Emergent nuggets: Reflections on the conference and interdisciplinary courses

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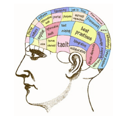
Two small, interconnected talks

- Implementing interdisciplinary courses

- Epistemological issue of connecting meaning and mathematics



Implementing interdisciplinary courses

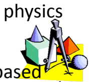
- My interdisciplinary courses:
  - Studio calculus physics (1998)
    - http://www.unh.edu/calculusphysics/
  - Math methods and classical mechanics (2002)
    - http://pubpages.unh.edu/~dawnm/connectm&m.html
  - Algebra based introductory physics for life scientists and pre-medical students (2007)
    - http://pubpages.unh.edu/~dawnm/phyls.html

Studio Calculus Physics (1998)

- Math colleagues: Kelly Black and Karen Marrongelle
- For honors physical science and engineering first year students (started as a small pilot and only now expanding to larger cohort)
- Why:
  - Calculus students did not see the utility of the mathematics
  - Calculus is a co-requisite course; in physics we could not really use calculus because the timing was off (differentiation needed week two; taught much later); focus was on special cases (e.g. constant acceleration)

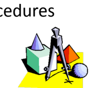
Studio calc/phys

- Main strategies:
  - Revise the order of the math topics to fit with physics topics
  - Connect mathematics and physics ideas
  - Use active learning (studio format), problem based learning (30-45 students only), U Washington tutorials
  - Take away lecture/lab/recitation fragmentation
- Still being taught, but not by developers
  - Professors like to teach it ("it's a great course to get tenure on", get to know the students)
  - Students like it (develop a learning community; learn a lot that they perceive as valuable; course less disjoint)



Math Methods/Classical Mechanics (2002)

- Math methods content: mathematical methods that physicists care about (Green's functions, Fourier transforms, linear algebra)
- Both are physics courses; not an unusual combination
- Physics majors mostly
- Motivation (same issues Melanie talked about with Lewis structures)
  - Text book divorced meaning/mechanism from procedures
- Strategy:
  - Create tutorials that link meaning/mechanism and mathematics
  - Similar work done by Brad Ambrose & Michael Wittmann



Introductory algebra-based physics for life scientists (current)

- Issues:
  - Standard course is watered down calculus course without attention to needs of audience (is salsa covered meatloaf really a Mexican dish?)
  - Students do not see the relevance of physics, yet it is required for all students (Bolker anecdote)
  - Students are mathematically underprepared, indifferent & procedure oriented
  - Students don't remember physics in their biology courses

Collaborators

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•Christopher Shubert, Physics, UNH
•Jessica Bolker, Biology, UNH
•James Vesenka, Physics, Univ. of New England
•Gertrud Kraut, Mathematics, Southern Virginia University

Strategies

- Co-teach with a biology professor (Jessica Bolker)
- Pick topics based on needs of biologists (this is the last physics course they will have)
  - More fluids
  - Strength of materials
  - Gradient-driven flows
  - Far less on rotations
- Rich biology based examples (bat echolocations, jetting jellyfish, falling cats, blood flow, seeing in water *vs*. air, ultrasound imaging) (Heller 1991)
- Connect meaning and mathematics
- Review mathematics (M. Carlson materials would be great!)
- Implement activities with an epistemological focus (Redish and Hammer 2009 AJP **77**(7) 629-642 ; Elby and Scherr; http://www2.physics.umd.edu/~elby/CCLI/index.html)

In reality, every physics course is an interdisciplinary course (there is always a lot of mathematics) – is the same true of mathematics and chemistry courses?

Challenges and Partial Solutions

- Time/Inertia/Whose job is it?
- Fear
- Lack of Knowledge base
- Differing goals/perspectives

Time/Inertia/Whose job is it?

- Whose responsibility is it to be sure that students in course B know how to integrate/transfer the ideas from pre-requisite course A? (Meltzer, "Calculus in the Disciplines" session) – not the students'!
- We are negotiating this now at UNH
- UNH is considering having co-enrollment in calculus 1 and studio physics 1 (not enough resources for increased numbers in studio calc/phys)
  - Takes time to negotiate a complimentary schedule of topics in calculus and physics
  - Trying to find a conceptual overview of derivative and limit (Oehrtman's approximation approach)
  - Takes time to re-work calculus lectures
  - Ideally, instructors will visit each others courses on occasion…
- It is not standard practice to have the calculus syllabus in hand when teaching the physics course

Fear

- We are most comfortable when we know A LOT more than our students about the topic at hand
- Several speakers have mentioned their discomfort with other fields and fear of making mistakes
- Many mathematics instructors outside of their comfort zone in a combined class.
  - We have had applied mathematics instructors who find this a great course; calc/phys could not have run without them; Kelly Black is an applied mathematician
- I have been caught a few times by students when I overstepped
  - Aneurysms
  - Active pumping of ions across cell walls
- I find that I'm not as careful in my wording on new topics (e.g. diffusion)

