

Intuitive ontologies for energy in physics

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Conceptualizing energy

What kind of thing do people think of energy as being?

... and what is the significance for instruction?

Theory and practices

Learning and expertise show best in what people do and say to learn together. [1]

We mostly analyze classroom discourse.

People understand the kinds of things that may exist in terms of sensorimotor experiences.

We examine physics discourse for embodied metaphors. [2-5]

People have good reason to think of things the way they do.

We identify the advantages and limitations of specific metaphors.

People have easy cognitive access to a variety of ontologies. [4]

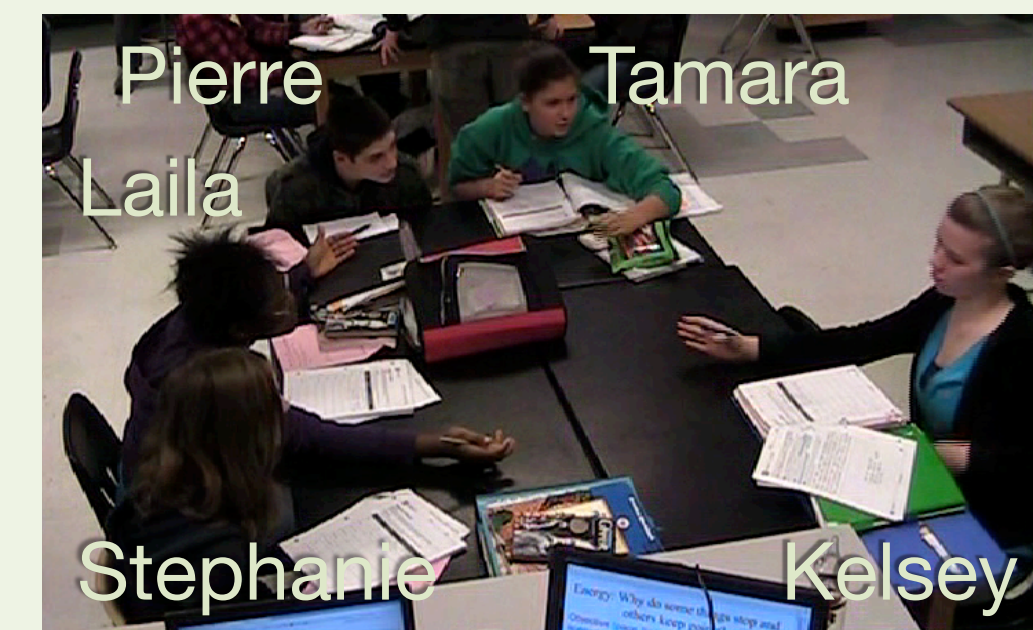
We promote disciplined, flexible use of metaphorical language in instruction.

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Data: Physics discourse

Leaves blowing in the street:
How is energy involved?
(8th grade, public school)

