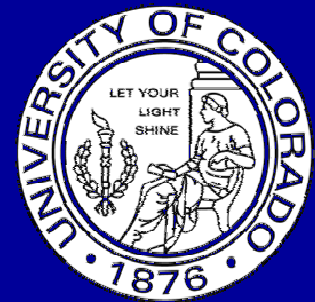


Interactive Engagement in the Classroom

Michael Dubson
Dept. of Physics
U. Colorado at Boulder
michael.dubson@colorado.edu

Please sit near the front, thanks!!

Please get a *clicker* .



Physics Education Research at the University of Colorado at Boulder

- Physics faculty:

Noah Finkelstein
Steven Pollock
Michael Dubson
Kathy Perkins
Carl Wieman

- Postdocs:

Sam McKagan
Linda Koch

Ph. D. students:

Wendy Adams
Jack Barbera
Kara Gray
Chris Keller
Pat Kohl
Noah Podolefsky
Chandra Turpen

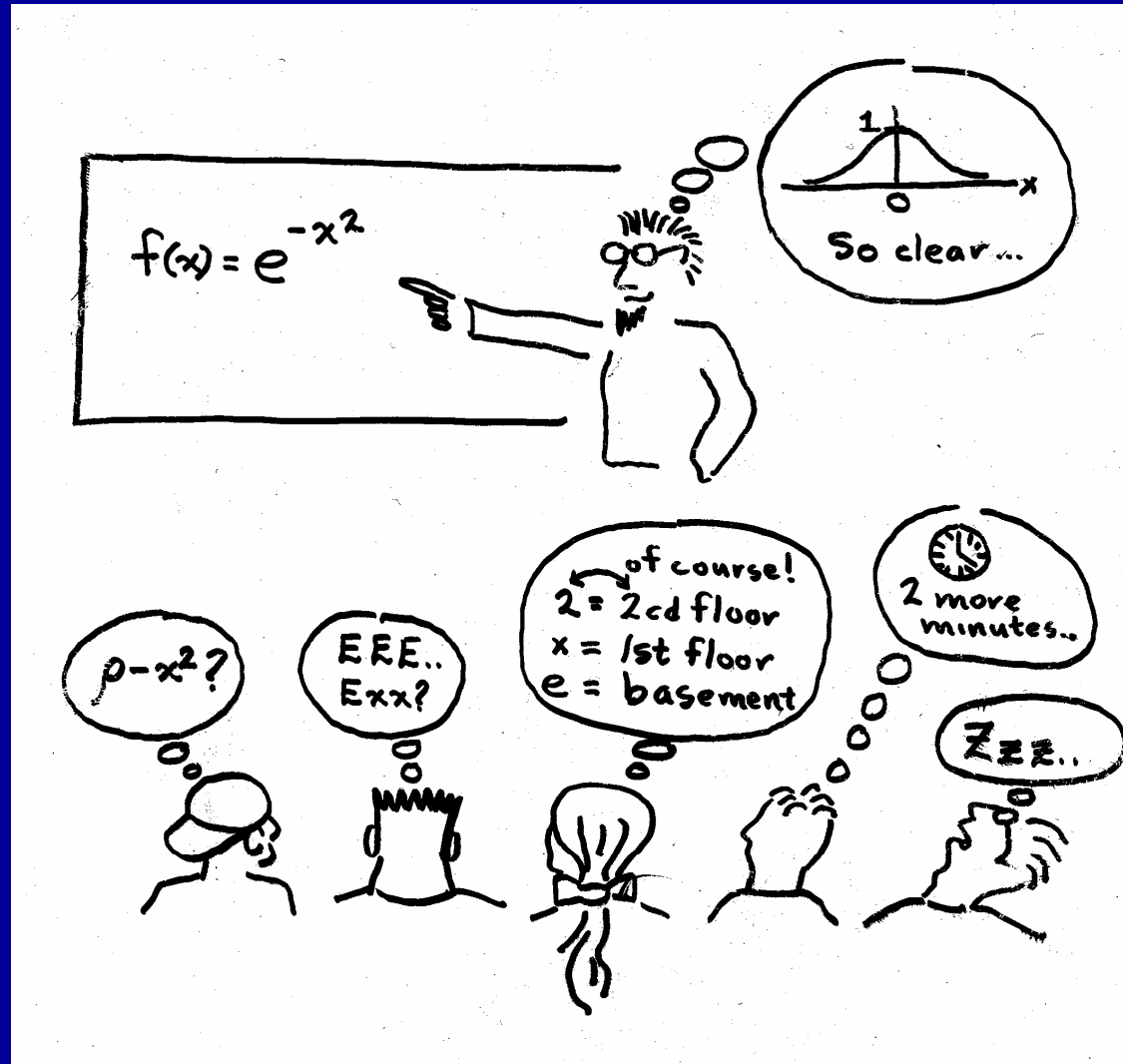
School of Ed collaborators:

Prof. Valerie Otero
Derya Cobanoglu
Danielle Harlow



[http:// per.colorado.edu](http://per.colorado.edu)

Novice vs. Expert



Clickers allow quasi-anonymous feedback.

- What is your age?

A) < 10 yrs

B) 10-20 yrs

C) 20-30yrs

D) 30-40 yrs

D) 40-50 yrs

D) 50-60 yrs

D) > 60 yrs

- If you were to significantly increase your teaching efforts, how would this affect your salary ?

A) Positively

B) Negatively

C) No effect

D) I don't know or I don't care

E) I don't teach at all

My primary field of study is..

- A) Physics or Astronomy
- B) Math or Biology
- C) Social science
- D) Humanities
- E) Other (Fine Arts, Law, etc)

Have you ever taken or taught a class that used clickers?

A) Yes

B) No

Concept Test /Peer Instruction

How many liters of Scotch Whiskey are stored in Scotland?

Hints: Scotch is aged ~10 years before sale. All Scotch is made in Scotland.

A) 300,000

B) 3 million

C) 30 million

D) 300 million

E) 3 billion

Expert / Novice views of problem solving

(Kathleen Harper, Ohio State, Physics Teacher April 2006)

- Problem solving is ..
 a process / a recall task.
- Problem solving begins with ...
 qualitative analysis / hunt for "the equation"
- Problem classification is based on ..
 deep structure / surface features.
- Tools include..
 graphs, diagrams, limits, conservation laws, etc /
 "the equation"

Students at CU are very busy and (like almost all of us) are intellectually lazy.

They have extensive training in :

- Symbol manipulation
- Getting the right answer
- Effort-minimization
- Survival

They have little training in:

- Sense-making
- Articulation of ideas
- Prioritization of knowledge
- Group work
- Solving vague problems

Course reforms at CU in the last decade:

- Concept Tests / Peer Instruction
 - Conceptual questions on exams
 - Online Homework (CAPA, Mastering Physics)
 - Physics Helproom
 - Washington Tutorials with undergraduate TA's
 - Pre/post tests to gauge effectiveness
 - Veteran/apprentice Team-teaching
 - Strong PER group formed
-
- Almost all freshmen classes transformed
 - Many sophomore classes transformed.
 - Efforts in upper-level courses beginning.

