Reform MIT Style: Student Evaluations vs. Scientific Evidence

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DUET – X-Talks (March 20 version)

http://odl.mit.edu/news-and-events/events/david-pritchard-course-reform-mit-style-student-evaluations-vs-scientific

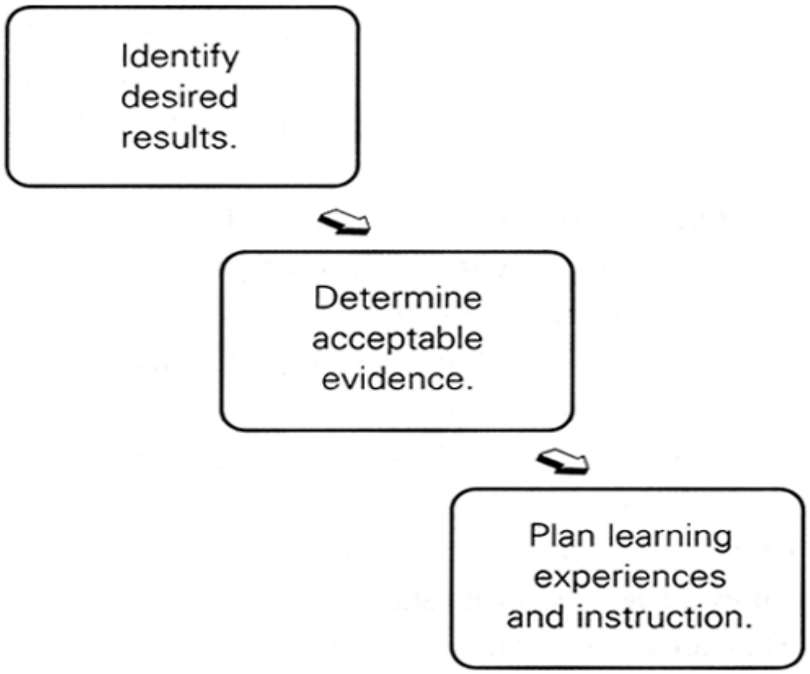
MIT Way: Engineering Design Process

Among the fundamental elements of the design process are (simplified for young adults):

- **ASK:** What is the problem? How have others approached it?
- **IMAGINE:** What are some solutions?
- **PLAN & CREATE: Design it.** Make it. **Test it out!**
- **IMPROVE:** What works? What doesn't? What could work better? Modify your designs to make it better. Test it out!

University Course Reform – Carl Wieman

- 1. Get Faculty on board with Goals, Assessments
  - https://www.researchgate.net/publication/296705160 The SEI Initiative
- 2. Apply Learning Theory and DBER
  - http://cwsei.ubc.ca Course Transformation Guide



Graphically, from Grant Wiggins

This Process Has a Special Name in Education
(Because It's Not Usual University Practice)

1. **Wiggins calls this *Backward Design***
2. contrast: traditional planning, wherein "a list of **content that will be taught is created/selected**"
3. And **Success evaluated by Student Evaluations**
4. **Reform: Specify Learning, not Teaching**

This in the MIT approach - but only for research

- **MIT uses #2 and #3 in education**
  - MIT Course Catalog: course = list of topics (x 8.01)
  - More on Student Evaluations Later

Embrace PER: David Hestenes is #1

Geometric Algebra

Force Concept Inventory

Modeling Theory

Modeling Instruction

Vass – Attitudes Survey

Lament – Hestenes 1987 on Pedagogy

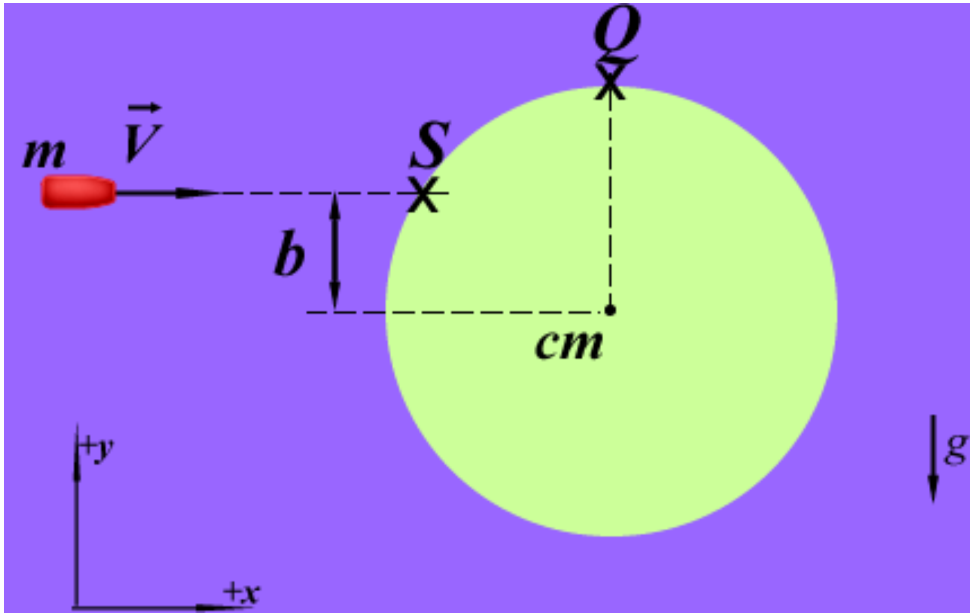
Pedagogical theory is generally held in low esteem by university scientists. But their own practices show how sorely it is needed. They practice in the classroom what they would never tolerate in the laboratory. In the laboratory they are keen to understand the phenomena and critically evaluate reasonable alternative hypotheses. But their teaching is guided by unsubstantiated beliefs about students and learning which are often wrong or partial truths at best. This kind of behavior would be as disastrous in the laboratory as it is in the classroom. Why don’t they evaluate their teaching practices with the same critical standards they apply to scientific research?

…Most physics professors take their teaching seriously, so it seems strange that they have not promoted the kind of coherent research program to improve teaching which they know is essential to the development of physics.

My Approach (Back Then): MIT Final Problems

Students can answer multi-Concept, multi-Stage

A disk of mass M and radius R rotates about the horizontal z-axis which passes through its center. A bullet of mass m moving with speed V hits the disk a distance b above its center of mass and sticks at point S on the edge of the initially non-rotating disk.



What is the minimum speed for the bullet such that the embedded bullet will overcome gravity and rotate over the axle?

