Research on Students' Reasoning about Interdisciplinarity

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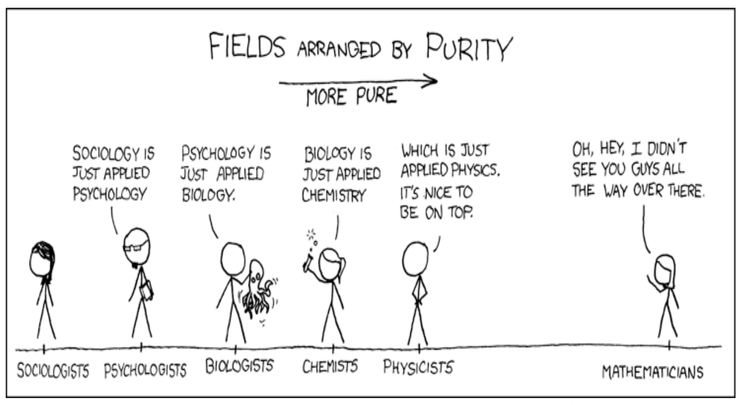
Motivation: Integration of physics and biology

In response to calls for greater integration of physics principles into undergraduate biology* and pre-health education, we have developed a new two-semester introductory physics course for undergraduate biology majors at the University of Maryland. As part of the NEXUS (National Experiment in Undergraduate Science Education) project,** the course seeks to break down traditional barriers that have led to the construction of disciplinary "silos."

NEXUS NATIONAL EXPERIMENT in Undergraduate Science Education

Question: How do students describe the relationship between the disciplines?

A number of students enrolled in the new interdisciplinary course described their view of the disciplinary relationships during case-study interviews conducted throughout the second semester of the course.



http://xkcd.com/435/

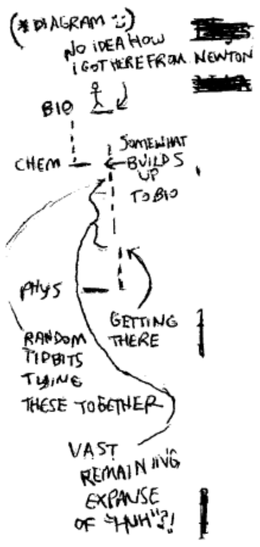
Result: General description of student statements about disciplinary relationships

Rather than viewing biology, chemistry and physics as existing in disconnected silos, or as overlapping only in a narrow range of common interest on a Venn diagram, our students showed a range of nuanced views about disciplinary relationships.

- Some students envision **hierarchical** arrangements that order the disciplines by degree of system complexity or by the spatial scale used to examine a particular system, or both.
- Students also allude to an **analogical** relationship whereby physics is embedded in a context that positions its relationship to biology via analogy.
- In other instances, students reference the way in which general physical principles impose **constraints** on biological systems, such as energy conservation and entropy maximization.

Students do possess resources for coherence-seeking across disciplines in a variety of ways, and the desire to do so.

Hierarchical View

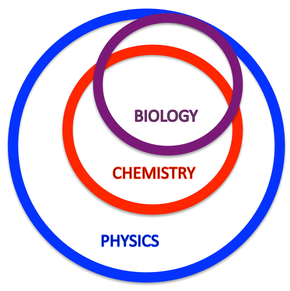


"**Physics** is like very much just **basic** everything, and then that **builds up** to all these particles and all these things you have in chemistry and then you get to biology… everything is just building from this [points to bottom] system after system after system **to like really complicated things**… So I think that we were just even **trying to fill in the gaps** here [between bio and chem] that we didn't know. We just jumped to here [points from physics to biology directly]. You don't have all this [waves across the whole spectrum]." –Anya, 02/06/2012

Anya sees the disciplines as built upon each other, with physics at the foundation. She has a deep faith that the connections exist, but would like to seem them spelled out more thoroughly and explicitly along the way.

