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Brittany Mureno
Western Washinton University

Eric McKenzie
Western Washinton University

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Investigating Transfer of Energy Concepts Learned in Physics to Biology Contexts*

Brittany Mureno, Andrew Boudreaux, Eric McKenzie, Emily Borda, Todd Haskell

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Abstract: Problem solving interviews were used to investigate student understanding of energy concepts in a biology course for preservice K-8 teachers. Interview subjects constructed an energy-based explanation for a biology scenario. Subjects had previously taken a physics course in which an energy-based model for interactions had been developed. Interviews were transcribed and analyzed to identify common themes in student reasoning. These themes describe discipline-specific understanding, but also cut across disciplines, providing insight into how learners make sense of energy as a unifying concept.

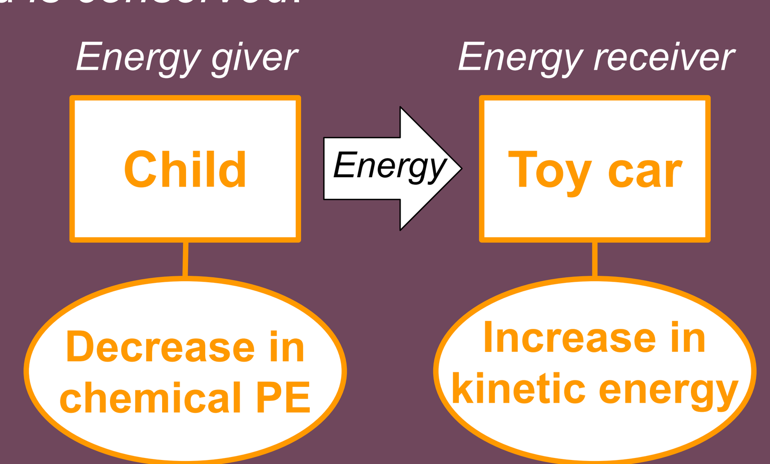
I. Introduction

The concept of energy unifies the STEM disciplines [1]. We would like students to recognize that energy in physics is the same as energy in biology. In the SCED 201-2-3-4 course sequence, students first develop an energy-based model in a physics context, and then are expected to apply that model in geology, biology and chemistry contexts. Transfer of learning, however, is known to be challenging [2]. We have studied the extent to which students are able to apply the energy model in new disciplinary contexts. This has included the use of interviews to generate rich descriptions of the reasoning students engage in during attempts to transfer energy concepts from the original physics learning context to novel situations in biology.

II. Background: An Energy-Based Model for Interactions

In the physics curriculum [3], students develop a model in which energy *is associated with objects, has different forms, can increase or decrease during an interaction, can transfer and transform during an interaction*, and *is conserved*.

Students apply the model to explain real world phenomena, using an energy diagram to represent an interaction. For example, when a child pushes a toy car, the car starts to move because its kinetic energy increases as energy is transferred from the child to the car.



III. Research Methods

Semi-structured interviews for qualitative investigation of student reasoning:

- 14 subjects recruited from biology course
- 50-min session with one recorded with Smart Pen.
- Think-aloud protocol, in which subjects were presented with a specific biology task (see below) and asked for a scientific explanation.

Interview task explores transformation of chemical potential energy to mechanical work & heat in context of human metabolism:

Deb eats a bowl of oatmeal and then goes on a five-mile run. Construct scientific explanations for the following: After eating, 1) How is Deb able to continue running?, and 2) Why does Deb get hot while running?

Thematic analysis was used to identify themes in student reasoning [4].

IV. Preliminary Analysis: Coding for Conceptual Resources

Transcripts were coded for instances of conceptual resources for understanding energy. These codes correspond roughly to the elements of the energy model presented in part II above. A coded transcript indicates where in their explanation the student "activated" these specific elements of the broader energy construct. Thematic analysis was then applied to identify themes in student reasoning.

V. In-Depth Analysis for Themes in Student Reasoning

Example of candidate theme: Students commonly activate potential energy as a conceptual resource in the *Deb-goes-for-a-run* task. This often occurs through reasoning about energy conservation, when a student concludes that a "mystery" energy form is involved. However, students are less likely to relate the new energy form to an observable indicator, and sometimes do not explicitly identify the new energy form as potential energy.