Bloom Taxonomy>Cognitive>Analyze & Synthesize

Mastering Design Philosophy

MIT Final Exam Performance is Metric
Homework Gives Most Learning

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

Assess Appropriate Response, Part of Grade

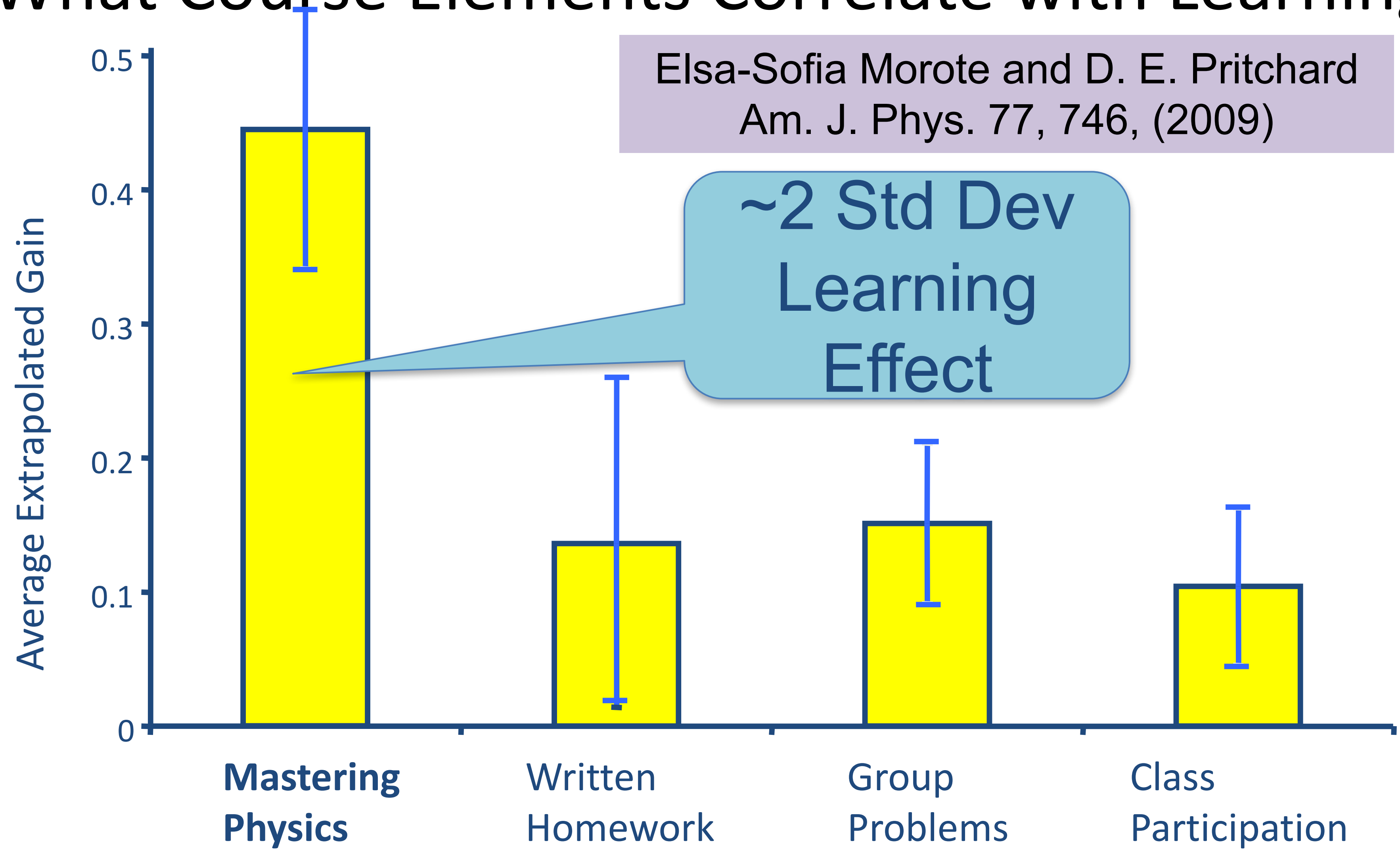
The tutor provides detailed assessment

Feedback improves the tutoring

Results:

- ✓Surprising amount of learning
- ✓detailed information/feedback to teacher
- ✓an expert program embodying human expertise

What Course Elements Correlate with Learning?



LEARNING: 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.)

Reforming *Your* Class

- **ASK:** What is the problem? How have others approached it?
- Problem is "What Should Students Learn?"
- *Have you Thought Beyond What Topics to Teach?*

You, your department, your university
-and your students(!)
Must Decide for Your Class

Let's Discuss some Ideas/Perspectives

What Should be Learned in Introductory Physics

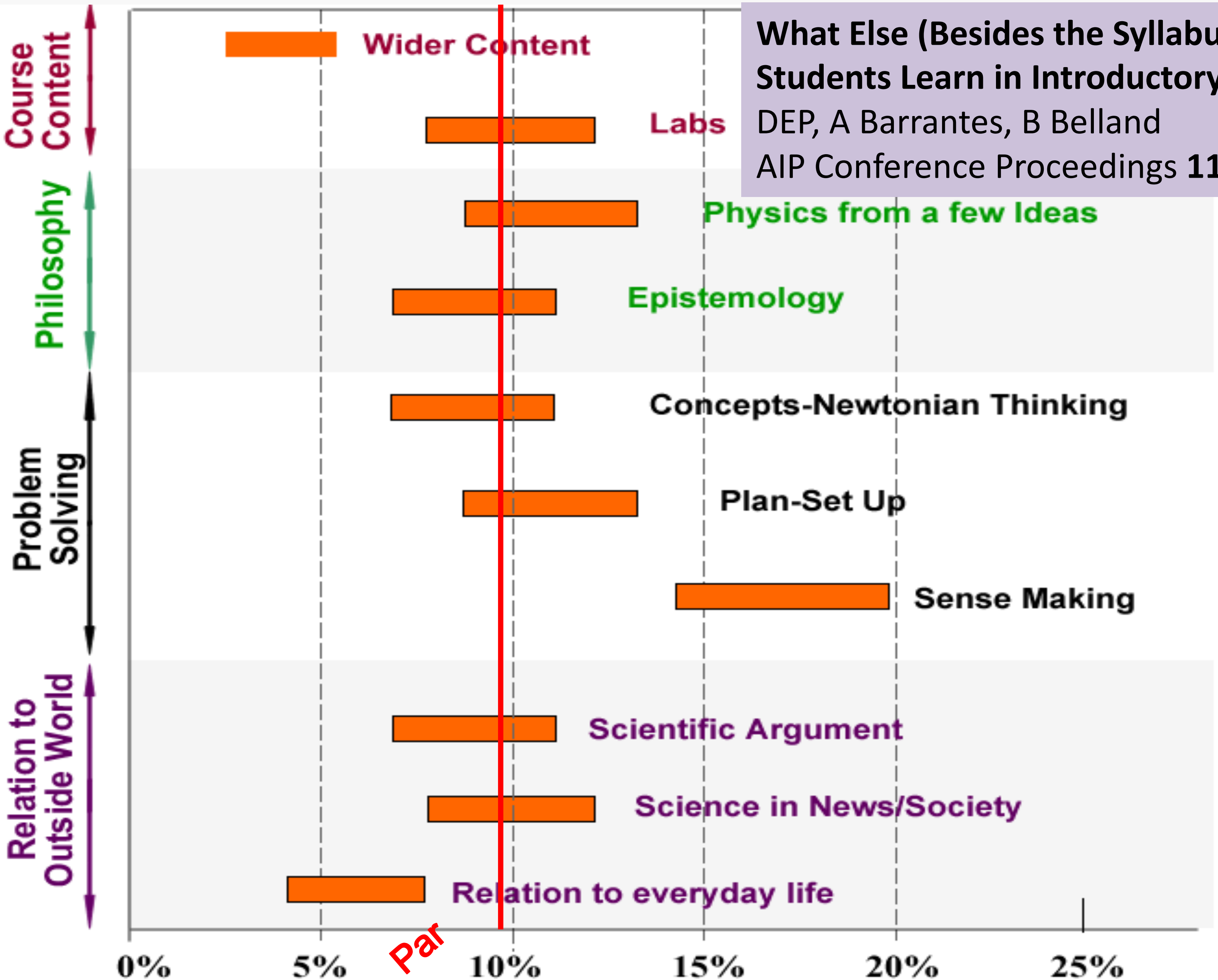
David E. Pritchard, Analia Barrantes, Brian Belland

ASKED 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?

Use Delphi Study

PROCEDURE: Asked people, especially AAPT/PERC
Distilled Free Responses down to ~12 responses in 4 categories

What ~700 Instructors Want to Teach



What Else (Besides the Syllabus) Should Students Learn in Introductory Physics?
DEP, A Barrantes, B Belland
AIP Conference Proceedings **1179**, 43 (2009);

DBER – Findings No One Knows About

This PDF is available from The National Academies Press at http://www.nap.edu/catalog.php?record_id=13362

Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering

Traditional Lectures → Active Learning

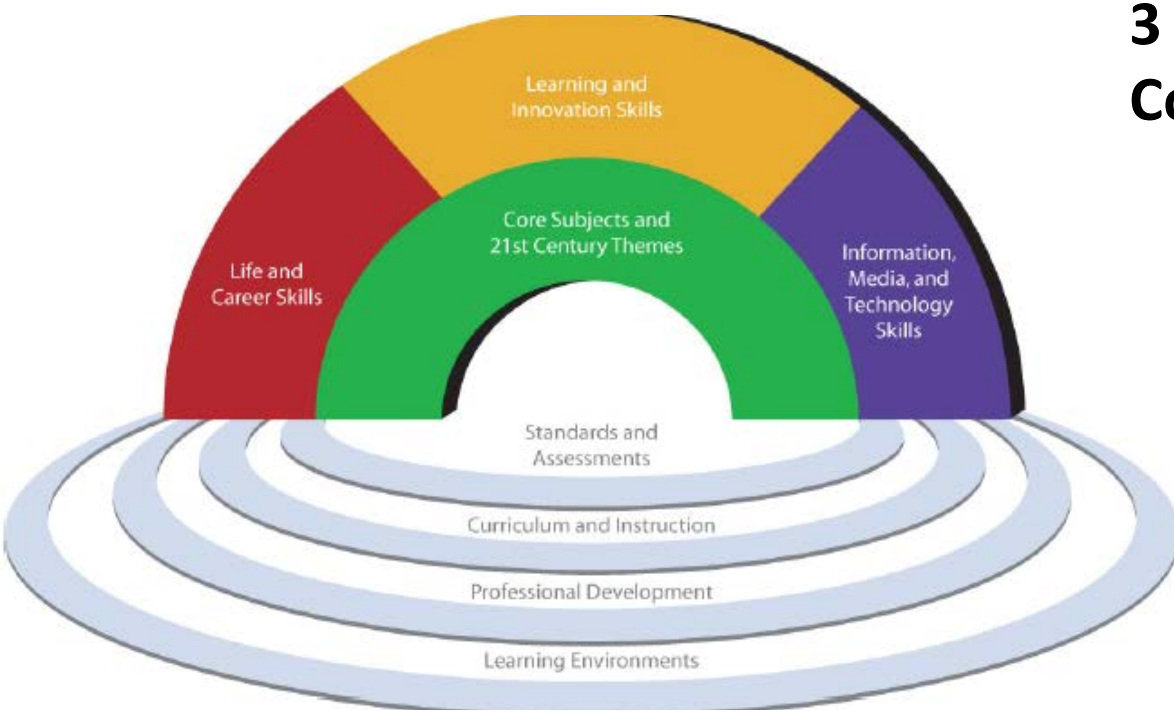
- Much better conceptual learning
- Improved Attitudes

ISBN 978-0-309-25411-3

282 pages
6 x 9
PAPERBACK (2012)

Susan R. Singer, Natalie R. Nielsen, and Heidi A. Schweingruber, Editors; Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research; Board on Science Education; Division of Behavioral and Social Sciences and Education; National Research Council

(P21.org) 21st Century Student Outcomes Common Core State Standards



3 r's (19th Century)
Core Subjects and Themes

4 c's: (NEW)
Creativity (and Innovation)
Critical Thinking
(and Problem Solving)
Communication
Collaboration

- Need ASSESSMENT, or it's all hype

My Reformed Class – What to Learn?

