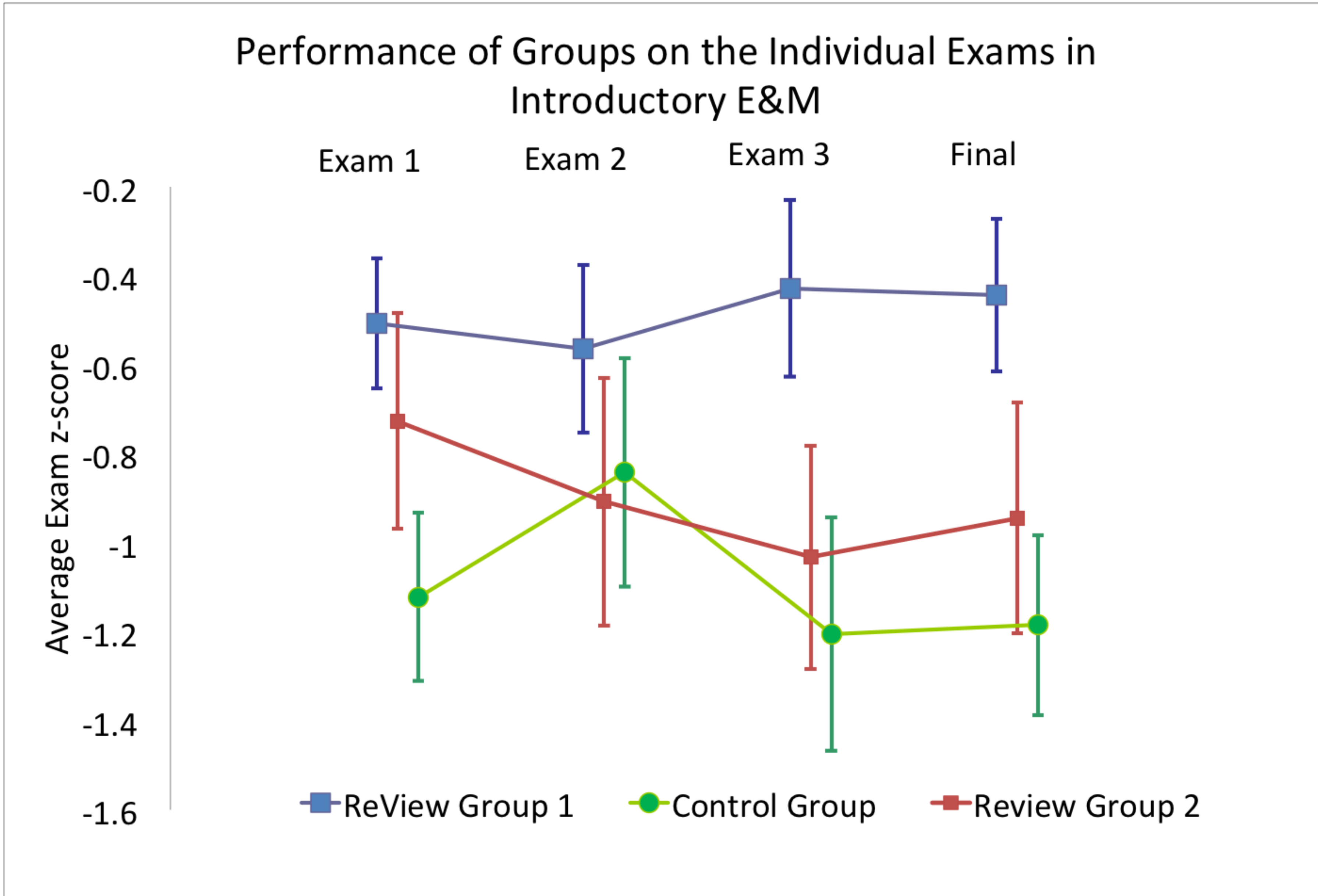
Agent of Change

$$\vec{F}^{net} = \sum \vec{F}_i \qquad \vec{J} = \int_i^f \sum \vec{F}^{ext}\, dt \qquad W = \sum \int F_i^{nc}\, dx + \sum \int \tau_a\, d\theta_a \qquad \vec{\tau}_a^{net} = \sum \vec{\tau}_{a,i} \qquad = \int \sum \vec{\tau}_a^{ext} dt$$

Model

Dynamics and Net Force	**Momentum and Impulse**	**Mechanical Energy and Work**	**Rotational Dynamics and Net Torque**	**Angular Momentum and Angular Impulse**
$\sum \vec{F}_i = m\frac{d\vec{v}}{dt} = m\vec{a}$	$\vec{p}_f = \vec{p}_i + \vec{J}$	$E_f = E_i + W_{f,i}^{nc}$	$\Sigma \tau_a = I_a \frac{d\omega}{dt} \equiv I_a \alpha$	$\vec{L}_{S,f} = \vec{L}_{S,i} + \int_i \vec{\tau}_{S,total}^{external}(t)\, dt$

Exam by Exam Performance in E&M 8.02



MIT TEAL Classroom Modeled after SCALE-UP

Take-home Summary?

- Reform your intro courses to teach skills/habits *you* think will benefit the 99%
- Homework Tutors Help with Tests
  - Free staff time for interactions w. students
- Can help students become more expert
- Full online courses great for blending
- MOOCs help those who help themselves
  - Good for data mining and education research