Why having a theory of learning changes what I do in class on Monday

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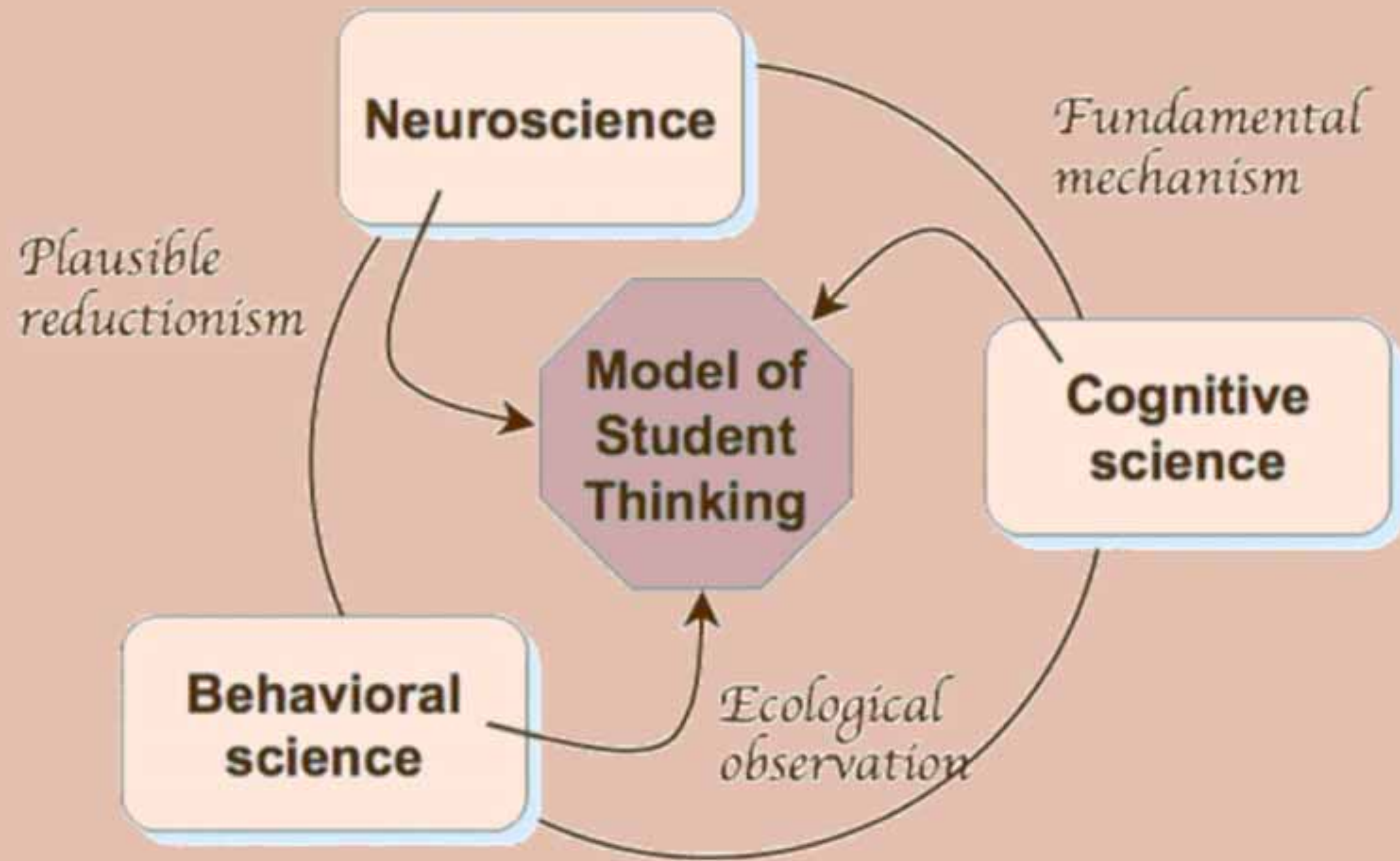
Outline

- What theory?
- What class?
- How theory changes my goals
- How theory changes my practice.

Triangulation



Redish, *Enrico Fermi Summer School in PER, Varenna* (2003)

Foothold ideas: Neuroscience

- Neurons connect to each other.
- Neurons send information to each other via pulse trains when they are activated.
- Neurons may be in various stages of activation.
- Neural connections can enhance or inhibit other neural connections.
- Learning appears to be associated with the growth of connections (synapses) between neurons.