- **ASK:** What is the problem? How have others approached it? Lots of Scientific Literature
- Students are Novices, not young Experts– Chi
  - Chi, Feltovich, Glaser *Cognitive Science 1981*
- Cognitive: lack Overview and Strategic Thinking
  - Problem Solving and Conceptual Understanding
  - Wm. Gerace PERC 2001
- Modeling – How Scientists Think - D. Hestenes
  - Simplifications only under specified circumstances
  - Hestenes papers 1990-6, AMTA (~6% of HS teachers)

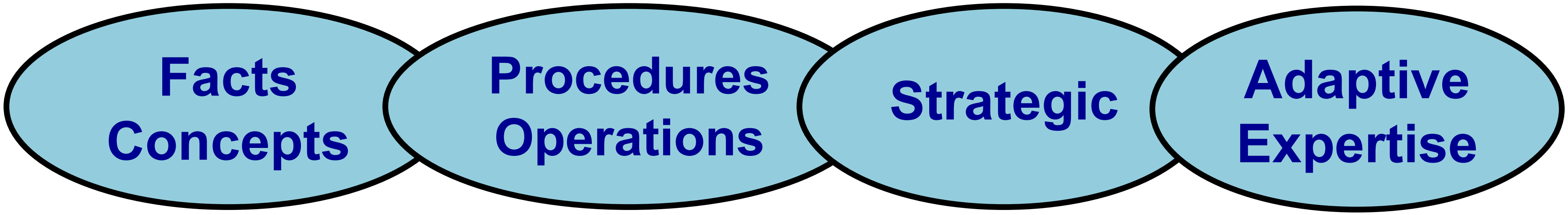
Levels of Cognitive Knowledge

$F^{total}=ma$

Draw Diagram
Find Components

Apply $F^{total}=ma$
to each mass

Create New
Ideas, Things



Textbook, Lectures
Peer Instruction

Problem Sets
Examinations

Problem Solving
- not Exercises

Basic Research

Challenging Exams

Designing

Most High Stakes Tests

Checking Your Answer

Estimation, Approximation

Most Publisher Products

MAPS Imparts This

Good PhD Thesis

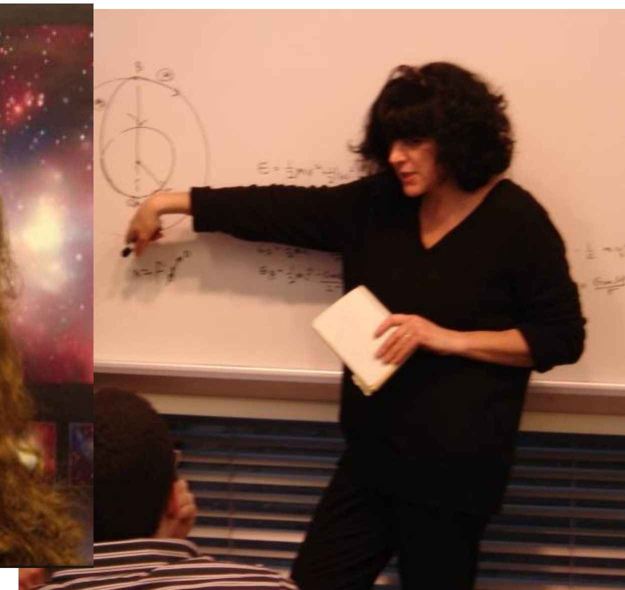
Known Answer, Intended Solution
Known Answer, Many Solutions
Unknown Answer, Novel Solution

Modeling Applied to Problem Solving

A Pedagogy for Strategic Problem Solving

http;//RELATE.MIT.edu

Dave Pritchard, Saif Rayyan, Raluca Teodorescu, Andrew Pawl, Carolin Cardamone, Analia Barrantes,



Saif Dave Raluca Andy Carolin Analia

Teaching Strategic Thinking
MAPS: Modeling Applied to Problem Solving

- Organize their mechanics knowledge
  - Rearrange knowledge into *Core Models*
  - Understand conditions of applicability
- Solutions are based on core models
  - Decompose problem into pieces
  - Apply *Core Model* to each piece
- New Student Perspective: *answer* → *solution*
- Assessment: MIT Final, Next Course, Scientific Attitudes, Mechanics Reasoning Inventory

Organization of Core Models (Mechanics)

← Core Physical Models →

← Structural Components →

Motion Variable

← Type of Motion →

Agent of Change

Interactions

System

Model

Core Models Map for Mechanics

Motion

- Change of Position → Translation
- Change in Orientation → Rotation about axis a

Motion Variable

Velocity

$$\vec{\mathbf{v}}(t) = \frac{d\vec{\mathbf{r}}(t)}{dt}$$

Momentum

$$\vec{p}(t) \equiv \sum_{i=1}^{masses} m_i \vec{\mathbf{v}}_i$$

Mechanical Energy

$$E = \sum_i^{bodies} [K_i + U_i]$$

Angular Velocity

$$\omega(t) \equiv \frac{d\theta(t)}{dt}$$

Angular Momentum

$$\vec{\mathbf{L}}_S^{total} = \sum_i^{bodies} [\vec{\mathbf{L}}_{S,i}^{orbit} + \vec{\mathbf{L}}_{cm,i}^{spin}]$$

Interactions

Interactions

- External Forces
- External Torques about axis a

Agent of Change

$$\vec{F}^{net} = \sum \vec{F}_i$$

$$\vec{J} = \int_i^f \sum \vec{F}^{ext}\, dt$$

$$W = \sum \int F_i^{nc}\, dx + \sum \int \tau_a\, d\theta_a$$

$$\vec{\tau}_a^{net} = \sum \vec{\tau}_{a,i}$$

$$= \int \sum \vec{\tau}_a^{ext} dt$$

NOTE: Zero Agent of Change Implies Motion Variable is Constant (“Conserved”)

System

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

Model

Dynamics and Net Force

$$\sum \vec{F}_i = m\frac{d\vec{v}}{dt} = m\vec{a}$$

Momentum and Impulse

$$\vec{p}_f = \vec{p}_i + \vec{J}$$

Mechanical Energy and Work

$$E_f = E_i + W_{f,i}^{nc}$$

Rotational Dynamics and Net Torque

$$\Sigma\tau_a = I_a \frac{d\omega}{dt} \equiv I_a \alpha$$

Angular Momentum and Angular Impulse

$$\vec{L}_{S,f} = \vec{L}_{S,i} + \int_i^f \vec{\tau}_{S,total}^{external}(t)\, dt$$

We Coach Students in Flipped Classroom
- Cognitive Apprenticeship

- → Students need pre-class preparation

  -- Online offers assessment with feedback

- → Made complete online text + problems

- **Class is ~ 75% students working problems in groups of 2 or 3**
- **15% is discussion of what's really important**
- **10% is comments on common mistakes**
- **Teacher + TA can handle ~ 10 groups**

Apprentices Critiqued by Masters & Journeymen (TA)