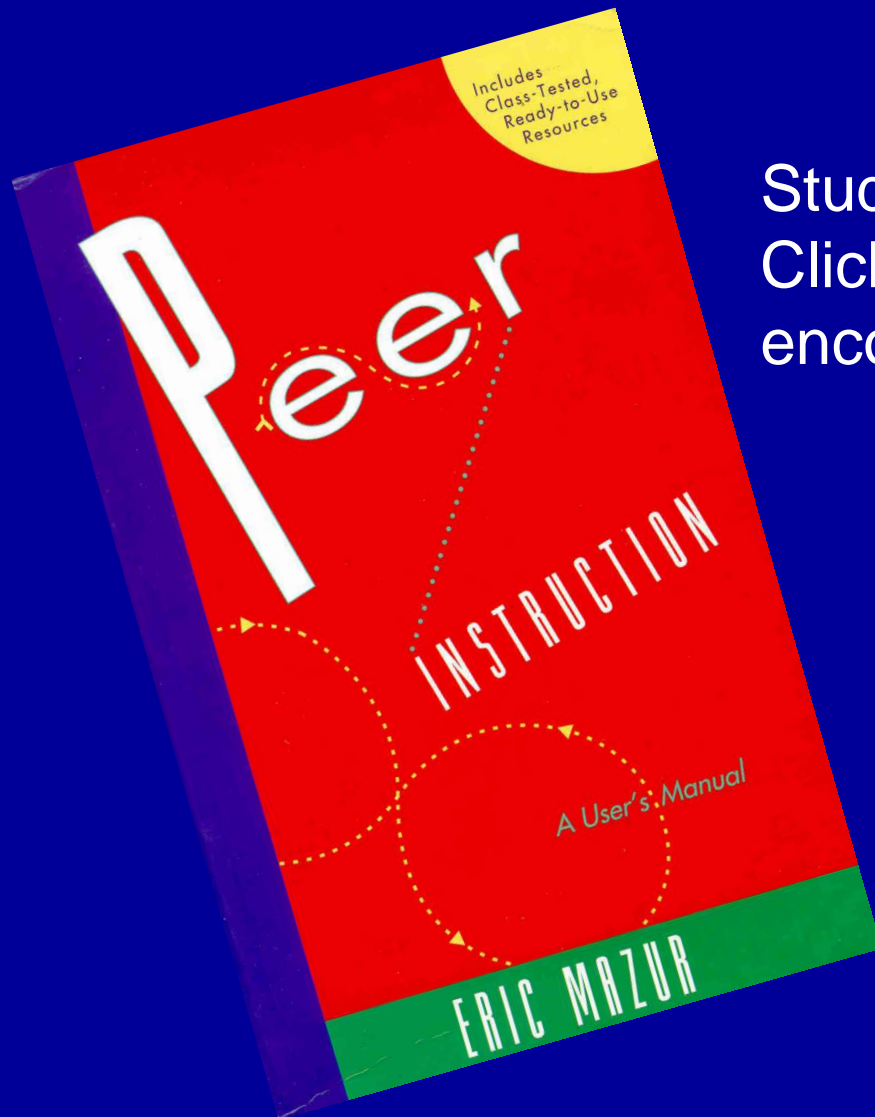
The Golden Rules of Lecture:

Rule 0.

Don't reinvent. It's too much work.

Faculty are much more likely to try something new, if it doesn't involve much more extra work.

Peer Instruction/ Concept Tests, Eric Mazur, Harvard 1997



Students are assigned to Clicker groups to encourage/enforce interaction.

Physics HelpRoom

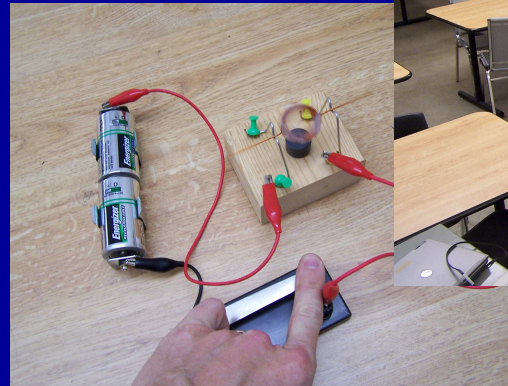
- All TA's and faculty hold office hours here.
- Hours staggered, room is always staffed.



Washington Tutorials replacing traditional TA-led recitations

Success required:

- Dedicated space / furniture
- Lab equipment
- Undergraduate TA's
- Proper training of staff

