Carl Wieman Science Education Initiative
at the University of British Columbia

2012-13 End of Year Event

Morning Session 9:30-noon

- **Carl Wieman:**
  Teaching that takes advantage of your science expertise
  Overview of CWSEI activities
- **Jackie Stewart:**
  Some Surprising Results from Research on Learning
- **Natasha Holmes:**
  New Roles of Teaching Assistants
- **Teaching Assistants Panel Discussion**

12-12:30pm, ESB Atrium – **Food & Conversation**

Poster session 12:30-2:30pm ESB Atrium

Details on what's happening

Teaching that takes advantage of your scientific expertise

Carl Wieman

Research-based instructional methods

"active learning", "student-centered", "collaborative learning", …

these are only tools–
underlying foundation is

Disciplinary expertise

"Expertise-centered" classroom

good teaching– use and transfer of science expertise

Will not make student an expert, just a step on the path (but as big as possible!)

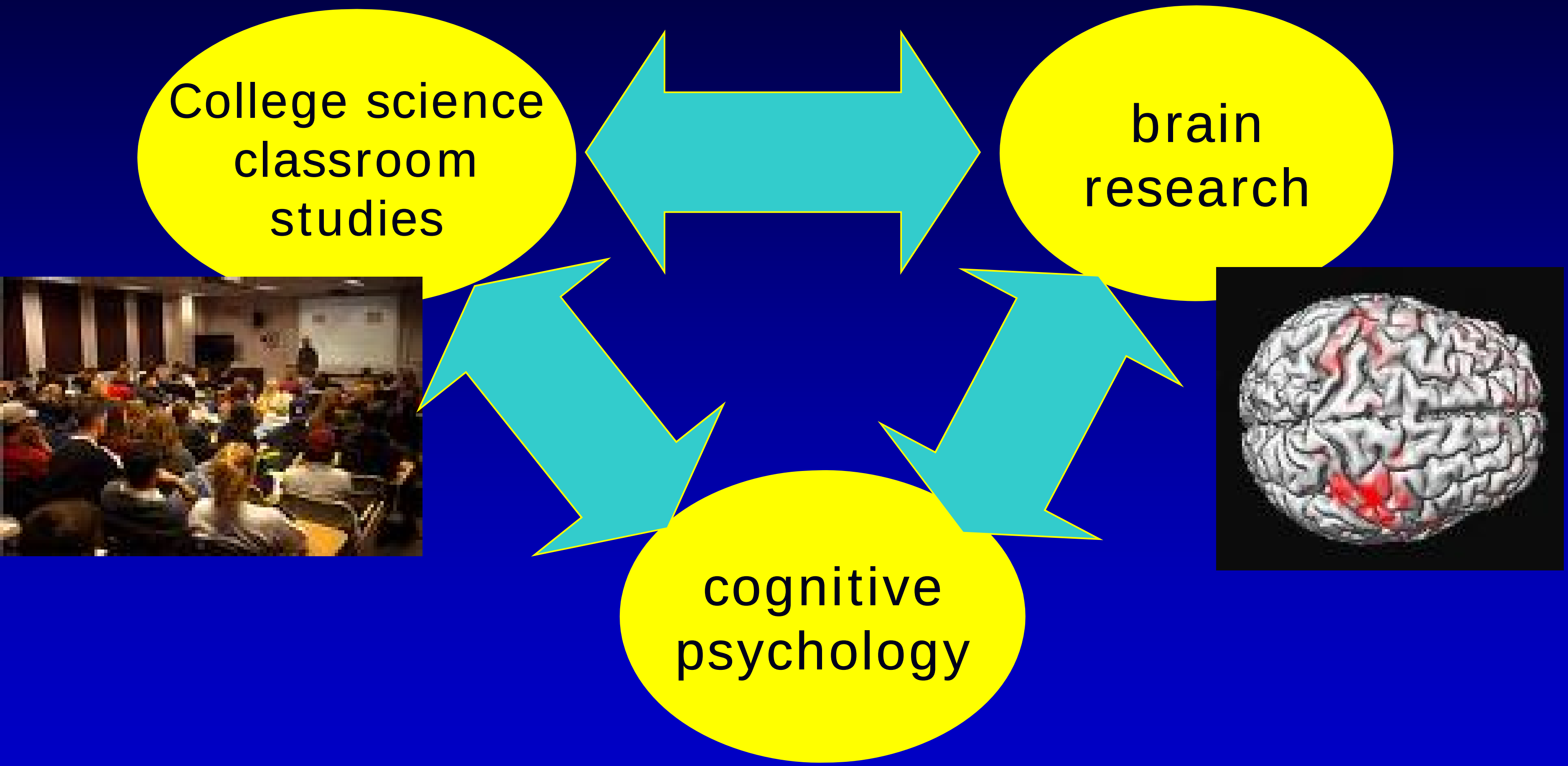
Outline for talk

I. What makes up expertise

II. How is it developed

III. How applies in the classroom-examples (where scientific expertise is needed)

Major advances past 1-2 decades
Consistent picture ⇒ Achieving learning



educational goal— thinking more like a scientist
"greater science expertise"

I. Expertise research*

historians, scientists, chess players, doctors,...

Expert competence =

- factual knowledge