- ***Sub-Claim 1:* Student reasoning falls on a spectrum of more informal to more formal (i.e., colloquial ways of talking about energy *vs* reasoning explicitly aligned with scientific energy model)**
- ***Sub-Claim 2:* Many students activate conceptual resources of *transfer* and *transformation*, but not a *mechanism* resource. These students fail to describe a specific mechanism associated with energy transfers, transformations and changes that occur as part of the process of metabolism.**

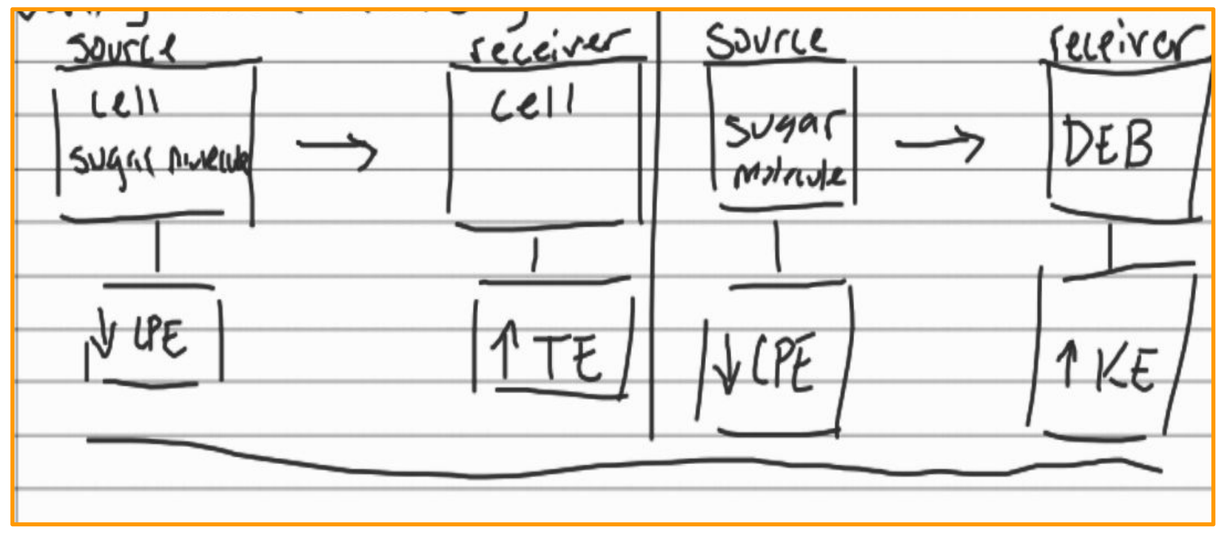
Evidence and Discussion

Transcript excerpt:
Interview subject A

"When the motion of, I guess the input of food energy, the stored energy when it is being output into kinetic energy there is also an output of thermal energy of her body and that is why she's hot."

Transcript excerpt:
Interview subject B

"I guess it would be kinetic energy if she's running still but whatever energy she is running on I think is from the decrease in chemical potential energy cause that still lines up with the law of energy conservation."



- Student A describes the situation more informally (e.g., "food energy") while Student B's reasoning is more explicitly aligned with a formal energy model (e.g., a "decrease in chemical potential energy")
- Student A's diagram clearly represents *transformation* between energy forms, but does not clearly associate specific energy forms with specific objects or systems. (Student A may be conflating matter and energy.)
- Student B's diagram, in contrast, has clear source and receiver objects for each energy transfer.
- Neither student articulates a microscopic mechanism for the energy transfers that occur as a results of Deb's metabolism.

VI. Conclusions and Next Steps

We have identified some patterns in students reasoning about energy that have important implications for instruction. Now that two layers of analysis have been performed on the transcript data (energy resource coding and thematic analysis), we can attempt to validate our claims more systematically. We plan to examine which resources are more or less available to students when they reason in an unfamiliar context. This may indicate which aspects of an energy model are actively transferred and which aspects tend to fall to the wayside as students engage in cross-disciplinary learning of energy.

References:

[1] "The Three Dimensions of Science Learning." *Next Generation Science Standards.* Accessed 13 May 2020.
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[4] Saldana, Johnny. *The Coding Manual for Qualitative Researches (3rd ed.)*. Sage Publications, 2016.

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