Kandel, Schwartz, and Jessell, *Principles of Neuroscience* (2000)

Implications

- “Neurons that fire together, wire together!” (Hebb’s rule)
  - Synapses that prove effective in activating a neuron grow more effective. (There are lots of both positive and negative synapses into every neuron.)
- “There’s no erasing in neurons!” (Not yet!)
  - Once a pathway has been well established it can be inhibited (suppressed) -- but that suppression is likely to be tied to a local context.

Foothold ideas: Cognitive science

- Memory has two distinct components:
  - Working memory
    - can only use a small number of “chunks” at a time.
    - labile, often lasting only a few seconds
  - Long-term memory.
    - contains a vast quantity of information.
    - highly stable and can store data for decades.
- Reasoning has two distinct components:
  - Serial processing / logical reasoning
  - Parallel processing / recognition - intuition

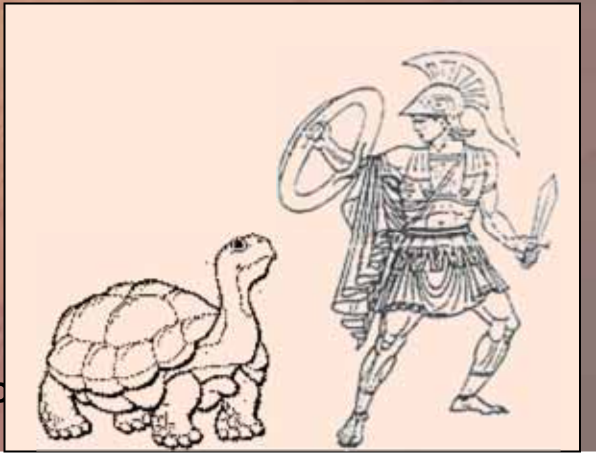
Baddeley, *Human Memory* (1998)

Hofstadter, *Fluid Concepts & Creative Analogies* (1996)

Implications

- Working → long-term requires repetition.
- Long-term → working memory takes time.
  - Activation by association
  - Priming can be complex and depend on unnoticed cues
- Logical reasoning relies on intuition

L. Carroll, *What the Tortoise Said to Achilles* (1895)



Foothold ideas: Behavioral science

- Selective attention: Framing
  - When we enter a situation, we (tacitly) make a judgment as to "What's going on here."
  - This has a powerful effect on the knowledge that is activated and primed for use.
- Coherent local activities: Games
  - Once we decide what we're doing, we activate a locally coherent set of "knowledge building" (epistemic) tools (or moves).

G. MacLachlan and I. Reid, *Framing & Interpretation*(1994)
I. Goffman, *Frame Analysis* (1997)
A. Collins & W. Ferguson, in *Educational Psychologist* (1993)

Implications

- Just because students don't use a bit of knowledge that we might see as necessary doesn't mean that they don't know it.
- When students engage in a "game", they may limit sharply the tools and skills they employ, possibly inappropriately.
- ***"Epistemology"*** – What students think they are supposed to be learning and what they think they are supposed to do to learn it.

Resource framework: Instructional implications

- Use of knowledge = activation:
  - Students can have knowledge but not use it appropriately. We need to probe what they know.
- Association / spreading activation:
  - How students' knowledge is linked is as important as what knowledge they have. We need to vary contexts in which a topic is seen.
- Control / selective attention:
  - Students may bring in epistemological misconceptions. We may need to help them change which filters they have turned on
- Intuition is critical
  - We need to find ways to develop intuition, not assume that it "comes for free" with practice.

What class?

- Algebra-based physics (full year)
- Mostly bioscience students
- Mostly juniors and seniors
- Mostly women

- Transformed via the NSF project *Learning How to Learn Science: Physics for Bioscience Majors* *(REC-008 7519)*

What goals?

- Build a sense of coherence
  - We want our students to not only "have" knowledge, but to associate it appropriately.
- Build complex skills
  - We cannot expect our students to "bind" diverse items immediately. We have to give them opportunities for doing it.
- Build appropriate expectations for what to do when.
  - A focus on narrow technique can create damaging epistemological misconceptions.

What changes?

- Epistemology über alles!
  - Keeping the meta-messages consistent.
- Building intuition
  - Strengthening intuition, not suppressing it.
- Peer instruction
  - With a difference.
- Homework
  - Less is more (and vice versa).
- Quizzes and exams
  - They should support not undermine our goals.

Epistemology über alles!

- To achieve epistemological gains,
  it appears necessary
  to be consistent throughout,
- It's not enough to describe e-goals early (first class, main handout)
  - Many students won't understand what you mean.
  - Others won't believe you.
- Other parts of the class (HW, lab, …) that don't support your e-goals can undermine them.

