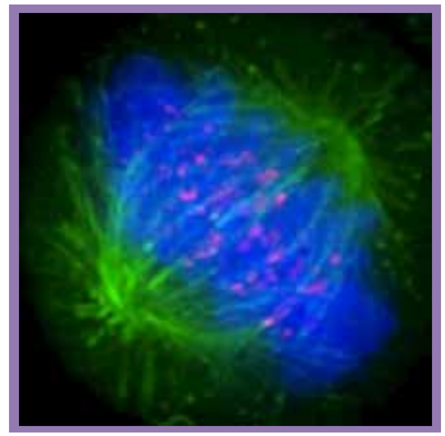

The role of context and culture in teaching physics: The implication of disciplinary differences

Edward F. Redish
University of Maryland

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This presentation
is dedicated to my good
friend and mentor,
Leonard Jossem
(1919-2009)

Outline of the talk

- Talking about thinking
  - A language and framework
- Context
  - How context plays a role
- Culture
  - Disciplinary cultures: how it affects how we teach our students. (The NEXUS project)
  - Broader cultures: some speculations
- Representation
  - Its cognitive role and its interaction with culture.

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“The most important leg of a three-legged stool is the one that’s missing.”

Talking about thinking

A language for discussing
context and culture

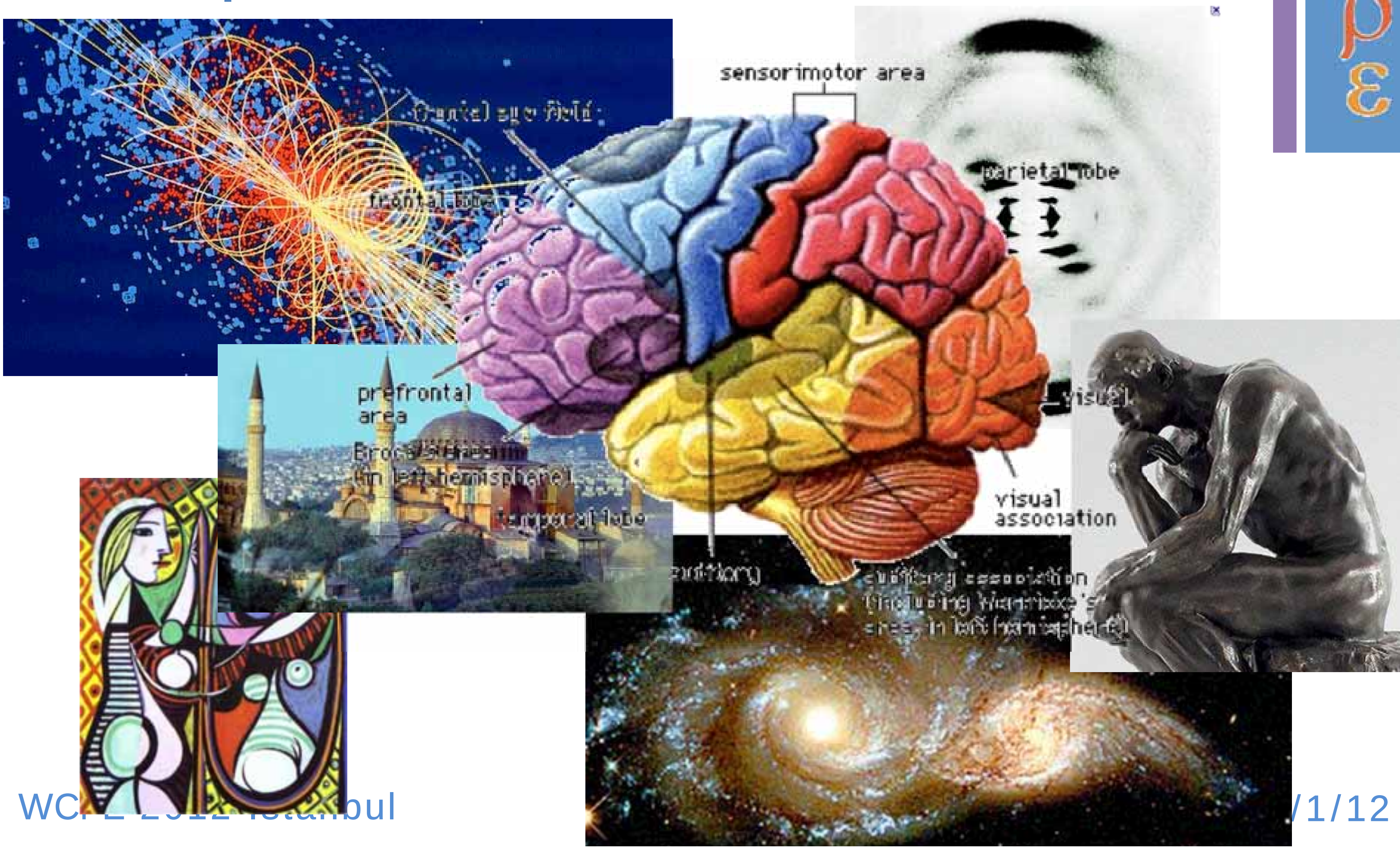
To understand how to teach science we have to understand something of what it means to understand.

- It's important to find an appropriate level of description for student thinking.
- ***Everything should be as simple as possible – but no simpler.***

Attributed to Einstein

- What's the appropriate level of description for a system as complex as a science classroom?

The brain is an amazingly complex and flexible device



We have to be careful not to create a description that's *too* simple.