- **Mental organizational framework** ⇒ retrieval and application

or ?

patterns, relationships, scientific concepts,

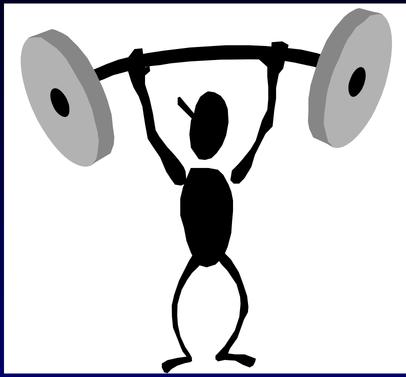
- **Ability to monitor own thinking and learning**

New ways of thinking-- everyone requires MANY hours of intense practice to develop.
Brain changed

Everyone requires about the same amount of time.

*Cambridge Handbook on Expertise and Expert Performance

II. Learning expertise*--



Challenging but doable tasks/questions

Practice all the elements of expertise with feedback and reflection. Motivation critical!

Requires brain "exercise"

Subject expertise of instructor essential—

- designing practice tasks
  (what is expertise, how to practice)
- feedback/guidance on learner performance
- why worth learning

* "Deliberate Practice", A. Ericsson research
accurate, readable summary in "Talent is over-rated", by Colvin

Components of scientific expertise

- concepts and mental models + selection criteria
- recognizing relevant & irrelevant information
- what information is needed to solve
- does answer/conclusion make sense
- **model** development, testing, and use
- moving between specialized representations (graphs, equations, physical motions, etc.)
- ...

To be learned, must be practiced with feedback.
Instructor must design learning tasks that embody.

Only make sense in context of topics.
Knowledge important but only as integrated part of broader expertise.