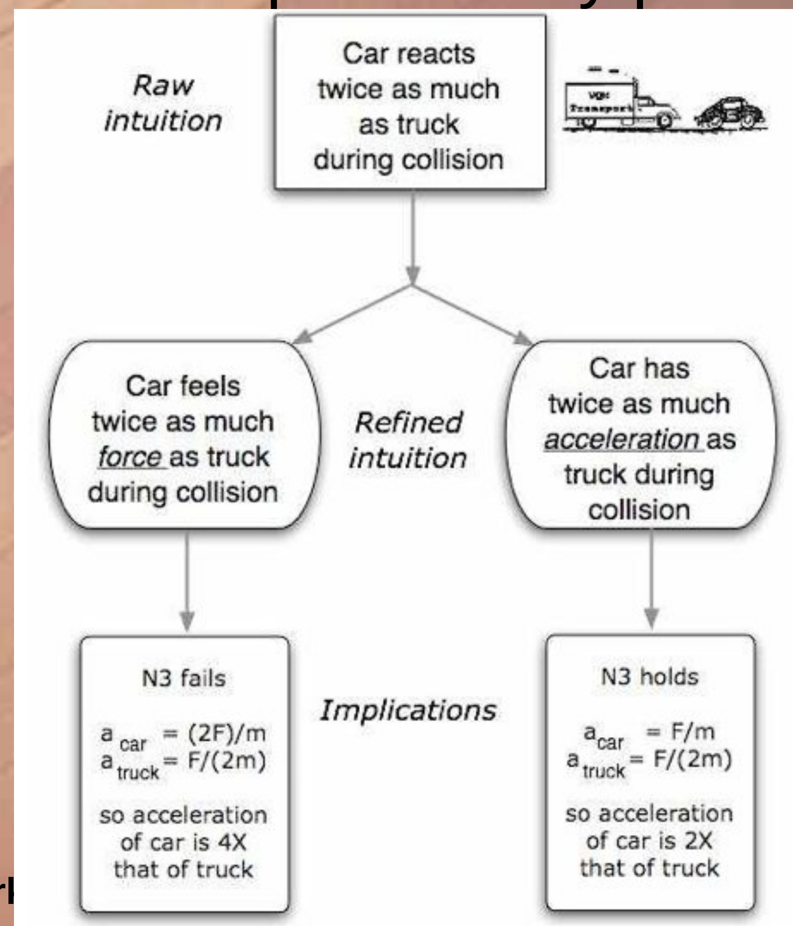
We want to strengthen student's physical intuition

- Pure cognitive conflict can be effective in producing good conceptual gains.
- But it can have an unintended side effect:
  - Elicit / confront / resolve
    can easily become
    Elicit / confront / suppress
    in a context dependent way.
- Students may learn the concept but restrict its use to the context of their physics class -- and learn that their intuition is not to be trusted.

Refine and reconcile rather than try to "replace"

Tutorials (replacing recitations) focus on intuition building using the technique of "Elby pairs".

(a) A truck rams into a parked car. Intuitively, which is larger: the force exerted by the truck on the car or by the car on the truck?
(b) Suppose the truck has mass 1000 kg and the car has mass 500 kg. During the collision, the truck slows by 5 m/s. How much speed does the car gain?



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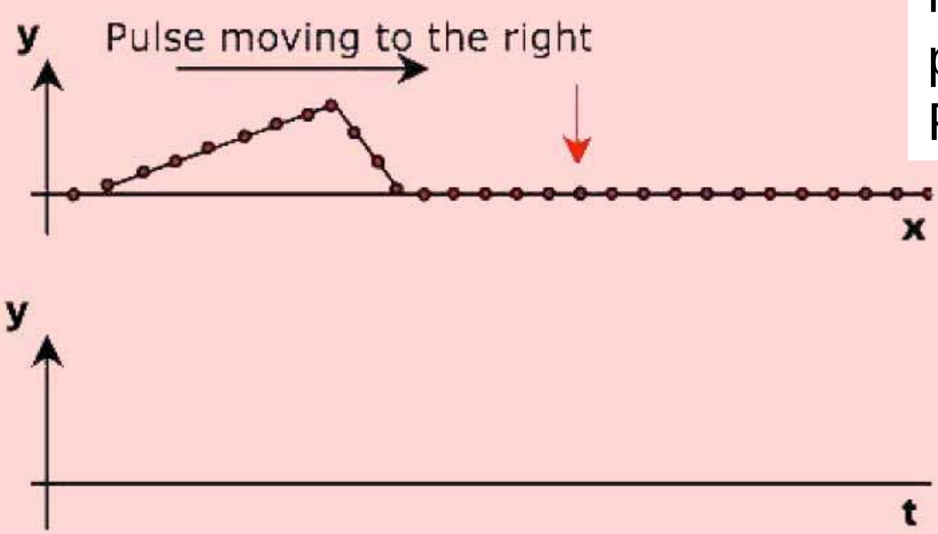
Peer Instruction: With a difference!

