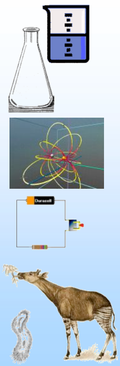

The challenge of interdisciplinary STEM service classes:

How can physics, chemistry, math, and computer science support a redesigned biology curriculum?

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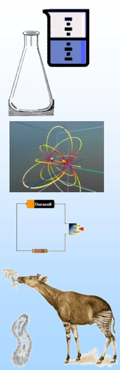
Supported in part by NSF grants: REC 04-40113 and DUE 05-24987

Outline

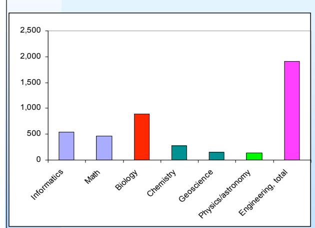
- The explosive growth of the biosciences
  - Why – and so what?
  - Implications for Education
  - Implications for Research
- We need to rethink our educational goals
- Content is not enough
  - Physics education research (PER)
  - Student knowledge of learning and knowledge: Parsing student expectations
- We have a unique opportunity for interaction and reform.



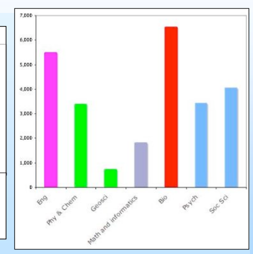
The Explosive Growth of the Biosciences

- *Why*
  — and so what?
- *Implications for education*
- *Implications for research*

Bioscientists already dominate US science



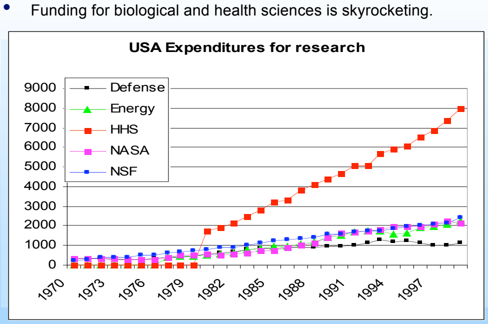
U.S. scientists and engineers, by field of highest degree and occupation category: 1997 (thousands)



Number of US Phds by field: 2001

The funding

- Funding for biological and health sciences is skyrocketing.



Why?

- Powerful new technology from chemistry and physics
- Dramatically enhanced understanding of how the human body works.
- Immense implications for the life and health of each of us.
- Everybody cares about this!

So what?

- The NAS/NRC has done a study calling for a major revision in how undergraduate biology is taught.
- For those of us who deliver educational services to this population, we may all have to rethink what we provide.

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A recommendation

- *Faculty in biology, mathematics, and physical sciences must work collaboratively to find ways of integrating mathematics and physical sciences into life science courses as well as providing avenues for incorporating life science examples that reflect the emerging nature of the discipline into courses taught in mathematics and physical sciences.*

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An opportunity for education reform?

- Bio students need to be introduced to a much wider variety of topics and information.
- Biology has for been phenomenological so the dependence on physics and chemistry and math is weaker than one might expect (or need).
- BIO 2010 suggests a much stronger dependence on chemistry, physics, and math, information sciences (for dealing with huge databases of information), and engineering (for biotechnology).

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Or an impossible bind?

- This is an impossible situation.
- You can't both give all biology students additional biology courses and additional service courses. There isn't time.
- These are not all (or even predominantly) future research scientists.
  - They include mostly practical folk with an eye on health-care or industry.

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A Research Opportunity

- The study of biosystems opens new research areas. Other fields are building hybrids with biology.
- Biochemistry is the oldest and strongest, but physics, engineering, information sciences, and math are starting to create hybrids.
- These are not just small spin-off "mom-and-pop" businesses. They are potential megastores of great importance. Their health needs to be fostered.

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Educational Implications

- We somehow need to figure out
  - how to teach bio students more of what we deliver to our majors, but more efficiently.*
  - how to keep open a path for prospective reachers in the hybrid fields.
  - how to provide what is needed by the less research-oriented health care students.

* If we could figure this out it would help our majors too!

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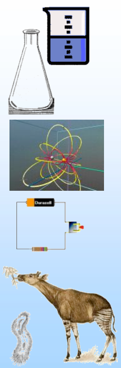


Rethinking Our Educational Goals

- *What do they think they want?*
- *A role for Discipline-Based Education Research (DBER)*

What do they (think they) want?

- The PER group at the U. of MN* has created a survey for bioscience faculty, asking what they want out of a physics survey course.
- On a 5 pt scale they chose
  - Basic principles behind all physics (4.7)
  - General qualitative problem solving skills (4.2)
  - Overcome misconceptions (4.2)
  - General quantitative problem solving skills (4.0)
  - Apply physics topics to new situations (4.0)

** http://groups.physics.umn.edu/physed/*

What do biology students need to learn?

- Intro biology today is still often a course in vocabulary – perhaps in concepts.
- There is rarely any problem solving.
- There is often much memorizing.
- There is rarely any reasoning with math.
- This structure has profound implications – and is going to need to be changed.