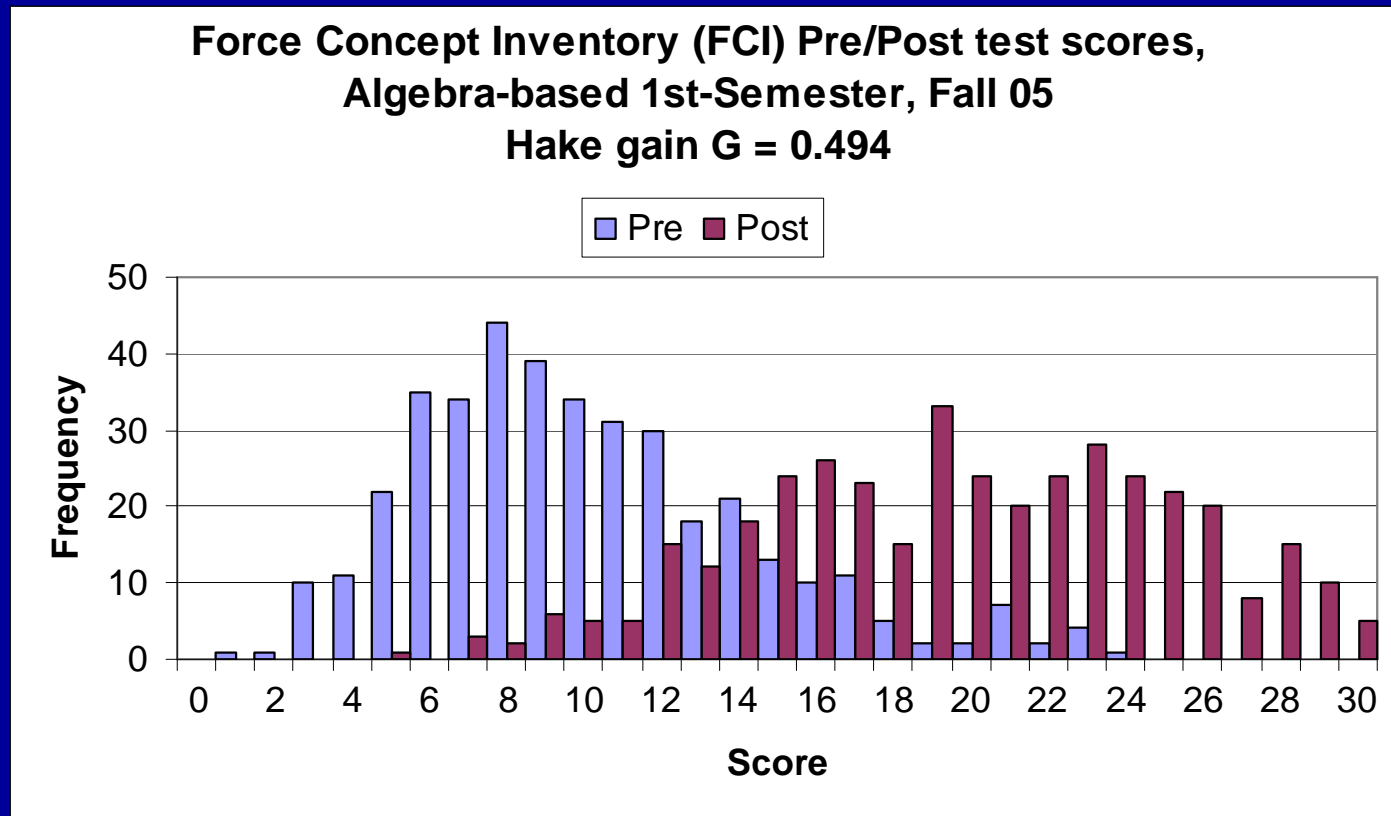


Assessment is essential.

Standardized Pre/post tests:

Physics 1 Mechanics: FCI, FMCE,

Physics 2 E&M: BEMA



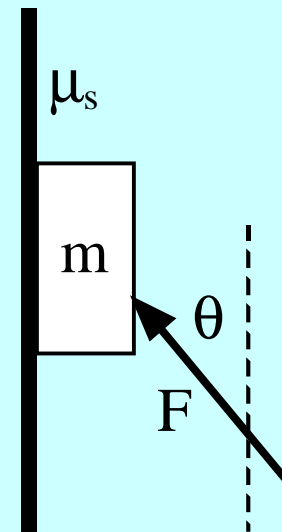
Students study for exams, so
put *qualitative* questions on exams,
questions that looks like Concept Tests

Would you like to answer a question about

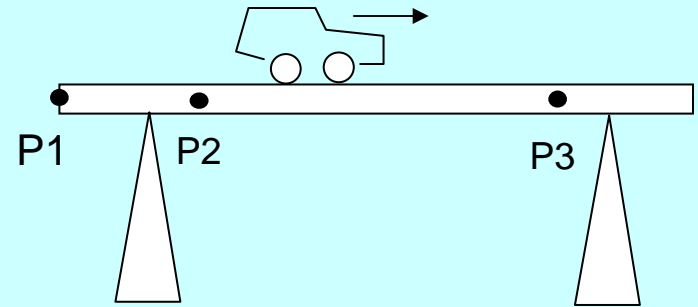
- A) static friction,
- B) torque, or
- C) DC circuits ?

A box of mass m is held stationary against a vertical wall by a force of magnitude F at an angle θ to the vertical. There is friction between the wall and the box, and the coefficient of static friction is μ_s . The **direction of the force of friction** exerted **on the box** by the wall is...

- (A) up (B) down (C) zero
- (D) not enough information given to answer the question.



A toy car with mass m moves along a massless wooden plank lying horizontally over two support posts, as shown. The car is rolling across the bridge from point P2 to point P3, (left to right). What can you say about the magnitude of the *net* torque (i.e. the sum of all torques) about the point P1?



- (A) It is increasing.
- (B) It is constant, and zero
- (C) It is decreasing.
- (D) It is constant, and non-zero.
- (E) Not enough information is given.

Rank bulbs A, B, and C in order of brightness from *brightest* to *dimmest*.

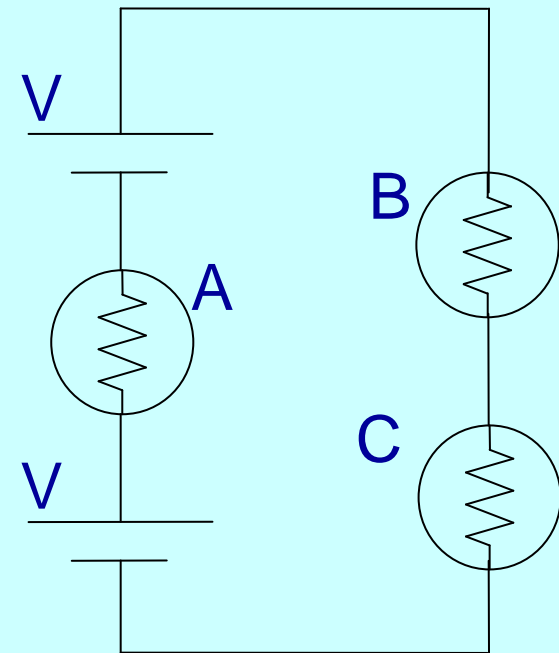
A) $A > B = C$

B) $A = B = C$

C) $A > B > C$

D) $B = C > A$

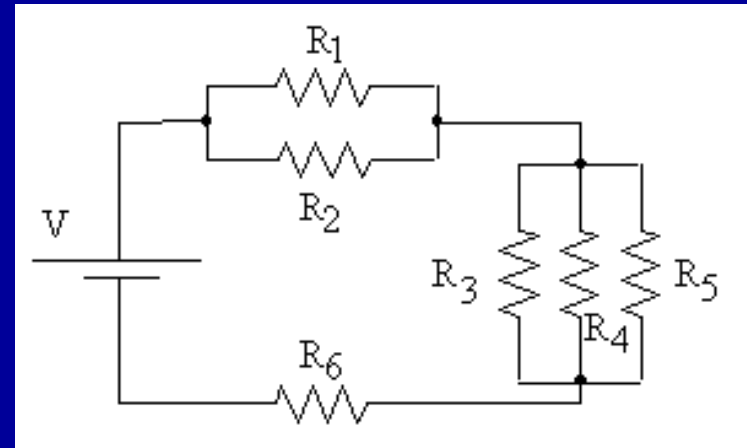
E) None of the above



Quantitative vs. Qualitative Problems

- Quantitative:

In the circuit, $V = 25V$, $R_1 = R_2 = 10\Omega$, $R_3 = R_4 = R_5 = 15\Omega$, $R_6 = 50\Omega$. What is the current through resistor R_3 ?



Qualitative.

When R_6 increases, the current through R_3 _____.

A) Increases B) decreases C) remains constant?

What happens during my class ?

- In a 50 min lecture,
 - Clicker question running when students enter room
 - ~ 20 min straight lecture at board in 5-10 min chunks
 - ~ 30 min on ~5 concept tests, discussion, demos
 - End with clicker question to be answered next time
- Group discussion enforced with clicker groups
- Traditional (difficult) homework questions
- Exams heavily qualitative/conceptual.
- Self-written formula sheet allowed on exams.

The Golden Rules of Lecture:

Rule 1.

It's OK to lecture less,

because they're not listening anyway.

(Scribe mode \neq listening)

- Use Concept Tests & Peer Instruction
- Active learning works, passive learning does not.
- Lots of demos, tied to Concept Tests
- Brief derivations, tied to Concept Tests
- Put lecture notes (+ everything else) on the Web.

