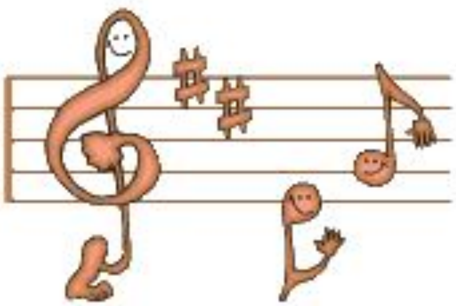
Thoughts on Teaching While Listening to Ravel's Bolero



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Outline

- **Motivation**
  - The goals of education have changed.
    We need to reach more students. How?
- **The scholarship of learning and teaching: An existence theorem**
  - We can treat the problem of teaching
    using the tools of science.
- **Climbing onto the shoulders of giants**
  - Research into human behavior has made great strides in the past 50 years and can offer some guidance.
- **Beyond content: The hidden curriculum**
  - Our real goals for student learning are often tacit.

Motivation

“The times they are
a-changin’.”

Changes since I went to college

- Technology opens and closes doors
- Evolution of job market
  - Loss of manufacturing jobs
  - Growth of service sector
- Increase in college population
- Shift in perception of our responsibility.

Changing needs

- Technology: Robots handle rote.
- Changing professions:
  Multiple careers and lifelong learning.
- Need problem solving
  and other higher order skills
- More science!
  (and more writing, and more
  geography, and more languages, and...)

Why is learning science so hard for so many students?

- Many students have trouble with their science classes.
- Many teachers are disappointed with their students' performance in their science classes.
- Many people find science difficult.
- Can't science teachers do a better job?

"And it was so typically brilliant of you to have invited a physicist."

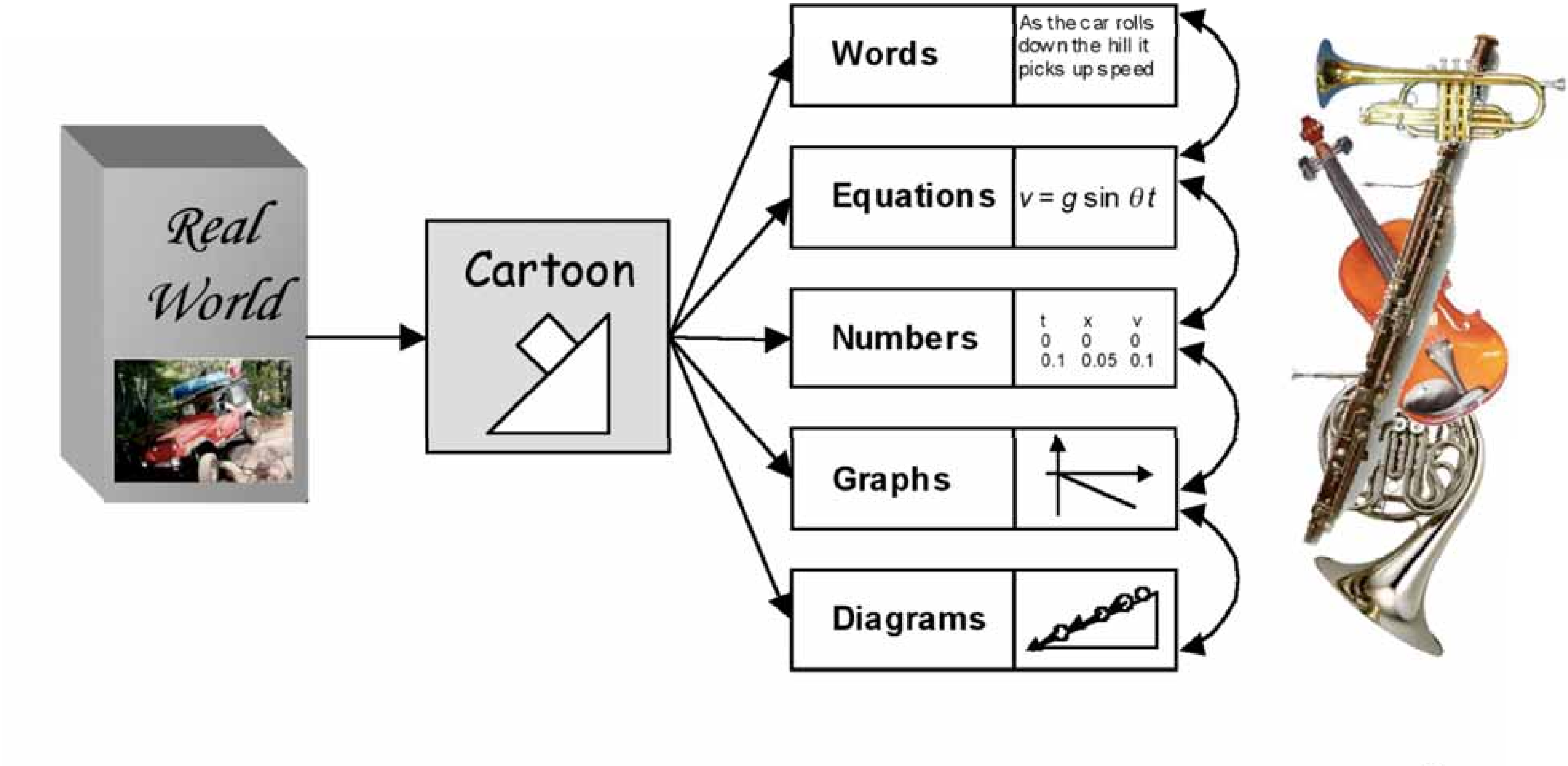
The Scholarship of Learning and Teaching: An Existence Theorem

"There's something there to measure!"

Can we actually study teaching and learning?

- One idea is to try to understand the successes and failures of teaching <u>in</u> science by using the methods <u>of</u> science – observation, analysis, testing...
- Does it make sense to do this?
- When I began to look into this (in 1991) I expected that any result would vary wildly depending on the details of who was teaching whom and how.
- An example about teaching the concept of velocity proved me wrong.

In physics we make a lot of use of multiple representations to help reify a concept