- Let's consider two exercises that illustrate some of my main points in your own brains.

+ Experiment 1: How good is your memory?

Thread	Thimble	Bed	Rest
Pin	Haystack	Awake	Tired
Eye	Knitting	Dream	Snooze
Sewing	Cloth	Blanket	Doze
Sharp	Injection	Slumber	Snore
Point	Syringe	Nap	Yawn

Roeddiger & McDermott J. Exp. Psych: Learning, Memory, & Cognition. 21 (1995) 803-814.

Experiment 1: How good is your memory?

İplik	Yüksük	Uyanık	Yorgun
Delik	Örgü	Yatak	Dinlenmek
Dikiş	Kumaş	Rüya	Uyuklamak
Sivri	Enjeksiyon	Battaniye	Horlamak
Samanlık	Şırınga	Kestirmek	Esnemek

Roeddiger & McDermott J. Exp. Psych: Learning, Memory, & Cognition. 21 (1995) 803-814.

How many
can you remember?

Did you have either of these words on your list?

- English

  Needle

  Sleep

- Turkish

  İğne

  Uyumak (or uyku)

Thanks for translation help to
- **Nilufer Didis**
- **Sevda Yerdelen-Damar**
- **Edip Özgür**

+ Experiment 2: How good is your concentration?

Simons & Chabris, Perception. 28:9 (1999) 1059-1074

How many passes did you count?

- Did you see anything else interesting happening?

A few important principles

1. Memory is *reconstructive* and *highly dynamic.*
   - Clusters of associated ideas matter.
2. *Selective attention* matters.
   - *Cultural expectations* control selective attention.
3. *Working memory is limited.*
   - At one time you can hold in your mind and manipulate a small number of items (4-10).

