PHY 305

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Research Paper

‘Investigating how students connect essential ideas across the science disciplines’

A number of reports and articles emphasize on the importance for undergraduate students to develop a coherent understanding across the sciences. I personally feel that people focus more on learning in depth than to learn on how to apply and interrelate the existing knowledge across various disciplines; either it being Science, or technology or something outside Science and Technology. I think that is one of the reasons why various universities are making changes in undergraduate education in order to make sure that learning is not all about knowing more but being able to connect ideas across the disciplines. Why are the changes majorly in undergraduate education? As far as I think, especially as I am currently an undergraduate student, would be to do with the fact that, that is the time when one is freshly out of high school and is exposed to a variety of options to choose from for one's majors or to decide on a degree to pursue. In short, when you are an undergraduate, you are taking the first step to building your career and your life. You are in that age where it is easier to mold yourself into the required form to face the real world outside of school. Hence, the importance of identifying how ideas connect across the disciplines would greatly enhance your chances of stepping up in the real world and excel in whatever your profession ends up being.

"Unfortunately, many existing assessments in undergraduate introductory science courses encourage rote memorization and factual recall instead of probing students' abilities to use scientific practices to make sense of phenomena." (Vashti, Sawtelle). PERL (Physics Education Research Lab) at MSU is an interdisciplinary collaboration that studies: how students learn physics and engage in physics practical, social, and contextual factors that promote student learning and engagement, assessments and educational technology use and practice. The goal of this research project is to investigate how students enrolled/ already have had experience in introductory college science courses draw connections between essential ideas that span chemistry, biology, and physics, and their everyday knowledge as the basis step to developing an assessment tool for use in examining cross-disciplinary connections. The project started this September with 13 interviews being conducted by some post docs (Emily E. Scott, and others), Research Associate, Dr. Sonia Underwood (Department of Chemistry), and Professor Vashti Sawtelle (Assistant Professor of Physics, Lyman Briggs College, Department of Physics & Astronomy). These interviews focused on five phenomena and students' understanding on them. Most of these students were enrolled in second semester physics, introductory biology and chemistry courses; and happened to be more inclined towards biology when it came to observing their majors. These interviews ask students to think through all the interdisciplinary phenomena (e.g. why do we get sick from someone sneezing?). We examined different resources such as protocols provided to us, that students in the interviews used to make sense of each of those interdisciplinary phenomena. Recorded interview audio files were transcribed and re-transcribed in some of the cases due to technical or human errors. Weekly/Bi-weekly meetings took place with the assigned post-doctoral research associate and faculty to code the interview data, manage in Google drive using Google documents and presentation to keep each other on the same page.

The five phenomena according to the protocols handed to us were: 1. ‘Sneezing near someone can make them sick.’ Why? 2. ‘When you hard boil an egg, the clear fluid inside the egg becomes a white solid.’ How? 3. ‘You touch a hot pan sitting on a stove and burn your finger. A blister forms where you touched the pan.’ How? 4. ‘Children get bigger over time.’ How? 5. ‘When a tech uses an ultrasound to create an image of a fetus, he/she puts the wand on the outside of the body and an image of the fetus inside the body appears on the screen.’ How? It must be noted that these were asked a little differently on actual interviews. To be more precise, the protein synthesis, i.e. ‘Children get bigger over time’ was changed to ‘How do Hollywood actors build big muscles and how does protein go from food to muscles?’ and the ultrasound question was changed to ‘Ultrasound is used to visualize a gallstone/fetus. How?’

Protein Synthesis was the phenomenon most appealing to me due to not being biology major and being curious about how and where does energy come from in our body to perform day to day functions and relating with how bodybuilders grow all those muscles. Also, as it felt like an opportunity to learn the molecular level of the complexity for the same caught my attention. Out of 13 people, 5 people (Brad, Kansas, Danielle, Jennifer and Rudee) had protein synthesis on their interviews and I have studied 5 of them. A little about them: Brad has a business degree and worked in consulting and is a medical major now. Kansas is a junior in Kinesiology. Danielle is a junior in Plant Biology. Jennifer is a junior in Human biology major and Rudee is a junior in Neuroscience major currently preparing for MCAT. The interview questions were more open-ended and were mostly macro level instead of prompting respondents to extract more on constructing examples on micro level, that could be something that could be expected to be taken care of as a step in future further in this project. In order to do that, the protocol questions, some of them given below would help. Questions like where did the amino acids come from, how did they get into the cell; asking questions like what do they think is happening on a cellular scale when a child grows and kinds of materials being added to the growing cell? What happens to them inside the cell? Does the process require energy to occur or if it's something that happens automatically? If they knew whether the process was endergonic or exergonic? Where does the energy come from and how does ATP provide with energy? Prompting for them to relate ATP, ADP and peptide bond.

