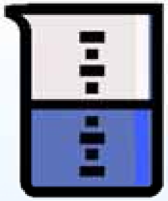
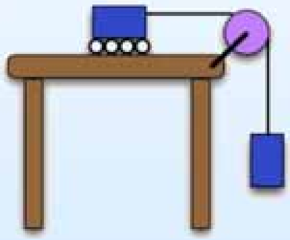
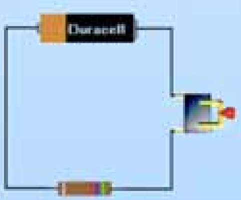




Content Is Not Enough: Helping students learn to “think science” with DBER

E. F. (Joe) Redish
Department of Physics
University of Maryland



PER:The framework

- Treat learning of physics
  as a scientific problem:
  - observe,
  - make sense,
  - engineer solutions,
  - theorize.
- Over two-and-a-half decades the community doing PER, has begun to develop a concensus on a number of issues.

PER: Main observational results

- Misconceptions:
  In every area of physics students show common errors and misunderstandings.
  - Errors are widespread and predictable.
  - A few common difficulties (< 10) appear to account for most student errors (> 80%).
  - Many of these student difficulties are robust and persist in the face of traditional instruction.

PER: The inference

- <u>Constructivism</u>:
  Everyone builds their new knowledge by using their existing knowledge to interpret new information
  - Students are not blank slates!
  - It matters what students bring into our class!
  - Students may not "hear" the same things we "say". We are going to need lots of feedback.

Note: I have not combined these by saying students "bring misconceptions" into their class. That ain't necessarily so!

PER: Measuring where we are

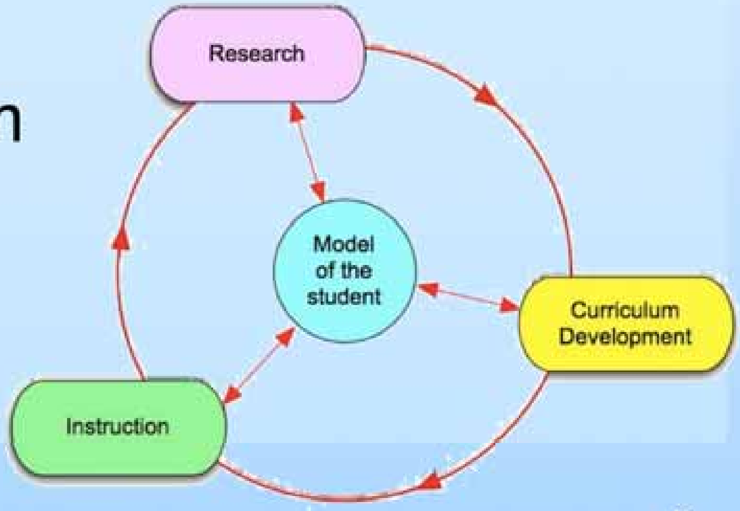
- <u>Conceptual surveys</u>:
  Researchers developed easily deliverable tests to probe large classes
  - Focus on areas students have misconceptions.
  - The distractors are attractive.
  - Teachers tend not to see the distractors, so the questions look trivial.
  - Students do more poorly than expected.
  - There are now > 20 such surveys available.

  These have convinced many faculty of the need for reform.

Note: These don' t necessarily give us insight into what' s going on. We need qualitative research to make sense.

