Using Integrative Analysis with Big Ideas to Support Causal Explanation

Collaborative Research: How Deep Structural Modeling Supports Learning with Big Ideas in Biology

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Causal Explanation in Science Education

Causal explanation is essential to learning with understanding (NRC, 2000; Russ et al., 2008; Windschtil et al., 2012; 2020)

The most prominent approach to teaching causal explanations is didactic and heuristically driven

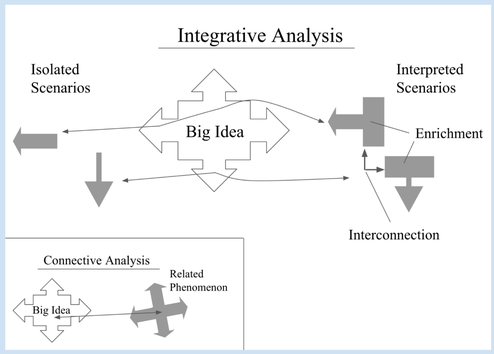
- -Highlighting causal information + opportunity to construct explanation + feedback (Windschitl et al. 2012; 2020)
- -Demanding causes (Sandoval, 2003)

A more generative alternative is "forward and backward chaining," where students instantiate abstract relationships onto novel situations (Machamer, Darden & Carver, 2000). This can lead to what John Dewey (1916) called "conjectural anticipation" in which students use abstract ideas to expect, find, and evaluate causes.

Chaining and conjectural anticipation of causes are suggestive of using big ideas as theories and models within scientific evaluation (i.e., analysis) as outlined by NRC (2012) but are not associated with evaluation in the instructional literature.

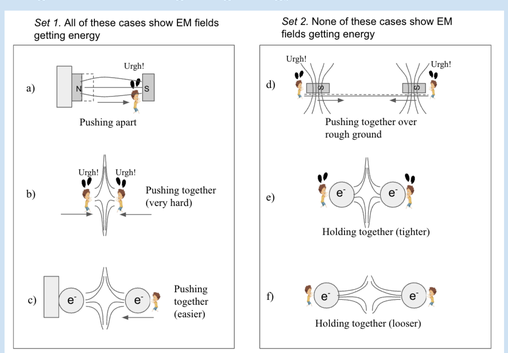
Integrative Analysis with Big Ideas

Using the big idea as a deep structure for interpreting isolated scenarios, thereby interconnecting the scenarios and enriching their meanings.



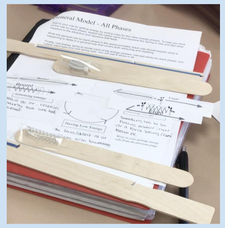
Modeling Energy Transfer as a Deep Structure

Use the cases below to write a general rule for what is happening when electromagnetic fields are getting energy:



See Capps & Shemwell (2020) and Shemwell et al. (2023) for more details.

Abstract, Meaningful, Efficient Model

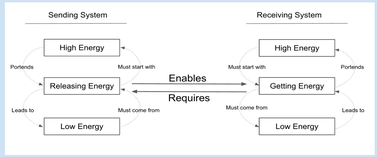


For getting energy, you're going to be putting, energy, into something, or creating a force, using like tension or something like that.

And then, to get to high energy, you would put a lot of force or pressure or tension on something, and it would just stay at that state.

And for low energy, um, you would have not as much energy or pressure at a constant state.

And for releasing energy, it's gonna release all of the pressure if you let go of it.



Causal Explanation Through Enriching and Interconnecting

Expecting a Cause

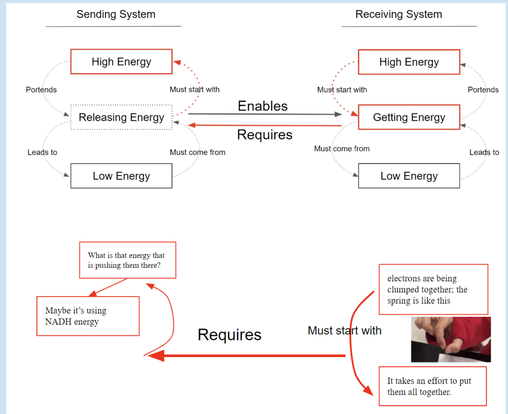
S1: All the protons are being clumped together. That's why the spring is like this [pinches fingers together]. Down here [down the ETC], the electrons have low energy, so they are very chill [flattens out and swipes hand]. There is a type of energy pushing them up, up here [points at the urgh stick at metal 1]. It takes an effort to put them all together [pushes hands together] because they are all clumped [in the IM space]. So we are trying to find out what is that energy that is pushing them there.