Rule 2.

Kill as Few Patients as Possible



AND FIFTY-SIX OTHER
ESSAYS ON HOW TO BE
THE WORLD'S BEST DOCTOR

by Oscar London M.D., W.B.D.

Morale is vital:

Talk to / listen to students, in lecture, in office hours, in the Helproom.

Feedback from students is essential.

If they learned something, but they leave hating the subject, you have failed.

Common denominator of poor teaching:
Teacher/Student disconnect

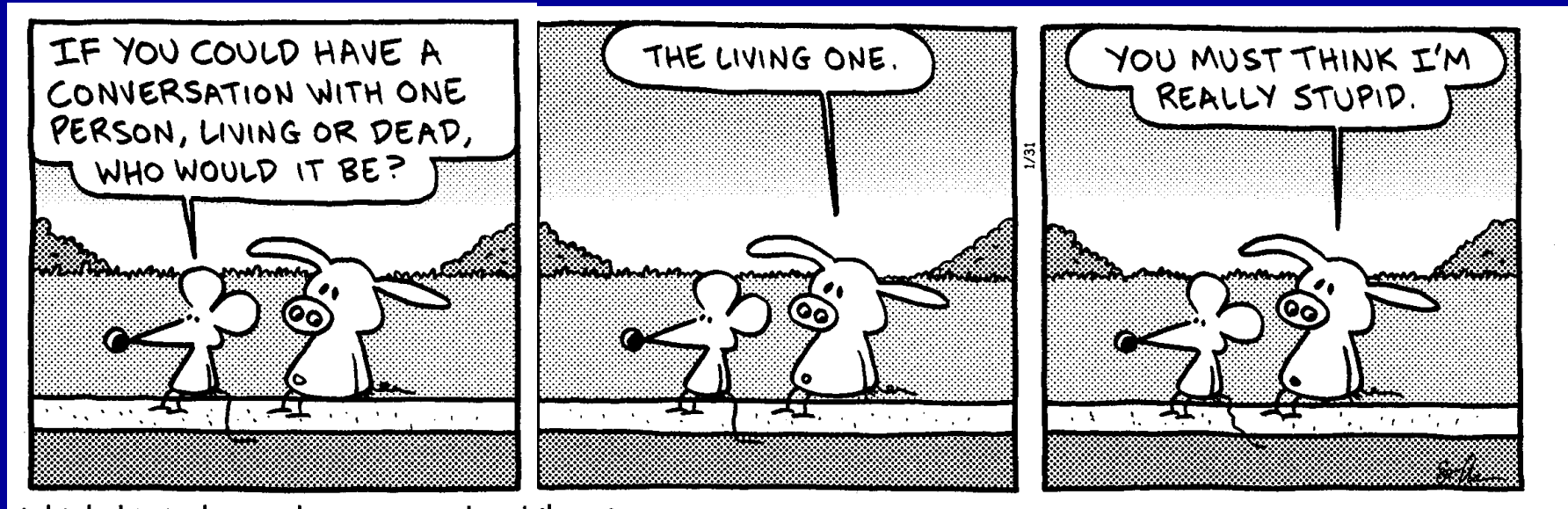
Rule 3.

Emphasize qualitative reasoning and conceptual understanding.

- in lecture
- on homeworks
- especially on exams

It doesn't matter if they can compute the acceleration, if they don't know what acceleration is.

Two-way conversations with students are vital,



because students can misinterpret what we say.

"Pearls Before Swine" by Stephan Pastis, 2002.

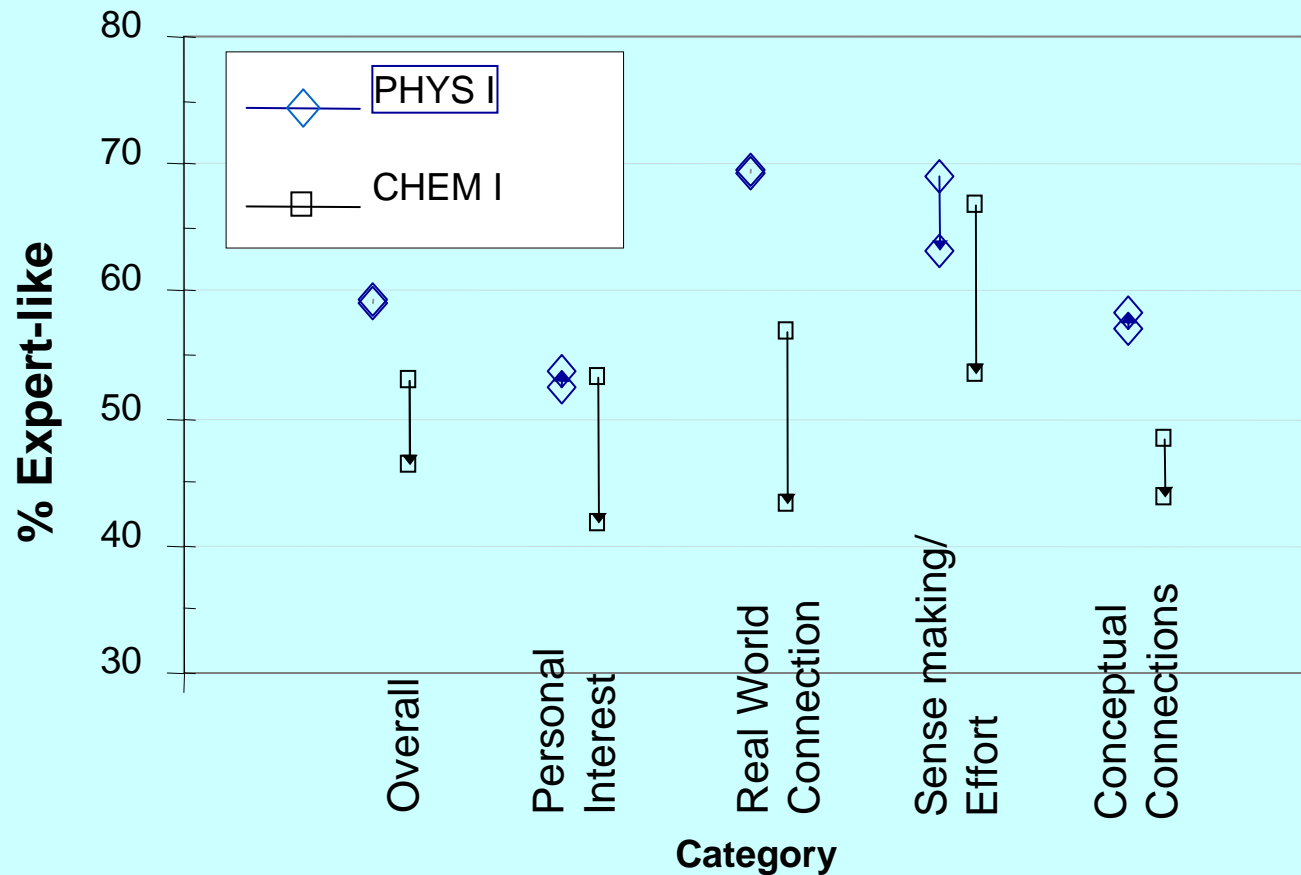
CLASS survey (Wendy Adams, Kathy Perkins)

Colorado Learning Attitudes about Science Survey

- When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.
- In physics, it is important for me to make sense out of formulas before I can use them correctly.
- Knowledge in physics consists of many disconnected topics.
- To learn physics, I only need to memorize solutions to sample problems.
- When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

A) Strongly agree B) Agree C) Neutral
D) Disagree E) Strongly Disagree

Attitudes about science and learning usually *decline* during freshmen science courses



Poor use of clickers..