PER: The engineering

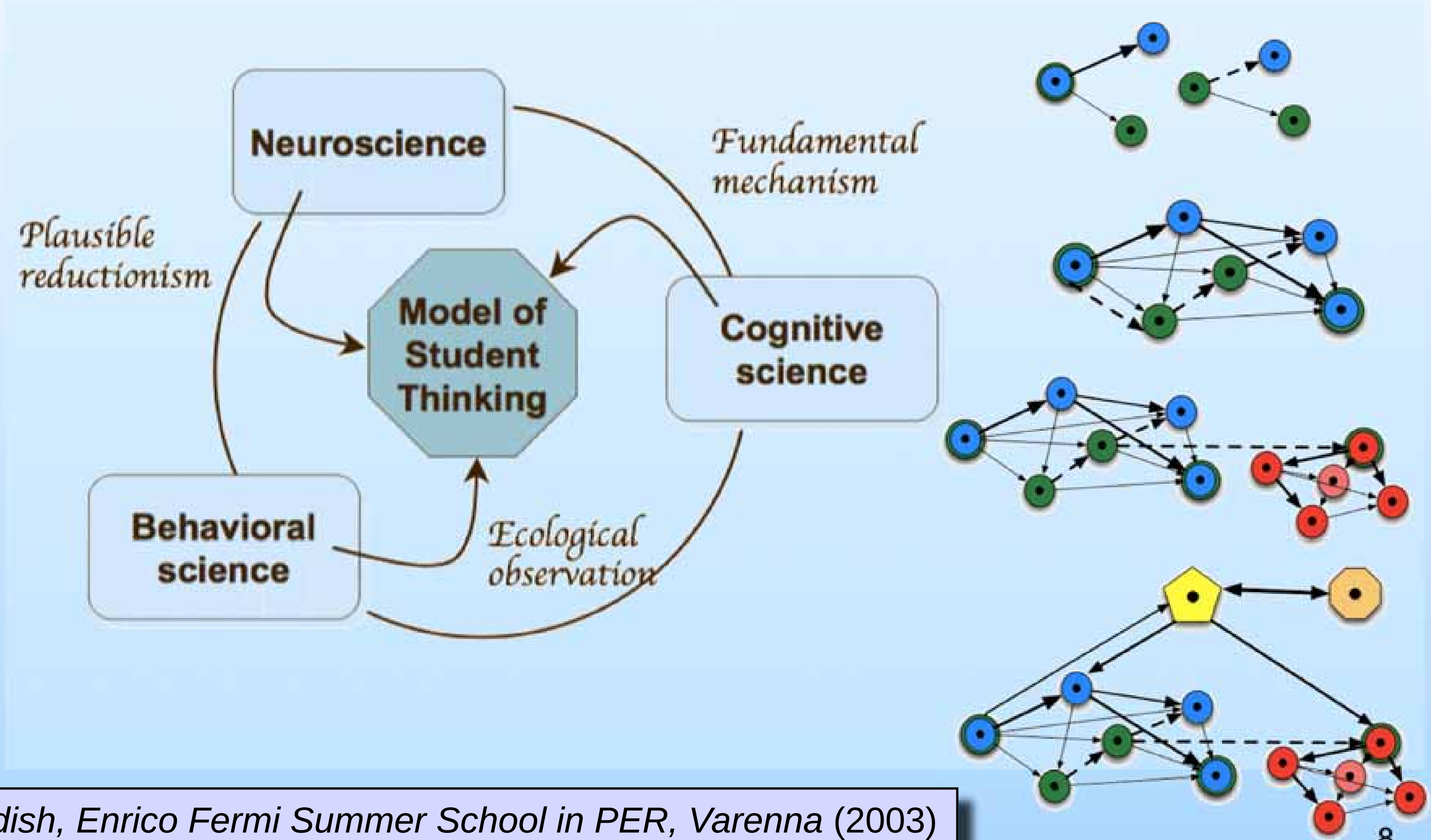
- Active learning:
  The idea of constructivism focuses on building of new ideas. Creating environments to guide students in what they have and what they build should help.
  - Over the past 15 years, research-based curriculum developers have created a variety of effective learning environments.



Theory?

- Most learning theories in education are organizing principles of phenomenology – guidelines rather than mechanism.
- They do not create a “micro” level that allows complex behavior to arise out of simpler structures via combination.
- It’s like trying to do chemistry without atoms.

PER: The resources theory



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

Theory: Example 1

Micro

Through experience, the brain creates tightly bound resources – clusters of neurons that reliably activate together.

→

Macro

We fail to recognize the components that go into a particular bit of knowledge we – as experts – may use in a unary fashion.

** Redish, Scherr, & Tuminaro, The Physics Teacher (May 2006)*

Theory: Example 2

Micro

In response to
new sensory input,
the brain activates
and combines
its resources
to make sense
of new experiences.

→

Macro

"Misconceptions"
may be something
reliably generated
on the spot, not a
mis-apprehension of
previous experience.

