Supplemental Material

CBE—Life Sciences Education

Franovic *et al*.

Supplemental Material

Supplemental S1. Interview protocol

Below is the entire interview protocol that KN and CF used when meeting with each participant. However, we wish to reiterate the semi-structured nature of these interviews. By no means did each interview ascribe directly to this protocol, as the instructors had several thoughts and ideas that we did not anticipate, or they brought up ideas early on in the interview that we had not intended to discuss until later. The protocol provided a general guide to maintain the discussion; however, most of the instructors provided far richer conversations than expected, resulting in altered trajectories well outside of the bounds to which this protocol is limited.

Provide participants with a general overview of the project

1. Things to mention:
    a. Goal of project – help students develop a more coherent understanding of energy in chemistry and biology.
    b. To achieve this – we are interested in understanding faculty perspectives on energy to see how you think about energy-related ideas as an instructor, and how you understand these ideas as an expert in your discipline.
2. Emphasize that **this is not a test**. We are genuinely interested in how you think about energy so we can get a better idea of how we might be able to help students understand these ideas as well.

Consent

3. Highlight important portions from the consent form
    a. Will record the interview and transcribe after
    b. Will de-identify the data following this session, giving a pseudonym which would be used if this data is published.
4. Explain the materials (i.e., zoom or recording device).

Introductions

5. KN or CF introduce themselves and thank participant for meeting
6. Ask about courses they teach/have taught, and area of research (if applicable)

Energy

7. Depending on the discussion so far, some ideas to include are listed below, but not all are necessary – these may be dependent on the participant and what they have decided to bring up at that point:
    a. How would you define energy?
    b. Does energy come up in your course(s)? How so?

c. How would you describe energy transfer? What is it?

d. How would you explain the mechanism of energy transfer? How does it happen?

e. Do you think about energy differently in a chemical or biological system?

The role of ATP in driving unfavorable processes

8. If they have not brought up ATP on their own, ask them about its role (suggested questions below):
    a. How do you think about the mechanism by which ATP is used as an energy source?

    b. How does ATP drive unfavorable processes?

Supplemental S2.

Table S1 includes each code, a description of the code, an example segment, the number of interviews in which the code occurred ("instructors with code"), and the number of total occurrences across all transcripts ("segments with code").

Table S1. Full codebook including codes, descriptions, examples, number of interviews with code, and number of segments with code.

Code	Description	Example segment	Instructors with code	Segments with code
Bond energy	Discussing energy changes associated with bond formation or bond breaking.	*"So those weak bonds are getting broken, and then stronger bonds are getting formed, and that the forming of those bonds is releasing energy" (*Olive*)*	13	43
Teaching/learning	When the participant discusses whether or not they understand a topic themselves or how to teach that topic; or when they discuss how students understand or learn ideas related to ATP or reaction coupling.	*"I've done it both ways. I've tried to show them the actual mechanism, and I feel like that's a little bit too much for them in second semester" (*Fig*)*	12	61
ATP hydrolysis	Discussing the hydrolysis of ATP, or the reaction of ATP with water.	*"we do go through a fairly detailed description of why hydrolysis of ATP is favorable" (*Ivy*)*	11	40
Coupled reactions	Discussing reaction coupling, vaguely or explicitly.	*"I talk about it in pairing the hydrolysis of ATP with unfavorable reactions." (*Jade*)*	11	38
Referencing disciplines	When the instructor explicitly discusses their own discipline or another discipline and how those disciplines teach/think about ATP.	*"what I want the students to do and the way that I talk about sort of the biology of it, is to highlight that there is a discrepancy between the way that biologists will often talk about it and the way chemists talk about it." (*Basil*)*	11	30
ATP Synthesis	Discussing the synthesis or formation of ATP	*"If you talk about ATP synthesis, right, you're using that protons all on the…the, inter membrane space coming back into the matrix." (*Dracaena*)*	9	23
Stability	Discussing stability of systems or molecules.	*"there's an intermediate and the intermediate is less stable than the final thing" (*Jade*)*	9	12

Gradients	Discussing membrane potentials or chemical potential gradients in the context of coupling or ATP.	*"that causes a change in the electrochemical potential energy across the membrane, which is stored there, it isn't stored in a particular molecule it is stored as a… gradient in a fi-, in a field, you know, and just a total potential energy thing." (*Ginkgo*)*	8	17
Phosphate transfer	Discussing the transfer of a phosphoryl group from one entity to another (typically from ATP to some other molecule).	*"I think most of the time, we mean, it is phosphorylating the substrate, and activating it based on a phosphoryl transfer." (*Ivy*)*	7	19
Enzyme	Discussing enzymes in the context of ATP or reaction coupling (including mentions of kinase).	*"And so when this ATP comes in, there's an enzyme that functions and breaks off two of those phosphates, and then there's, it will join with sort of your growing DNA chain." (*Olive*)*	7	17
Common intermediate	Discussing a "high-energy" or "phosphorylated" intermediate involved in reaction coupling.	*"instead of having the phosphate just go to free phosphate, let's donate it to another molecule and have it become a phosphorylated intermediate." (*Monstera*)*	6	23
Explicit exclusion of a mechanism	If the participant explicitly mentions that they do NOT address a mechanism (how/why) of ATP being used as an energy source	*"Now we've got 7.6. Now we can drive a reaction that has free energy change of less than 7.6 k calories per mole in the other direction. And so, we but we don't really get into how do we couple those reactions? How do we specifically go in there?" (*Monstera*)*	5	12
Biological example	This code is used when the participant gives a biological example of ATP being used.	*"the simplest example would be muscle contraction. Right. You need a lot of power to proceed for muscle cells to contract and relax." (*Philodendron*)*	5	11
Equilibrium	Discussing equilibrium (or concentrations of reactants/products) in relation to reaction coupling or ATP.	*"…then the second reaction will carry that in terms of the intermediate and it gets drawn along, drawn along, just an example of what le Chatelier's principle. You're, you're shifting equilibrium for the second reaction by loading up with react."* (Gingko)	4	17
Conformational change	Discussing some conformation or shape change that is caused by ATP.	*"No, so, the, the, the form of the enzyme, the conformation of the enzyme is different between the ATP bound and the ADP bound. So when you hydrolyze, and release, you know, so when you hydrolyzed, that ATP, you're going to usually release the phosphate but you get a conformational change of the protein related to that" (*Lily*)*	5	11
Activation energy	Discussing a "barrier" or the activation energy required for a reaction.	*"your molecules here and if you put enough energy, you kind of have an average energy that's up at this level. If you increase that energy up, now you have enough to actually overcome the activation energy that's associated with that" (*Basil*)*	4	4