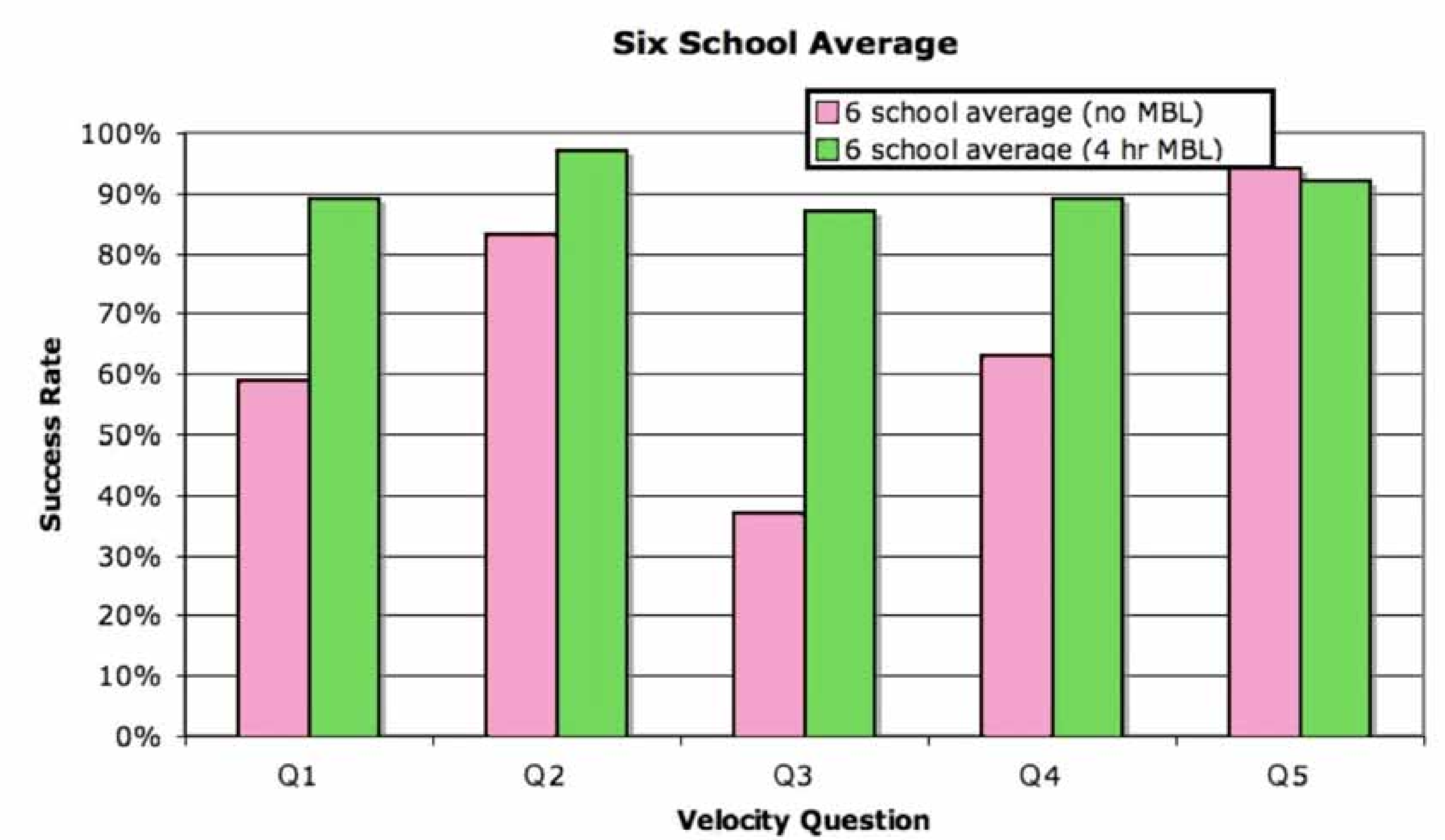


Velocity: A Hard Concept

- Distinguishing a quantity, the change of a quantity, and the rate of change of a quantity is difficult, even for students who have successfully completed calculus.
- Careful studies* (including detailed interviews) show college students have trouble figuring out what a graph of a motion's velocity will look like.

** D. Trowbridge and L. McDermott, Am. J. Phys.* ***48****, 1020-1028 (1980)*

Most students can learn to translate a velocity graph



* *R. K. Thornton, private communication; and*
R. K. Thornton and D. R. Sokoloff, Am. J. Phys. ***58****, 858-867 (1990)*

A problem with the students? Or with the instruction?

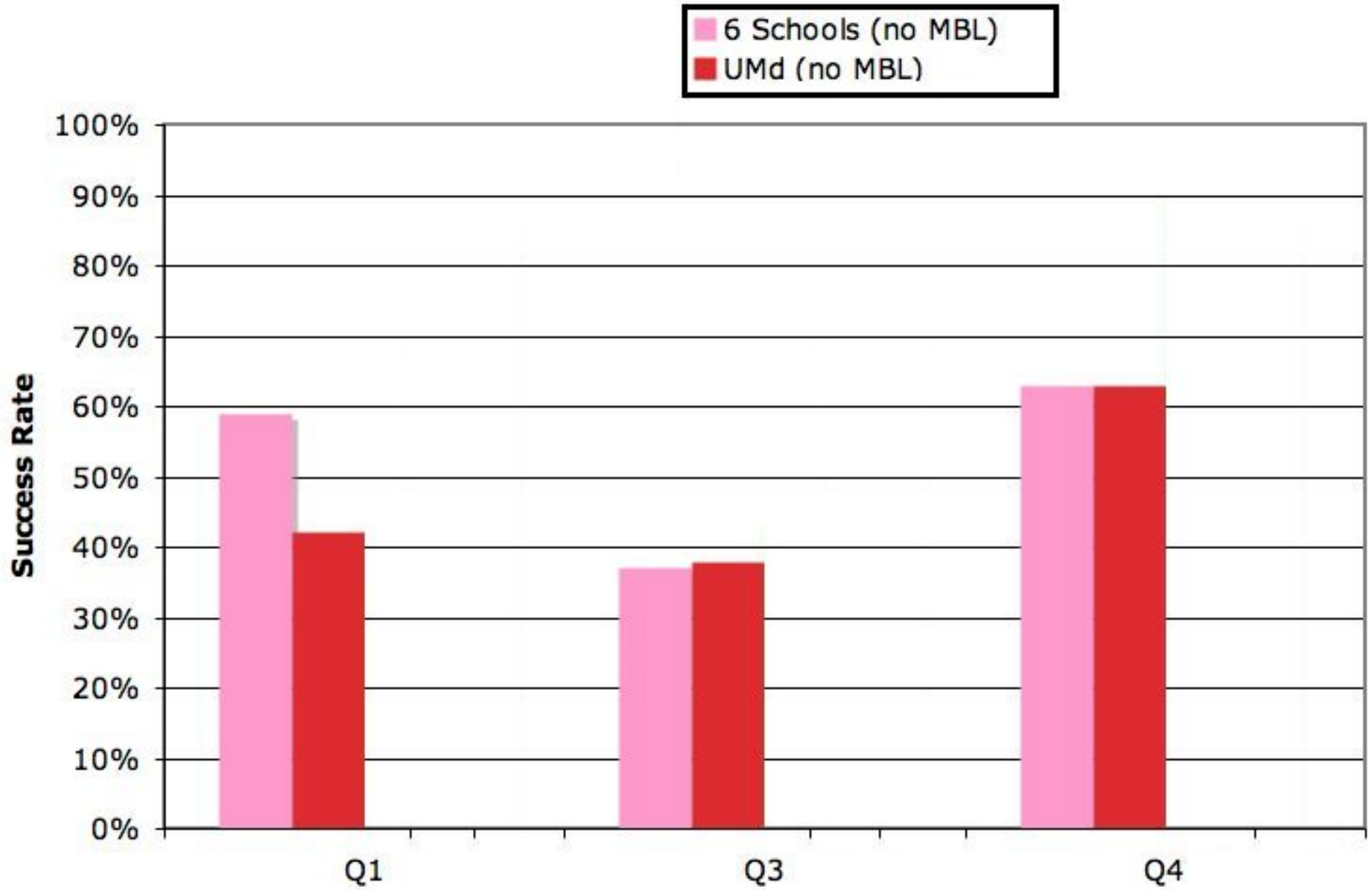
- Thornton and Sokoloff* documented that traditional lectures, HW, and recitations do not do well in helping students solve these problems.
- Success rates (for Questions 1, 3, & 4) remain ~50% after instruction.
- Four hours of interactive labs (MBL) improve success rates to ~90%.

** R. K. Thornton and D. R. Sokoloff, Am. J. Phys.* ***58****, 858-867 (1990)*

I didn't believe it

- I was confident that I could beat the reported 6-school results with my lectures.
- I carefully prepared 3 hours of lecture using everything I (thought I) knew about lecturing.
- Attendance was excellent and the students were attentive.
- I gave the problem on the next mid-semester exam.