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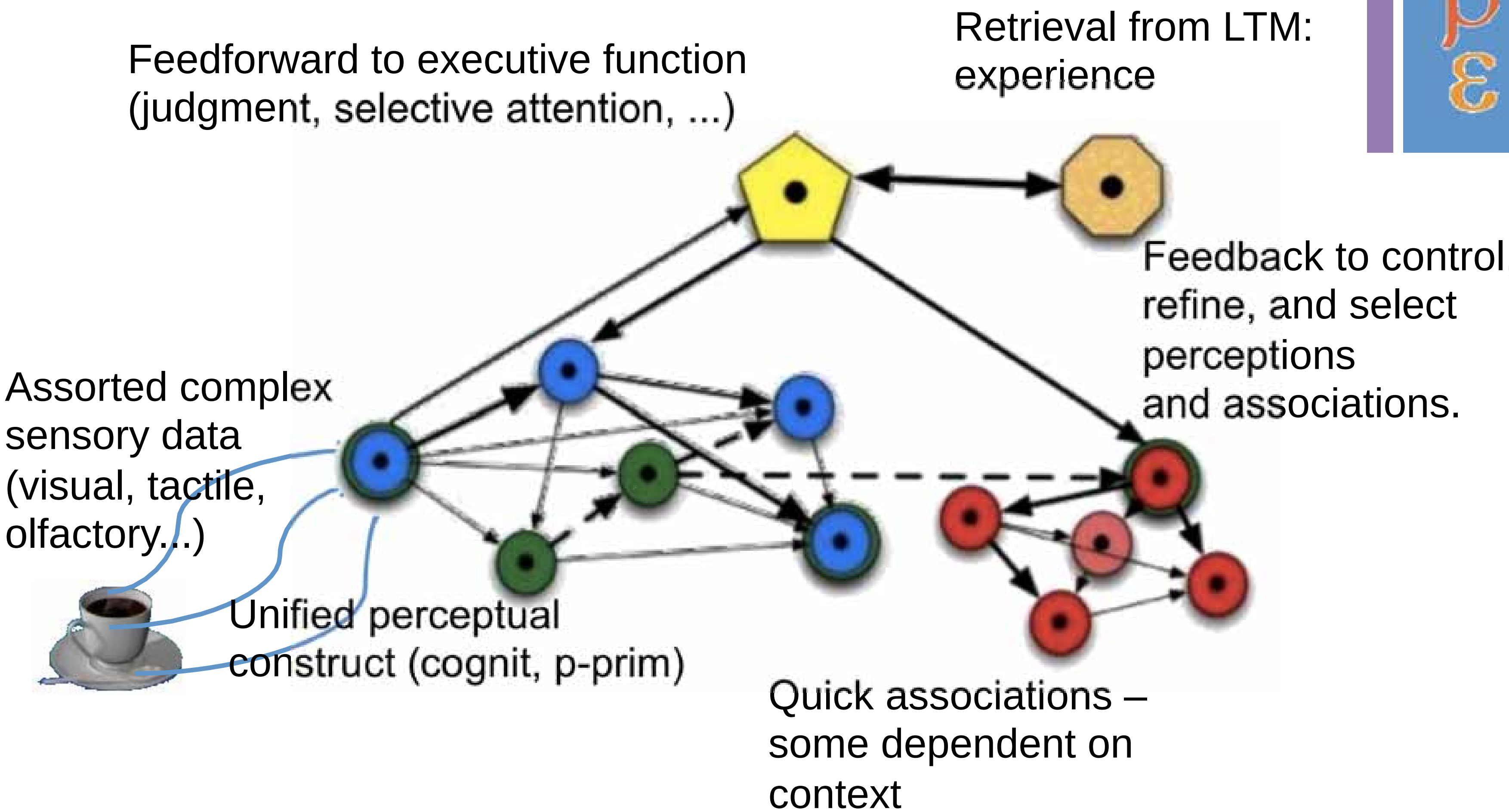
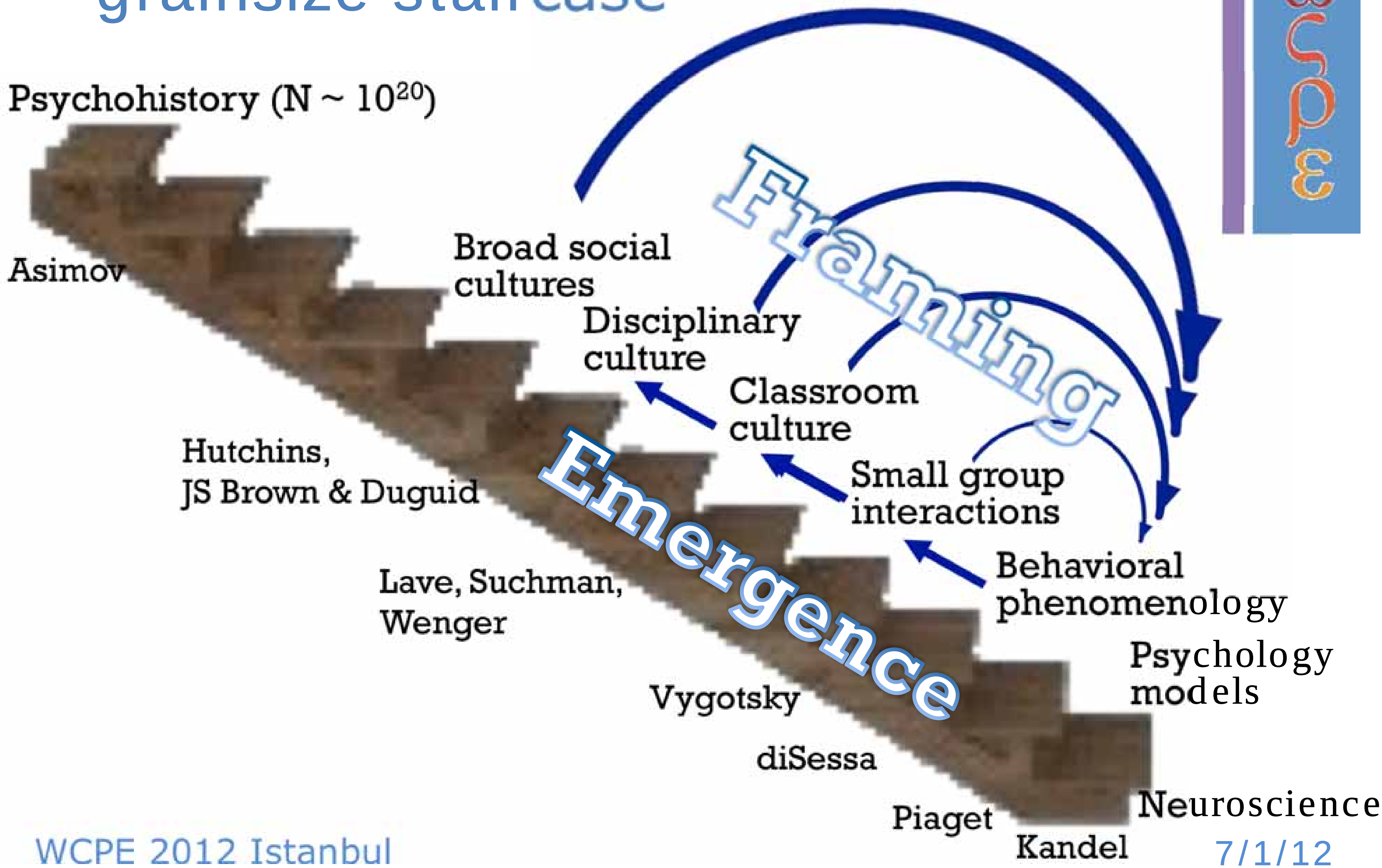
A structure for thinking about thinking



Key concepts for discussing CC&R

- Framing –
  - The process of "choosing" a set of data in your environment to selectively pay attention to – equivalent to deciding that everything else can be safely ignored.
- Epistemology –
  - Knowledge about knowledge: both global and local
    - What is the nature of the knowledge I am going to learn in this class and what is it that I need to do to learn it?
    - What of the knowledge that I have is appropriate to use in a particular problem or situation?
- Ontology –
  - What kinds of things are we talking about?

+ The cognitive/socio-cultural grainsize staircase



Framing

- The behavior of individuals in a context is affected by their *perception* of the social context in which they find themselves.
- That perception acts as a control structure that governs which of their wide range of behavioral responses they activate/use in a given situation.