These are hard problems!

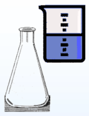
- These requests are "beyond content."
- What do they mean?
- We know them when we see them – but do we understand them well enough to figure out how to teach them?
- A new phenomenon might help – discipline-based education research (DBER).

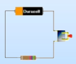
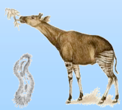
A role for DBER?

- Our experience at the college level with education reform designed by scientists is not encouraging.
- Our experience at the pre-college level with education reform designed by education specialists is not encouraging.
- A new phenomenon – the combination of scientists doing education research (DBER) shows promise.

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).



Content is not enough: Learning to “Think Science”

- *An Overview of Physics Education Research (PER)*
- *Student knowledge of learning and knowing: Parsing student expectations*

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

- Constructivism:
  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

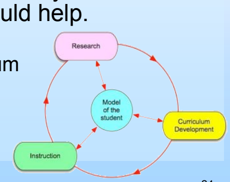
- Conceptual surveys:
  Researchers developed easily deliverable tests to probe large classes
  - Focus on areas students have misconceptions.
  - The distractors are attractive.
  - Teachers tend not to see the distractors, so the questions look trivial.
  - Students do more poorly than expected.
 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

  These have convinced many faculty

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

PER: The engineering

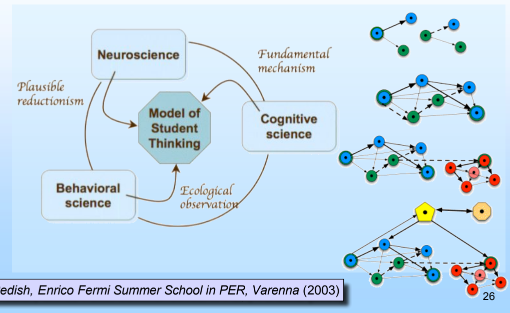
- Active learning:
  The idea of constructivism focuses on building of new ideas. Creating environments to guide students in what they have and what they build should help.
  - Over the past 15 years, research-based curriculum developers have created a variety of effective learning environments.



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 then 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?

Epistemology

- 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.

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.

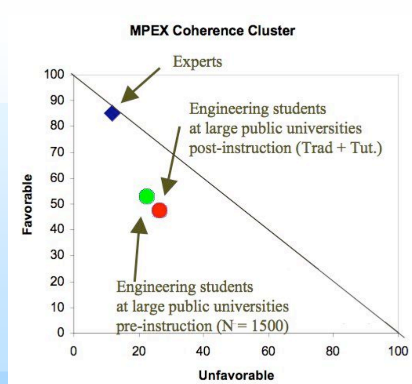
** W. J. Perry, Jr. (1970), A. Schoenfeld (1985), D. Hammer (1988), M. Belenky et al. (1996)*

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.



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."

If t > 35 m

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

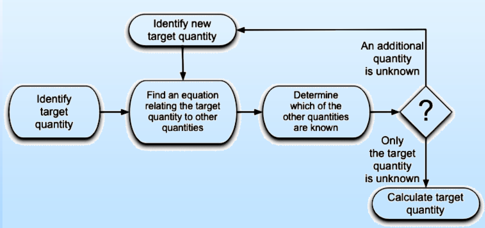
- In watching students solving physics problems we have observed:
  - They tend to work within a locally coherent organizational framework — one that only employs a fraction of their problem solving resources.
  - They may "shift gears" to a new kind of activity when one fails to prove effective.

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.

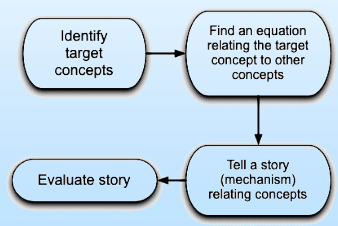
An E-game

- Recursive plug-and-chug



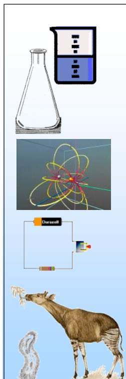
An E-game

- 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.



What can we do together?

Implications: Who?

- To produce the kind of deep reforms we are talking about in biology, we need input from many disciplines:
  - Biologists
  - Chemists
  - Physicists
  - Mathematicians
  - Information scientists and engineers
  - Educational research specialists
  - Cognitive scientists

Implications: What?

- For the kinds of reforms in biology education contemplated by the Bio2010 study, we need communiction among the different groups.
- This isn't easy!
- Mostly, in a university, service course disciplines rarely communicate with the clients they serve.

Implications: What?

- The changes in biology (and medicine) are not over. A lot can be expected to happen in the next few decades.
- This means we cannot expect to have a major reform effort and be done with it.
- We have to be prepared for continuing change.
  - This is a good thing because there is too much to do in one fell swoop!

Implications: How?

- Local reforms
- Communication
- Bottom up and top down.
- New structures?
- Technology?

For more information on PER and the Maryland PERG
http://www.physics.umd.edu/perg/