The actual questions were more like how does eating a lot of protein result in larger muscles, what actually goes on with energy when you are synthesizing protein and how is energy involved when bonds are breaking and reforming? Which was also rephrased as, at a cellular level, if breaking bonds on amino acids and forming a peptide bond sounded familiar to them. Does ATP provide energy to help in reactions? How are getting energy from eating and using energy to break things down connected? In order to figure out how they were making relations between physics (if any!), biology and chemistry, some reflection questions were asked. For instance, Brad was asked if he felt like he used his knowledge from biology, chemistry and physics when answering the questions. According to him, it depended on the question but he thought that he used a little bit of everything. Since he loves biology, he was able to incorporate it more into his answers.

Much of the analysis done up to this point has been focused mostly on looking at individual interviews and describing what was going on in the interviews and coding, which basically means tagging for physics, chemistry, biology and everyday experience even. One of the good examples would be where Brad talks about 'density' when he was asked how germs get into someone's body from the sneezing phenomenon. We tagged density as everyday experience, chemistry and physics. He had a decent understanding of processes at a molecular level and was mostly able to reason about the phenomena in those terms. For instance, he brought up the hydrolysis of water and removal of Hydrogen and Hydroxide ion from amino acids (Biology) example and tried to relate it with the protein synthesis. He didn't use the term DE - phosphorylation but did mention ATP and ADP as source of energy.

Danielle was asked the egg-boiling phenomenon before the protein synthesis one so she ended up writing down Gibbs free energy equation (Thermodynamics! (Physics and Chemistry)) And hesitated with bond breaking/forming and heat absorption/release concept but finally corrected herself at the end. She contributed in this discussion by fairly using everyday examples like, going to a grocery store to buy some cereal and looking at the box to check out the ingredients and nutrition facts in order to know how much vitamins, minerals, proteins, carbohydrates and fats one is consuming. I would personally say that she was probably the one student who covered quite a bit of concepts and touched on molecular level too; conserves molecular form; " *You are what you eat. You can't build muscles by eating fat because muscles aren't made of fat; fat is made of fat. You need protein to build muscles which is made of protein*." (Danielle, Transcript (42:30)). (Biology). One of her very interesting and thought provoking examples was the chicken and blueberry one where she said, "*When building muscles, eat chicken which has carbohydrates and proteins; carbohydrates are ADP and ATP which is the energy used to break up what we consumed as protein, it required energy there…when it formed into muscle, it released energy, which made us hot and sweaty, but now we have the muscle because we had the building blocks for it*" (Danielle, Transcript (52:55)). She links matter and energy story about muscle building. (Biology/Chemistry). She also mentioned Calvin Cycle as she was thinking in terms of photosynthesis but also recognizes that photosynthesis has nothing to do with in humans. Regardless, it's another way of relating energy production in protein synthesis with that in plants. With reflection questions, biology, chemistry and a little bit of physics because talked about the bind breaking and bond forming thermodynamics equation. She had a well-balanced sense of molecular levels science and correlation between matter and energy.

When asked the main question 'How does eating a lot of protein result in larger muscles, intentions were to get a view on molecular approach on the entire process, but instead they focused on Macro level more where people would talk more on tissue level or organismal level rather than atomic-molecular level. Students recognized the nature of molecules in digestion and biosynthesis but were unable to provide molecular mechanisms (Brad, Kansas and Rudee). Students also focused at muscle construction at the tissue level, with exercise as the process that builds muscles (Jennifer). As discussed earlier though, Danielle ended up talking in molecular/atomic level. Kansas: (Biology): "*When they eat and work out, they're breaking down muscle fibers and when muscles repair, they rejoin and become stronger. With more protein intake, that gives you more amino acids to build proteins and bind the muscle back together*." Another point analyzed was how all the five students focused on protein sources rather than the protein construction (Biology); "*Diet is going to be a huge part. They'll cut out unhealthy foods, definitely pick up a lot of protein, like meat, fish, supplements. They're working out more. The intake of good calories, not fat calories, is going to be higher to support the body working harde*r" (Jennifer, Transcript (39:25)). It was certainly good to conclude that people were sure that fat doesn't get converted to muscles just because one consumes proteins or works out, "*When you lose fat, you gain muscles, but your fat won't turn into muscle. It gets broken* *down so you can keep going*"(Jennifer, Transcript (49:50)). I would tag it as an everyday knowledge. In short, she focused on muscle building and protein synthesis at the level of tissues, such as how muscle fibers are damaged and repaired to build muscles; when shown the molecular reaction of amino acids forming a peptide chain, she said she hadn't studied the process at that level yet.