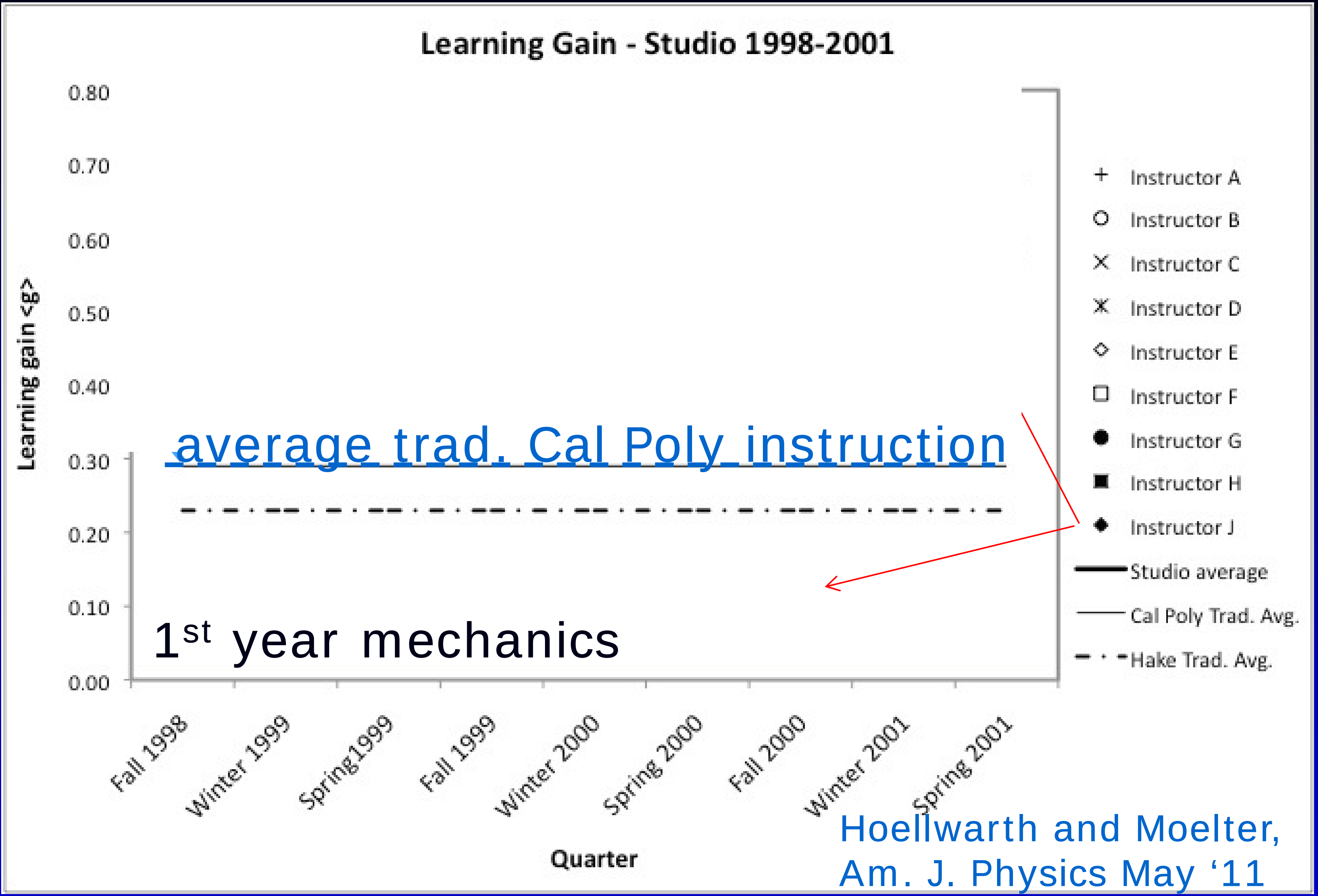
IV. Data– samples from physics courses

2012 US Nat. Acad. Sciences review. "Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Sci. and Eng."
[university level science and engineering]
(NAS press, free download)