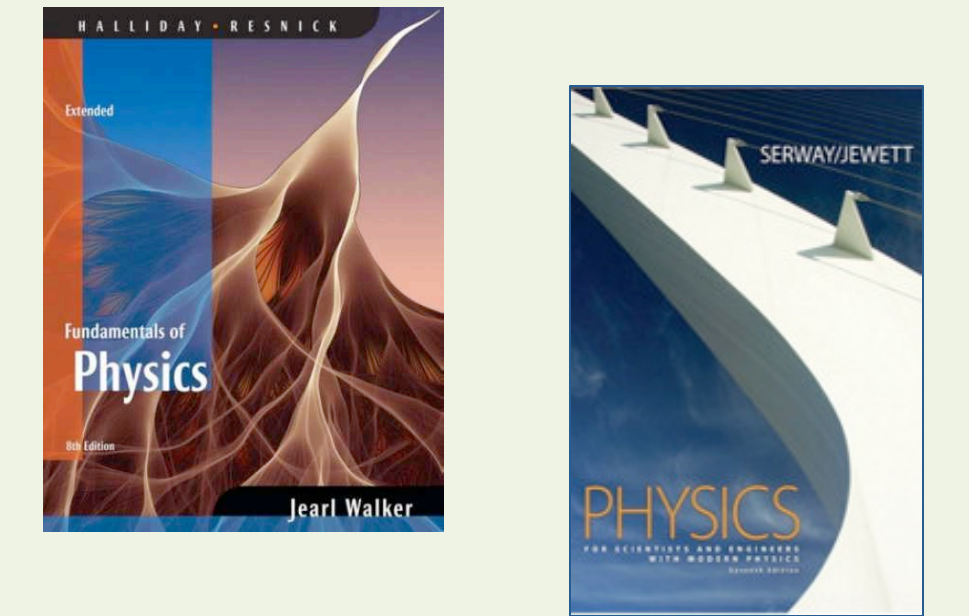


Tamara: All right. Leaves in street. I don't think so. Cause it's just the wind.
Laila: Yeah. I don't think I don't think the leaves in the street have energy. They have a type of energy, but-
Kelsey: But is wind energy?
Laila: Wind is energy.
Tamara: Oh, should we write it down?
Kelsey: Well they're getting wind energy.
Pierre: But it's not talking about the wind.
Laila: -about the wind, it's just talking about the leaves in the street. Leaves - leaves in the street, do they have energy.
Tamara: No.
Pierre: They are pushed by energy
Laila: They have energy, but they do not have the energy, like, to move.

Laila: But wind - I don't think wind has energy. Well it has energy
Kelsey: You can use wind to like power stuff
Laila: Is it - to create energy. Wind-
Kelsey: It can be a source of energy.
Laila: Yeah, your wind is like your foot on the pedals.
Kelsey: Yeah. It's a source of energy.
Laila: I don't really think-
Kelsey: I mean the leaves have a source of energy.
Laila: The leaves have a source of energy but they don't have like energy to move they're talking about its motion. Is motion energy there and I don't think the leaves have motion energy.

Kelsey: But the leaves were moving.
Laila: But they're moving because of the wind. I'm saying if you could have-
Kelsey: That is their source of energy.
Laila: -leaves in the street without, without, if we had leaves without the wind, it wouldn't move then. I'm just thinking of both cases.
Kelsey: True but I mean but like a bus without gasoline wouldn't move either.
Laila: No, true.
Kelsey: And like a bicycle without pedals, a pedaler, wouldn't move either. So.
Laila: I don't know I just feel like a leaf wouldn't
Stephanie: It seems like it is but
Laila: But I feel like in my mind I feel like it's energy! It's involved in a type of energy. I'm going to put yes-slash-no, because it's involved in a type of energy.

Additional physics discourse (about energy levels) from standard college texts



Energy as a substance



Energy is a kind of stuff (invisible, massless, etc.); objects are containers that can have such stuff in them. [5-8]

Grammatical indicators:
Energy is *in* objects; objects *have* or *get* energy.

Leaves in the street *have* energy.
They're *getting* wind energy.

SUPPORTS conservation, presence in objects, transfer, flow

Ontologically similar to **electric charge**:
permeates material objects and changes their quality without adding significant mass or volume



Variation: Fuel

- Literal material substance
- Stores "useful" energy
- Used up (transformed into non-fuel substances)

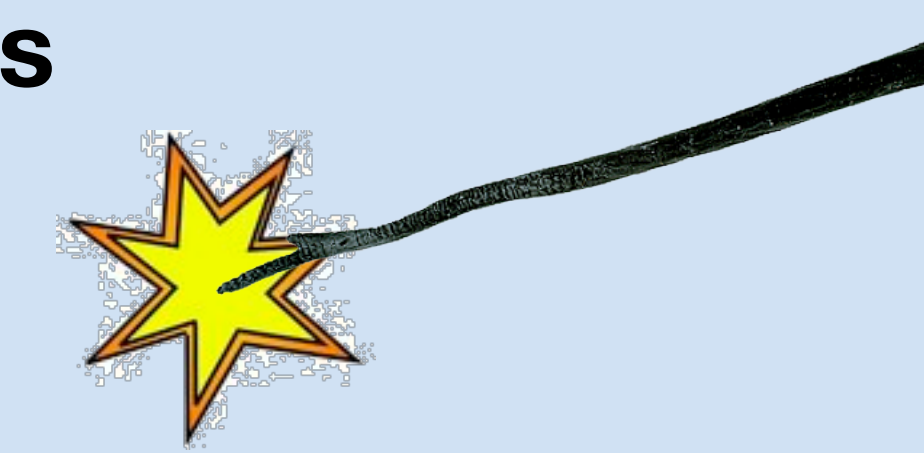


Wind can be a *source* of energy. You can *use* wind to *power* stuff. Leaves wouldn't move without *wind* as a bus wouldn't move without *gasoline*.



Can be productive if learners can think of fuel as *having* energy rather than *being* energy

Energy as a stimulus



Energy has an effect on objects: it makes things happen.