After the in-depth analysis, it's clear that when asked how consuming protein resulted in larger muscles, all five students focused on protein sources instead of protein construction. Brad, Jennifer and Danielle have same things to contribute, which are basically, we get protein from different sources and that protein breaks down further into amino acids that provide energy (Biology and Chemistry). When asked how does protein actually go from food to muscles, the big idea here is similar to polymers breaking down into monomers and examples used to support this are hydrolysis of water by Kansas and Brad, Photosynthesis and biosynthesis by Danielle (Biology and Chemistry). Moving on to the next question, which was to figure out if energy was involved when bonds are breaking and reforming, almost all of them had some idea about energy but could not describe it in terms of physics or on microscopic level. But all five people had some idea about ATP, ADP and that energy is required to form a bond and released to break a bond; "*DNA produces RNA that creates a template that matches amino acids together appropriately to make the necessary protein for a cell…Enzyme uses ATP to match two amino acids and attach them*" (Brad Audio file (0:55)). Furthermore, the only person who actually picks up pen and paper to draw/write is Danielle for the thermodynamic equation (Physics). Rudee tries to approach in a molecular way while Jennifer attacks the question on a tissue based level. Rudee: (Biology): "*If you were making a bond, you are acquiring energy, and then you acquire the energy through like, food you eat. Then that allows you to... make peptides*" indicating that protein is used to build the structure of cells. Next question was to know if ATP provides energy to help in reactions and they all approach differently again, Kansas was able to differentiate between energy required to move the body and what drives chemical reactions but no mention of relation between energy and chemical reactions. Brad, Rudee and Jennifer mention terms like ATP and enzymes but didn't know of the process. Danielle talked about bond formation and photosynthesis and carbohydrates as form of energy (Biology and Physics).

When students were asked what they thought they were using, all five of them agreed that there was not much physics to be dealt with for this given phenomenon. They associated physics with more mathematics and calculations. Jennifer knew she used all the subjects but tended to lean towards Biology. Rudee knew she used Physics too along with obvious choices as Biology and Chemistry, but also said that whenever she thought about Physics, it would mostly be about solving for force or tension in a pulley, etc. Kansas and Brad couldn't see themselves centered on physics at all due to their lack of concrete knowledge in it. Hence, it was mostly biology and chemistry.

I personally feel that it could be because all five of them belonged to more or less from Biology field, they could not envision any physics or much physics used in the phenomenon. I did find working on this phenomenon challenging as the prompts were not too clear and were open ended, implying no head on molecular analysis about actual protein synthesis which sort of makes me want to believe that may be the introductory biology courses don't involve a lot of information on basic protein synthesis process. I could be wrong in coming to that conclusion but I feel like may be the only way to find this out is to conduct a couple of more interviews and have clear prompts to get more in-depth opinions or data or gain more knowledge on the same rather than making it an open discussion. Considering the phenomenon, there's unfortunately no clear cellular based information and students stayed mostly on the surface level. After we were handed the protocols and before the interviews were conducted, I would say I was more ready for a different set of responses but that is only because I did my research in advance, as I am no expert on this topic either. I am assuming, it could be because even though it's a basic phenomenon, it's not as easy and unfolded as one might think it might be. Surface level knowledge is where we are at in this project for this particular phenomenon so far and to know more about it, we need to dig students with deeper questions during any more interviews to be conducted in future. Another observation was that if the questions were slightly rephrased, respondents had different set of responses and the entire analysis done right now is after spending a lot of time with each transcript and audio file. It's highly possible that after a certain question was asked, student didn't immediately had an answer that interviewer might be expecting, but sometime down the line students might have had an answer to it. Some of the tiny issues that we had was to make sure all of us were on the same page, we had to match up the audio files with the transcripts and some of them had large repeated chunks or an entire chunk missing. Addressing these issues in our meetings with the project members was helpful. Hopefully we will be able to continue this project further with ease but hard work and reach to a solid conclusion and can end up making some significant changes to the undergraduate education and bring people from all sciences together.

I had a really great time working on this project and would love to continue working on it in near future. I would like to thank Prof. Vashti Sawtelle for giving me this wonderful opportunity in believing in me. Prof. Danny Caballero for introducing me to her and filling me more on this ongoing project beforehand. Emily and Sonia for very helpful notes, strategies and great guidance throughout. Also, Justin Gambrell for being a great research partner.