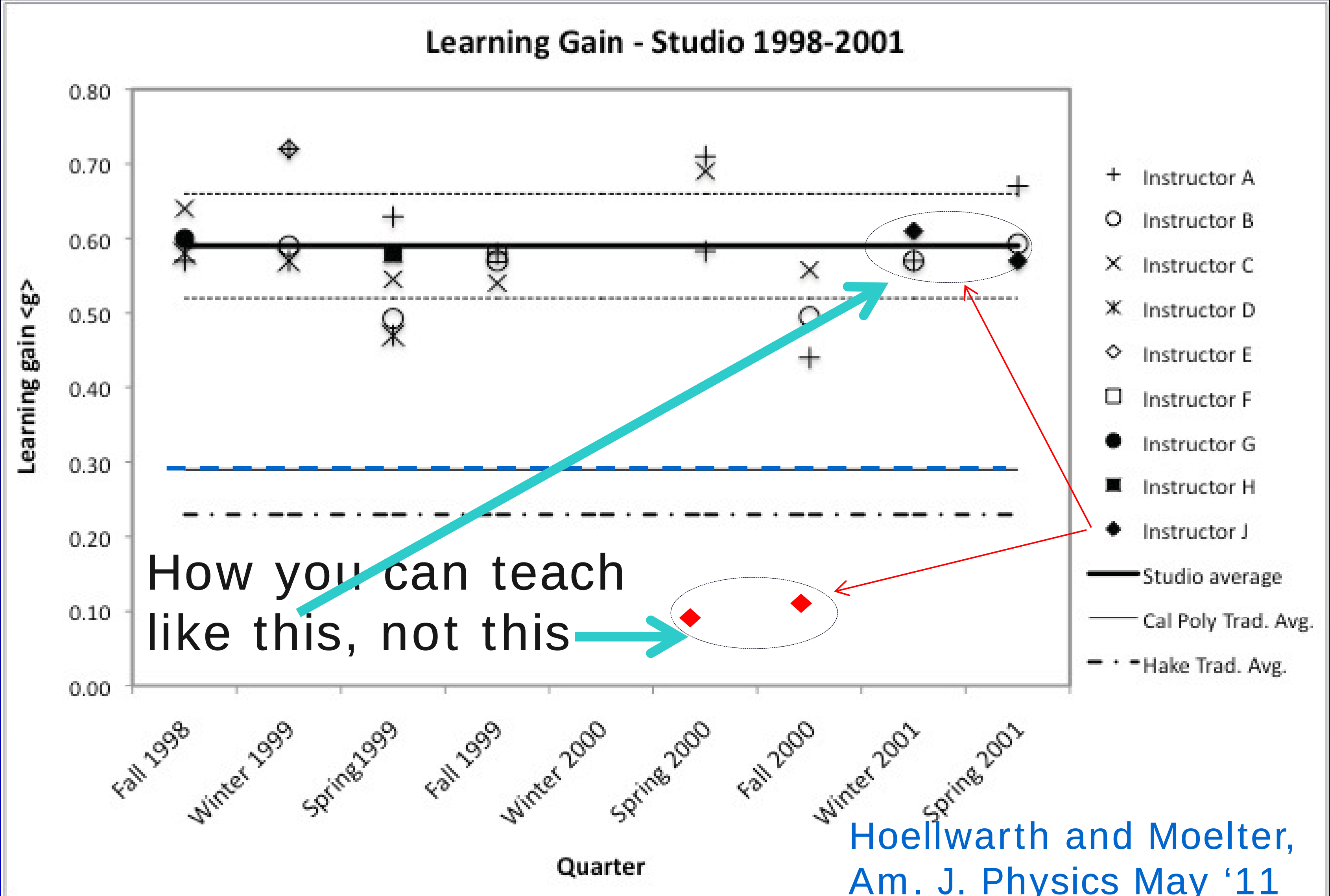
~ 1000 STEM research studies showing methods with consistently better results than traditional lecture.

Example: Conceptual learning—
apply concepts like physicists?

California Polytech Univ. study
Used standard widely-used test of 1st year mechanics concepts. Pre and post course.



9 instructors, 8 terms, 40 students/section.
Same prescribed set of in-class learning tasks.



Hoellwarth and Moelter, Am. J. Physics May '11

DON'TS Common mistakes

On problems for HW, in-class, & exams

- Provide all information needed, and only that information, to solve the problem
- Say what to neglect
- Not ask for argument why answer reasonable
- Only call for use of one representation
- Possible to solve quickly and easily by mindlessly plugging into equation/procedure

- ~~concepts and mental models + selection criteria~~
- ~~recognizing relevant & irrelevant information~~
- ~~what information is needed to solve~~
- ~~How I know this conclusion correct (or not)~~
- ~~**model** development, testing, and use~~
- ~~moving between specialized representations (graphs, equations, physical motions, etc.)~~

III. How to apply in classroom?
(best opportunity for feedback & student-student learning)

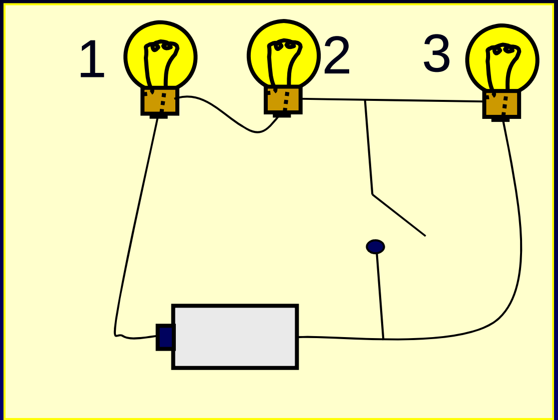
example

Student practicing thinking like scientist, with feedback
Where science expertise of instructor manifest