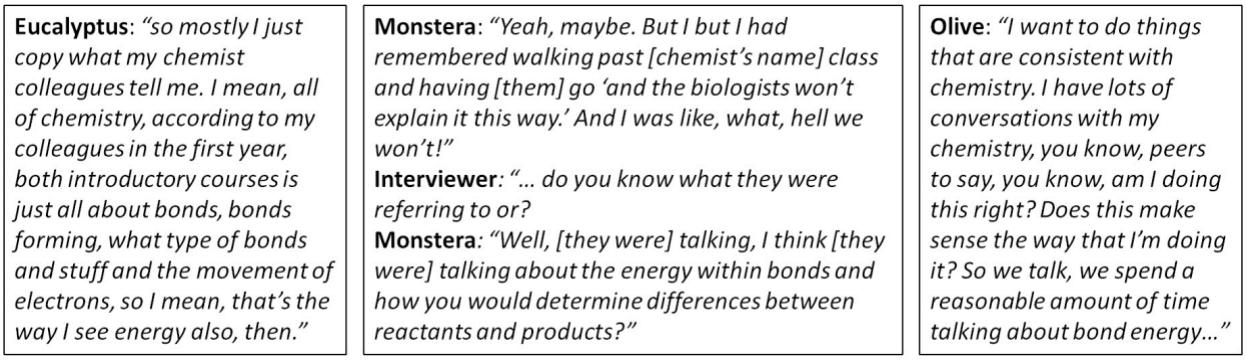
Calculations	Discussing calculations involved in ATP or reaction coupling from either a teaching perspective in the course, or content-related in understanding how ATP works.	*"we would talk about the delta G equals delta H minus T delta S. And we will also then try to tie it into well, under cellular conditions, it's actually different than under standard conditions." (*Ficus*)*	3	11
Phosphate repulsion	Discussing the charge repulsions of neighboring phosphate groups on ATP	*"because these phosphate groups have negative charges, so they're sort of repelling each other. And which makes these oxygen phosphorus bonds a lot weaker than they otherwise would be." (*Olive*)*	3	5
Suggested resolution	When the instructor mentions or suggests some way of talking about ATP that might be more productive or useful for students.	*"we've always thought about how do we talk about energy in terms of ATP cleavage? Maybe we should be talking about energy in terms of ATP formation." (*Monstera*)*	2	5

Note 1: Codes are listed in decreasing order of the number of interviews in which they occur.
Note 2: Some example segments include additional codes other than the one for which it is exemplifying.

Supplemental S3.

Figure S1 provides example excerpts for the code *referencing disciplines*. These specific examples are from three biologists who mention a desire and/or effort to align content with chemistry.

Figure S1. Example excerpts for *referencing disciplines* from three biology instructors.



Supplemental S4.

Table S2 includes additional excerpts for the *teaching/learning* code, showing that other instructors expressed experiences that were not positive.

Instructor	Excerpt
Myrtle[b]	*"...in terms of how we talked about the role of ATP, we've clearly, I've clearly been doing that wrong."*
Lily[b]	*"And we just had [inaudible] the difference between an intermediate and a transition state. So today-, I guess today caused some confusion."*
Olive[b]	*"You know, I have a, I have a, I would think a low-ish level of understanding, but I try to teach students in a way that I'm not undoing things that they're learning in chemistry."*
Eucalyptus[b]	*"ATP is an A and a T and a P. There's like, it's all highlighted in yellow with sparky little sunlight shapes around it like 'pchooooo!' that must be that right? So it must be in there? And then 'PCHOOOOO!' Yep. So I think it's, I think, I think the representations they see in the textbook become what they say on the test."*

Ivy[bc]	*"we tend to use a lot of shorthand in our language, we would get really sloppy in our language and we're expecting students to sort of see through that, um, you know, despite it being a high level biochemistry bond-, class, we still say ATP has high energy bonds."*
Basil[c]	*"it's really hard for students to carry this idea. Because when we talk- when they often talk about it in biology, they're sort of the, hey we break the, you know, ATP bond and energy comes out."*
Fig[c]	*"knowing how to teach that connection… It's hard. It's something I struggle with. And I kind of feel like I'm very fortunate, because chemistry is the first class."*

Instructors listed according to discipline (green[b] = biology, blue[bc] = biochemistry, grey[c] = chemistry)