enriching

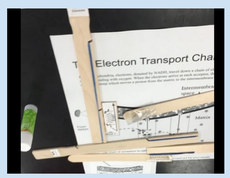
interconnecting (requires)

enriching while interconnecting (requires)

interconnecting (must start with)



Finding and Evaluating a Cause



Maybe it's using NADH energy… and struggles [shows hands shaking as he pushes them together] to put them [protons] over here [in the membrane] to be fully charged…

proposing a high energy candidate

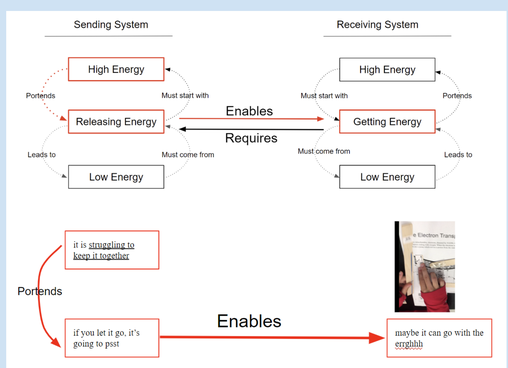
enriching

S1: Maybe this one [grabbing the stretched NADH electron stick] because it is struggling to keep it together, and if you let it go, it's going to pssst [hands show releasing motion], so maybe it can go with the errghhh [setting electron stick with proton stick]

finding a high energy candidate

enrichiching and interconnecting (portends)

interconnecting (enables)



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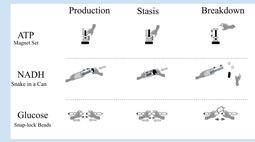
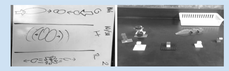
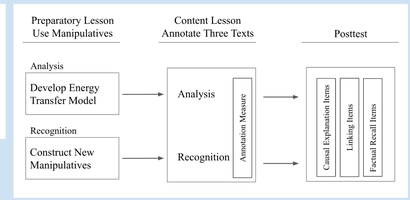
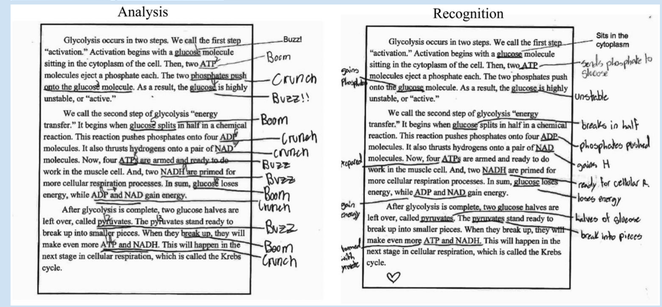
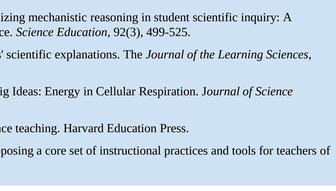
Causal Explanation in a Quantitative Study











Findings from Shemwell et al. (2023).

Discussion

1. Interconnecting and enriching novel information within a big idea structure (integrative analysis) helps students to expect causal relationships, motivating a search for particular causes that students are capable of finding and evaluating.
2. Interconnecting and enriching are facilitated by a big idea structure that is both meaningful and abstract:
   - -Comprised of simple and intuitive elements and relationships.
   - -Applicable under transformation to a range of situations.
1. Big ideas (and models of them) have important uses beyond planning instruction and culminating instruction. These need to be better elaborated.

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