- Build associations, not answers
  - Sometimes draw answers from class.
  - Call for creativity.
  - Have students consider and defend answers given.
  - “Forget” to give the “right answer” at the end of the discussion (but give it if they ask).
  - Some problems not pre-planned

A sample PI problem

If this is the space graph (photo at an instant of time) what does the graph of the position as a function of time look like for the bead marked with a red arrow?



More such problems at

http://www.physics.umd.edu/perg/role/PIProbs/ProbSubjs.htm

Homework: Less is more!

- No exercises!
- Encourage group work
- Fewer problems, subtler, explanations and writing required.
- Varied types
  - Essay questions
  - Estimations
  - Representation translation
  - Context rich problems

A sample HW problem

Suppose you are using a camera and wish to have a larger image of a distant object than you are obtaining with the lens currently in use. Would you change to a lens with a longer or a shorter focal length?

(Hint: Note that the object distance is essentially fixed.)

Address this question in two ways:

* by drawing and interpreting appropriate geometrical diagrams
* by appealing to the lens equation and the expression for lateral magnification and demonstrating your result mathematically.

If your two approaches do not agree, explain which one is correct and why the other is wrong.

More such problems at
http://www.physics.umd.edu/perg/abp/TPProbs/ProbSubjs.htm

Quizzes and Exams

- The best way to motivate a frame shift is with a graded exam!
  - This population is very sensitive to grades -- even small numbers of points.
- Learning a new frame requires repeated and explicit attention!

Quizzes

- Quizzes are given weekly.
  - They test on the previous week's concepts (mostly tutorial).
  - Multiple choice: show epistemological as well as conceptual issues.
  - Worth only 10 points (out of a total of 1000 for the semester).
  - Given Monday first thing (after collection correct answers given).
  - Returned graded Wednesday first thing: answers chosen discussed along with possible reasons they were chosen (class discussion).

Sample quiz problem

- Consider two identical capacitors. Capacitor #1 is connected to a battery until one of its plates has a charge +Q, and the other has a charge –Q. Capacitor #2 has no voltage difference across the plates as shown in the top figure at the right.
- The capacitor #1 is disconnected from the battery and the two capacitors are connected together as shown. Once things have settled down, how has the <u>magnitude of the E-field</u> between the plates of capacitor #1 changed from its initial value?

  A. It has remained the same.

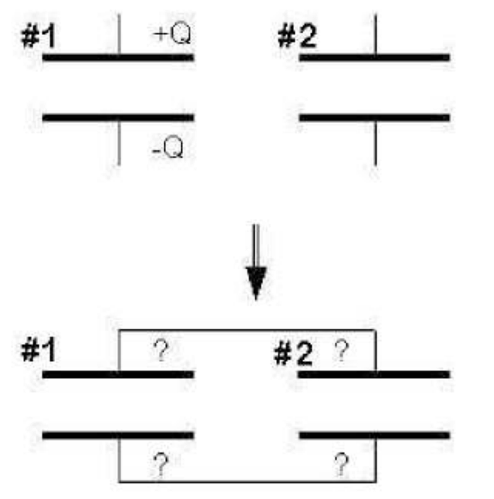
  B. It has increased by a factor of 2.