- solely for taking attendance
- for quizzes or high-stakes testing
- only occasionally, or at set times

Better use of clickers..

- Integrated into lecture, frequent
- Require or encourage peer instruction
- Mix of difficulty: very easy to very difficult CTs
- Generous credit for any answer
- Low grade impact (~2%)

Worse Concept Tests

- merely test recall
- involve blind application of formula/recipe
- involve many numbers

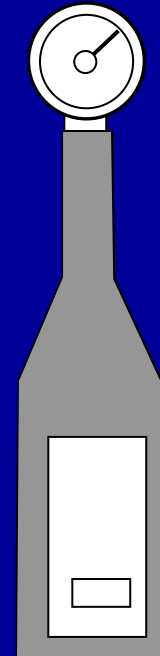
Better Concept Tests

- check qualitative understanding (no calculator)
- apply familiar skills in new contexts
- multiple questions to lead thru multi-step reasoning
- test a learning goal

Concept Test

An unopened bottle of Champagne, equipped with a pressure gauge, has been sitting on the shelf for a long time. The bottle is given a brief, vigorous shake. What happens to the pressure in the bottle?

- A) The pressure remains unchanged (within 1%)
- B) The pressure decreases significantly.
- C) The pressure increases significantly.



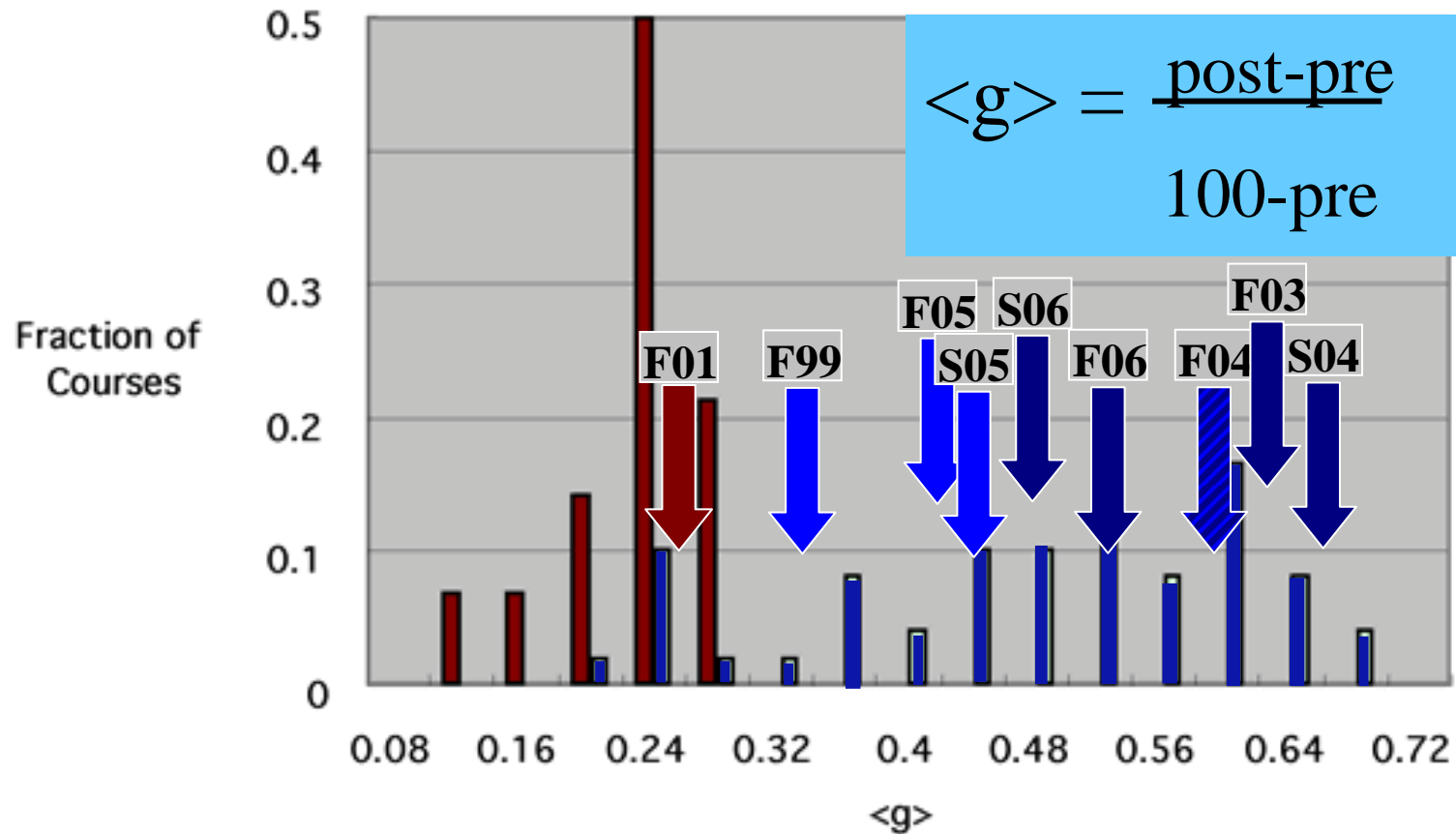
Conclusions:

- Novices don't think like experts. Training students to think is just as important as delivering course content.
- Interactive engagement in the classroom is usually more effective than traditional instruction.
- Concept Tests and Peer Instruction are the way to go.
- We should all worry student attitudes, not just student knowledge.

Please give back your clicker.