Hammer, Elby, Scherr, and Redish, in Transfer of Learning (2004)

Theory: Example 3

Micro

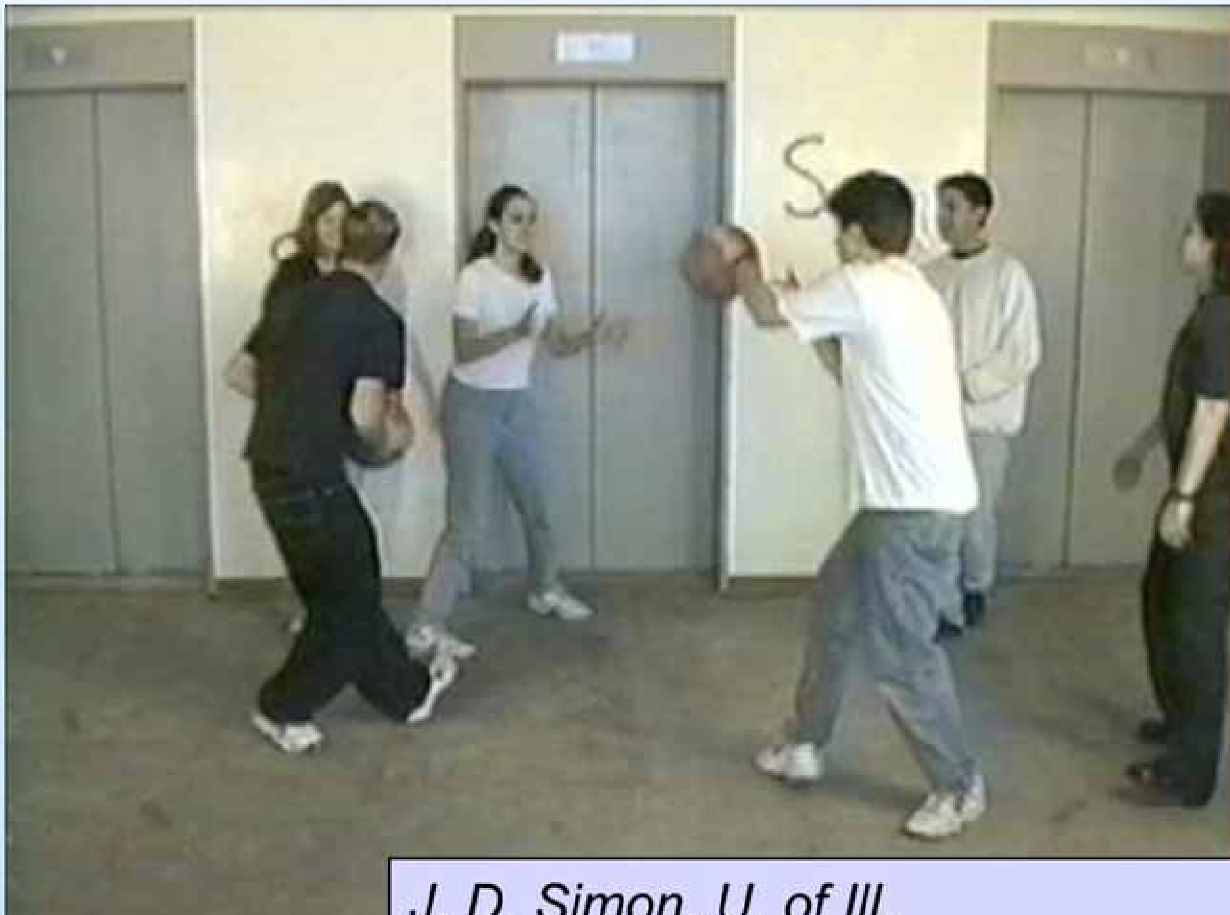
The brain takes early stage processed data and feeds it forward to retrieve stored knowledge that is fed back to affect later processing stages.

→

Macro

Leads to gestalt effects, mishearing, selective attention, and a range of other phenomena.

Count the passes!



J. D. Simon, U. of Ill.,
http://viscog.beckman.uiuc.edu/djs_lab/

Selective Attention

- One way these feedback control structures play out is through selective attention.
- There is too much in the world for our brains to process at once.
- We learn to select and ignore, *framing* our situation — deciding what matters and what doesn't quickly and (often) unconsciously.

D. Tannen, Framing in Discourse (1993)
I. Goffman, Frame Analysis (1997)

Expectations Matter

- It's not just concepts – what students think they're doing is crucial:
  - What is the nature of the knowledge they are learning?
  - What do they have to do to learn it?
- Part of science is about learning a new vocabulary – but students often mistake that for the science.
- Students can develop epistemological as well as content misconceptions.