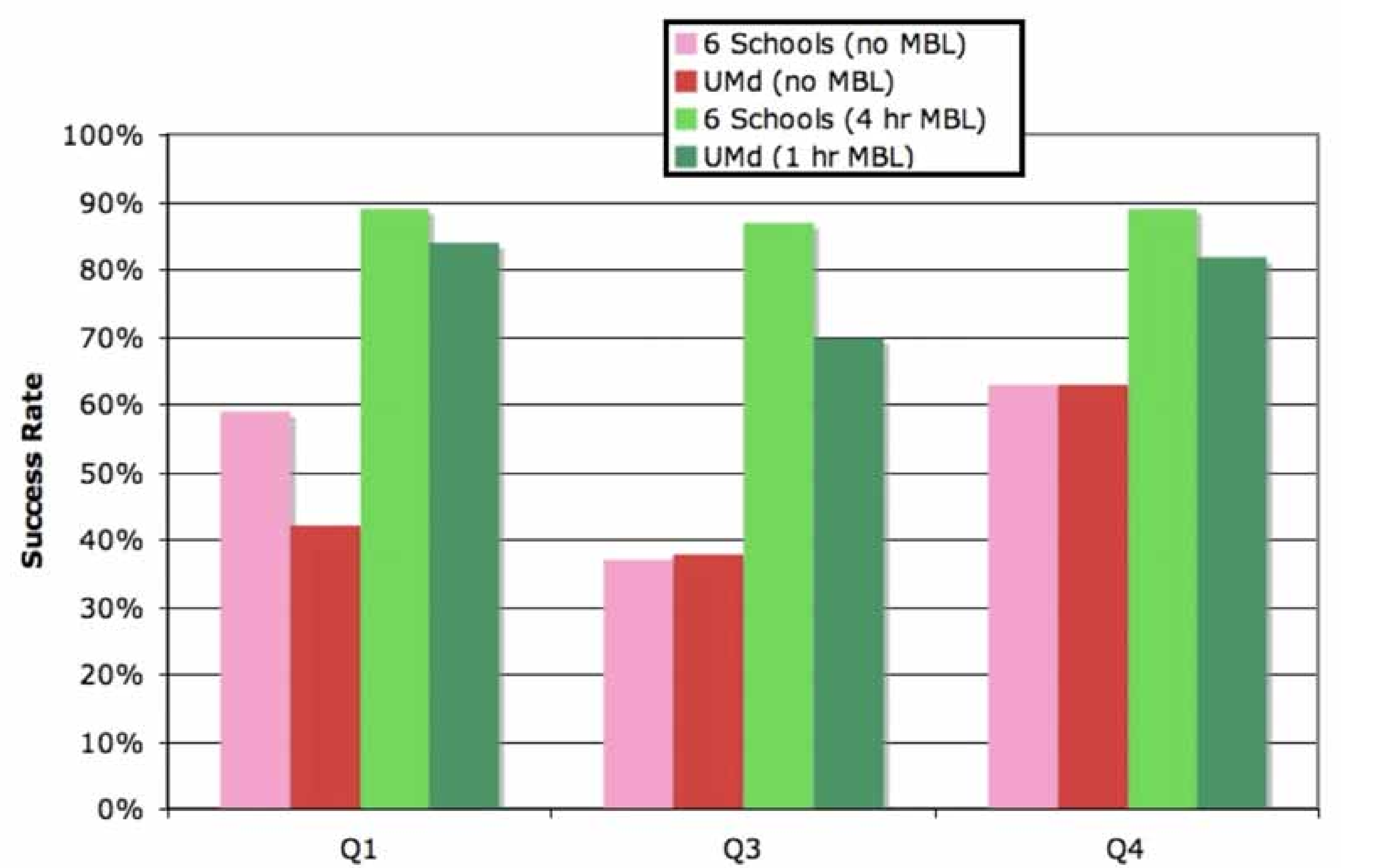
My result was the same as everyone else's



Another approach

- The next time I taught the course,
  (two years later) I transformed the recitations into a more active learning environment (tutorials).
- I created a 1-hour lesson
  based on the T&S 4-hour labs.
- I reduced my lecture effort to 1 hour.
- I again gave the problem on the mid-semester exam.
- Less instruction produced better results.

Comparison



** E. Redish, J. Saul, and R. Steinberg, <u>Am. J. Phys.</u>* ***65****, 45-54 (1997)*

"There's something there to measure."

- What surprised me here was that the pattern was so robust.
- I had expected that the result would vary substantially.
- I did the experiment and "got the answer in the book" – I hadn't even known there <u>was</u> a book.

SoTL: Creating a community of scholars

- *A new goal*:
  to learn about teaching and learning
  using the tools and methods of science.
- *A new scholarship*:
  the scholarship of teaching and learning.
- *A new community*:
  a collaboration among education researchers
  in education and in the disciplines.
- *The hope*:
  to convert good teaching from an art
  that only the most talented can do
  to a craft that can be explained and taught.

DBER

- Applying SoTL at the college level requires disciplinary expertise.
- Discipline-based education research (DBER) is carried out by disciplinary specialists from within the context of their disciplines.
- PER (Physics Education Research) has been active for 30 years.

Some university physics departments with PER groups

- Arizona State U.
- U. of Colorado *
- Florida International *
- Harvard U. *
- U. of Illinois *
- Kansas State U.*
- NC State U. *
- NM State U.
- U. of Maine *
- U. of Maryland
- MIT *
- U. of Minnesota *
- N. Dakota State U. *
- The Ohio State U. *
- U. of Oregon
- Oregon State U. *
- U. of Pittsburgh
- Rochester Inst. of Tech.
- Seattle Pacific U.
- Swarthmore College
- Texas Tech U.
- Towson U. *
- U. of Washington *

** = 2 or more faculty in physics*

...about 30 more

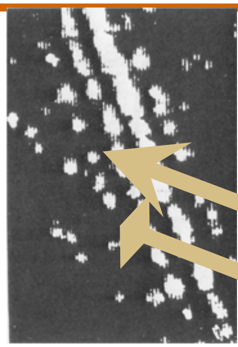
The UMd PERG/BERG:

- **Faculty**
  - Joe Redish (Phys)
  - Todd Cooke (Bio)
  - Andy Elby (Educ)
- **Research Faculty**
  - Ayush Gupta (Phys)
- **Postdocs**
  - Chandra Turpen (Phys)
  - Jessica Watkins (Phys/Bio)
  - Julia Svoboda (Bio)
  - Vashti Sawtelle (Phys)
- **Grad Students**
  - Brian Danielek (Educ)
  - Ben Dreyfus (Phys)
  - Ben Geller (Phys)
  - Colleen Gillespie (Educ)
  - Kristi Hall (Educ)
  - Mike Hull (Phys)
  - Eric Kuo (Phys)
  - Tiffany Sikorski
- Visitors
  - Sevda Damar (Turkey)
  - Partha Roy (India)
  - Arnaldo Vaz (Brazil)

Climbing onto
the shoulders of giants

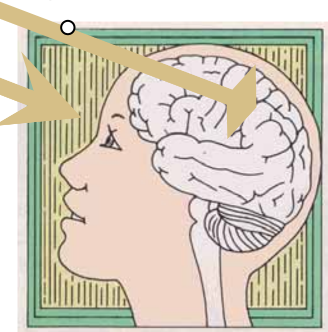
"It's always better
to build on what is known
than to continually re-invent
the flat tire."

