Responding to a Call for Change

- Biology students are becoming a significant proportion of the service load of a physics department – enough that we should provide a course that meets their needs.
- Biologists are calling for [1][2]
  - Better development of Scientific competencies
  - More coherence among the disciplines
- Project NEXUS – A multi-university demonstration project created by HMII to provide science courses for a biology major
  - Physics (UMBC)
  - Chemistry (Purdue)
  - Math for Bio (UMBC)
  - Capstone Synthesis (Miami U)

A Team of Interdisciplinary Experts

- 7 Physicists
- 4 Biologists
- 4 BioEducation Specialists
- 3 Physicists
- 2 Biologists
- 2 Chemistry Specialists (Purdue, UMBC)

NEXUS/Physics: Using a Research & Design Approach to Build an Interdisciplinary Course

- Redesign the physics for biologists course so that it has authentic value for biology students – in both content and skill development [3][4][5]
- Position the course within the biology curriculum
  - Assume will be taken in the second year
  - Chem, Bio, and Calculus as prerequisites
- Innovative content focused on the need to support student learning
- View the development as an iterative process where research with student response to the curriculum informs what we do in the next iteration [6]
- Maintain critical components – quantification, mathematical modeling, mechanism, multiple representations and coherence (among others)

Change of Topics from a Traditional Introductory Physics Class

<table>
<thead>
<tr>
<th>Biology components of HW Assignments</th>
<th>Change</th>
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</thead>
<tbody>
<tr>
<td>Kinematics</td>
<td>Include atomic and molecular examples from the beginning</td>
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<tr>
<td>Dynamics</td>
<td>Expand the treatment of thermodynamics</td>
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<tr>
<td>Electricity</td>
<td>Biologists have a weak understanding of mechanics. Many think bonds “store” energy and release it when broken (“Piñata model”). We build the connection from basic physics concepts to help them understand chemical bonding and exothermic reactions in a more effectively.</td>
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<tr>
<td>Waves</td>
<td>Include discussions of kinetic theory, diffusion, and randomness</td>
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<tr>
<td>Light</td>
<td>An Examples of New Content: Understanding Chemical Bond Energy [8]</td>
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The chemical reaction of ATP hydrolysis is the primary source of energy in basic biological metabolic processes. Putting in a small amount of energy allows one to break a phosphate bond in ATP. That phosphate then bonds with the surrounding water, forming a strong bond and releasing usable energy.

The students discussing the process of ATP hydrolysis (ATP $\rightarrow$ (O-$P$) $\rightarrow$ (O-$P$-$P$) $\rightarrow$ ATP) make the following comments:

- Justin: “The O-$P$ bond in ATP is called a high-energy bond because the energy released when ATP is hydrolyzed is large. That released energy can be used to do useful things in the body that require energy, like making a muscle contract.”
- Will: “I thought chemical bonds like the O-$P$ bond in ATP could be modeled by potential energy curves like this, where $V$ is the distance between the O and the P. If that’s the case, then breaking the O-$P$ bond in ATP would require me to input energy. I might not have input enough energy to break it. What if O-$P$ happens to be a weak bond, but shouldn’t I have to input at least some energy?”

How do Kim infer from the PE graph that breaking the O-$P$ bond requires an input of energy? What’s right? Or can you reconcile their statements?

Biologists all know that “ATP is the currency of biological energy” but often have a weak understanding of chemistry. Many think bonds “store” energy and release it when broken (“Piñata model”). We build the connection from basic physics concepts to help them understand chemical bonding and exothermic reactions in a more effectively.

Goals for the Course

Coherence-seeking between
- Physics topics (“crossing chapters”)
- Physics, biology, and chemistry
- Physics and everyday knowledge (“feet on the ground”)

Meta-representational competence
- Representation translation
- Choosing when to make representations
- How representations display information
- Building mathematical competence: Thinking with mathematics

Modeling
- Being explicit about modeling and models
- System schema
- Explicating the value of “toy models”

New Laboratories [7]

- Develop student research skills
  - Focus on Sensemaking
  - Focus on Experimental Design
  - Focus on the Value of Quantification
- Convey a modern view of physics
  - Use modern equipment and tools
- Foster interdisciplinary transfer
  - “What biology do you learn from a physical measurement?”

For more info: http://nexushysics.umd.edu

References

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Contact: redish@umd.edu