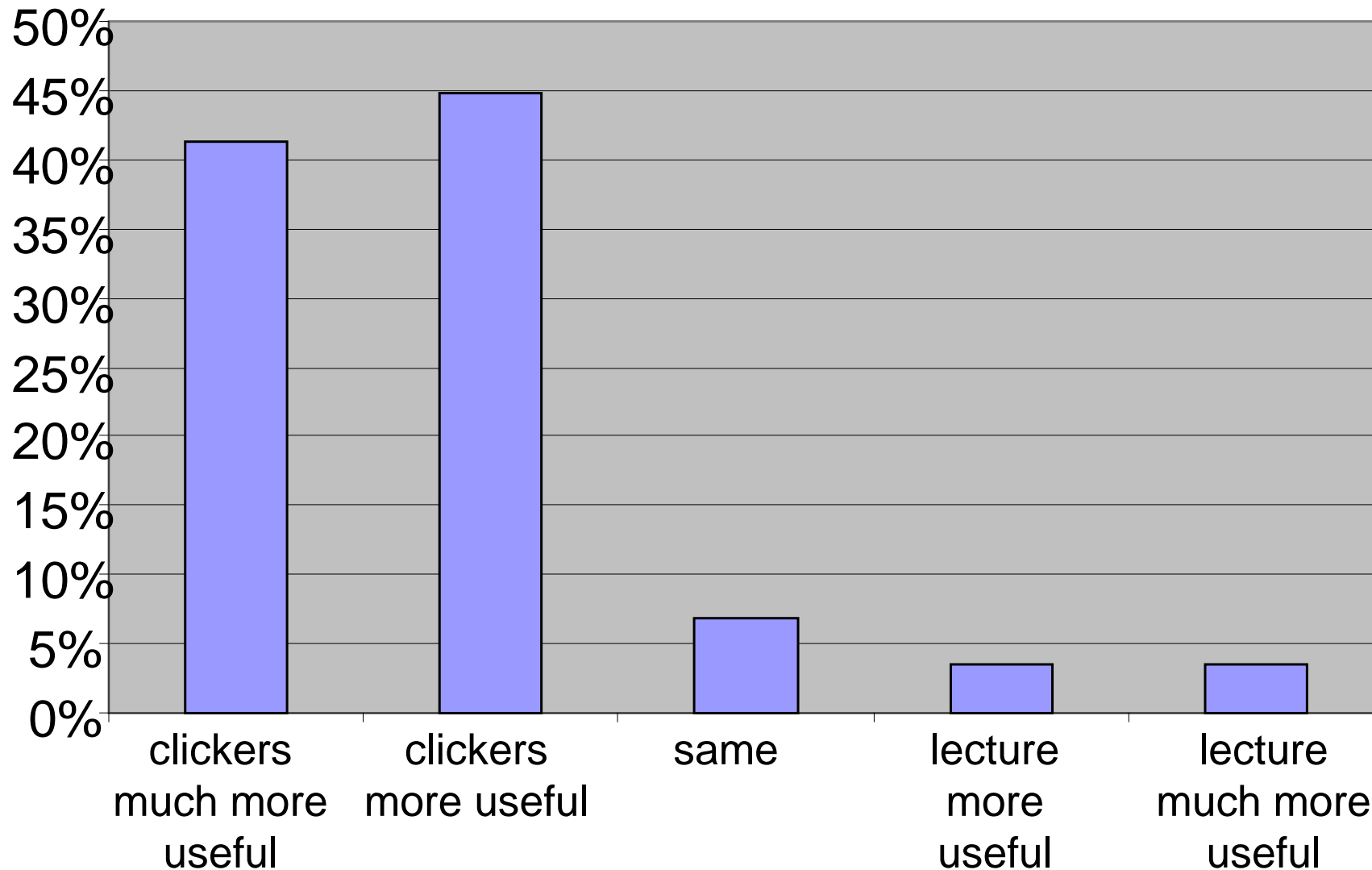
Force Concept Inventory

red = trad, blue = interactive engagement

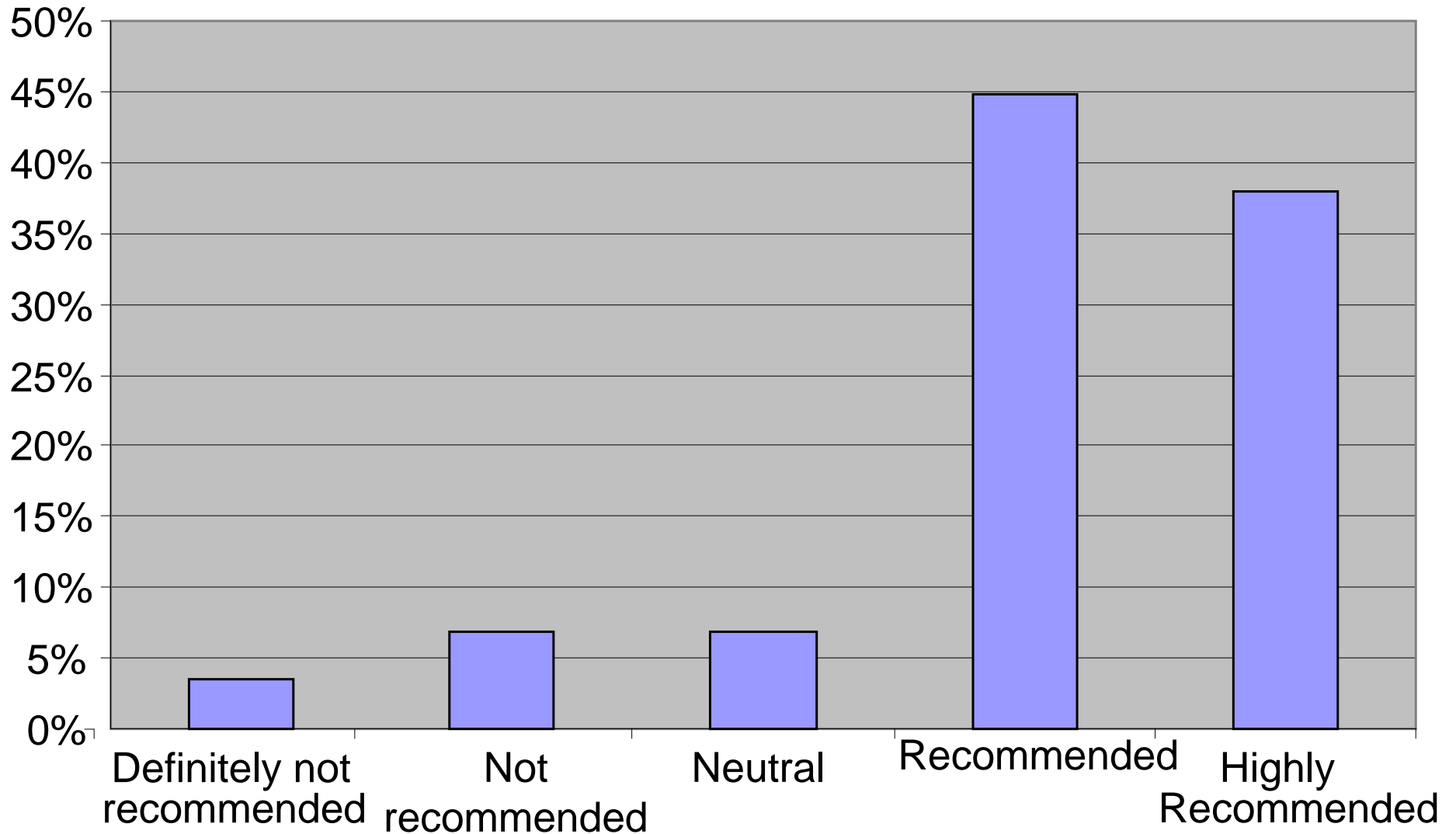


R. Hake, "...A six-thousand-student survey..." AJP 66, 64-74 ('98).

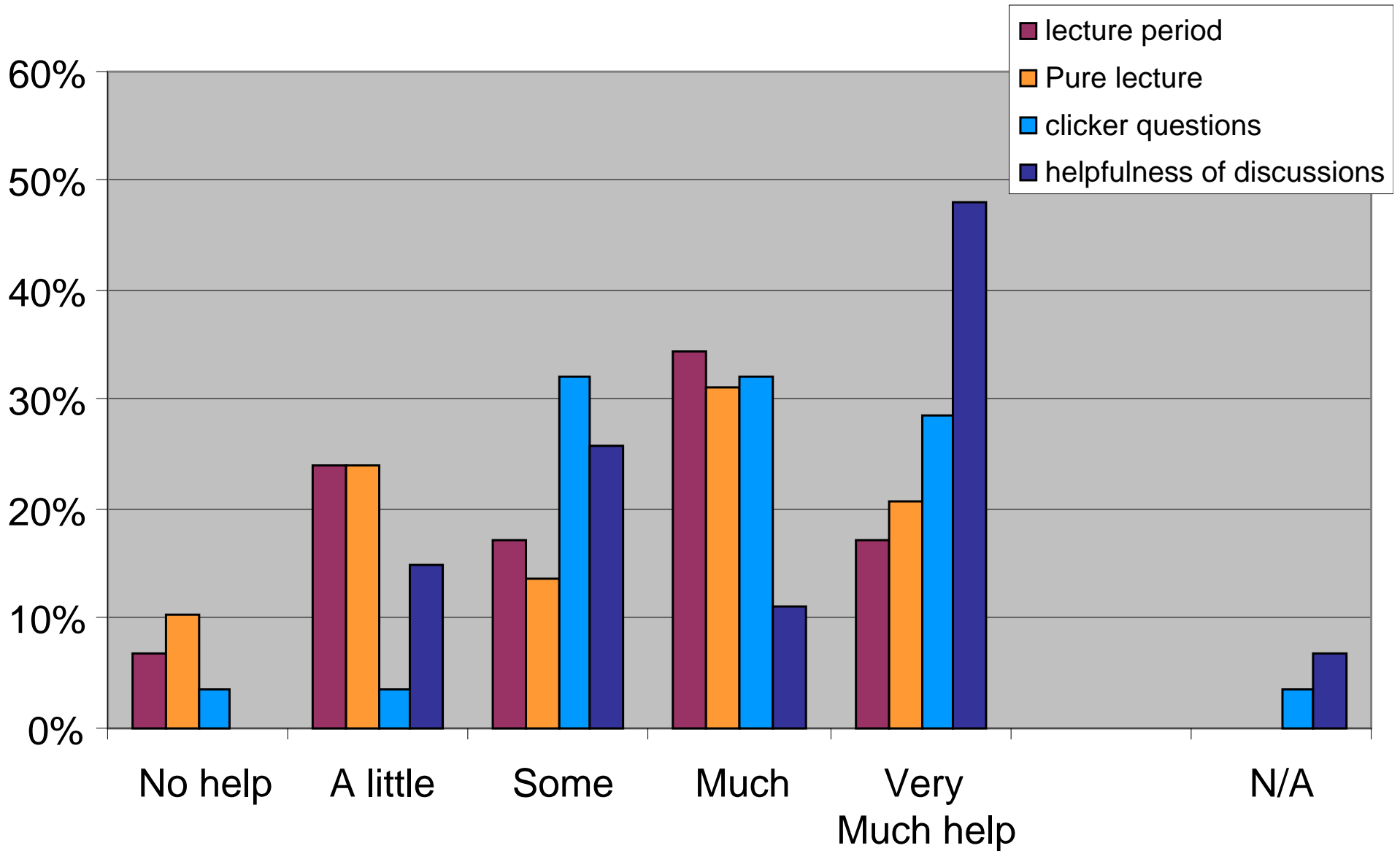
Survey Q12. How useful for your learning is the addition of clicker questions compared to pure lecture with no clicker questions?



Survey Q7. Would you recommend using clickers in upper division (2210 or higher?)



Helpful for learning?



Confer with your 3 or 4 nearest neighbors
(and no one else) and vote as a block.

Vote A, B, C, D, or E, but vote the same as
your neighbors.

Frustration/Magnetic domains

PHYSICS X

Oral Exam practice

for 2nd -year Graduate students

Weekly 1-hour seminar

- Order-of-magnitude estimation
- Vague problems
- Dimensional analysis
- Undergrad physics review
- What is essential?
- Quick results, physical arguments

Physics Numbers (what every physicist should know)

Sizes

atom: 0.2 – 0.3 nm = 2 – 3 angstroms

nucleus: ≈ 10 fm = 10^{-14} m

wavelength of visible light: 400 nm to 700 nm = 0.4 to 0.7 μ m

earth: radius ≈ 6000 km

Energies

1 eV = 1.6×10^{-19} J

1 cal ≈ 4 J

chemical bond ≈ 1 eV or less

nuclear bond ≈ 1 MeV