Lack of a knowledge base

- What is the whole broad picture of neurons (for example)? What can I ignore?
  - As part of our grant, we are working to gather a packet of information on each topic to give instructors a broader perspective.
  - We want to have other biology folks use these packet to say this is what you saw/will see in physics and how it connects to what we are doing (relates back to "Whose job is it?)
- What are the student misconceptions/difficulties in mathematics? What are best practices for teaching mathematical topics?
  - Can we create a resource paper of math ed literature for those outside the field?
  - Is there comparable information needed by others outside of physics/ chemistry?

Lack of knowledge base, part 2

- What kinds of physics do biology students need? (similar question: what do physics students really need to know about differential equations?)
  - Talk to lots of biologists:
    - Steve Vogel - author of several biomechanics texts
    - Biology professors at UNH
      - Those who work at organismal level
      - Those who work at cellular level
    - Need to talk to Kinesiologists…
  - All life scientists are not the same..
  - Sit in on classes (Blanchard sat in on many classes that used diff eq; wrote a text book based on actual needs)

Differing goals/perspectives

Our goals versus student goals: Pure course *versus* service course

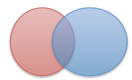
- In the "calculus in the disciplines" session:
  - What would we lose if we taught calculus with units?
  - Is calculus only a service course? Take this to the limit: What if every out-of-major course were purely a service course?
  - How much of the beauty of mathematics can/should we impart to our students
- Same thing could be said about "physics in the disciplines" and "chemistry in the disciplines"
- Naïve solution:
  - Choose a few key ideas (conservation laws in physics?) to impart the beauty & coherence (like Thomas H's "enduring understanding"?)
  - But also give applications (is this analogous to Ayush's carrot cake?)

Biologist goals *versus* Physicist goals: real world *versus* understanding

- Steve Vogel (author of several biomechanics texts): biology is messy; engineers are willing to deal with the messiness (via Black Boxing/ ignoring some details), physicists are not. For example, the drag coefficient is NOT constant, and dealing with that is important.
- Joe Redish: but the whole goal of physics is NOT Black Boxing.
- Jessica Bolker (our zoology collaborator): if you Black Box (as she does in her development course) it is important to be clear that you are doing it, and why.

Discussion after David M's talk on thermo in physics and chemistry

- Stacy remarked:
  - Are differences bad (e.g sign differences/battery versus current)? Should we raise consciousness of students that differences are okay and why.



Summary: Challenges and Partial Solutions to Interdisciplinary courses

- Whose job is it to help students integrate concepts across courses? The faculty in BOTH courses
  - Need to have faculty who are committed to quality interdisciplinary courses in spite of lack of rewards
- Fear
- Lack of Knowledge base
  - Create appropriate resources
- Differing goals/perspectives
  - Disciplinary differences must be acknowledged to the students
  - Student motivation in a required course remains an issue

Part 2: Connecting meaning and mathematics

Student epistemologies (beliefs about knowledge)

- Unproductive beliefs:
  - Science is a collection of unrelated facts
  - Conceptual learning is useless (Ayush's student)
  - Mechanistic reasoning is useless (Melanie's recalcitrant students)
  - Mathematics is just for getting numbers
- Productive beliefs:
  - Science ideas should make sense
  - Scientific knowledge is constructed

Evidence that students sometimes see equations as a way to get a number:

Simplify:

$$2x + 3x + 4$$

Student answer:

$$2x + 3x + 4 = 0$$

$$x = -\frac{4}{5}$$

A studio calculus physics student

- "I see more in equations than other students do"
- What is there to see? A story!

Theoretical digression..

Resources: knowledge in pieces

- diSessa (1993) – phenomenological primitives (Cognition & Instruction, **10**(2&3) 105-225)
  - There are small bits of knowledge
    - Closer means stronger
    - Maintaining agency
  - Neither right nor wrong in themselves, but productively or unproductively applied
  - Loose collection of independent ideas (not coherent)
  - Activation is context dependent
  - Flexible and easy to change

KIP/Resources are of many kinds

- "Conceptual" - means physics concepts
- Mathematical
- Epistemological

Sherin: symbolic forms (mathematical resources)

- Cognition and Instruction, **19**(4), 479-541, 2001.
- Allow students to connect concepts with symbols
  - Can invent their own equations to describe a physical situation
  - Can read meaning out of equations
- For example […x…] means that the quantity depends on x and […] means that it does NOT depend on x.
- Students can and do use equations for more than finding numbers.

Hammer 1996

- "…propose a view of education research as providing perspectives that expand, refine, and support instructors' perceptions and judgment…"
- Am. Jour. Phys. **64**(10), 1316-1325, 1996.