Epistemology

Students' Epistemological Expectations

- Research in a variety of fields* show that student expectations about the nature of knowledge and the process of learning plays a powerful role in what they get out of a course.
- My research group and I began exploring this question for students in introductory physics in 1993.

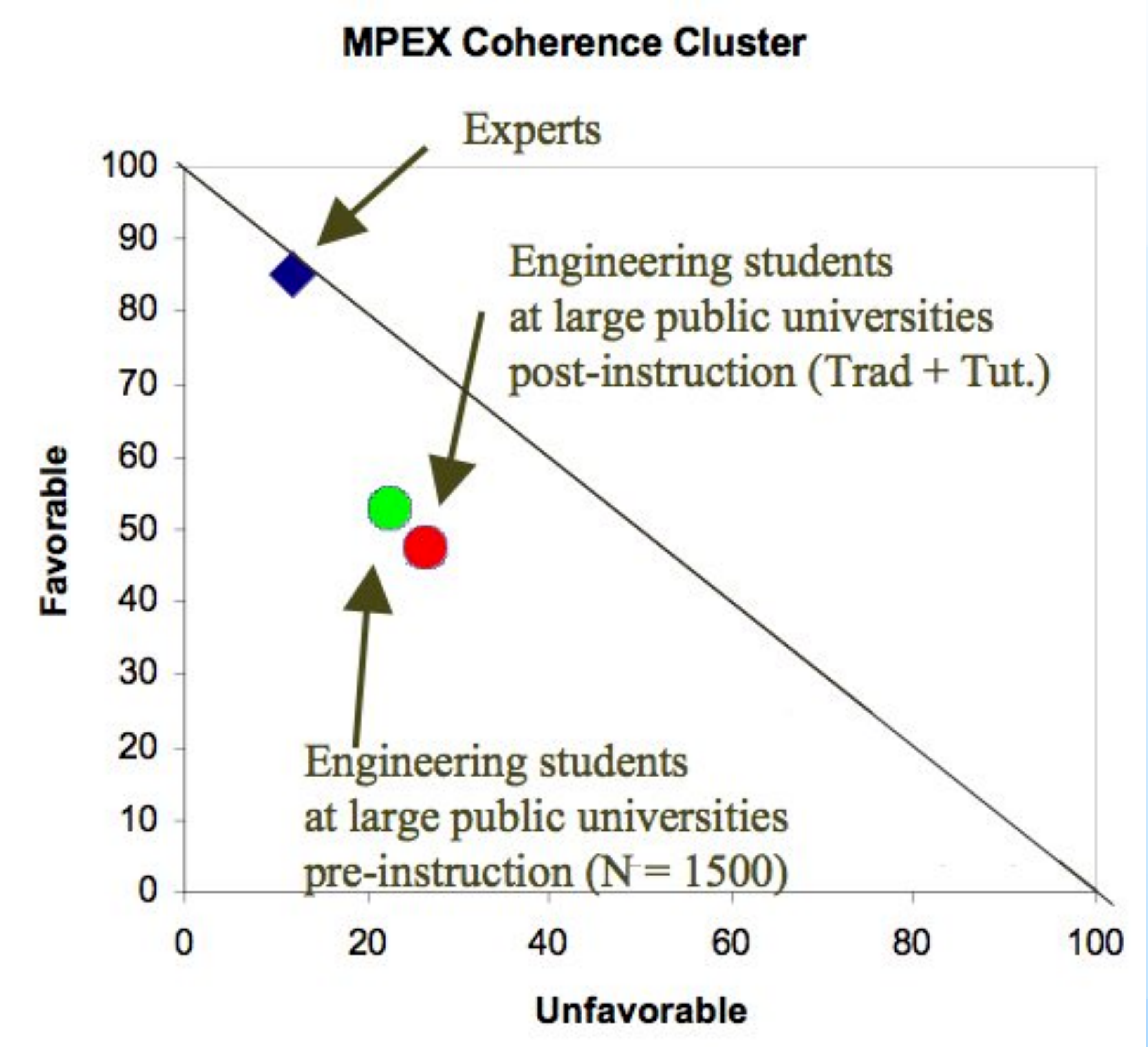
** W. J. Perry, Jr. (1970), A. Schoenfeld (1985), D. Hammer (1988), M. Belenky et al. (1996)*

The MPEX

- To get some measure of student expectations towards learning and knowledge, we developed *The Maryland Physics Expectations survey*. (“agree-disagree,” 34 statements)
- General topics probed include
  - Coherence (vs. pieces)
  - Concepts (vs. formulas)
  - Independence (vs. authority)
  - Reality link
  - Math link

MPEX Results

- Our study with ~2000 engineering students showed mediocre student expectations upon entry. They deteriorated as a result of a physics course.
- The effect wasn't large but it was very robust. Studies with > 10,000 students at dozens of universities showed the same effect.