Example from teaching about current & voltage

1. Preclass assignment--Read pages on electric current. Learn basic facts and terminology. Short online quiz to check/reward. (Simple information transfer. Accomplish without using valuable expert & class time)

2. Class starts with cognitive task:



When switch is closed, bulb 2 will
a. stay same brightness,
b. get brighter
c. get dimmer,
d. go out.

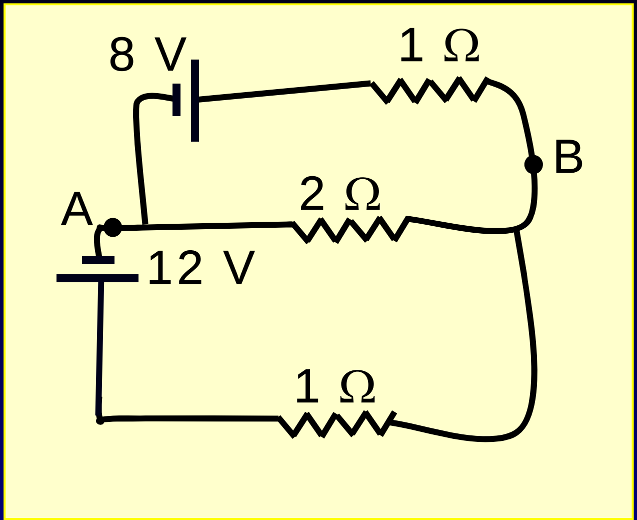
answer & reasoning

Physics expertise in question design:

- Recognize expert conceptual model of current.
- Recognize how physicists would use to make predictions in real world situation.
- Find motivational aspects in the physics
  ("Lets you understand how electricity in house works!")

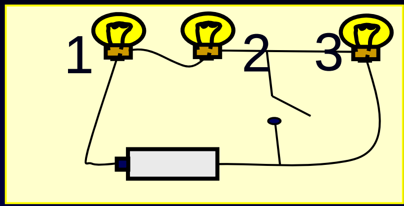
The conventional alternative:

"Here is circuit with resistors and voltage sources. Here is how to calculate currents at A and B and voltage difference using the proper equations.... "



Has NONE of the expertise in light bulb question design:

- Recognize expert conceptual model of current.
- Recognize how physicists would use to make predictions in real world situation.
- Find motivational aspects in the physics
  ("Lets you understand how electricity in house works!")



When switch is closed, bulb 2 will
a. stay same brightness, b. get brighter
c. get dimmer, d. go out.

3. Individual answer with clicker (use *conceptual model*)
(accountability=intense thought, primed for feedback)

4. Discuss with "consensus group", revote.
Practicing physicist thinking– examining conclusion, finding ways to test, further testing & refining model.
Science expertise of instructor — evaluating student thinking.
Listening in! What aspects of student thinking like physicist, what not.

5. Demonstrate/show result

6. Instructor follow up summary– feedback on which models & which reasoning was correct, & **which incorrect and why**

Physics expertise—all the above (& on display)

Wouldn't it be a lot quicker and more efficient if I just started class by telling this to students?

Expertise invisible to them, information meaningless = no learning of expertise

7. Large number of student questions. Testing and refining conceptual model. Range of application? Experimental proof?
Extension of ideas into new contexts, including many real-world situations.
(with guidance, covers a lot of course material)

Very high demands on scientific expertise

Intellectually challenging and FUN!

Students-practicing scientific thinking.
Immediate Feedback— fellow students, clicker result, experiment, targeted instructor guidance

Example 2. Worksheet activities.

Do in class in small groups, turn in. (15-20 minute+)
Problem solutions shown in old lectures often easy to turn into good worksheet activities.