New resources and perspectives I've gained this week

- Heuristics (Vincente)
- Perceptuo-motor activity (Ricardo)
- Argumentation schemes (Renee)
- Emotions matter (Ayush)
- New ways to think about how/if/why students transfer (Joe and Sanjay)
- Building on what students know (Karen)

Returning to meaning and mathematics

Listening to students from a resource perspective

- Goals for our life science students:
  - To be to be able to see the story in a given equation
  - To be able to construct partial equations based on data/experience
  - NO derivations!

Example from our class

- Students were successful in “creating” Coulomb’s law (force between two charged particles)

$$F_{Coulomb} = \frac{\text{charge}}{\text{distance}} \Rightarrow \frac{kq_1q_2}{r_{12}^2}$$

- Student reasoning: like magnets which repel more strongly when closer

Another example

- Students were unable to “re-create” the Lorentz force law after seeing two demonstrations (angle dependence left off intentionally)
- http://www.youtube.com/watch?v=a_-jvKFunOI

$$F_{Lorentz} = qvB$$

- In a clicker question, they choose nearly equally all these different forms, even when reminded what happens when the denominator goes to zero:

$$qv/B; \quad vB/q; \quad qB/v$$

Conclusion

- Useful resources can be unavailable in unfamiliar contexts (not activated)

Use of symbolic forms

- Exam question: How would you explain to a friend who understands the cosine function why in the formula

  x(t) = 15cmCosine(2πft)

  there is a 2πf in the phase? That is, why is it not x(t) = 15cmCosine(ft) or 15cmCosine(t)?
- One possible answer: the 2πf ensures that the period of 15cmCosine(2πft) is 1/f = T

Student answers

- 20% - vague or misapplication of ideas from waves
- 12% - "in the cosine function, there is a $2\pi f$ in the phase because it is in relation to radians and the circle"; "the $2\pi f$ refers to the unit circle where cosine = 1. Without the 2π the wave function would not work"
- 30% - Noted that 2π is the period of the cosine

More student answers

- 35% - both frequency and 2π matter:
  - *"2π represents the amount of space the wave takes, or the period, f is the frequency… cosine describes the shape of the wave. The reason the formula is structured as it is and not any other way is because both terms are meaningful and important in relation to the shape."*
  - *"… if f were not used, all oscillations would be at the same speed"*

Yet more student answers

- 2% - "When working with trig function graphs such as the cosine, everything must be in radians. 2π is the normal period for a cosine graph, which is why it is there. The ft is there to change the period of the graph to fit the system it is representing."

Conclusions

- Dependence was a very useful symbolic form here for many students
- The conversion from time to radians was not yet clear to almost all.
- I needed a richer knowledge base to teach this more effectively

Content: Exponential decay

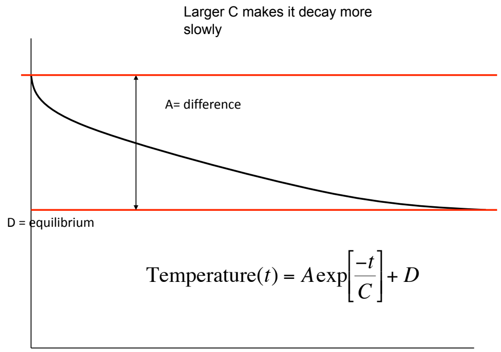
- Examples covered in class
  - Population growth
  - Money in savings account
  - Damped pendulum
  - Cooling curve
  - Resistor/capacitor circuit
  - Concentration gradient across cell walls (Nernst potential)

Cooling lab

- Students observe the cooling curve of a hot object to room temperature
- They investigate the mathematical parameters

$$\text{Temperature}(t) = A\exp\left[\frac{-t}{C}\right] + D$$

- They connect the parameters to physical observables



Research/Design Questions (Shubert, in progress)

- Is there a correlation between pedagogy, materials and functional student epistemologies?
  - What cues student approaches to specific modeling tasks as observed in situ and validated in reflection?

Movie clip

- Students are trying to figure out how changing "D" changes the plot
- What do you see in this clip through your lens?

Observations of this group

- On task all the time (except when one goes to get water)
- All students are making sense all the time
- Use limiting cases
- Use knowledge from other classes
- Willing to revise/revisit earlier answers
- Paying attention to fine details of their own wording

Sadly, most groups were not this productive and framed the activity as doing just enough to get a decent grade

Summary

- Epistemological focus
  - Must be a part of the content and the pedagogical strategy as it greatly effects what students do for this class
  - Students can be guided to connect meaning and mathematics, but we need a knowledge base to do that well
- Knowledge in pieces/symbolic forms
  - Gives a productive way of listening to students, both as a teacher and a researcher.