room temperature: $kT_{\text{room}} = 0.025$ eV

visible photon: 2 – 3 eV

solar constant (solar power per square meter striking Earth) 1000 W/m²

Masses

electron = 9.1×10^{-31} kg = 0.511 MeV/c²

proton = 1.67×10^{-27} kg = 938 MeV

$m_{\text{proton}} \approx 1800 m_{\text{electron}}$

Densities

water: 1 g/cm³ = 1000 kg/m³ (cubic meter of water is a metric ton)

air: $\approx 10^{-3}$ water

elements: 2–20 g/cm³

Speeds

sound (in air) ≈ 340 m/s (1 mile per 5 seconds)

light: 3.0×10^8 m/s

Pressure

sea-level air: 15 psi $\approx 1.0 \times 10^5$ Pa (1 Pa = 1 N/m²)

Constants (SI units)

$k_B = 1.38 \times 10^{-23}$

$N_A = 6.0 \times 10^{23}$

$e = 1.6 \times 10^{-19}$

$h = 6.6 \times 10^{-34}$ (h-bar $\approx 10^{-34}$)

$G = 6.7 \times 10^{-11}$

$\epsilon_0 = 8.9 \times 10^{-12}$

)
 $G = 6.7 \times 10^{-11}$

$\epsilon_0 = 8.9 \times 10^{-12}$

The Fundamental Assumption of Statistical Mechanics:

In an isolated system, in thermal equilibrium, all
accessible microstates are equally likely to occur.

In Physics X, 12 grad students, who had ALL had taken both senior
undergrad and grad-level Stat Mech courses, were asked to identify
the Fundamental Assumption of Stat Mech.

How many of the students answered (somewhat) correctly?

