Assessing for shifts in learner's transferrable energy reasoning strategies

Lane Seeley – Department of Physics, Seattle Pacific University

Introduction

Addressing the energy challenges of today and tomorrow will require energy experts in fields from municipal government to public health. These experts will draw from their diverse, sophisticated and nuanced understandings of energy in society that go far beyond static lists of energy facts. For these reasons we suggest that energy education efforts should prioritize energy reasoning strategies in addition to energy content knowledge. In this study we will focus on two specific dimensions of energy reasoning:

- **Rigorously attending to energy conservation and tracking when analyzing specific energy scenarios and**
- **Using diagrams as tools for problematizing and refining energy ideas.**

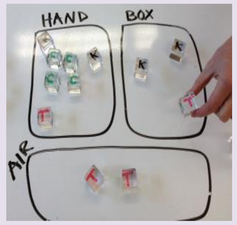
In order to support learner growth in these two dimensions it will be important measure that growth. This paper will describe preliminary efforts to assess energy reasoning strategies.

Instructional context

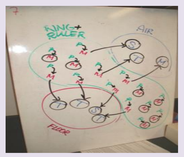
An innovative, 2-week, professional development course on energy, co-taught by SPU faculty, visiting faculty, and K-12 teachers. Our instructional approach includes:

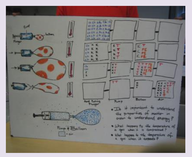
- **Scaffolding productive learner engagement with specific scenarios that foreground challenging aspects of the energy concept**
- **Collaboratively constructing dynamic energy representations that recruit learner ideas about real situations, mandate energy tracking, encourage sense making and promote scientific questioning and reasoning.**

Energy Theater



Energy Cubes





Energy Tracking Diagrams

Assessment Design

- **Strategically chosen scenarios for which rigorous attention to energy tracking is likely to lead to unexpected and/or counterintuitive results.**
- **Pre-post constructed response probes which encouraged diagraming and energy tracking.**

Atwood's Machine Example

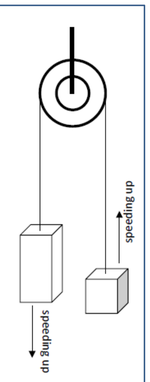
Two wooden blocks are connected by a piece of string which runs over a smooth, lightweight pulley as shown in the figure. The tall block is moving downward and speeding up. The short block is moving upward and speeding up. The total energy of each block is equal to the sum of its kinetic energy and its gravitational potential energy.

(a) Draw an energy tracking diagram to show what is happening during this process. If you aren't completely sure what is happening with energy, describe what you know and feel free to speculate when you are uncertain.

(b) Which of the following statements best describes the total energy of the larger block? (You can assume that the total energy of the block includes gravitational energy which results from the interaction of the block and the Earth.) (Circle one)

I. The total energy of the larger block is increasing.
II. The total energy of the larger block is decreasing.
III. The total energy of the larger block is not changing.
IV. It is not possible to determine whether the total energy of the larger block is increasing or decreasing.

(c) Explain your reasoning.

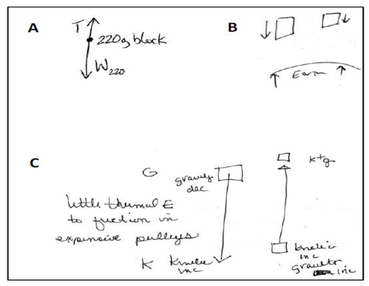


Assessment Results

Correct answers and reasoning (N = 22) pre (18%) post (36%)

Pre-assessment:
- minimal use of diagrams
- diagrams appear to illustrate reasoning that has already happened rather than being used constructively as tools in the reasoning process

(A) tension force on the larger block was upward and the acceleration was downward
(B) relative strength of the gravitational pull between the blocks and the Earth
(C) at the beginning 'energy is gravity from big block. At end, energy is K from big block + K & G from little block.'



Post -assessment:
- significant increase in the number of diagrams (3 → 22)
- majority of diagrams now appear to be used constructively as reasoning tools

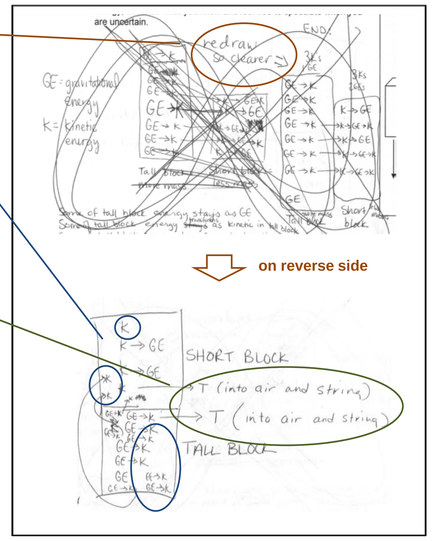
'Marcy': incorrect response → correct response

Iterative Refinement
"redraw so clearer"

Diagram supported quantitative reasoning
"The tall block has more mass, so even though it is speeding up at the same rate as the short block, it has more kinetic energy than the short block"

Rigorous attention to energy tracking and conservation
"It must be decreasing. It loses some energy as thermal to the environment. Plus some of its gravitational energy that is transformed to kinetic is transferred to (the) short block."

Metacognitive sense-making
"Imagine no short block, the large block would fall faster because it kept all of the kinetics for itself."



'Sara': extensive diagram supported scientific reasoning

Pre-assessment: Sara's pre-test was characteristic of many pre-test responses. She did not include a diagram and her reasoning was limited in scope.

"The energy of each block gets converted from potential energy to kinetic energy as they move. The amount of energy remains almost the same, w/ some being 'lost' as thermal energy."

Post-assessment: Sara's post-test response exemplifies the use of diagrams to support energy reasoning among participants who did not arrive at the correct answer

Sara's diagram is both elaborate and unfinished.

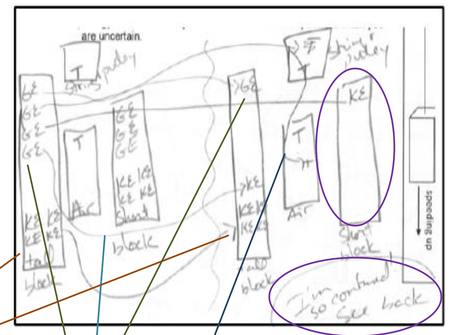


Diagram Supported Reasoning

"I get that the larger block is converting GE (gravitational energy) into KE (kinetic energy) as it is falling"

"I know KE is rising because it's going faster"

"I know GE is lowering because it's getting closer to the center of the Earth"

"Some GE is converted to TE (thermal energy) in air as the block rubs against the air"

Metacognitive sense-making

"Now the energy story of the short block is totally baffling to me. The short block is gaining both KE and GE. It is moving faster and getting farther away from the center of the Earth. The force story tells me this is because the big block, which is more massive, is pulling on the short block. However, I can't figure out the energy story. I can't figure out how to ↑(increase) the KE & GE in the short block. My only idea is to treat the 2 blocks and the string as 1 object. As a whole, the system is gaining in KE and lowering in GE."

ENERGYPROJECT
Seattle Pacific UNIVERSITY
FACET INNOVATIONS
Supported in part by NSF grant DRL0822342