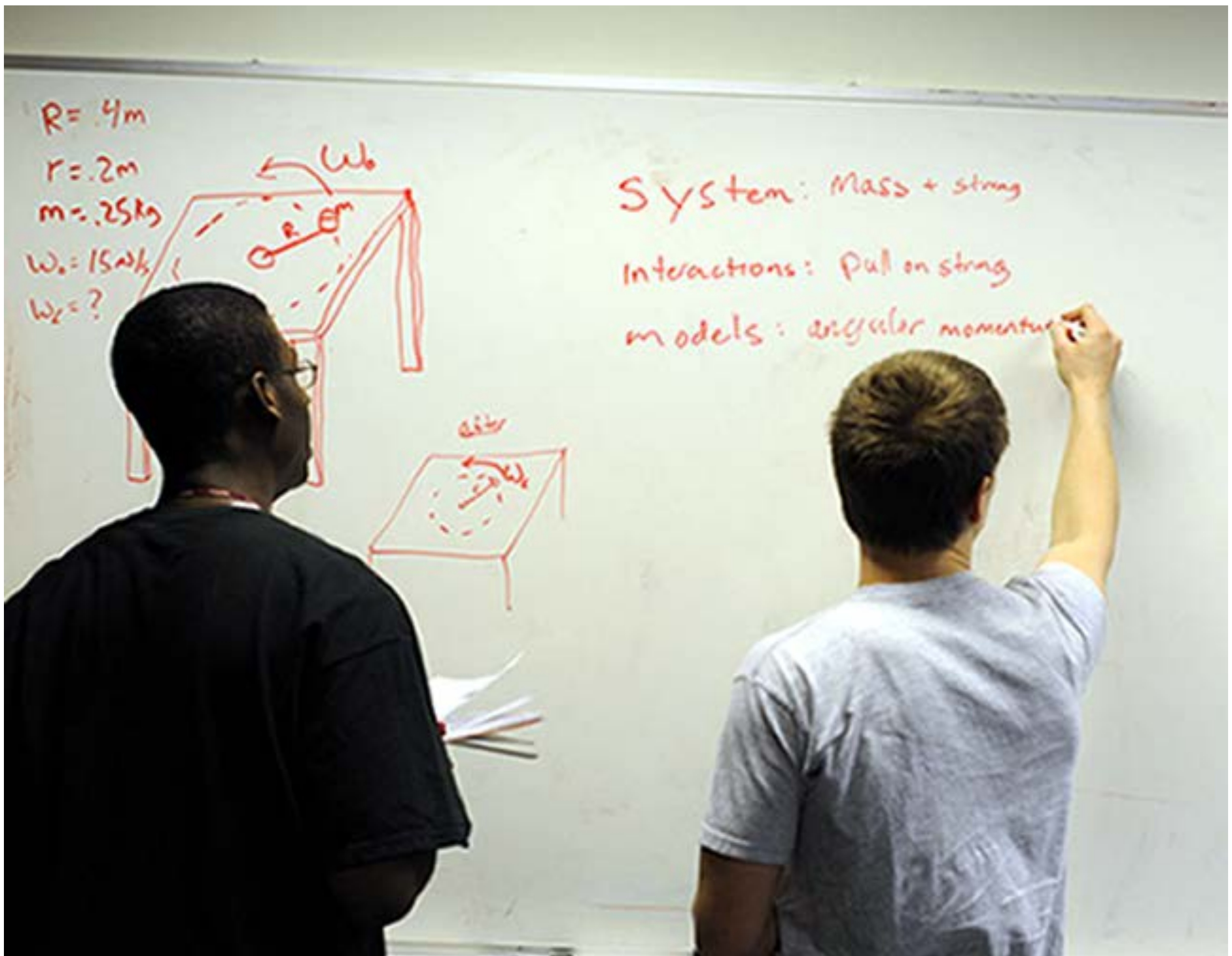
Students work in pairs, sometimes observe other groups
Staff are pro-active and reactive and available for help

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).



“Flipped” instructor and students

Normally Lecturer is animated and students are passive or distracted

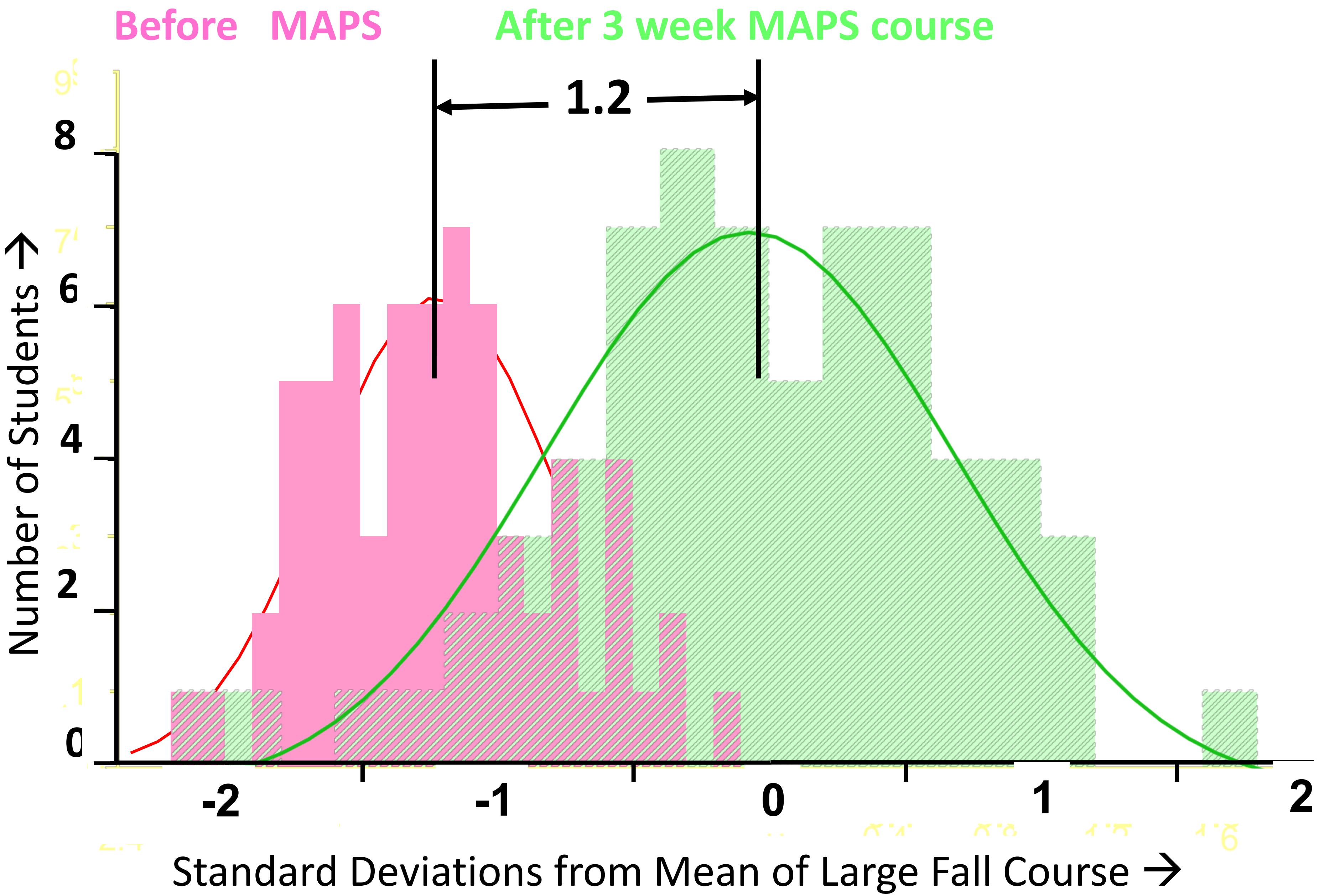
Flipped: All Students are animated and TA is distracted

Evidence: Successes of MAPS

MAPS Helps Students Learn to Solve Problems

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

Improved Performance – MIT Final



Colorado Learning Attitudes Science Survey-3 parts

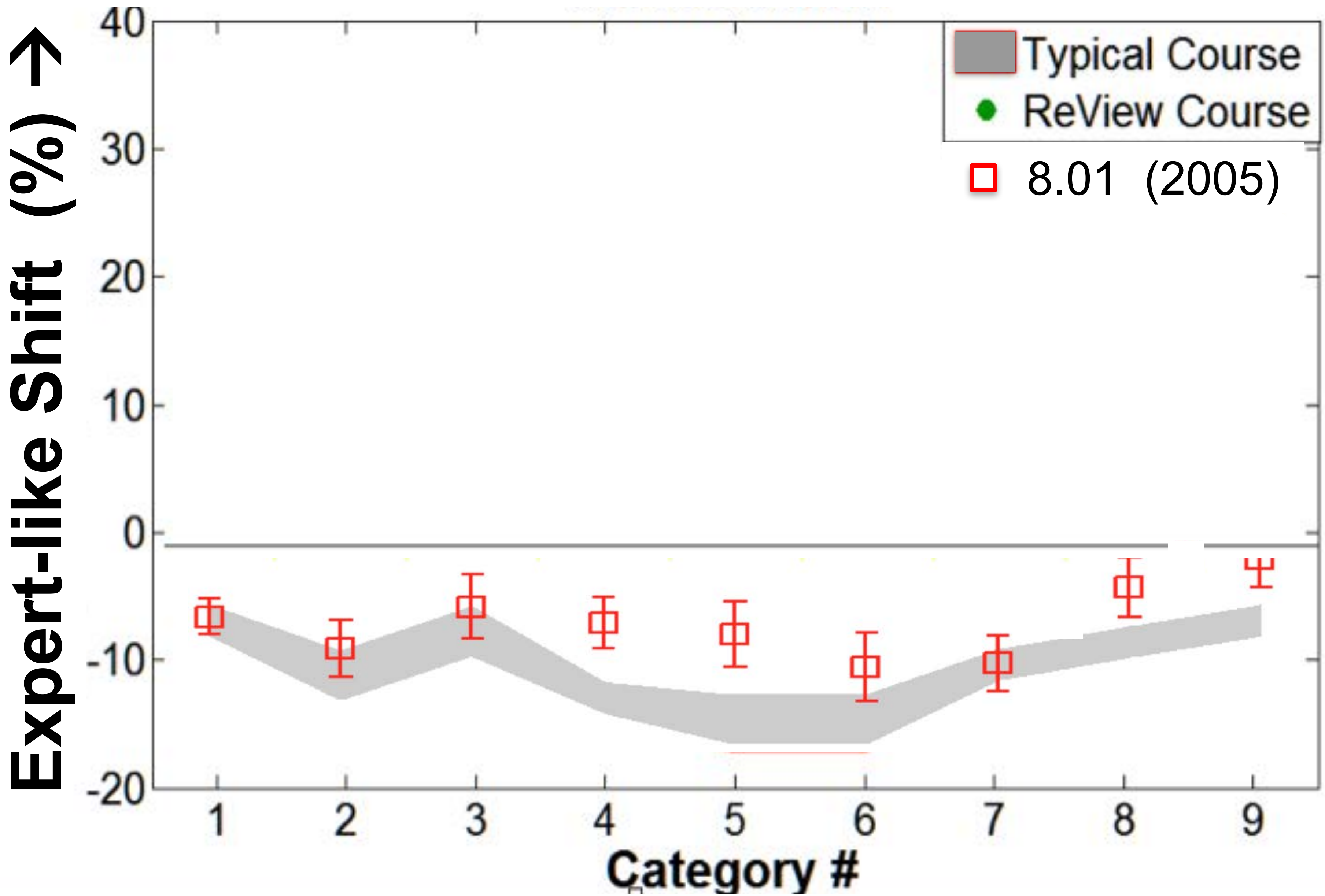
- Real-World Relevance
  - I think about the physics **I experience in everyday life**.
  - I am not satisfied until I understand **why something works the way it does**.
  - Learning physics changes my ideas about **how the world works**.
  - I study physics to learn knowledge that will be useful in my **life outside of school**.
  - The subject of physics has little relation to what I **experience in the real world**.
- Personal Interest
  - There are times **I solve a physics problem more than one way** to help my understanding.
  - To understand physics **I discuss it with friends** and other students.
  - To understand physics, I sometimes think about **my personal experiences** and relate them to the topic being analyzed.
  - When studying physics, I relate the important information to **what I already know** rather than just memorizing it the way it is presented. Reasoning skills used to understand physics can be **helpful to me in my everyday life**.