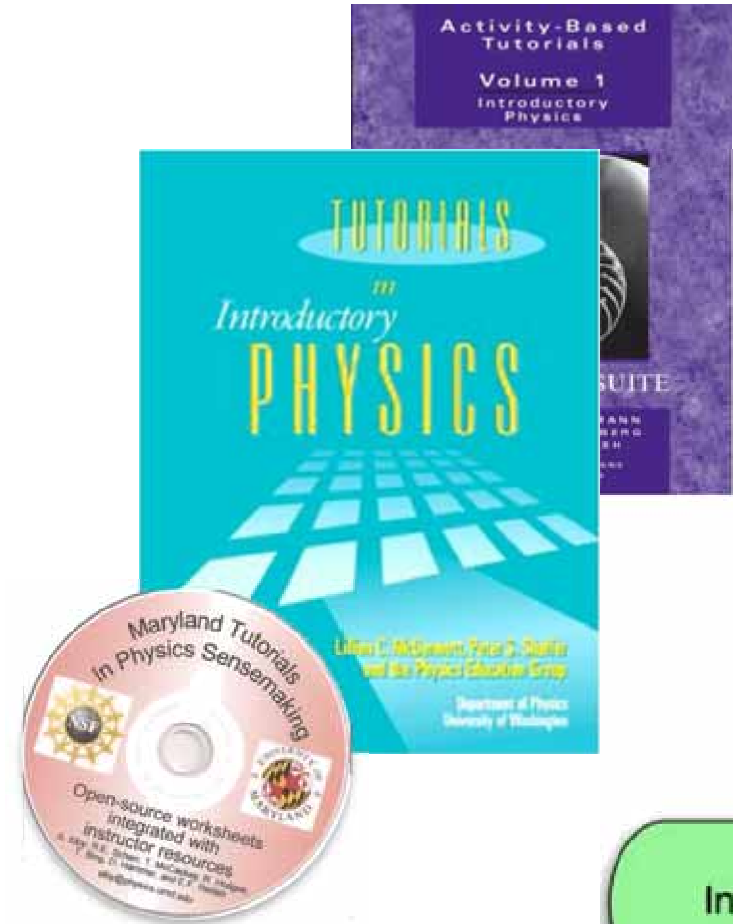
Context

An example: Tutorials

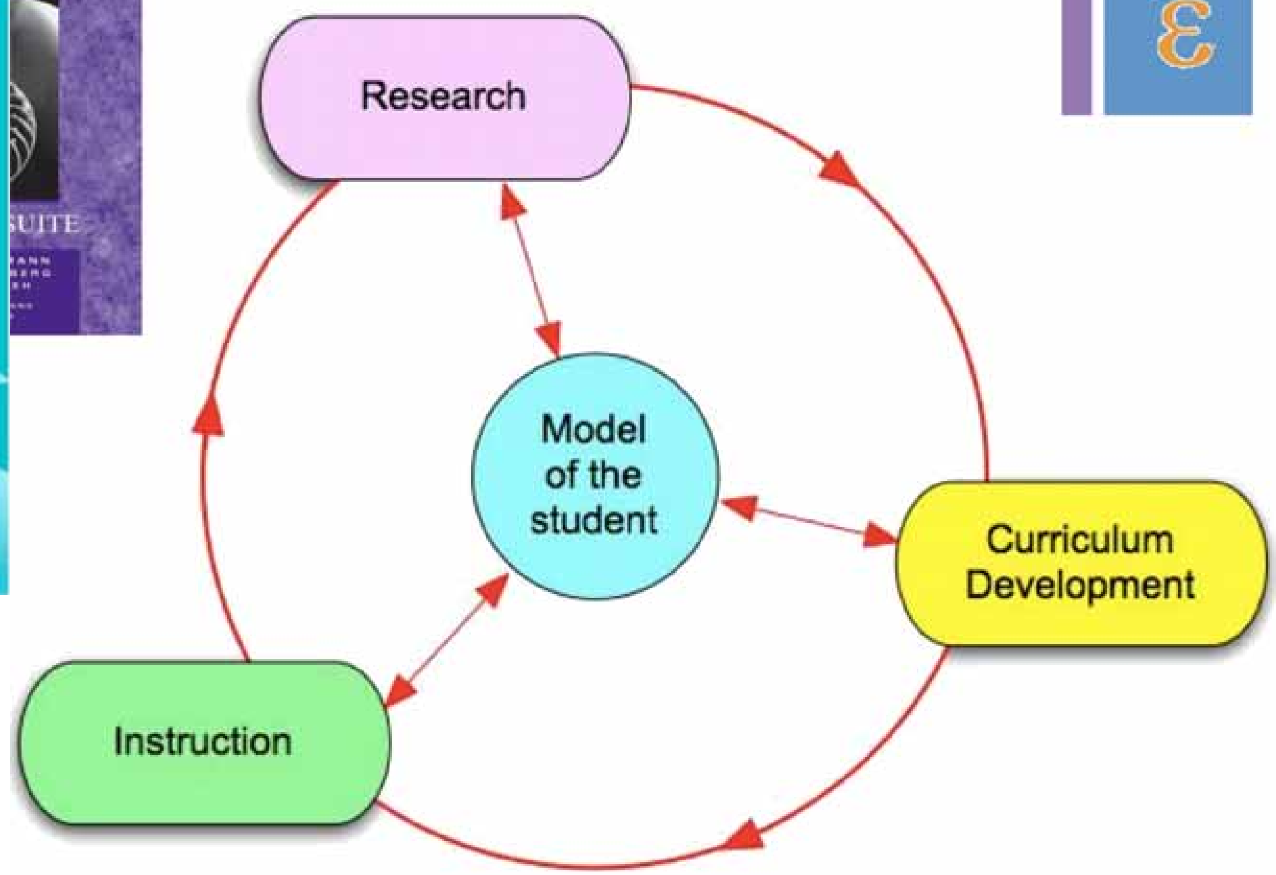
- Tutorials are **research-based** worksheets done in small groups.
- Students are guided through expressing **their own ideas**, comparing them with observations and reasoning qualitatively.
- The critical component of the environment is **independent small group discussion**, *lightly* facilitated by an instructor.