MPEX Coherence Cluster
Experts
Engineering students
at large public universities
post-instruction (Trad + Tut.)
Engineering students
at large public universities
pre-instruction (N = 1500)
Favorable
Unfavorable
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100

Other studies have extended what has been learned

- Wendy Adams & Carl Weiman: CLASS (Phys, Colorado)
  - Almost all students, even those giving unfavorable responses, *know* what the favorable response is. They just don't think it applies to them.
- Stacy Bretz: ChemX (Chem, Miami of OH)
  - Chemistry students show similar starting expectations and deteriorations.
  - Upper division chemistry students have much better expectations. Is this learning? Or filtering?

How Do Epistemological Expectations (EEs) Matter?

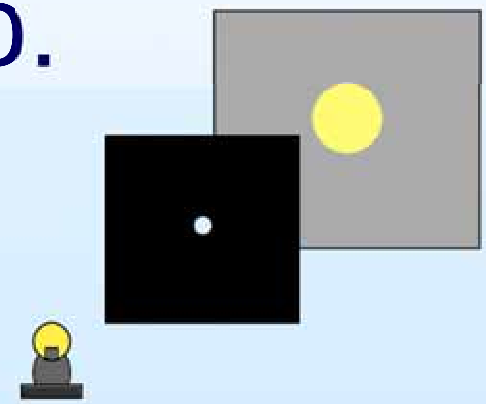
- In the project *Learning How to Learn Science*, we studied how bioscience students learned in college physics.
  - We modified each component of the course (lecture, lab, recitation, HW) so much of the learning would take place in a place where we could watch it.
  - We videotaped ~1000 hours of students working together on physics worksheets, labs, and HW.
- Explore "functional epistemology" in student problem solving by watching them.

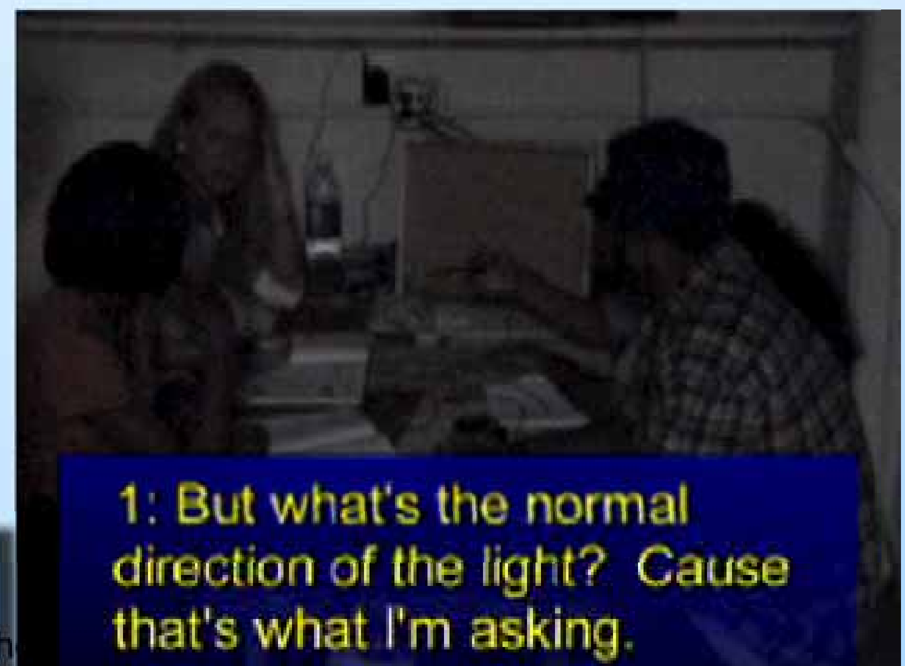
What we found

- Students' EEs played a powerful role in what they took from a lesson or how they approached a homework problem.
- Two examples:
  - "Make it physics oriented."
  - "He gave it in another problem."