Self Confidence ~ "Prob. Solve Soph."

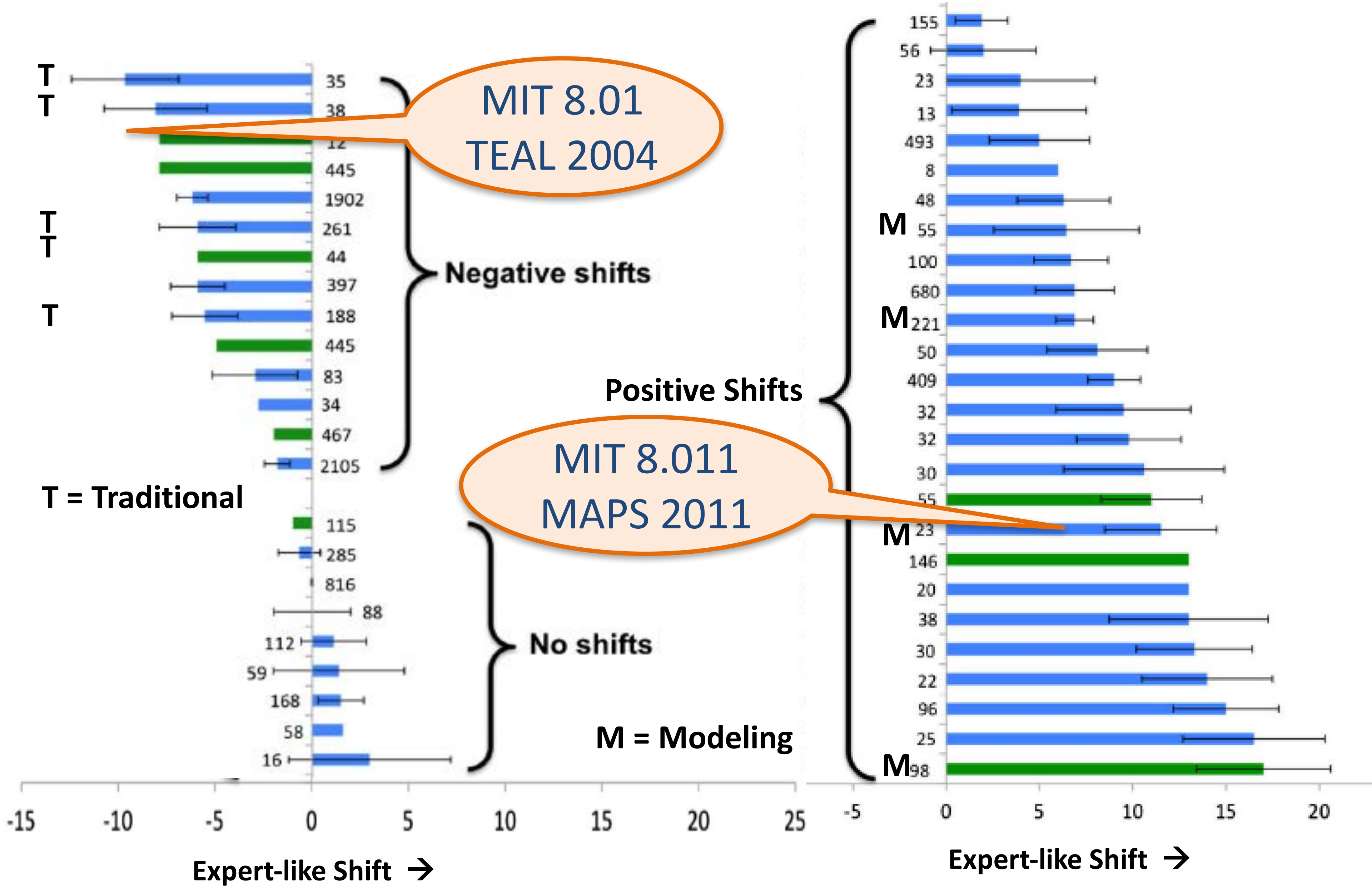
This category is 6 questions, five on self-confidence):

- **After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.**
- **If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.**
- **If I get stuck on a physics problem, there is no chance I'll figure it out on my own.**
- **I enjoy solving physics problems.**
- **I can usually figure out a way to solve physics problems.**
- **If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.**

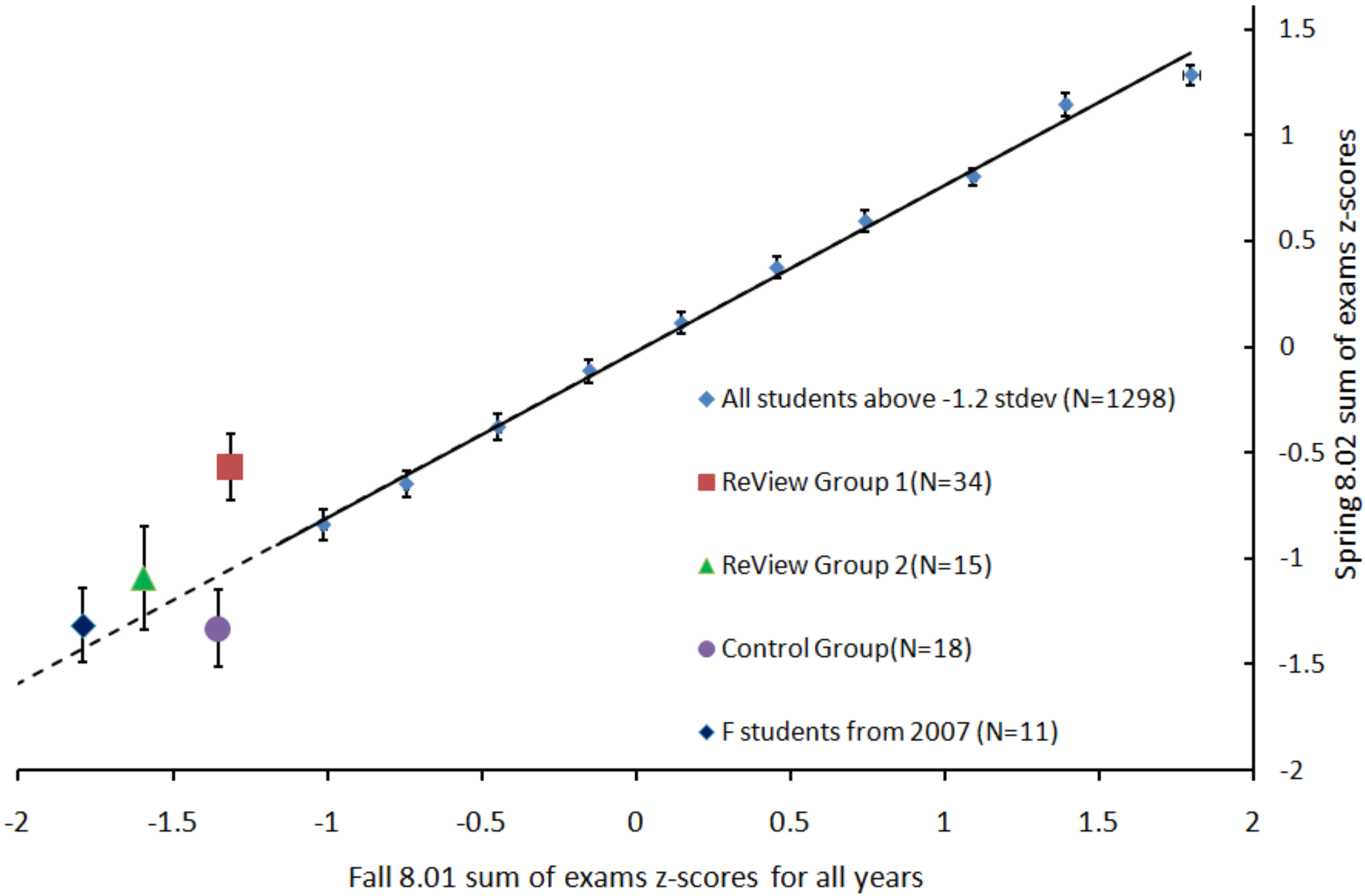
MAPS vs. 8.01 on CLASS: across all categories