L. C. McDermott, et al., *Tutorials In Introductory Physics* (Prentice Hall, 1998)
M. Wittmann, R. Steinberg, E. Redish, *Activity-Based Tutorials* (Wiley, 2003)
A. Elby et al., *Open Source Tutorials* (UMd, 2008).

Tutorials



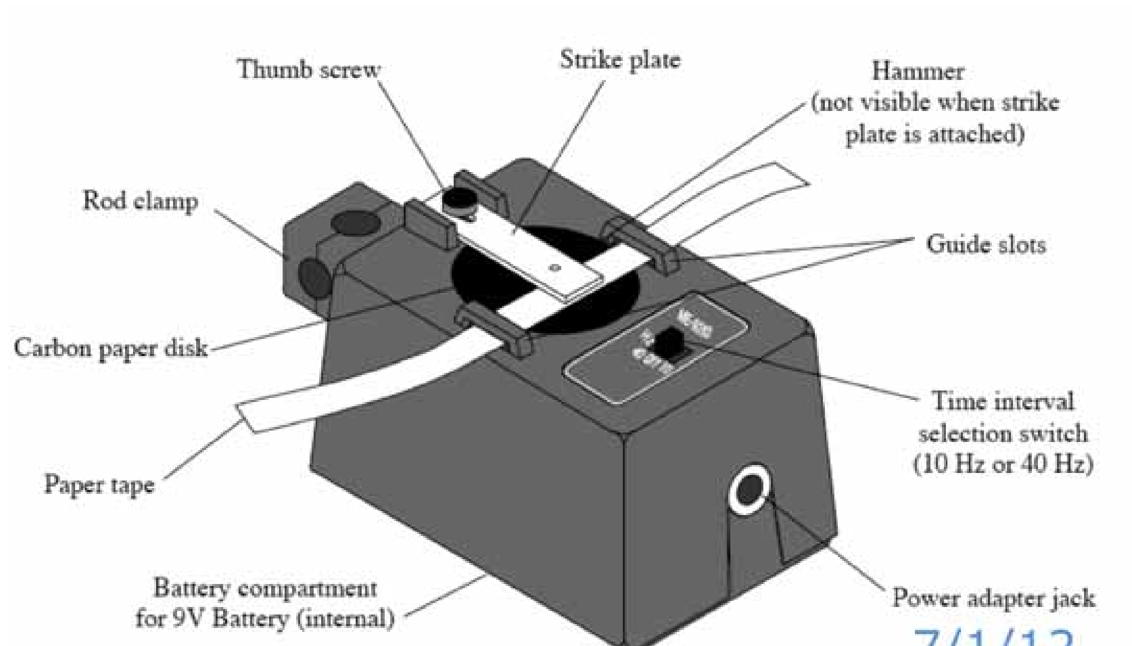
Activity-Based Tutorials
Volume 1
Introductory Physics
TUTORIALS
in
Introductory
PHYSICS
Maryland Tutorials in Physics Sensemaking
Open-source worksheets integrated with instructor resources



Research
Model of the student
Curriculum Development
Instruction

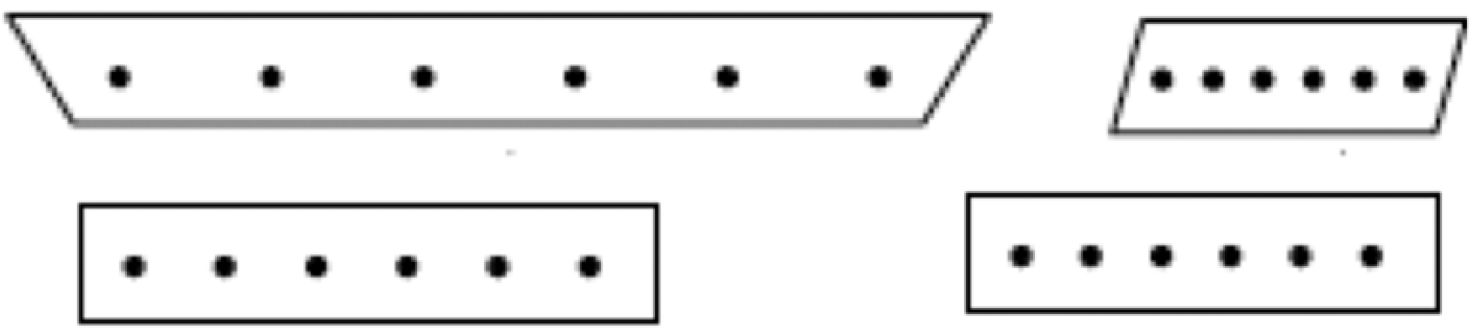
An example

- In our first tutorial of the year, students are asked to analyze speed.
- Paper tapes are made beforehand by a machine tapping at regular intervals (6 times/sec). A cart attached to the tape slowly accelerates down a long ramp.