Science is an interaction between the real world and the minds of scientists

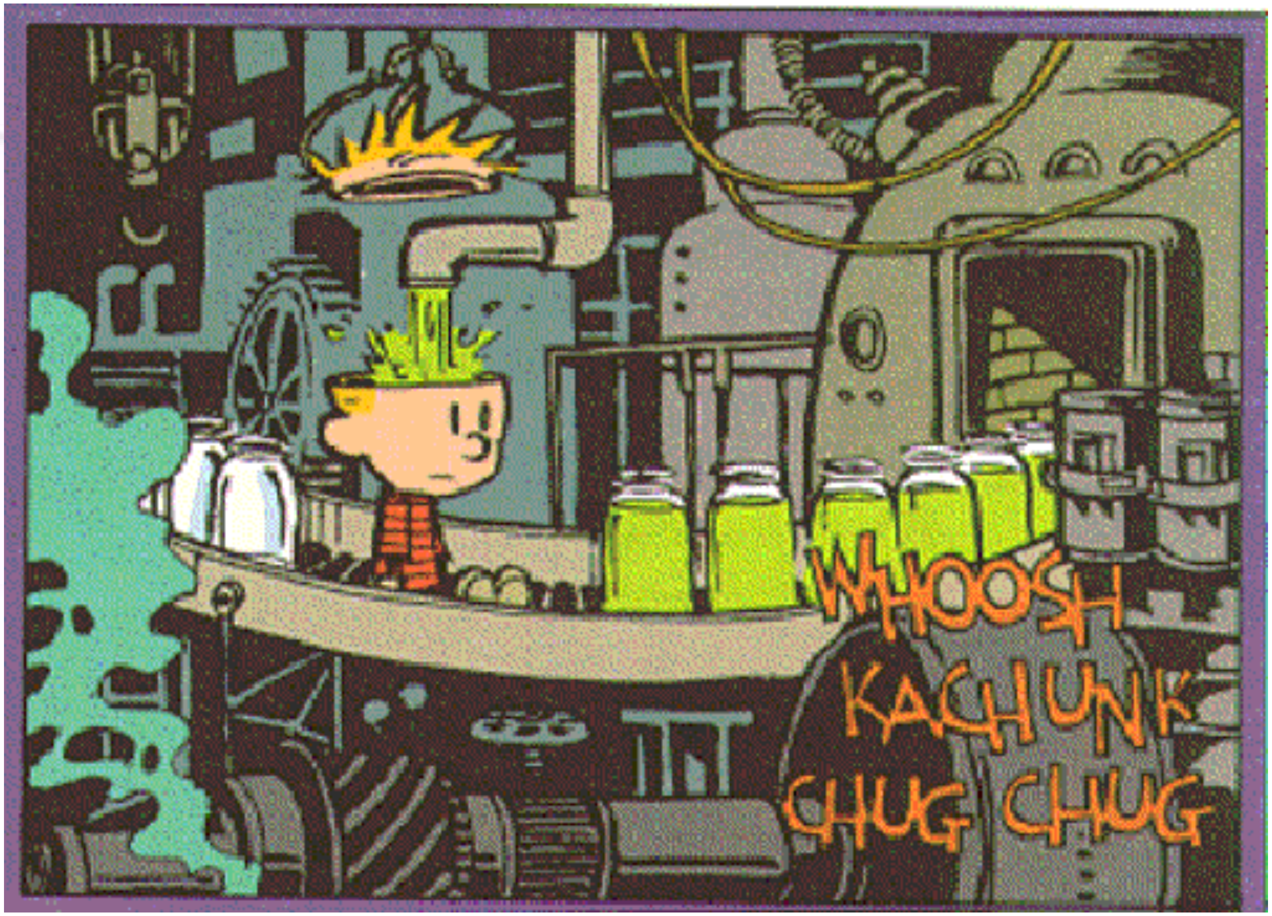


$$-\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi = i\hbar\frac{\partial\Psi}{\partial t}$$

- When we only study one side of the interaction, we miss a critical part of the phenomenon of science.