EEs tell a student what to pay attention to.

- In this videoclip, 4 students in college physics are working on a Tutorial* on light and shadow.
- They have been asked to explain why the bulb, mask, and screen produce the pattern of light they see on the screen and what would happen to it if the bulb were moved up.





** L. C. McDermott et al.,Tutorials in Introductory Physics (2001)*

Epistemological resources and framing

- We interviewed student #3 for 6 hours of physics problems after the class was finished.*
- *Finding*: Students' EEs can vary from one instructional environment to another and can affect what they take away from that instruction, including their conceptual learning.
- We refer to the process of activating EEs (tacitly – not consciously) – deciding what one is doing and what are the relevant resources to use – as *e-framing*.

** L. Lising & A. Elby, Am. J. Phys. (2005)*

EEs tell students what is appropriate to use

- In the next videoclip, a student is discussing with some other students (and at this point with a TA) the solution to an estimation problem.

Problem: Estimate the difference in air pressure between the floor and ceiling in your dorm room.
(Hint: The density of air is ~ 1 kg/m^3.)

The student has decided she needs the volume of the room.

- After much struggle and discussion, she comes up with an answer.

“He gave it in another problem”?

- This student seems very focused – and ignores the comments made by the TA. What is she doing?

Organization of Student Problem Solving

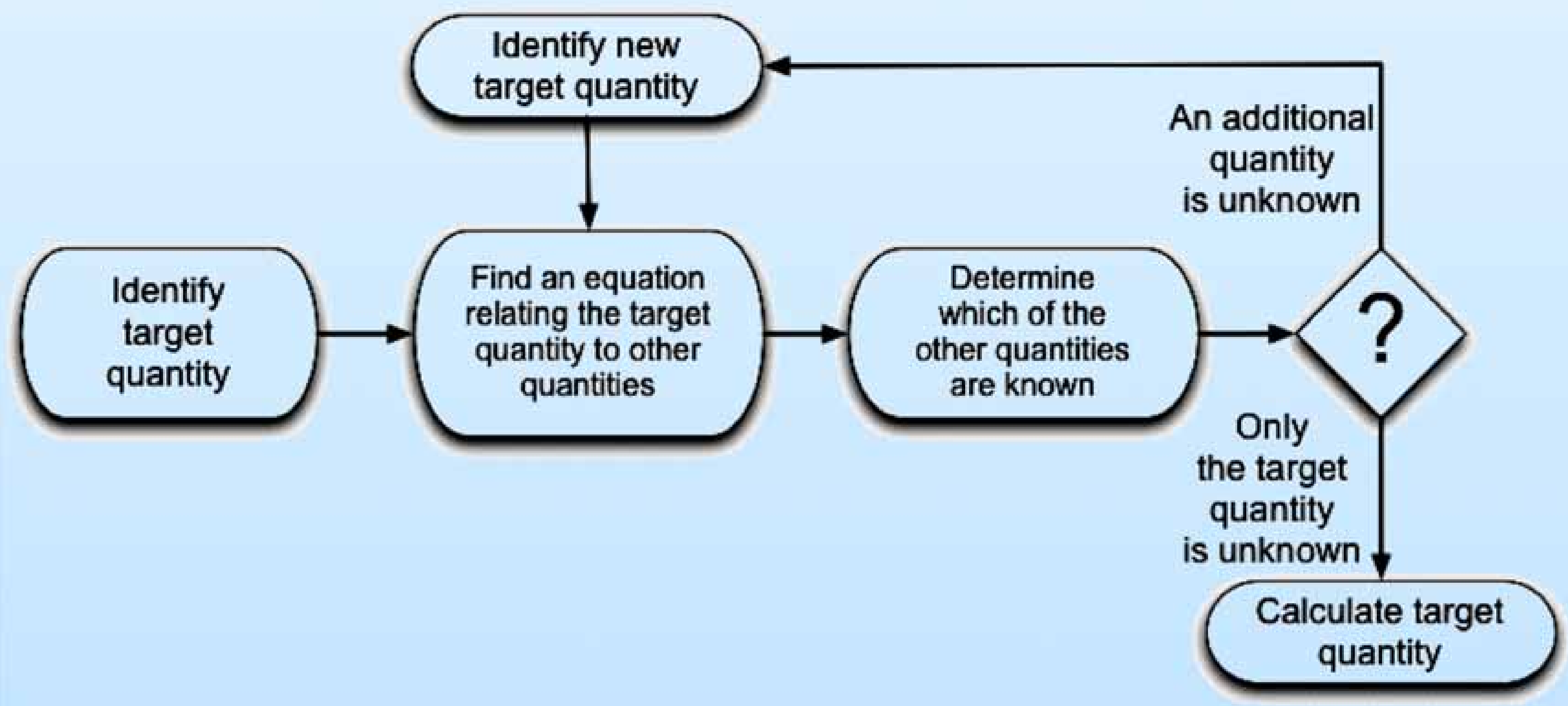
- In watching students solving physics problems we have observed:
  - They tend to work within a locally coherent organizational framework — one that only employs a fraction of their problem solving resources.
  - They may "shift gears" to a new kind of activity when one fails to prove effective.