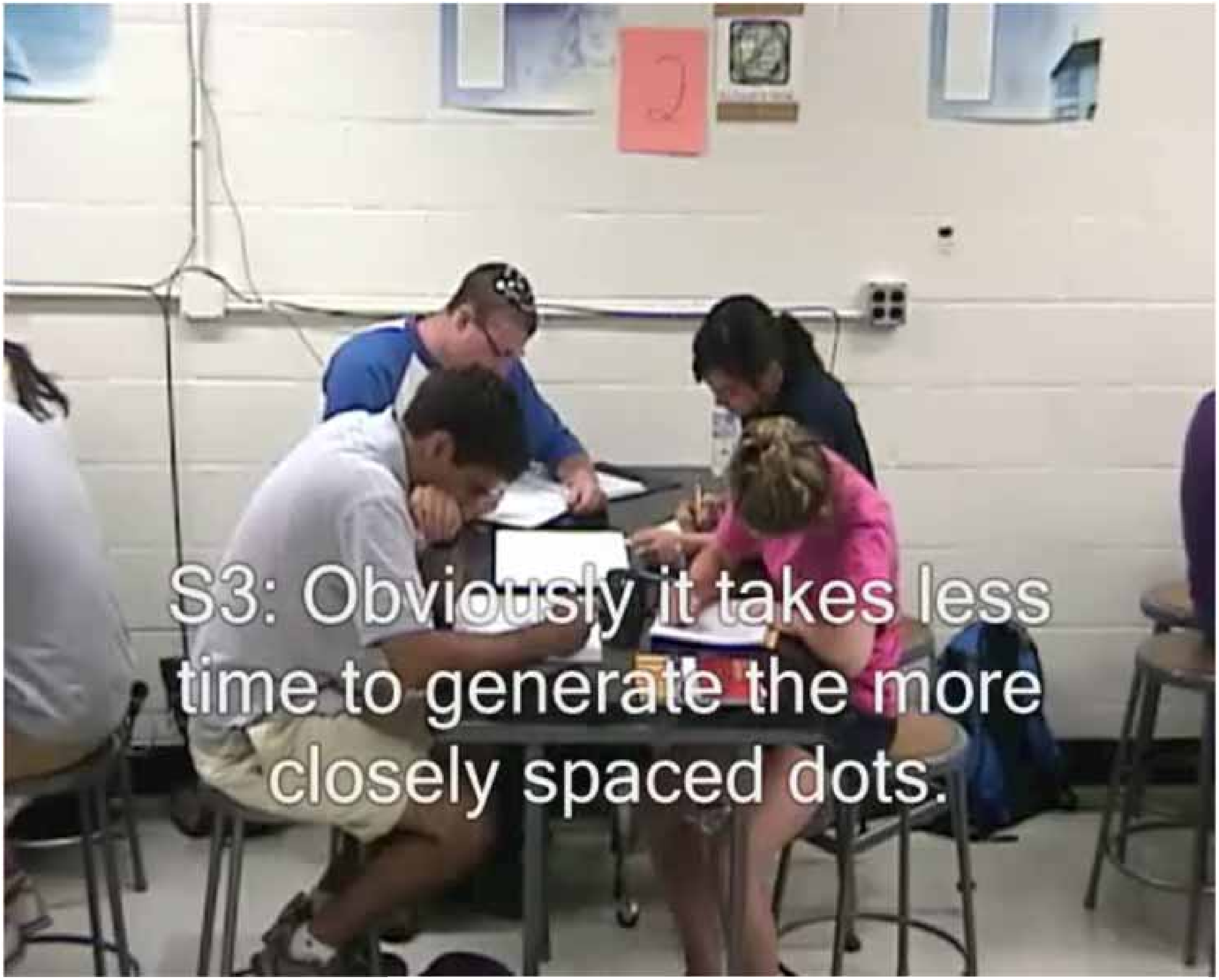


The task

- Each group of students is given 4 tapes containing 6 dots and asked “Which tape took the longest time to make?”



+ The result



B. Frank, PhD Dissertation, U. of Maryland, 2010

A few minutes later

Implication: Context

- In their first look, the students activated a common primitive element – "more is more". They framed the task as ***answer-making***; that the result could be found directly and did not require considering the mechanism of the process carefully.

- Later, in a new context, they reframed the task as ***sense-making***; one that required thinking carefully about the mechanism.

- I refer to a student error that commonly and reliably appears in a given context as a ***misconception.*** Sometimes, these are robust and hard to undo; but sometimes, they are created on the spot and are context dependent. In this case it is a framing error.

The take-away message

- Context
  - Student responses don’t simply represent activations of their stored knowledge. They are dynamically created in response to their perception of the task and what’s appropriate.
  - The (often unconscious) choices the make are often determined by social and cultural expectations (framing).