Instructor moves from group to group, sampling and providing brief feedback. At regular intervals, or when sees common difficulty, pulls class together to provide general feedback, ensure all on same page.

An example from eye development in cavefish

adapted from Michelle Smith, PLoS Biology, **10** (2012)

Restoring sight in blind cavefish

Richard Borowsky for Current Biology 18, R23-24

This article is about the blind cavefish, *Astyanax mexicanus*, from a variety of caves in Mexico. The experimenters unravel some of the genetics behind how blindness and other characteristics of blind cavefish came about.

Blind Cavefish Can Produce Sighted Offspring

Brian Handwerk for National Geographic News January 8, 2008

A general audience article about the findings in the Borowsky, 2008 paper. The article begins by stating that **it's a miracle** that blind cavefish can produce sighted offspring in one generation.

Expertise and motivation clear. Current genetics topic.

Problem to solve today. Miracle or normal genetics? If genetics, how many genes involved?

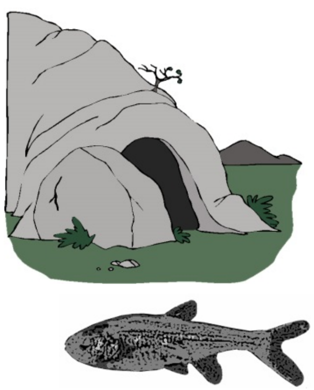
Borowsky, R. (2008). Restoring sight in blind cavefish. *Current Biology. 18,* R23–R24.
Handwerk, B (2008). Blind cavefish can produce sighted offspring. *National Geographic News.*

Cavefish natural history

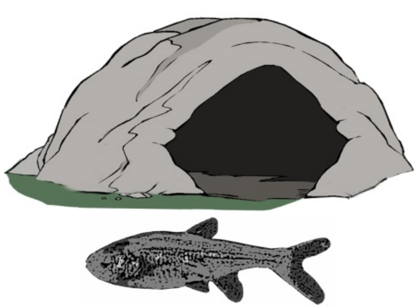
-The Mexican cave fish lives in a series of unconnected caves.

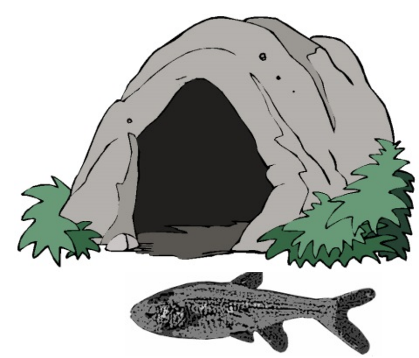
-Fish found in the caves have been blind for millennia.

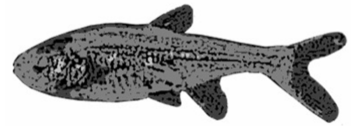
-Cavefish can still interbreed with surface fish!



Are mutations in the same gene or different genes responsible for blindness in separated cavefish?