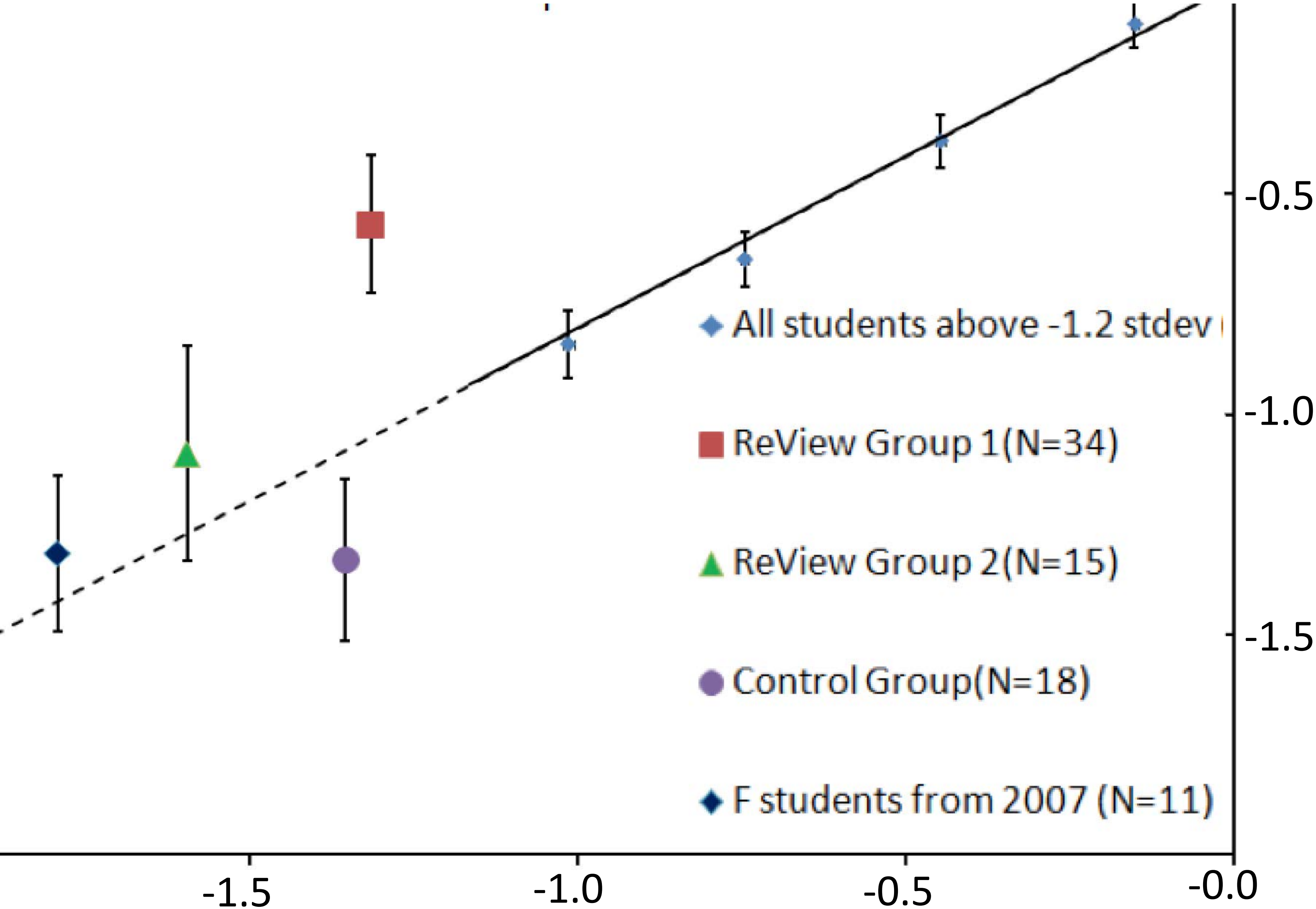
CLASS Shifts – Madsen et. al. PRSTPER 2015



Transfer to E&M Course vs Mechanics



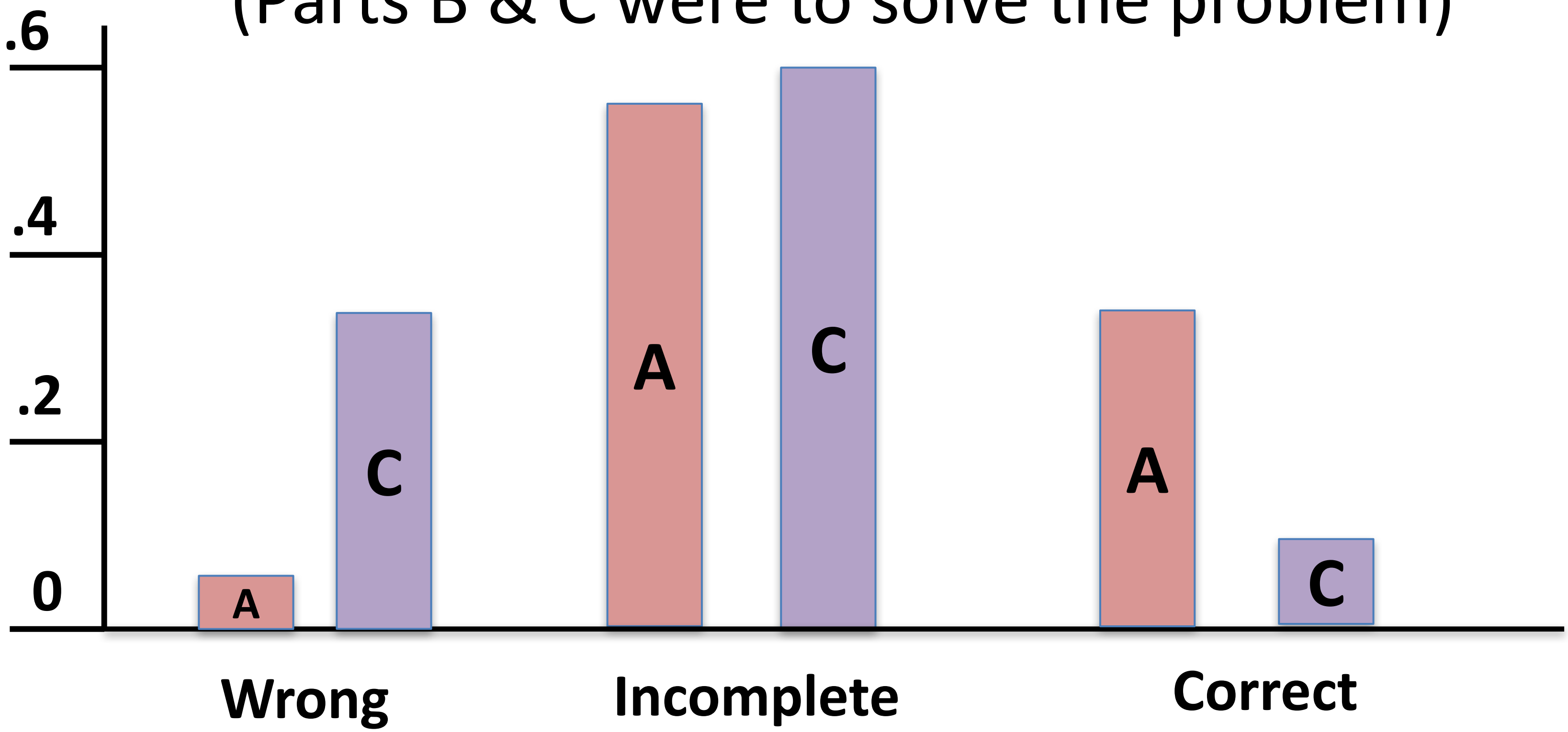
z-scores E&M vs. z-score Mechanics



Neither A nor C Can Write Problem Plans

- On Final, part A was "write a plan in words"