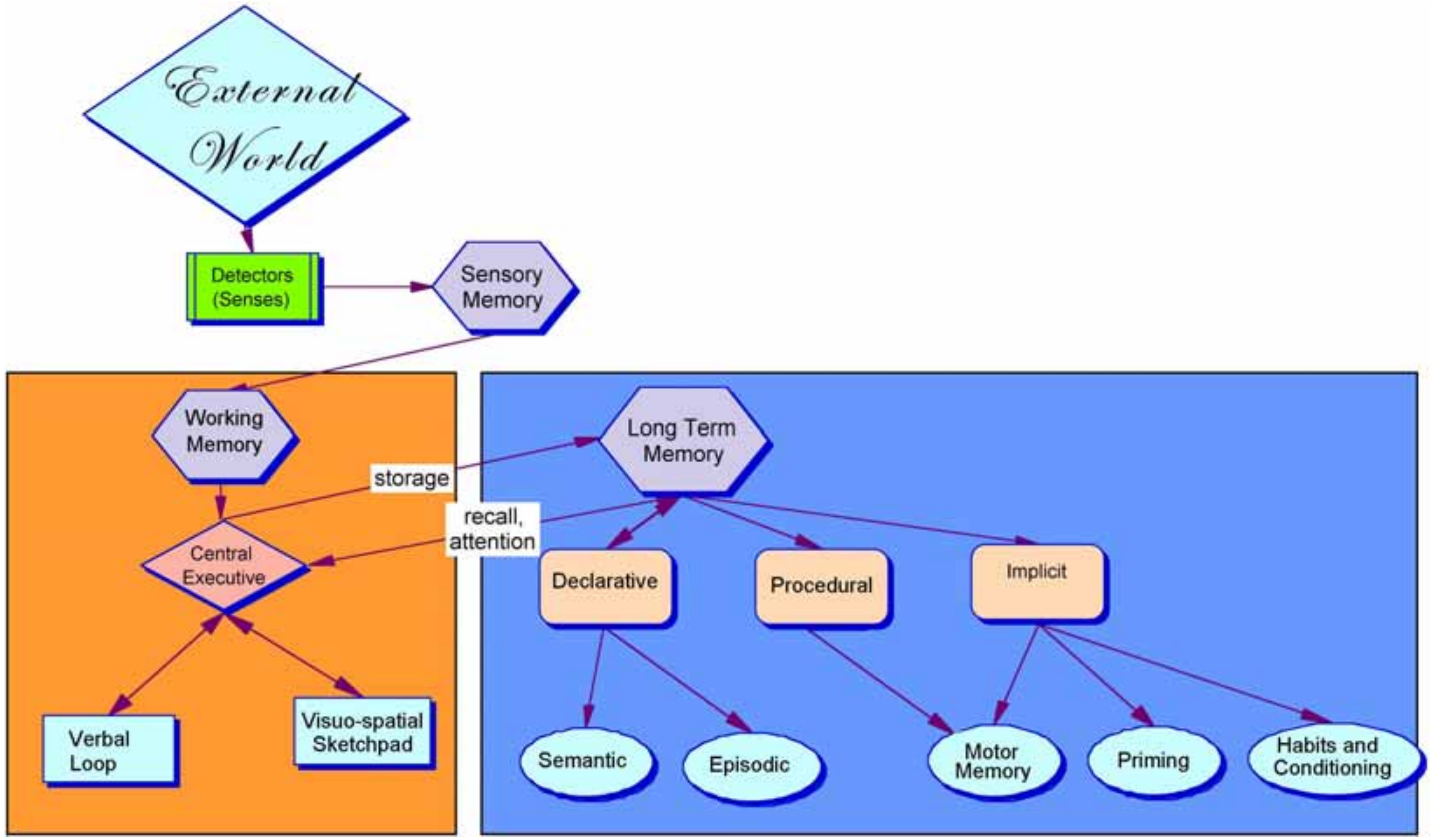


A Model of Student Learning



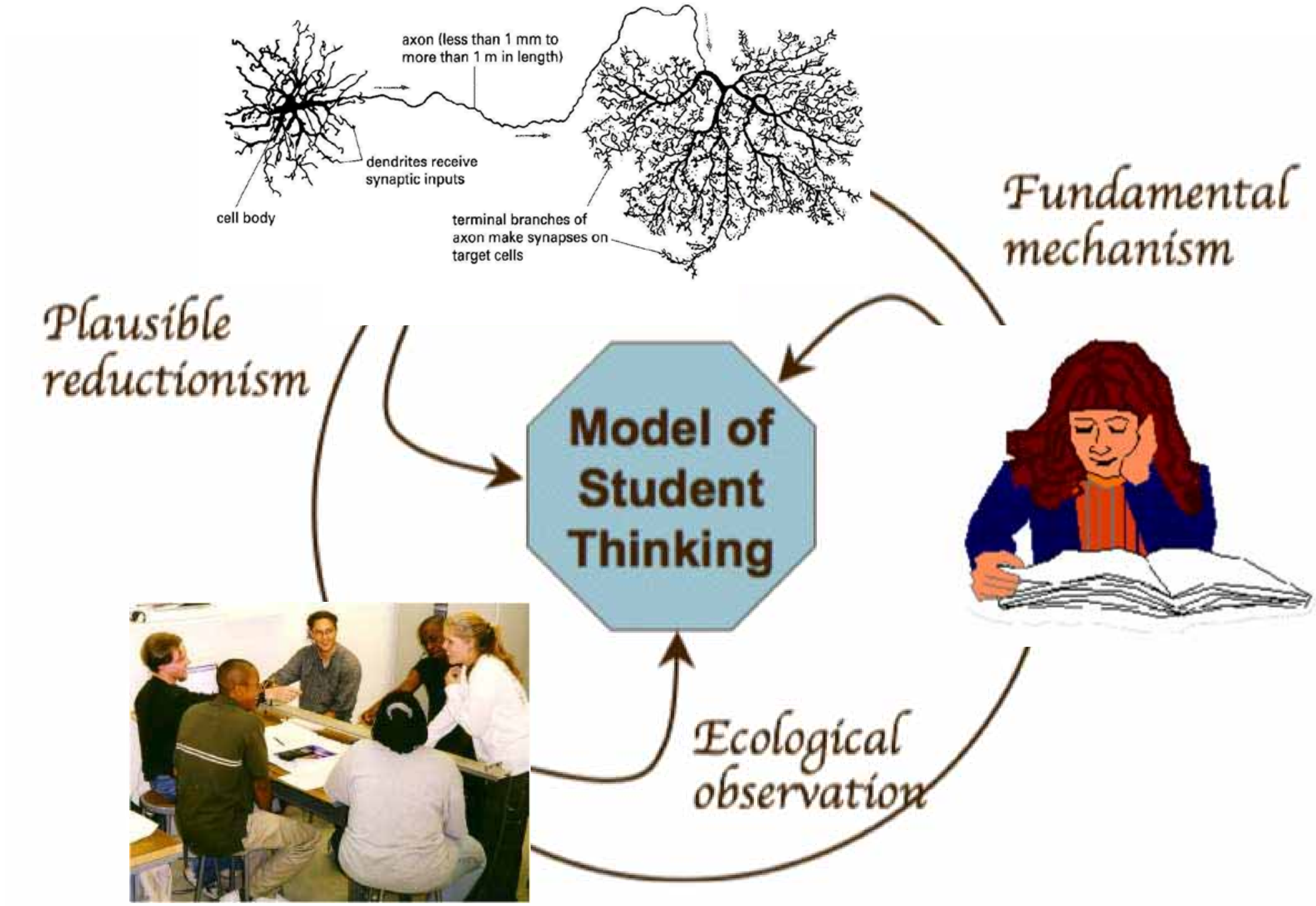
Bill Watterson *Calvin & Hobbes*

A model of the mind



Adapted from A. Baddeley, *Human Memory: Theory and Practice* (Allyn & Bacon, 1998). and L. R. Squire and E. R. Kandel, *Memory: From Mind to Molecules* (Sci. Am. Lib., 1999).

Triangulation



*The Resource Model:** *
Foothold ideas

- Activation
  - A perception / awareness of something corresponds to the activation of a set of linked neurons. **
- Association
  - The activation of bit of knowledge can lead to the activation of others ("spreading activation")
- Binding
  - Different bits of knowledge can become tightly tied so they always activate together – the user becomes unaware of their separate parts.
- Selective attention
  - Contexts can suppress, prime, or activate clusters of knowledge.

* D. Hammer, Am. J. Phys. Suppl. **68** S52-S59 (2000)
E. F. Redish, Fermi Summer School Lectures (2003)

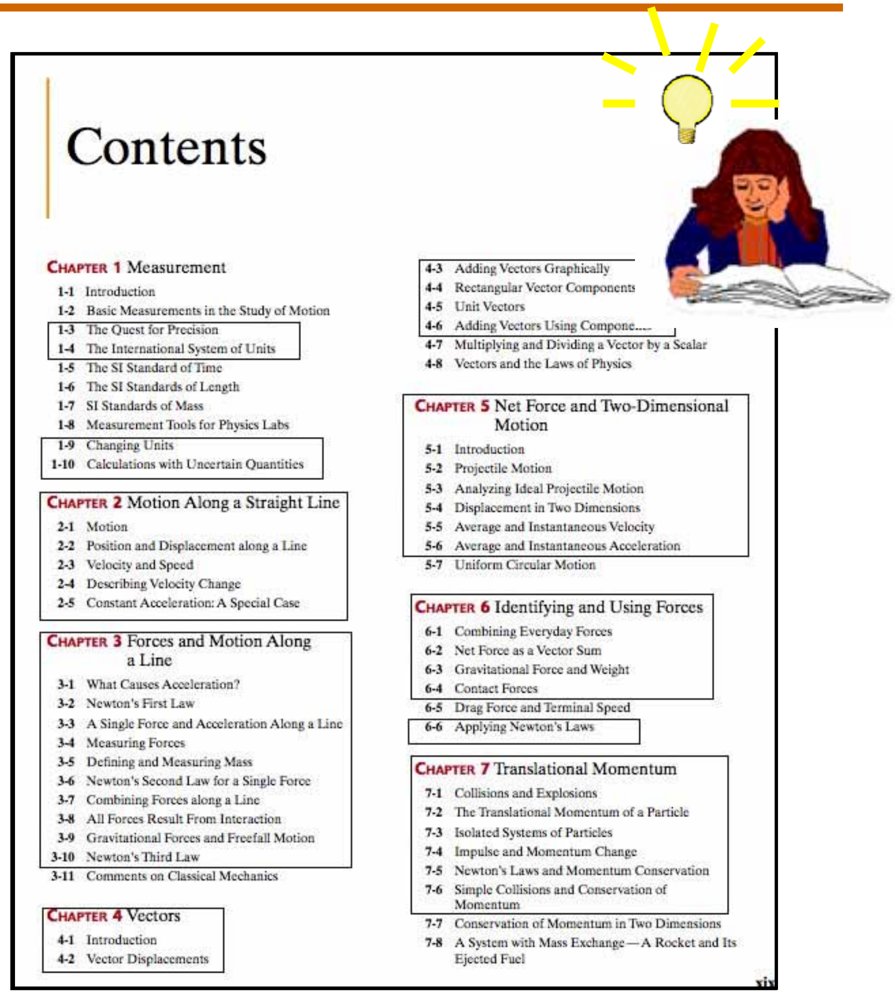
** J. Fuster, *Memory in the Cerebral Cortex* (MIT Press, 1999).

Beyond Content: Explicating the hidden curriculum

What are our real goals
for the students in our classes?

The Hidden Curriculum

- Typically, when we prepare our syllabi, we select what content we intend to “cover” – the notes in the melody line.
- But what we really want our students to learn is more than just a set of facts: it’s a way of thinking – the fully orchestrated “musicality” of the subject



Contents

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Some elements of the hidden curriculum in physics

- Concepts
  - Know what you're talking about!
- Coherence
  - Look for links!
- Quantify
  - Express relationships mathematically!
- Reasoning
  - Figure out implications!
- Relate
  - Make sense of everyday experience and connect it to the physics you are learning!

Concepts

"What matters
is not only learning,
but making sense
of what you're learning."

Making sense

- Many students see science as a collection of facts – studying for science is like memorizing instead of learning to speak.
- But science is a way of thinking – a process as well as a set of facts.
- First, you need to understand what it's *about*.