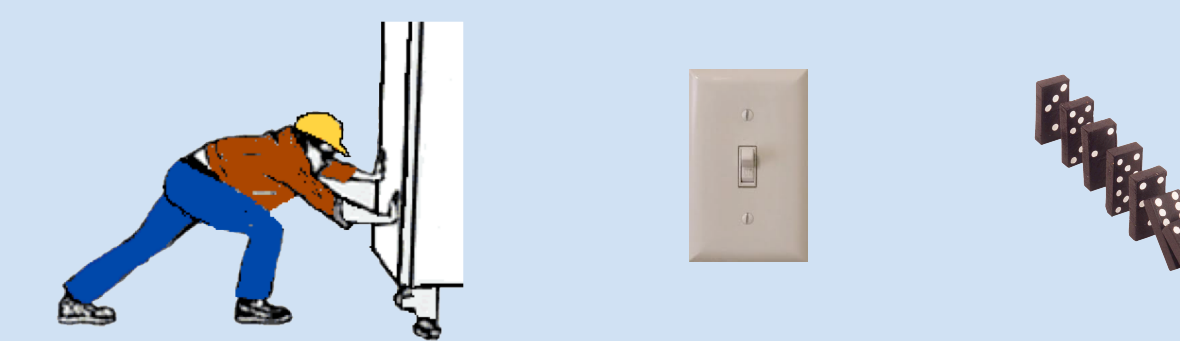
Grammatical indicator: Energy *acts on* objects.

Leaves in the street *are pushed by* energy.
Wind *is* energy.
Wind is like your *foot on a pedal*.
Leaves wouldn't move without *wind* as a bicycle wouldn't move without a *pedaler*.

SUPPORTS sociopolitical discourse (necessity of energy for activity), association of energy with forces ("ability to do work")

Ontologically similar to **force** or *agent that exerts force*:

General trigger or impetus for action



Variation: Activation/Fulfillment

Energy is a stimulus whose effects are specific to the object being stimulated:
steel becomes magnet, lights turn on, cars move, rubber stretches



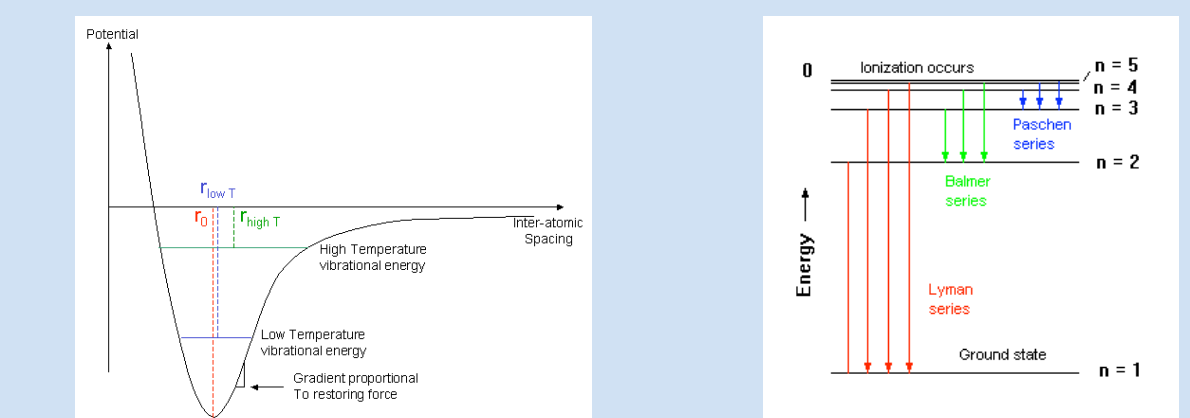
Energy as a vertical location



Energy is an ordered set of vertical locations. [5]

Grammatical indicator:
Objects are *at* energies.

The kinetic energy of the cart gets *higher* as the cart speeds up.
The electron makes a transition *from* the n=2 energy level *to* the ground level (n=1). [9]
One way an electron makes a quantum jump *up to* a greater energy level is to absorb a photon. [10]



SUPPORTS first law of thermodynamics (increasing energy takes effort)

Ontologically similar to **electric potential**

- ✦ **Multiple and overlapping metaphors** for energy complement one another in complex representations of physical phenomena. [4]
- ✦ **Each contributes to a valid understanding** of energy in physics.
- ✦ Instructors who appreciate each metaphor's **advantages and limitations** are better prepared to use them as a resource for instruction.