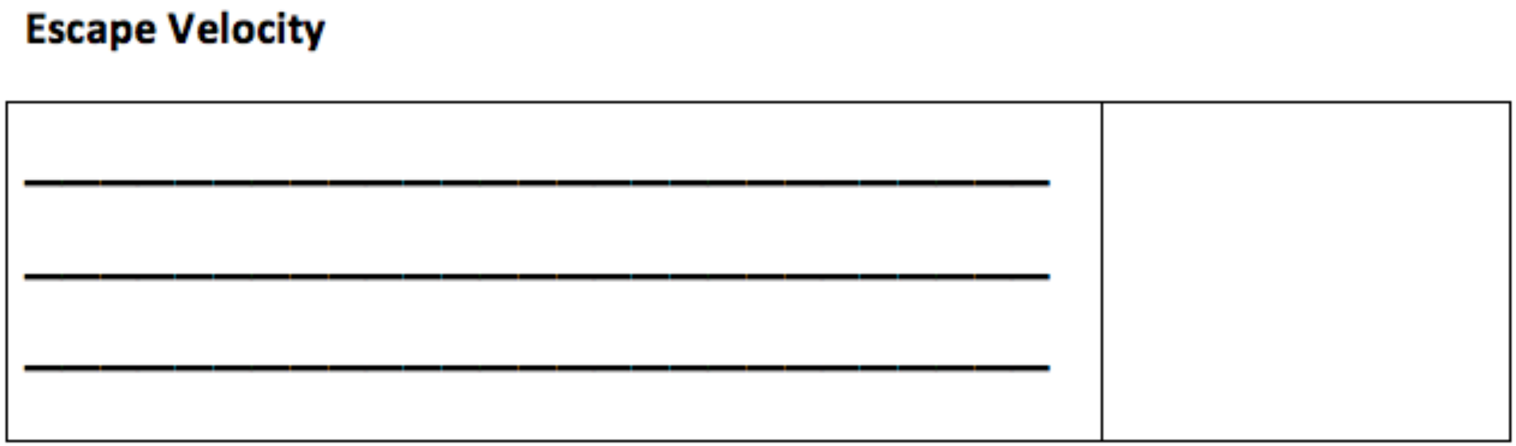
(Parts B & C were to solve the problem)



Students said they wrote the plan *after solving the problem*
Often the problem solution was correct/wrong
While the written plan was incomplete

Tweet Sheets

- Students Fill in Tweet Sheet after doing problem
- Can bring them to Quizzes and Tests



- Only ~ 20% bring them to the tests!
- Majority: didn’t know what to write, no time
- A few: “Once I wrote it, I didn’t need it.”

MIT Subject Evaluation

- *Instructors* - to modify and improve the approach, pedagogy, and content of the subject for the future
- *Departments* - to evaluate faculty for promotion and tenure
- *Notice:* Ratings highly correlated; this is typical

	AVG	1 2 3 4 5 6 7
Subject expectations were clearly defined	5.8	
Subject's learning objectives were met	5.7	
Assignments contributed to my learning	5.9	
Grading thus far has been fair	5.9	

Rating Scale: 1=Too Slov Applicable (4 is best)

	AVG	1 2 3 4 5 6 7
The pace of the class (content and assignments) was:	4.7	

	AVG
Average hours you spent per week on this subject in the classroom	4.9
Average hours you spent per week on this subject outside of the classroom	7.9

Rating Scale: 1=Very Po

	AVG	1 2 3 4 5 6 7
Overall rating of the subject	5.0	

Rating Scale: 1=Strongly Agree, N/A=Not Applicab

PHYSICS SUBJECT QUESTIONS	AVG	1 2 3 4 5 6 7
The lectures contributed to my learning.	5.4	
The recitations contributed to my learning.	5.4	
The online materials offered were effective.	4.9	
The textbooks and other readings offered were effective.	4.4	

Research on Student Evaluations: Titles!

- **Student Evaluation Of College Teaching: A practice in Search of Principles**
  - *College Teaching* Vol. 52 , Iss. 4 (2004) B. Algozzine et. al.
- **“How'm I Doing?” Problems with Student Ratings of Instructors and Courses**
  - *Change: The Magazine of Higher Learning* Williams & Ceci *Volume **29,** 13 (1997)*
- **Instructor Fluency Correlates with Students’ Ratings of Their Learning and Their Instructor in an Actual Course**
  - *Creative Education,* Vol.7 No.8, (2016)

Fluency Hurts; Disfluency Helps Learning

- Fluency – ease of communication, understanding
- Study 1 experiments found that information in hard-to-read fonts was better remembered (87% vs. 73%) than easier to read information. Study 2 extended this finding to high school classrooms (0.4 Std Dev effect).
  - Fortune favors the ***Bold*** (*and the italicized*): Effects of disfluency on educational outcomes *C. Diemand-Yauman et. al.* Cognition **118**: 111-5 (2010)

Scholarship on Student Evaluations

- **Based on the present data, we know that it is at least possible for student ratings to be extremely systematic and reliable, yet invalid!**
  - *Change: The Magazine of Higher Learning* Williams & Ceci *Volume* ***29,*** *13 (1997)*
- **We find that teacher quality matters substantially and that our measure of effectiveness [success in following course] is negatively correlated with the students' evaluations of professors.**
  - *Economics of Education Review 41 (2014) 71–88* Michela Braga, Marco Paccagnella, Michele Pellizzari

Strongest Study: AFOSR N=10k

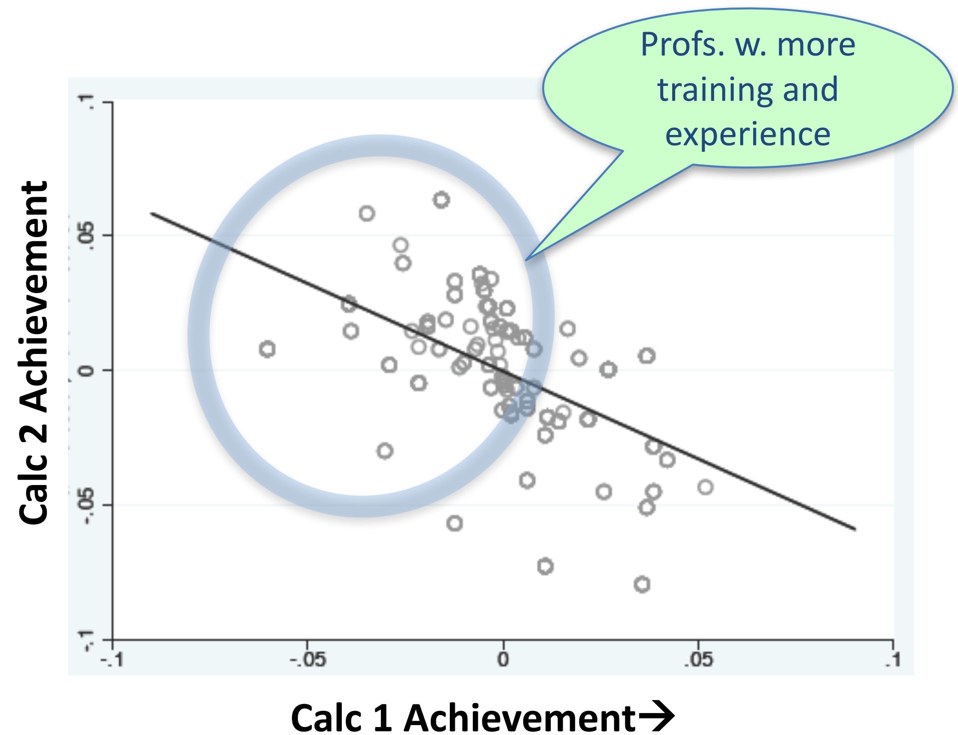
Cassie & West 2010

Effect of Instructor on Calc 1 and Calc 2

Control for gender, athlete, SAT-M, SAT-V, etc.

Students Randomly assigned to sections

We …. present evidence that professors who excel at promoting contemporaneous student achievement teach in ways that improve their student evaluations but harm the follow-on achievement of their students in more advanced classes.



Useful questions are about Product, Should ask about it's Effect on Student

- I enjoyed this course
- I learned new ways to think about my world
- Increased my interest about *this subject*
- Skills that will help me in life
  - Improved Writing ability
  - Improved Collaboration
  - Improved Critical Thinking

Good Idea: Replace Evaluation with CLASS

NRC Advice for Physics - ENDING

- *Adapting to a Changing World--Challenges and Opportunities in Undergraduate Physics* (Langenberg, 2013) – Recommendations

…The major result of this committee's deliberations, expressed in more detail in the recommendations below, is that the physics community pursue this vision by making significant changes in undergraduate physics education that are grounded in scientific evidence.