The Montillation of Traxoline

- It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristeriate large amounts of fevon and then bracter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.
- *Answer the following questions in complete sentences. Be sure to use your best handwriting.*
  - 1. What is a traxoline?
  - 2. Where is traxoline montilled?
  - 3. How is traxoline quaselled?
  - 4. Why is it important to know about traxoline?

Attributed to Judith Lanier, MSU

How confident are you that you could answer these questions?

1. I am very confident that I could get all the answers.
2. I am pretty sure I could get all the answers.
3. I think I could get most of the answers.
4. I think I could get some of the answers.
5. I don’t think I could get the answers.

Concepts Research

- Good conceptual understanding means not only knowing the answers, but knowing what the answers mean.
- Since 1980 research has shown that introductory physics students bring use knowledge from their everyday experience and previous instruction to interpret what they are learning.
- This often leads them to misinterpret our teaching, resulting in common misunderstandings, which can be resistant to instruction (“misconceptions”).

*An Example: The Force Concept Inventory (FCI)**

- The FCI is a 30 item multiple-choice probe of student understanding of basic concepts.
- The choice of topics is based on careful thought about what are the fundamental issues and concepts in Newtonian mechanics.
- It uses common speech and common situations rather than cueing specific physics principles.
- The distractors (wrong answers) are malicious – they are based on research that reveal the students' most commonly identified misconceptions.

D. Hestenes, M. Wells, G. Swackhamer, The Physics Teacher **30, 141-158 (1992)*

What's the appropriate analogy?

Conductor

Teacher

Orchestra

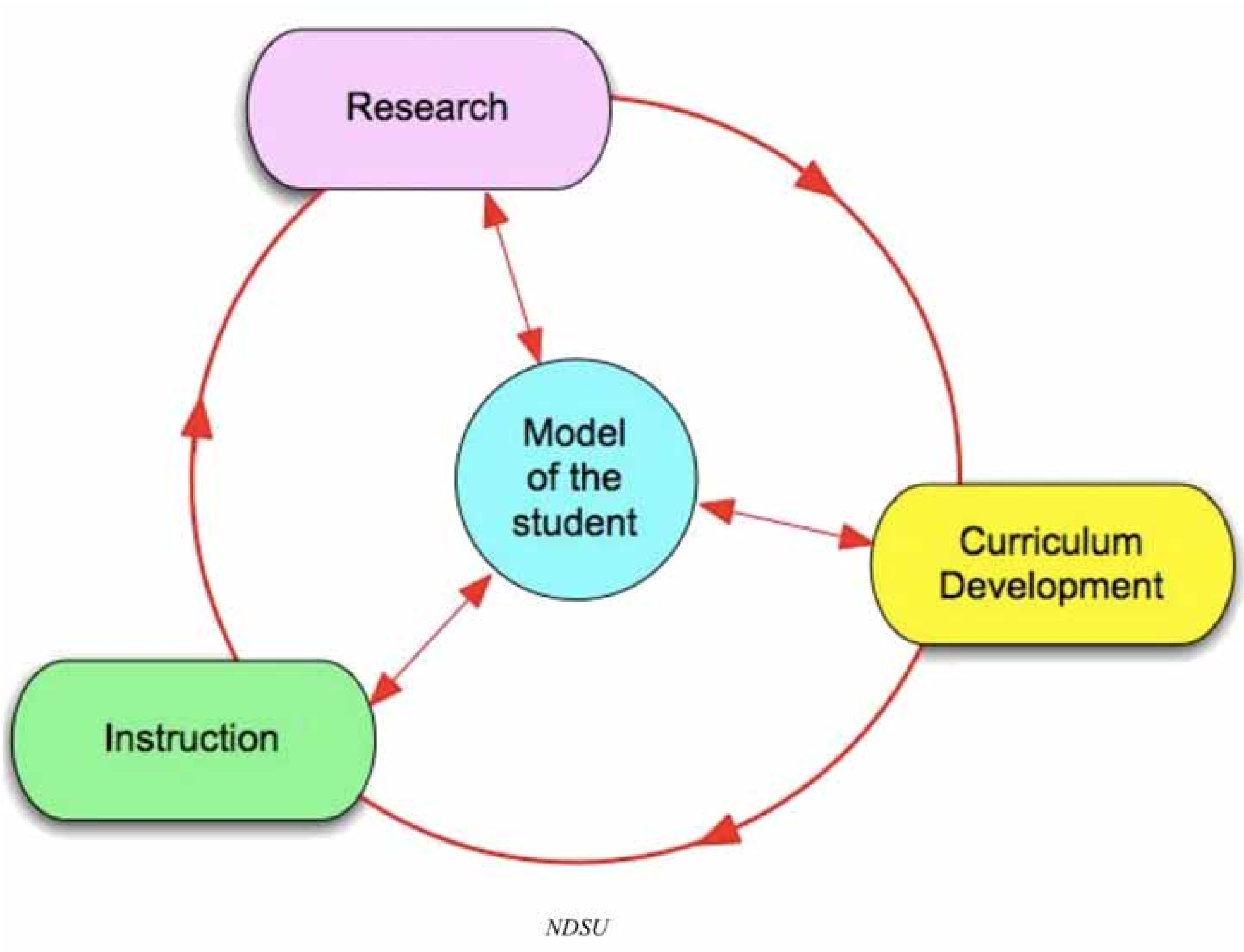
Students

Audience

Students

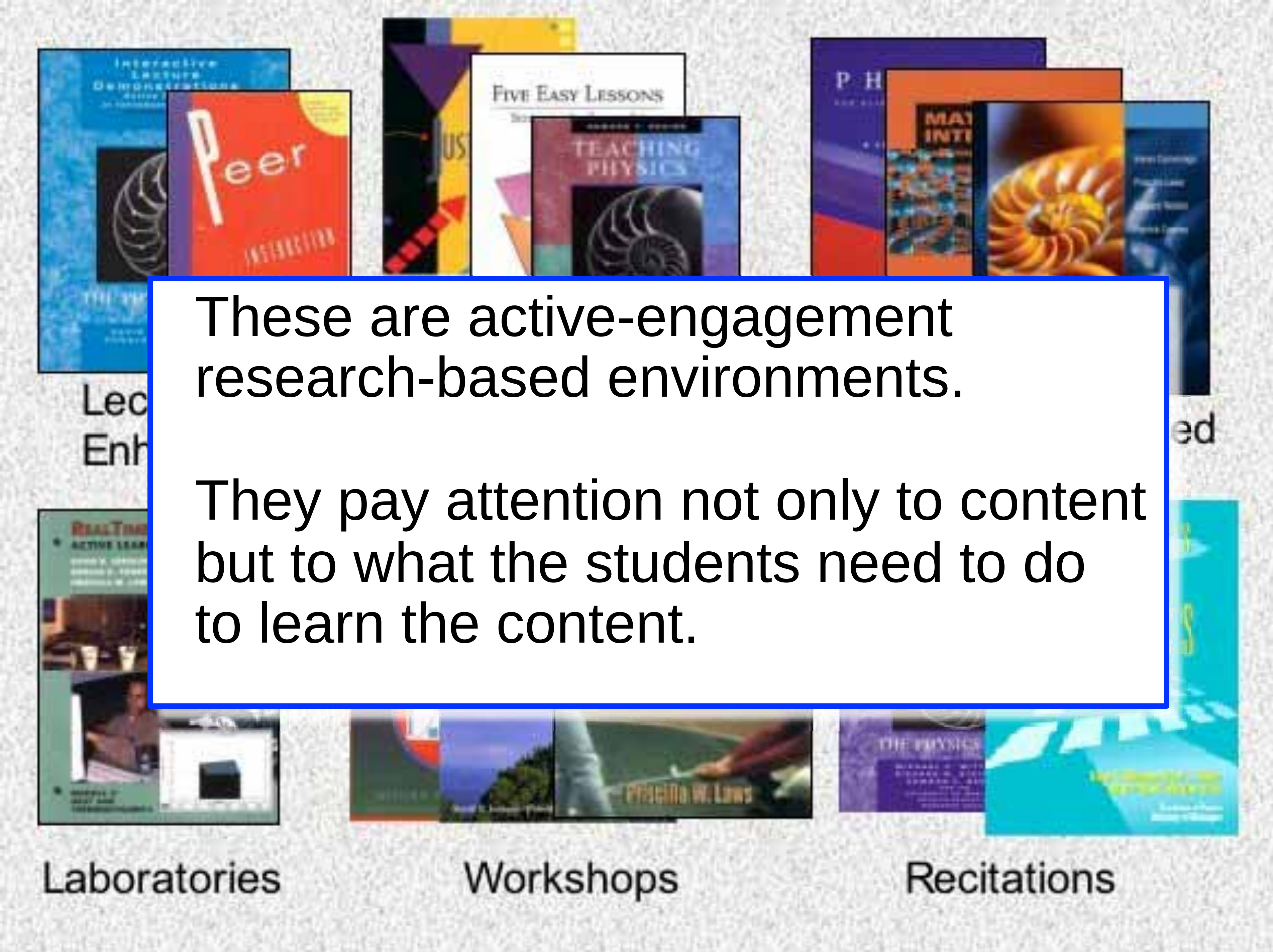
How many concerts do you have to listen to before you get good at playing an instrument?