E-games and E-frames

- *Epistemic games* — a coherent local (in time) pattern of association for building knowledge or solving a problem.
- *Epistemological frame* — a selective attention decision (often tacit) as to what are the appropriate e-games to play in a given situation.

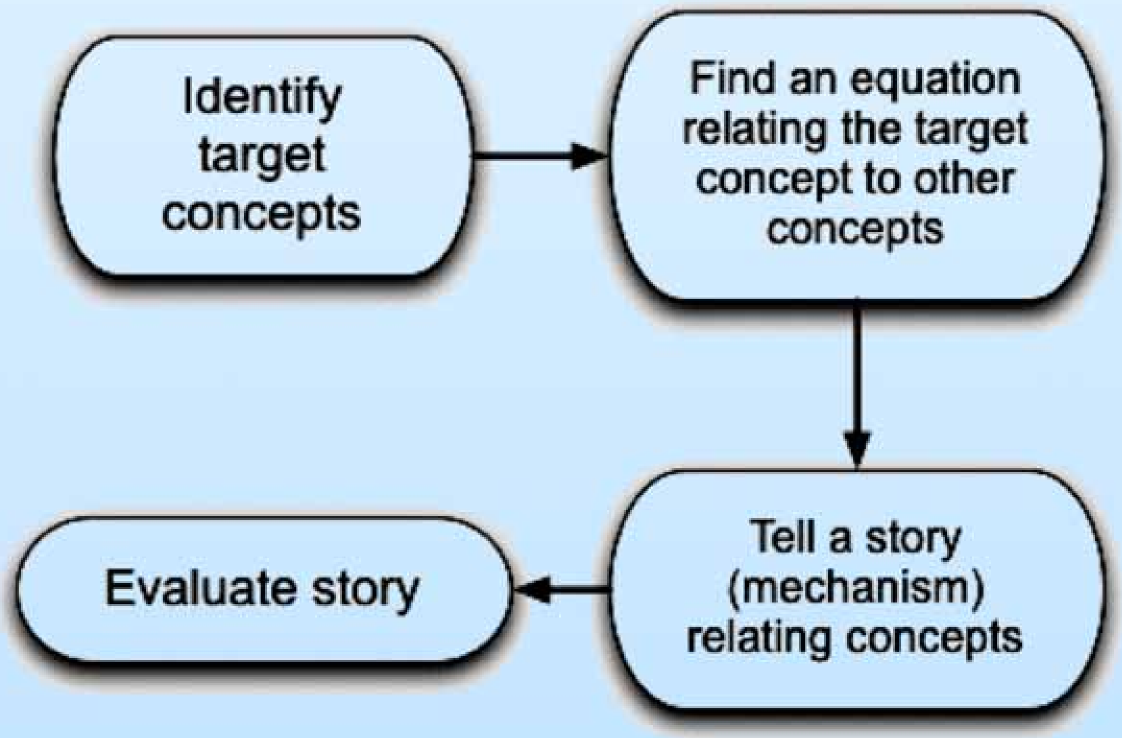
An E-game

- Recursive plug-and-chug



An E-game

- Mapping meaning to mathematics



What does all this tell us?

- Learning is a complex problem.
- If we want to understand the deeper issues of process as well as content, we can’t be satisfied with what makes superficial sense to us.
- More than content matters.

Product warning label!

- If DBER is attempting to be a “science,” it is a young one.
- Much has been learned, but much is still uncertain.
- As with any young science, we are learning more questions than answers.
- There is no philosopher’s stone for education (just as there wasn’t one for chemistry, despite the hopes of early alchemists).