  C. It has increased by a factor not equal to 2.

  D. It has decreased by a factor of 2.

  E. It has decreased by a factor not equal to 2.

  F. You cannot tell from the information given.

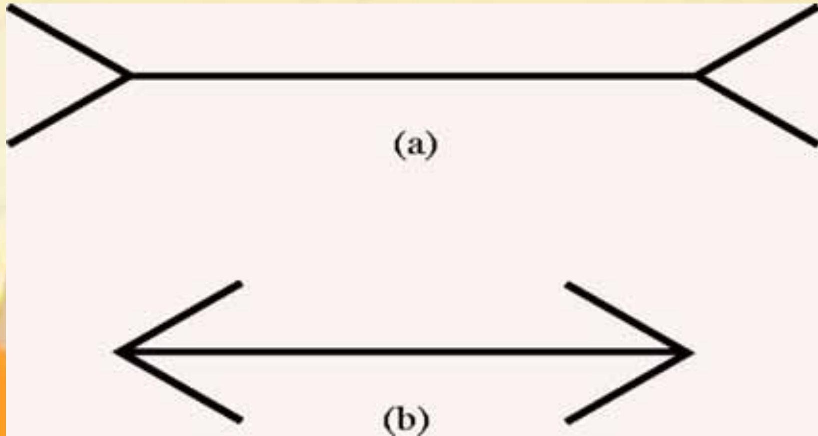


Exams

- Hour exams given twice a term.
- Mix of problems
  - Representation translation (mult.ch.)
  - Two symbolic manipulation problems focusing on use of principles
  - Estimation
  - Essay
- Given on Friday, returned and gone over in class Monday
- Makeup exam Thursday out of class
  - Can be taken by anyone
  - If you retake, you get the average of your two grades

Sample essay question

- During the first week of this class we discussed the danger of one-step recall and showed examples of how our memories can mislead us. Have you had an example in this class where one-step recall led to you an incorrect answer, but where a more carefully considered approach led you to realize that you had a more correct intuition? If so, give the example, your first answer, and the correct answer. Give a plausible reason why the first answer seemed to be correct at first glance and what you knew that made you see it in a different way. *Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity*


(a)
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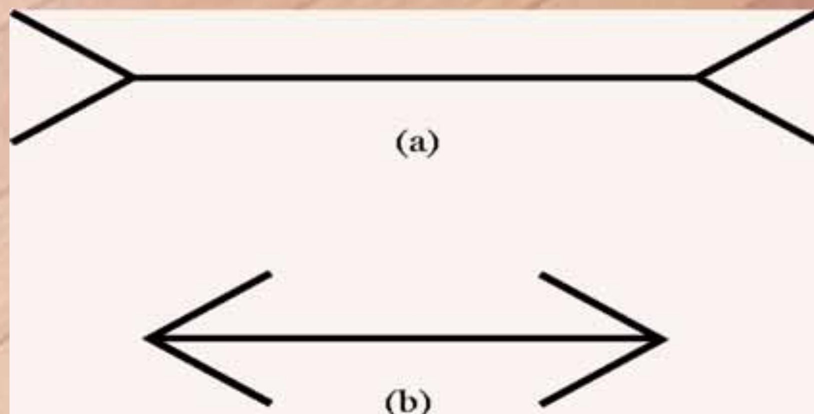
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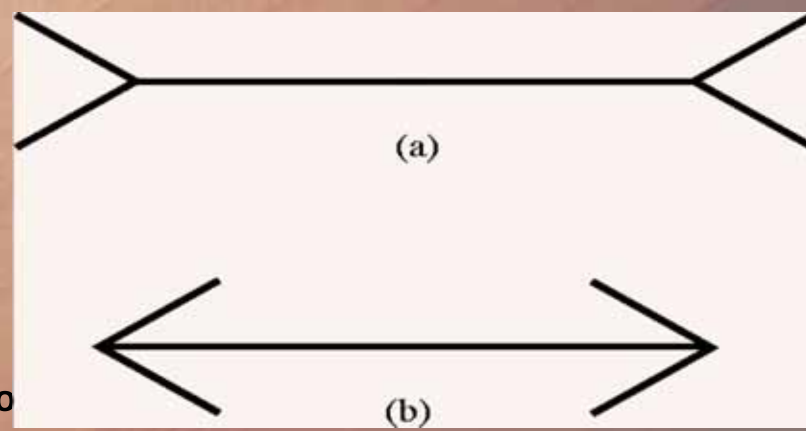
(a)
(b)

Summary

- Some of the things I have talked about doing, I have done for a long time -- without a theory -- because it “felt right.”
- Others I have added because I now have a better sense of “what’s going on” in class.
- As a teacher, my sense of the class is that it is much improved. Students are a bit nervous at first, but “get on board” as a result of an overall coherence to the class.

One testimonial

- I took your physics 2 class last semester. I received a B in your class and thoroughly enjoyed it for one primary reason: THINKING. Your class taught me more than just physics, it taught me to THINK. I was the kind of guy that would try and memorize information without trying to think about it. This method of memorizing without integrating proved inefficient in a number of my science classes. But after taking your class and doing your infamous estimation problems and thinking about the concepts I learned something very important about myself: I am capable of thinking and I love it.

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