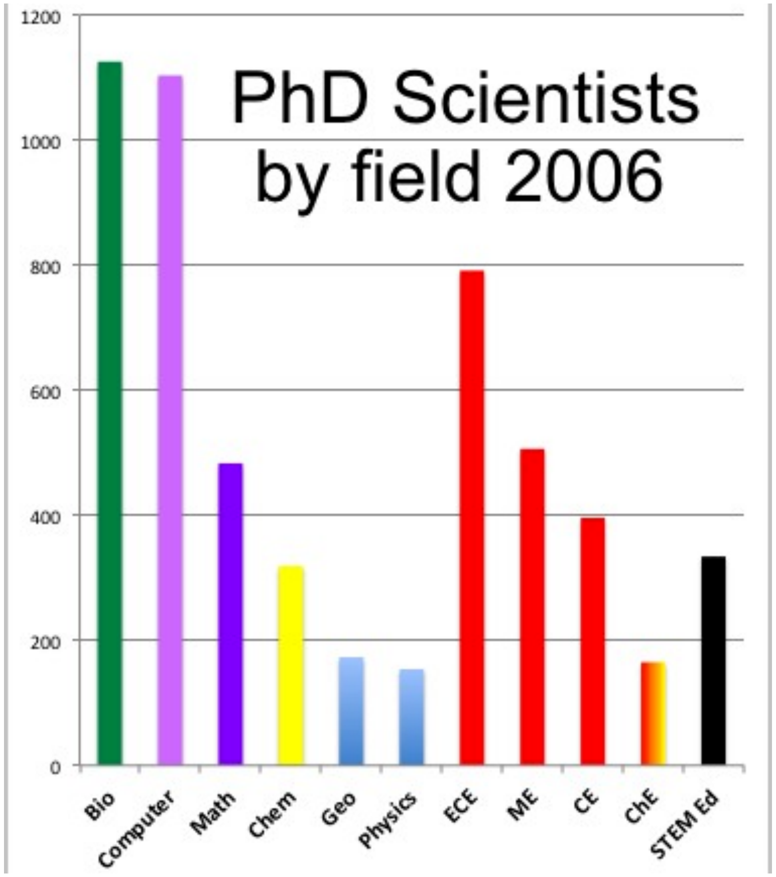
Culture:
The disciplines

CC&R

- Culture
  - Culture is the broad set of common expectations based on experiences that control the students' perception of a situation (framing) and therefore affects their activation and organization of the knowledge they bring to bear in a particular context.
  - 1: Disciplinary cultures — Professional
  - 2: Disciplinary cultures — Student view
  - 3: National / ethnic cultures

Physics is a fairly small profession among the sciences.

- As a result, in many countries, most of our teaching is in service courses; primarily to engineers and biologists.
- Recently we have been offered a challenge.



The SFFP Report

- In 2009, Association of American Medical Colleges working with HHMI published ***Scientific Foundations for Future Physicians*** – a call for rethinking education for biologists and pre-medical students in the US to
  - bring in more and better coordinated science – biology, math, chemistry, and physics
  - focus on scientific skills and competencies

Project NEXUS

- The result is the **N**ational **Ex**periment in **U**ndergraduate **S**cience Education
  - A 4-year, 4-university $1.8 M project of the Howard Hughes Medical Institute
- At UMCP we have opened an interdisciplinary conversation to create a physics course designed to meet the needs of biologists and pre-health-care-professionals.

We put together a team of nearly 40 professionals

- Development team
  - 7 physicists
  - 4 biologists
  - 3 biology education specialists
- On-campus discussants
  - 3 physicists
  - 4 biologists
  - 2 chemists
  - 3 education specialists (phys, bio, chem)
- Off-campus collaborators
  - 7 physicists
  - 1 biologist
  - 2 chemistry education researchers

Starting in a hard place

- It turned out there were significant cultural differences between biologists and physicists.
- Biologists saw most of the traditional introductory physics class as useless and irrelevant to biology – and the physicists claim “we can apply physics to biology examples” as trivial and uninteresting.
- Physicists saw a coherent structure with no room for change.

After many interesting and illuminating discussions

- We came to an understanding of what it was the biologists needed and how the disciplines perceived the world and their science differently.

Changes in the culture and expectations of the course

- Organize the course so that it will have authentic value for biology students in their upper division bio courses.
- Do not assume this is a first college science course.
  - Biology, chemistry, and calculus are pre-requisites.
- Do not assume students will have later physics courses that will "make things more realistic"
  - Explicitly discuss modeling and the value of understanding "simplest possible" examples.
- Choose different content from the traditional by including molecular and chemical examples and topics of more importance to biology.
- Maintain the crucial components of "thinking like a physicist" – quantification, mathematical modeling, mechanism, multiple representations and coherence (among others).

+ Revising the content

- **Expand**
  - Atomic and molecular models of matter
  - Energy, including chemical energy
  - Fluids, including fluids in motion and solutions
  - Diffusion and gradient driven flows
  - Dissipative forces (drag & viscosity)
  - Kinetic theory, implications of random motion, statistical picture of thermodynamics
- **Reduce substantially or eliminate**
  - Projectile motion
  - Universal gravitation
  - Inclined planes, mechanical advantage
  - Linear momentum
  - Rotational motion
  - Torque, statics, and angular momentum
  - Magnetism
  - Relativity

The culture of the disciplines

- There is much more than changing the table of contents and the prerequisites.
- From each level of their experience with a discipline – small group, STEM classes, broader school experiences – students bring control structures (framing) that tell them what to pay attention to in the context of activities in a science class.
- Their framing of the activity affects how they interpret the task and what they do.

Physics

- Intro physics classes often stress *reasoning from a few fundamental (mathematically formulated) principles*.
- Physicists often stress building a complete understanding of the *simplest possible (often abstract) examples* – and often don't go beyond them at the introductory level.
- Physicists *quantify* their view of the physical world, *model with math*, and *think with equations*.
- Physicists concerns themselves with *constraints* that hold no matter what the internal details. (conservation laws, center of mass, ...)

Biology

- By its very choice of subject, biology is *irreducibly complex*. (Oversimplify and you die.)
- Most introductory biology is *qualitative*.
- Biology contains a critical *historical* component.
- Much of introductory biology is *descriptive* (and introduces a large vocabulary)
- However, biology – even at the introductory level – looks for *mechanism* and often considers micro-macro connections.
- Biologists (both professionals and students) focus on *real examples* and *structure-function relationships*.