"Well I mean **physics** is micro and macro.. but physics, yes, like I would say that it does look at things in like a **stripped down** sense. Not just in the sense that you're zooming physically into **small scales physically** but… you're talking about vacuums and things that don't exist. You just **take out variables and context**, whereas in other sciences it's more difficult to do that because you wouldn't see the phenomenon you're trying to investigate… so yeah, physics gets at like more **complex relationships by stripping things down**. All sciences do that but yeah I would say that physics is sort of the most basic science in a sense." – Gregor, 05/09/2012

Gregor evokes both the spatial scale and the complexity scale when describing the vertical axis of the hierarchy. His complexity axis seems "flipped" with respect to Anya's.

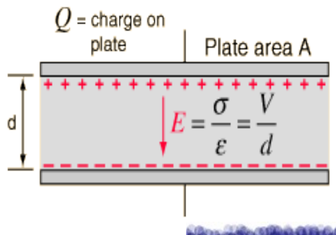


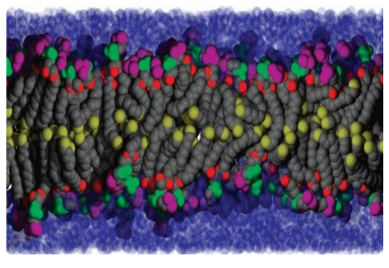
Wylie draws the nested circles depicted above as he describes the disciplines.

"This is the knowledge that physics covers, and this is the amount of knowledge that chemistry covers, and then biology utilizes concepts of both, so it's another different **subset**… physics I think is the **pure** science, you can **break anything down into physics**.. and you know, the properties of the chemical particles can be broken down into molecules and energy…" – Wylie, 04/06/2012

"I mean really it's just an issue of **scale**… it would be very **difficult to investigate a biological system if you are only looking at one piece of that system**… I mean, yes, you can look at one protein but you **don't understand what a protein is in the context of a cell** and what that protein does in the context of a cell and then in the context of a body, or the system and then even **further out to how that impacts interactions between organisms**." – Gregor, 05/09/2012

Analogical View

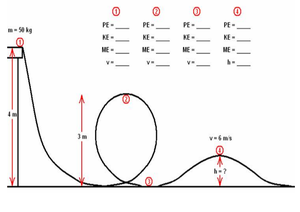


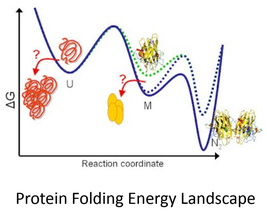


A simulation of a lipid membrane imbedded in water, Pastor, Venable, & Feller, *Acc. Chem. Res*. (2002) **35**, 438-446

"The capacitor with the two strips - this can be rolled up and **modeled** like a cell membrane. And I asked him a question: 'Would the positive side be like the phospholipid heads? Or the tail?' Like I was confused as to how the capacitor model fits into like a cell membrane. So I mean I guess, **it's hard to visualize how it directly translates into a biological system**… I'm more familiar with the cell membrane and how a cell works, as opposed to two strips of metal… I mean I know that they [metal strips] are there but I never thought about it… **since I've had more experience, more background about cells, it would be easier for me [using a biological analog] to get a picture that makes sense**. " – Hollis, 02/26/2012

Constraint View





Protein Folding Energy Landscape

"Yeah, so there are questions on the MCAT that are just 'this ball is rolling down a hill, you know, what is its KE going to be at the end?' So you know it doesn't put that in a biology context, but it's still a valid physics question… because the reasoning that **would have applied to a biological setting would have been very similar to the reasoning applied to a physics problem**." – Wylie, 04/06/2012

Implications: How do we use these descriptions?

While the descriptions expressed by these students are likely context-dependent, they nevertheless inform the ways in which course messaging is coming across to students, and how we might articulate the disciplinary relationships in further iterations of the course. Further emphasis on the analogical and constraint-based views of disciplinary relationships may be warranted, both in the classroom and in our tasks, as these views might more easily motivate the "jump" from physics to biology.

References
* *Scientific Foundations for Future* Physicians (AAMC/HHMI, 2009), Vision *and Change in Undergraduate Biology Education* (AAAS/NSF, 2011)
** http://www.hhmi.org/news/nexus20110608.html

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