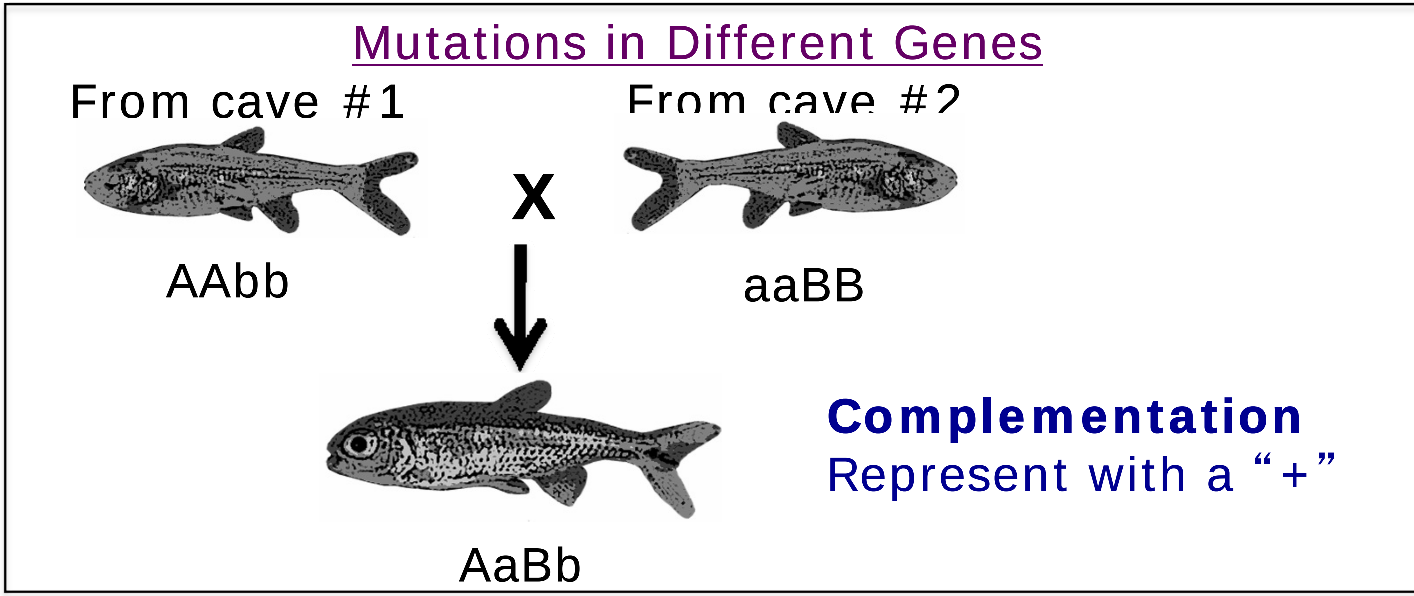


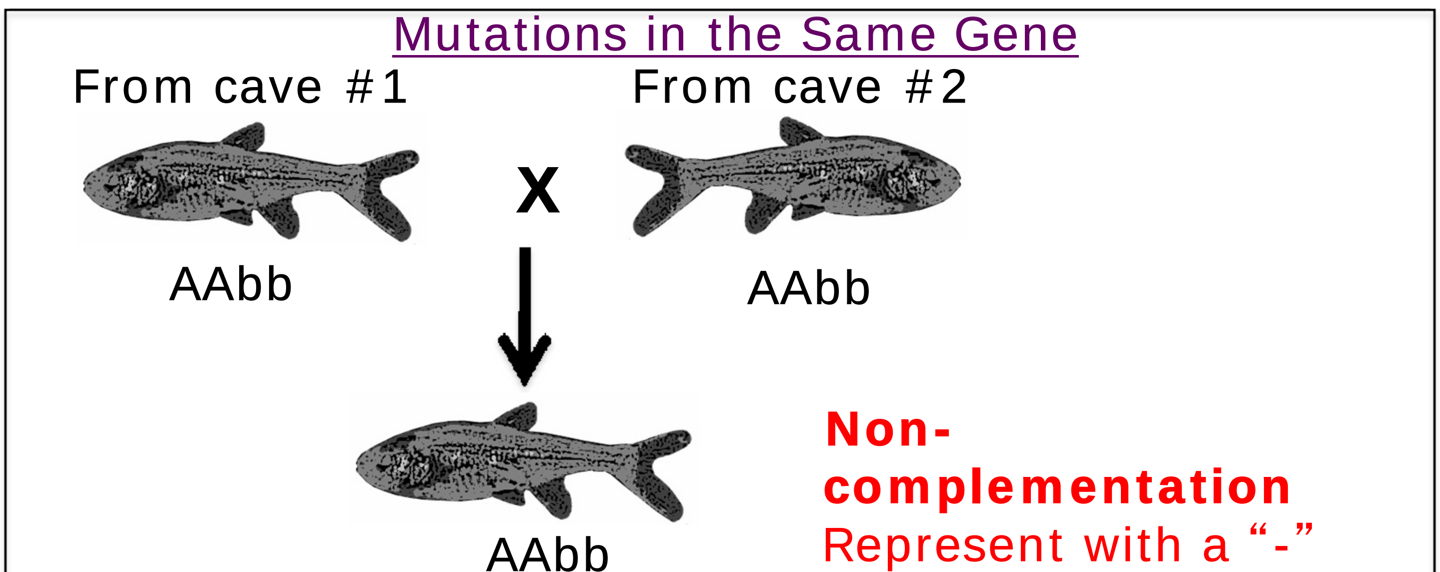


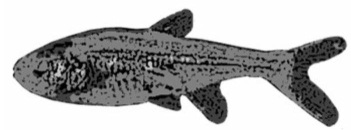


1. A blind fish from a true-breeding line in one cave was crossed to a blind fish from a true-breeding line in another cave. If the mutation that causes blindness is in two different genes in the two fish, what would you see? Explain your reasoning.

What instructor might interject <u>if necessary</u> to be sure all understood 1.







1. A blind fish from a true-breeding line in one cave was crossed to a blind fish from a true-breeding line in another cave. **If the mutation that causes blindness is in two different genes in the two fish, what would you see? Explain your reasoning.**

2. Using A Complementation Table

You isolate 3 fish strains from different cave ponds, all the fish are blind because of autosomal recessive mutations. You mate the fish together and get the following results:

#1, #2, #3=Parental fish strains from different caves

#1 #2 #3

#1 – –

+

#2 – –

+

#3 + +

–

Offspring phenotypes:

- = no complementation, blind fish

+= complementation, fish can see

Where do strains #1 and #2 have defects? Explain.

3. Adding more fish

You isolate two more blind fish strains (#4 and #5), cross them to #1, #2, and #3, and get the following results:

	#1	#2	#3	#4	#5
#1	-	-	+	+	+
#2	-	-	+	+	+
#3	+	+	-	+	-
#4	+	+	+	-	+
#5	+	+	-	+	-

Based on these results, at least how many genes are working to produce sight? Justify your conclusion.
How could you test this?

Worksheet implementation details: add extra "challenge questions" at end, for groups that get done faster. Carbonless copy paper, turn in and keep copy.

Conclusion– Effective teaching develops expertise. Practice thinking like scientist with feedback essential for learner.
Scientific expertise of instructor essential
(much more so than when lecturing)

<u>Good References:</u>

S. Ambrose et. al. "How Learning works"
Colvin, "Talent is over-rated"
cwsei.ubc.ca-- resources, references, effective clicker use booklet and videos

NAS Press, "Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering" (free download of PDF)