Student attitudes towards interdisciplinarity: Some data

- We have interviewed students about their attitudes towards mixing the sciences in two classes:
  - *Organismal Biology*
    A required bio class that explicitly uses a lot of physics and chemistry.
  - *Physics for Biologists*
    The first implementation of the NEXUS physics course that brings in a lot of bio and chem.

Ashlyn is studying the diffusion equation in her Organismal Biology class. (The distance that something diffuses in a time t is proportional to the square root of t.)

I don't like to think of biology in terms of numbers and variables.... biology is supposed to be tangible, perceivable, and to put it in terms of letters and variables is just very unappealing to me....Come time for the exam, obviously I'm going to look at those equations and figure them out and memorize them, but I just really don't like them.

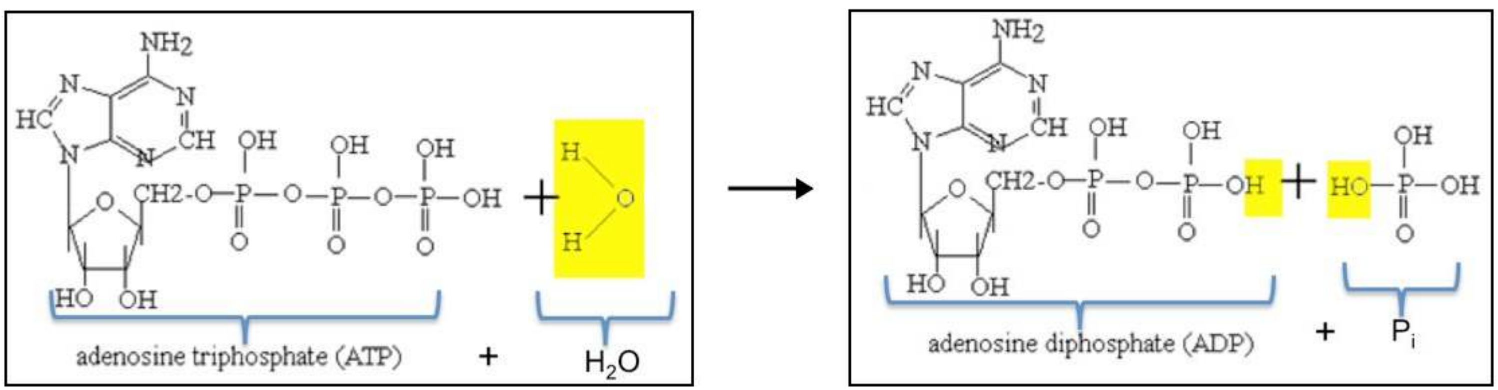
Ashlyn prefers to keep her sciences separate.

I think of it as it would happen in real life. Like if you had a thick membrane and tried to put something through it, the thicker it is, obviously the slower it's going to go through. But if you want me to think of it as "this is *x* and that's *d* and this is *t*", I can't do it.

Biology students bring cultural/disciplinary expectations to their classes that may get in the way of trying to create interdisciplinary instruction – but it may be context dependent. Later in the interview, Ashland got excited about how math explained scaling relation (surface-volume).

+ An example from NEXUS Physics: A chemistry "misconception"

- A critical biochemical process is the hydrolyzation of ATP. This is the primary reaction that delivers energy in biological systems.
- Students in both chemistry and biology have trouble seeing that a "bound state" has negative energy and that energy is released by going from a weakly to a strongly bound state.
- We propose that physics can help by connecting a better understanding of potential energy to chemical processes.
- In chemistry it is often identified as a "misconception" that students assume "energy is stored in the ATP bond" whereas really the energy comes from going from the weaker ATP bond to the stronger OH-P bond.



+ A question from the chemistry-education literature

An O-P bond in ATP is referred to as a "high energy phosphate bond" because: (choose all correct ans.)

✖ A. The bond is a particularly stable bond.

✔ B. The bond is a relatively weak bond.

✖ C. Breaking the bond releases a significant quantity of energy.

✔ D. A relatively small quantity of energy is required to break the bond.

	NEXUS	Galley
A	32%	41%
B	47%	31%
C	79%	87%
D	26%	7%

W. C. Galley, J. Chem. Ed., 81:4 (2004) 523-525.

I put that when the bond's broken that energy is released. Even though I know, if I really think about it, that…you always need to put energy in,…to break a bond. Yeah, but -- I guess that's the difference between how a biologist is trained to think, in like a larger context and how physicists just focus on sort of one little thing. … I answered that it releases energy, but it releases energy because when an interaction with other molecules, like water primarily, and then it creates like an inorganic phosphate molecule that…is much more stable than the original ATP molecule…. I was thinking that [in the] larger context of this reaction [it] releases energy.

It may not be a miscon-ception.
It may be a framing issue.

About 1/3 of the students said both "the bond is weak" and "the bond releases a lot of energy". Gregor sees both as right – and has good reasons for his claim. In a biological framing, it is entirely natural to view it this way.

The take-away messages:

- Context and culture matter!
- In our redesign of introductory physics for biology students, we find
  - Understanding the dynamics of students' context-dependent responses is crucial in designing effective lessons.
  - The disciplinary cultural expectations of both faculty and students play a big role in how each group perceives our courses.

For more information

- Come to our symposium (PS04.04.S):
  - Changing perspectives through interaction of diverse communities, A. Vaz, J. Julio, E. Redish, *et al*., and D. Zollman
- Visit our webpages
  - *http://umdberg.pbworks.com/*
  - *http://physics.umd.edu/perg/*
  - Or Google: Project NEXUS UMCP

Teşekkür ederim