Do research-based active-learning environments do better?

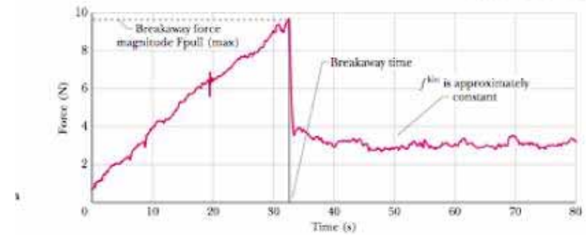


These are active-engagement research-based environments.

They pay attention not only to content but to what the students need to do to learn the content.



*Tutorials**
(N=20-30 subsets)



- Tutorials are research-based worksheets done in small groups (3-4).
- Students are guided through expressing their own ideas, comparing them with observations and reasoning qualitatively.

** L. C. McDermott, et al., <u>Tutorials In Introductory Physics</u> (Prentice Hall, 1998)*

** M. Wittmann, R. Steinberg, E. Redish, <u>Activity-Based Tutorials</u> (Wiley, 2003)*

Imagine a head-on collision between a large truck and a small compact car. During the collision:

(1) the truck exerts a greater amount of force on the car than the car exerts on the truck.

(2) the car exerts a greater amount of force on the truck than the truck exerts on the car.

(3) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.

(4) the truck exerts a force on the car but the car does not exert a force on the truck.

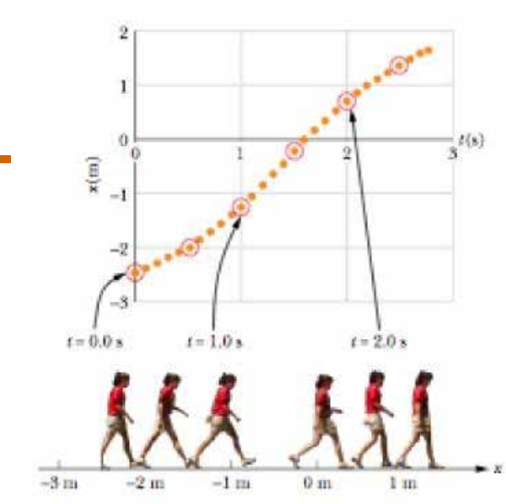
(5) the truck exerts the same amount of force on the car as the car exerts on the truck. ➔

With modified instruction (N=280)

Option	*Pre*	*Post*
(1)	62%	16%
(2)	2%	1%
(3)	1%	0%
(4)	0%	0%
(5)	35%	83%

Workshop Physics (N = 20 - 30)*

- In a WP room
  - An “active-engagement” model: there is (almost) no lecturing.
  - Students use computer tools for observation and modeling
  - Students are (lightly) guided through the construction of physics ideas.
  - Ideas are motivated by (quantitative) observations.



** Priscilla Laws, Workshop Physics Activity Guide (John Wiley & Sons, 1997)*

Active engagement instructional models produce better gains

- We gave the FCI before and after instruction in 1st semester university physics in 15 universities who were using 4 instructional models:
  - traditional (lecture) + recitation
  - traditional (lecture) + tutorial (RB)
  - traditional (lecture) + group problem solving (RB)
  - workshop physics. (RB)
- We observed both primary and secondary implementations of the research-based curricula.

**J. M. Saul and E. F. Redish, "Evaluation of the Workshop Physics Dissemination Project", U. of Maryland preprint, April 1998*

Results

- The research-based curricula showed improvement in the fraction of the average possible gain in concept learning as measured by the FCI:

$$< g > = \frac{(posttest\ average - pretest\ average)}{(100 - pretest\ average)}$$