NRC Advice for Physics - ENDING

- ***Adapting to a Changing World--Challenges and Opportunities in Undergraduate Physics*** **(Langenberg, 2013) – Recommendations**

In spite of the numerous challenges facing undergraduate physics education, a realistic future includes introductory physics courses that students view as an opportunity to exercise their thinking rather than their memory; learn approaches to solving problems that transfer to other (STEM) courses; improve their expertise in and attitudes toward learning science; and see the relevance of physics to their future lives and to the world around them. In this future, more students, especially women and minorities underrepresented in physics, will decide to major in physics and teach others about it.

END

8.011 Correlation of Instruction & Tests

Group		Final	Quizzes	Δ-Quiz	Mastrng	LON-CAPA	W Pset	Attendance
Assessment	Final	1	0.6	0.31	0.31	0.2	0.32	0.42
	Quizzes	0.6	1	0.3	0.41	0.22	0.63	0.61
	Δ-Quiz	0.31	0.3	1	0.25	0.07	0.29	0.09
Online	Mastrng	0.31	0.41	0.25	1	0.49	0.43	0.35
	LON-CAPA	0.2	0.22	0.07	0.49	1	0.12	0.28
Homework	W Pset	0.32	0.63	0.29	0.43	0.12	1	0.69
Class	Attendance	0.42	0.61	0.09	0.35	0.28	0.69	1

8.01 residential (2015)

Assessment	Final Ex	1	0.54	0.54	0.52	0.86	0.21	0.11	0.16	0.2
	Ex #1	0.54	1	0.42	0.42	0.74	0.18	0.11	0.22	0.28
	Ex #2	0.54	0.42	1	0.45	0.77	0.17	0.09	0.03	0.07
	Ex #3	0.52	0.42	0.45	1	0.76	0.15	0.07	0.1	0.03
		0.86	0.74	0.77	0.76	1	0.23	0.12	0.16	0.18
Online	Wks 2-4	0.21	0.18	0.17	0.15	0.23	1	0.66	0.07	0.08
	Wks 5-11	0.11	0.11	0.09	0.07	0.12	0.66	1	0.08	0.09
Homework		0.16	0.22	0.03	0.1	0.16	0.07	0.08	1	0.34
Class		0.2	0.28	0.07	0.03	0.18	0.08	0.09	0.34	1

Fundamental Expert-Novice differences

Expert	Novice
Conceptual knowledge impacts problem solving	Problem solving largely independent of concepts
Often performs qualitative analysis, especially when stuck	Usually manipulates equations
Uses forward-looking concept-based strategies	Uses backward-looking means-ends techniques
Has a variety of methods for getting unstuck	Cannot usually get unstuck without outside help
Monitors and checks progress while problem solving	Problem solving uses all available mental resources
Is able to check answer using an alternative method	Often has only one way of solving problem

State of Knowledge Expert vs. Novice

EXPERT	NOVICE
Store of domain-specific knowledge	Sparse knowledge set
Knowledge richly interconnected	Knowledge mostly disconnected, amorphous
Knowledge structured hierarchically	Knowledge stored chronologically
Integrated multiple representations	Poorly formed and unrelated representations
Good recall	Poor recall

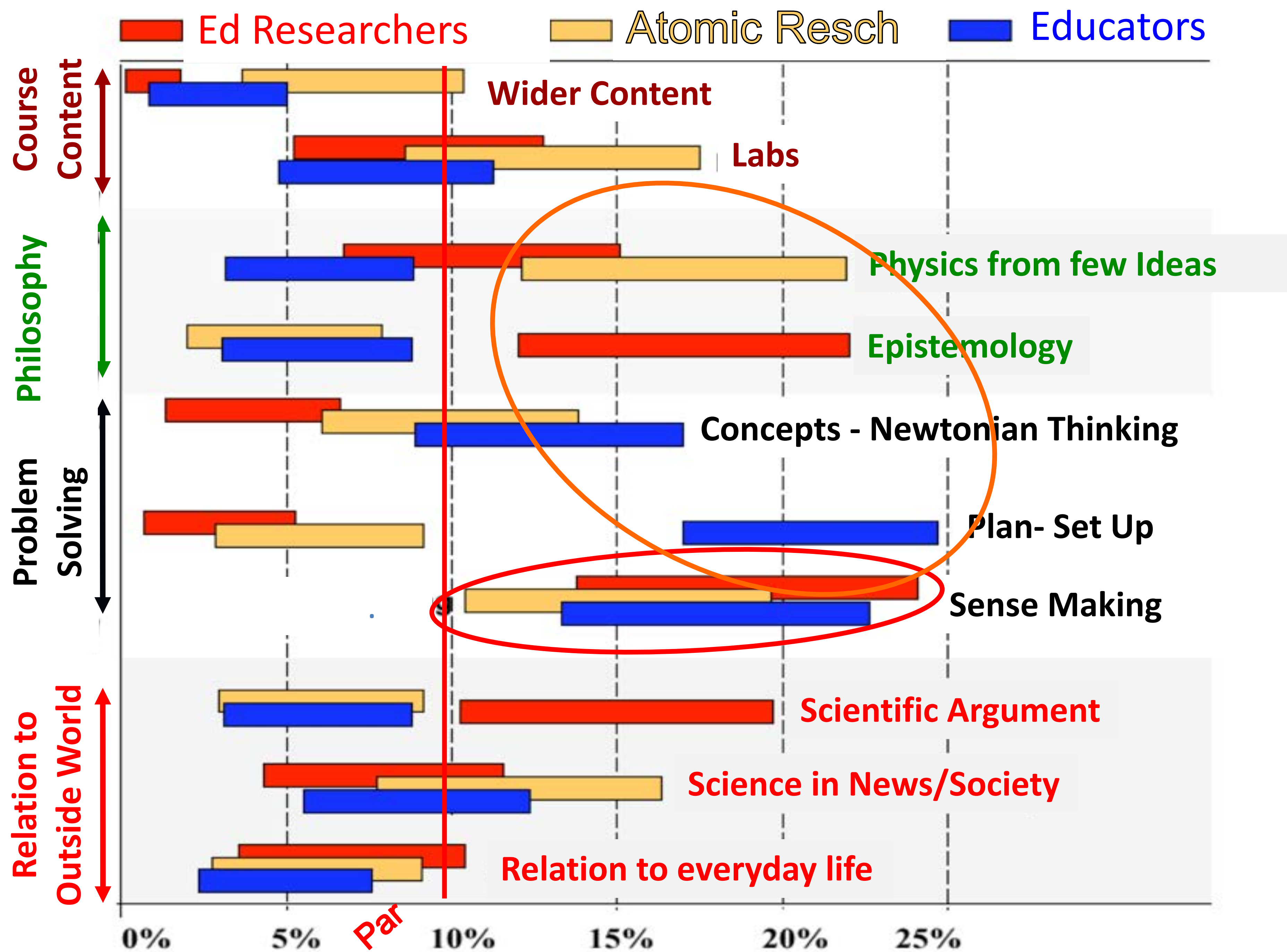
Remember: We Want to Improve Outcomes

- **There is, therefore, no evidence that the use of the questionnaire was making any contribution to improving the overall quality of teaching and learning of the departments, at least as perceived by the students.**
  - *Does the Use of Student Feedback Questionnaires Improve the Overall Quality of Teaching?* D.Kember, D.Leung, K.P.Kwan *Assessment and Evaluation in Higher Education* 27 May 2010 pp.411-425

10 Questions, 4 Categories,

Course Content	More Content: Gyroscopes, QM, Nuclear Discovery-based or Traditional lab
Scientific Ideas	Physics comes from a few ideas Epistemology: how do I know, derivations
Problem Solving	Concepts - should be Newtonian Thinkers Problem Solving - concepts, plan, set up Sense–making of solution, estimation
Physics & World	Communication of Solution & Science Understand Science in News/Society Relation to everyday life/things

Removed: Scientific Method, Vocabulary (too few responses)


Ed Researchers
Atomic Resch
Educators
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
0%
5%
Par
10%
15%
20%
25%

Students

Average of Instructors

r = - 0.4! Professors vs Students?

- Catalog says College will turn students into professionals who solve problems
- 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 futures life

Scientific Education Improvement

Read the literature

Identify the problem or possible improvement

Plan (with committee?) approach

Modify instructional procedure/material

~~Survey Student and Staff Approval~~

Assess the Outcome

Rethink and Recycle

Publish the New Results

Goals of MAPS

Frequent Complaint (a CLASS question)

After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

Goals: Students Solve Problems

1. **Measurably better**
2. **Starting from Concepts**
3. **With better organized knowledge**
4. **With more expert learning attitudes**
5. **With Transfer to future E&M problems**

MAPS aids Transfer, Core → Problem

Idea: Models represent declarative and procedural knowledge to facilitate strategic ***Modeling*** approach

Models for Basic Core Principles	←differentiate→	**Modeling *process* to solve problems**

Theory, general physical principle/concept	**Application**: solving of specific problems
Hierarchies to organize syllabus	Applies syllabus content
Existing knowledge	Student-constructed knowledge
Each Model has Allowable Systems, State variables, Restrictions on Interactions, Laws of Change, useful definitions and representations	Each Problem is approached using Problem Modeling Rubric: **System, Interactions, Model**