A) 0 B) 1 C) 2 D) 4 E) 8

PhET:

Physics Education Technology

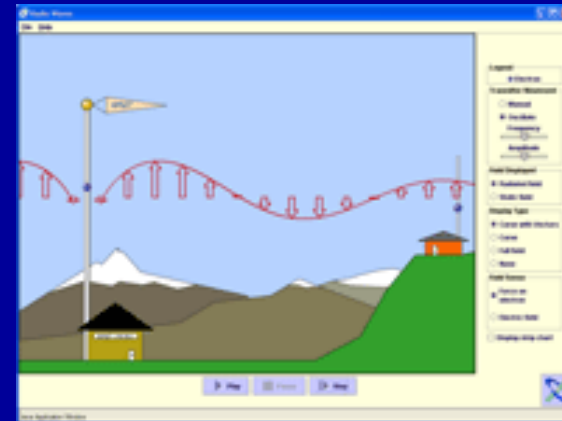
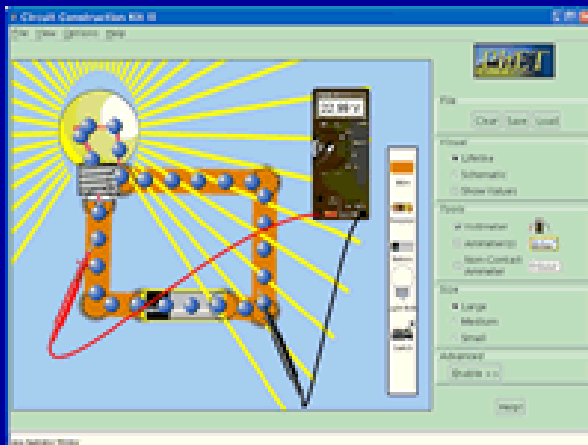
<http://phet.colorado.edu>



- 50+ interactive computer simulations
- Downloadable
- Free
- Classroom-tested



PhET screen shots



Arithmetic Workout

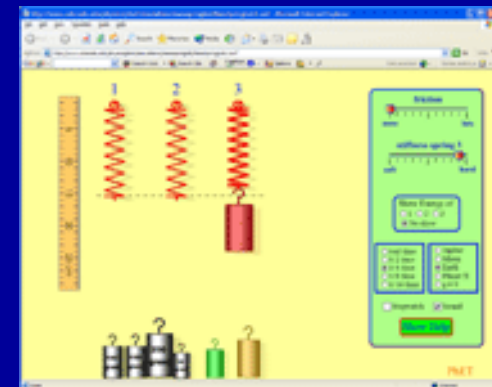
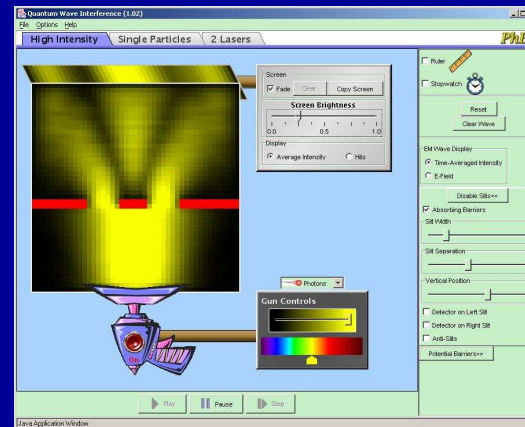
X	1	2	3	4	5	6	7	8	9
1			3			6	7		
2	2								
3	3				15	18			27
4					20				
5					25				
6									
7		14		28					
8									64
9					45				

? × ? = 40

Wrong. Try again.

Multiply
 Subtract
 Divide
 Level: 1 2 3
 Score: 13
 Clock
 100.9 Time (sec)

 Sound



Students at Colorado-Boulder are very busy and (like almost all of us) are intellectually lazy.

They are expert at :

- Symbol manipulation
- Getting the right answer
- Effort-minimization
- Survival

At CU, they have little training in:

- Sense-making
- Articulation of ideas
- Prioritization of knowledge
- Group work
- Solving vague problems

Interactive Engagement in Thermal Physics

- 50% time lecture at board
 - no lengthy derivations in class
 - complete derivations on Web lecture notes or assigned as HW
- 50% time concept tests (discuss/vote/discuss)
- A few more qualitative questions on homeworks.
- A few more conceptual questions on exams.

Problems:

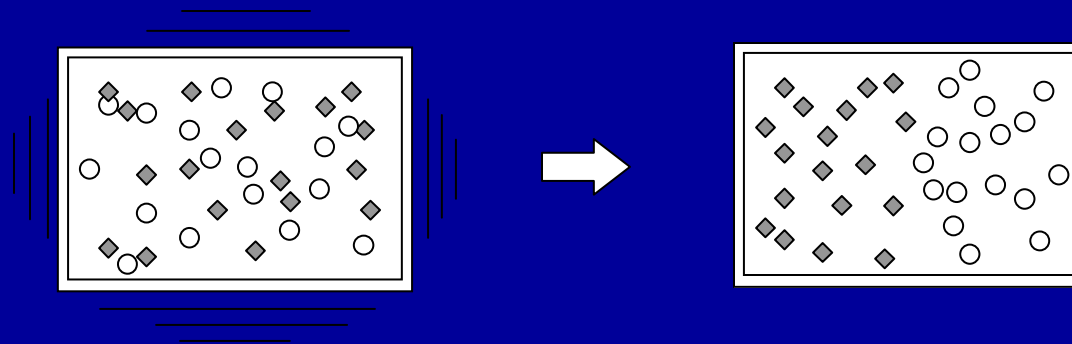
- No assessment pre/post test!
- Concept Test construction very time-consuming
- No assessment pre/post test.

Concept Test

A macroscopic system is in thermal equilibrium, meaning it is in a state of maximum entropy. If the system is mechanically agitated, can the system go out of equilibrium, so the entropy decreases?

A) Yes

B) No



Student feedback very positive:

2 of 30 students objected to Concept Tests

Enthusiastic response from others:

- More than half the students listed Concept Tests as the single most effective aspect of course.
- "Concepts emphasized – really helpful to get beyond the math"
- "Please teach quantum, no one understands it"

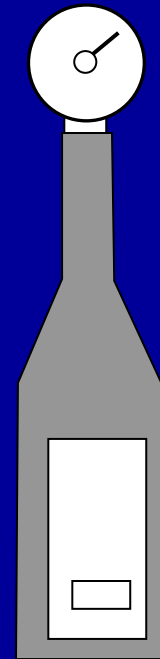
Reform sustainable?

In the 4 semesters since reform,

- 2 professors have used Concept Tests
- 2 professors have taught traditional course.

An unopened bottle of Champaign, equipped with a pressure gauge, has been sitting on the shelf for a long time. The bottle is given a brief, vigorous shake. What happens to the pressure in the bottle? (A brief shake will raise the temperature $< 0.01^\circ \text{C}$)

- A) The pressure remains unchanged
- B) The pressure falls significantly.
- C) The pressure rises significantly.



Other CU Boulder PER Studies

Student Reading habits:

Noah Podolevsky (grad student).

"Suzy doesn't do the reading and she's getting an A"

Student Attitudes toward Science and Learning:

Wendy Adams and Prof. Kathy Perkins

- Students know how experts think and they know students think differently.
- Students attitudes almost *always degrade* after 1st Physics Course