slides to be posted—cwsei website

extras below

What is the role of the teacher?

"Cognitive coach"

- Designs tasks that practice the specific components, of "expert thinking", appropriate level
- Motivate learner to put in LOTS of effort
- Evaluates performance, provides timely specific feedback. Recognize and address particular difficulties (inappropriate mental models, ...)
- repeat, repeat, ...-- always appropriate challenge

Characteristics of expert tutors*

(Which can be duplicated in classroom?)

Motivation major focus (context, pique curiosity,...)
Never praise person-- limited praise, all for process

Understands what students do and do not know.
$\Rightarrow$ timely, specific, interactive feedback

Almost never tell students anything-- pose questions.

Mostly students answering questions and explaining.

Asking right questions so students challenged but can figure out. Systematic progression.

Let students make mistakes, then discover and fix.

Require reflection: how solved, explain, generalize, etc.

*Lepper and Woolverton pg 135 in Improving Academic Performance

How are students practicing thinking like a scientist?

- forming, testing, applying conceptual mental models (deciding what is relevant and irrelevant)
- testing their reasoning & conclusions
- critiquing scientific arguments

\+ feedback to refine thinking
(fellow students, clicker results, experimental test of prediction, instructor targeted followup)

Works educationally *because* instructor's science expertise is used in both task design and feedback. Provides "deliberate practice" for students.

True of all research-based instruction.

Principles from research for effective learning task all levels, all settings

1. Motivation *(lots of research)*

basic psychology, diversity

2. Connect with prior thinking, proper level of challenge. *(group work expands range)*

3. Apply what is known about memory
   a. short term limitations– don't overload
   b. achieving long term retention

*4. Explicit authentic practice of expert thinking. Extended & strenuous. Timely & specific feedback.

5. Checking that it worked.