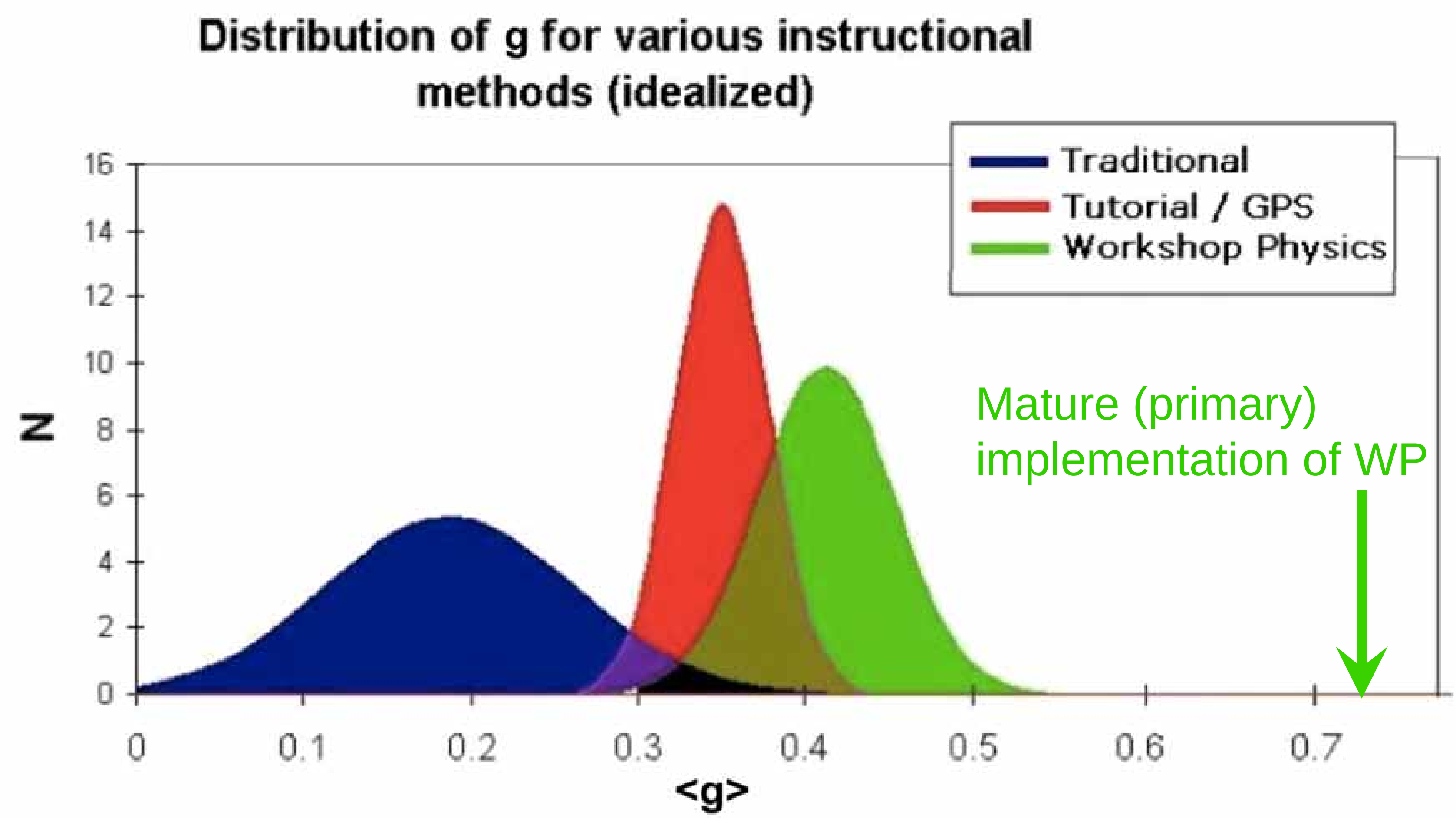
$<g> = 0.20 \pm 0.03$ traditional

$<g> = 0.34 \pm 0.01$ recitation modifications

$<g> = 0.41 \pm 0.02$ Workshop Physics (early secondary implementations)

$<g> = 0.73$ (Dickinson College)

FCI Conceptual Learning Efficiencies



J. M. Saul and E. F. Redish, "Evaluation of the Workshop Physics Dissemination Project", U. Md. preprint (1998).

Can it be done in a large lecture setting?

- WP was developed for small classes (N= 25-30) with a prof and a TA (or peer guide). This is too expensive for a large lecture class.

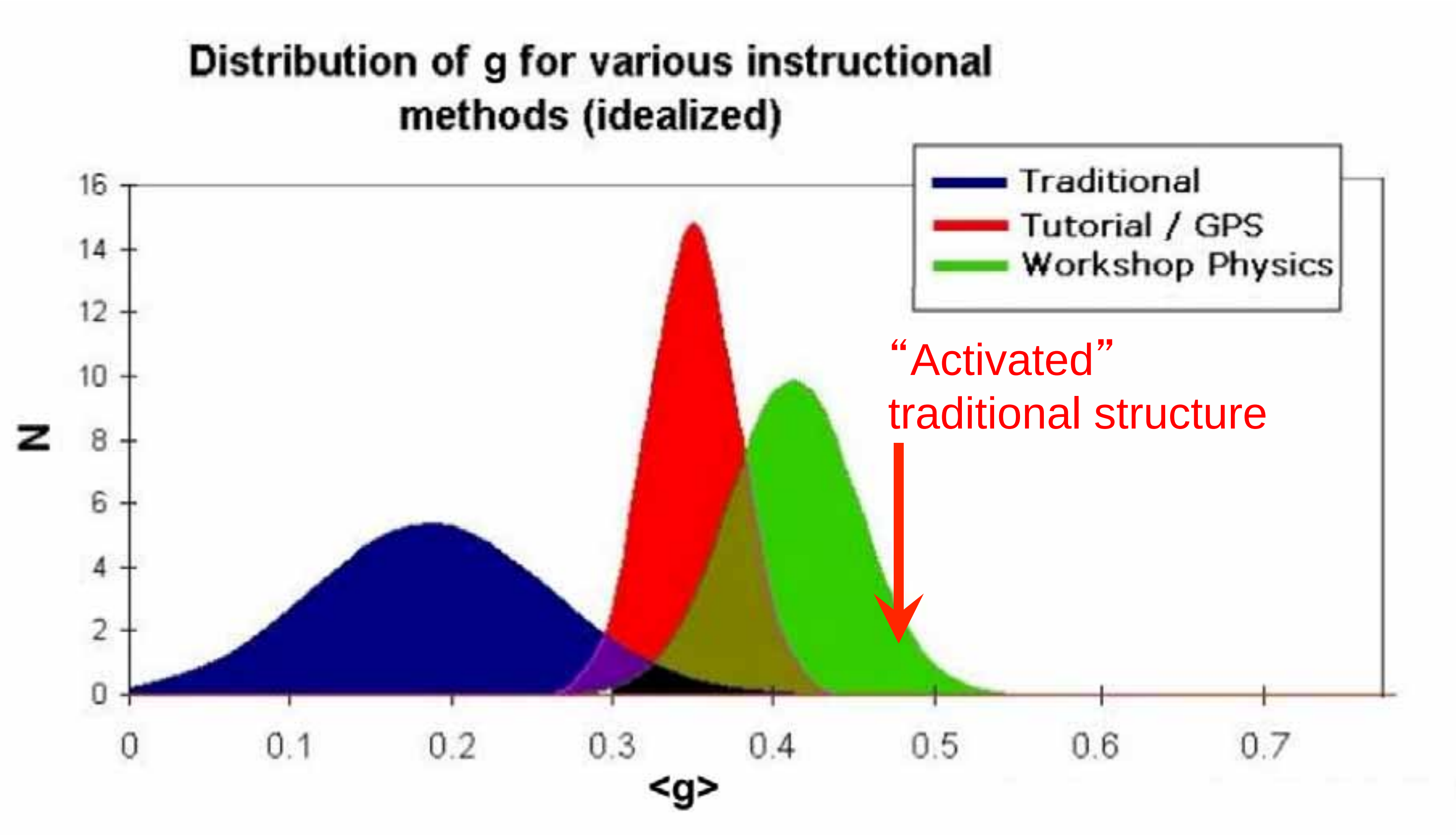
- In a 5-year NSF funded project* we explored whether we could "make the student into the orchestra instead of the audience in a large lecture" (N = 200) using ~ the same resources as in a traditional class.

**Learning How to Learn Science: Physics for Bioscience Majors NSF DUE-ROLE 2000-2005.*

We focused on helping students understand hidden curriculum goals

- We explicated the hidden curriculum early and often.
- We modified every part of the class to make it more active and engaging.
  - We introduced clickers in the lectures
  - We replaced recitations by active learning tutorials
  - We replaced cookbook labs by explorations
  - We eliminated exercises and expanded the time spent on doing "thinking problems" for homework
  - Exams reflected these changes.

Gratifying results



Take-away messages

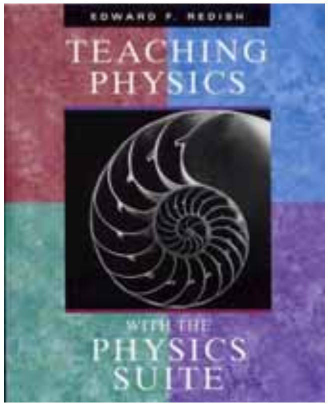
- There's more to learning than a "melody line" (content): There's "orchestration" (hidden curriculum).
- Research can help us find out how students "work" (and don't work).
- Technology may create better environments – but it's not about the technology.
- What matters is not what we, as instructors, do, it's what the students do.
- Research knowledge lets us create more effective learning environments – not just for content, but also for hidden curriculum.

And finally – and best of all…

- You don't have to do it all yourself!
- Robust and growing research communities blend education and disciplinary scientists in a scholarship of teaching and learning in
  - Physics
  - Chemistry
  - Math
  - Engineering
  - Astronomy
  - Geoscience
  - ...with more on the way!

For more information see:

- The website of the U. of Maryland's Physics Education Research Group
  - *http://www.physics.umd.edu/perg/*



- E. F. Redish, *Teaching Physics with the Physics Suite* (John Wiley and Sons, Inc.)
  - *http://www2.physics.umd.edu/~redish/Book/*