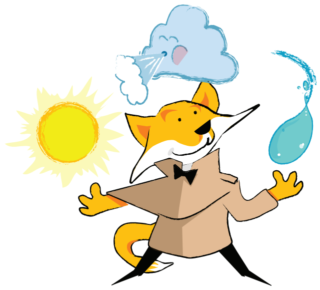


Lesson 4: Mapping Energy Increases and Decreases

Overview

In this lesson, students begin to consider how the amount of energy available changes as it is transferred from an energy source to the intended energy receiver. Students discover that not all of the energy available from a source is transferred to the receiver in useful forms.

Teacher Background

People have long put their knowledge of energy transfers and transformations to use in their everyday lives. Evidence of purposefully engineered energy use dates back as far as one million years ago when humans first began using fire to cook food, keep warm, and protect themselves from wild animals. Using fire for these purposes stands as one of the greatest energy breakthroughs of all time. Imagine what the world was like for early humans as they began using energy sources such as wood, water, and sunlight in progressively more sophisticated ways to accomplish various tasks. What would early humans think of the ways energy is used today?

While students continue to create and evaluate energy maps as they investigate everyday energy interactions, they also begin to consider how the amount of energy changes as it moves from an energy source to an energy receiver. Energy changes are discussed as decreases and increases as opposed to discrete quantities. It is intuitive that there would be a decrease in some form of energy in the source and an increase in some form of energy in the receiver as energy is transferred from one object to another. Before students are introduced to such ideas as "energy cannot be created or destroyed" (known as the First Law of Thermodynamics), energy efficiency and conservation, it is important for them to consciously consider what is happening to the amount of energy available as it is transferred. As students continue to map energy transfers and transformations, they begin to consider these in terms of how useful they are in achieving the intended effects for the intended receiver.

Key Ideas

- When an interaction occurs, there is a decrease in some forms of energy in the source and an increase in some forms of energy in the receiver as energy is transferred from one object to another.
- Not all the energy that goes into a device or process gets used in the way that people intend. As energy is transferred from one object to another, some transferred energy is likely to be transformed into heat.

Lesson Goals

Students will:

- identify the energy increases and energy decreases for an interaction in general terms.
- describe "intended" energy transfers and transformations and "unintended" energy transfers and transformations.

Vocabulary

energy efficiency: using less energy to perform the same function.

energy transfer: the movement of energy from one object, substance, or system to another.

energy transformation: energy changing forms.

2

Preparation

- Build and practice using a spool racer.
- Assemble the materials students will need to build spool racers. Determine how to effectively distribute and manage building materials.
- (Optional) Have a lamp with an incandescent light bulb on hand as a prop as students revisit the energy maps for this interaction.
- Make certain that there are enough colored markers for student pairs. Pairs will need a green and red marker to identify increases and decreases in energy.
- Copy Teacher Resource 4.1: Everyday Energy Interactions and cut the examples into individual strips. Each pair of students will need one example (one strip).
- Review Teacher Resource 4.2: Possible Responses for Everyday Energy Interactions to get a sense of the transfers and transformations students are likely to map. Please note that the resource is not exhaustive. Students may describe additional transfers and transformations.

- (Optional) Copy and precut Student Handout 4.2: Energy Map Words. Put word sets into resealable bags or envelopes for easy distribution.
- Prepare 20 beans in a paper cup for each pair of students.

Materials

Item	Quantity
Student Handout 4.1: Building a Rubber Band Powered Spool Racers	1 per pair
For spool racers: • rubber band • empty thread spool • paper clip • tape • metal washer • cotton swab	1 set per pair
Scientist's Notebook	1 per student
Teacher Resource 4.1: Everyday Energy Interactions	1 per class cut into strips
(Optional) Index cards (3" x 5") or Self-stick notes	10-15 per pair
Teacher Resource 4.2: Possible Responses for Everyday Energy Interactions	1 for teacher
Chart paper	1 piece per pair
Markers (make certain there are green and red markers for each pair in the set)	1 set per pair
(Optional) Student Handout 4.2: Energy Map Words (precut and put into resealable bags or envelopes)	1 set per pair
Dry beans, 20 per student pair in small paper cups (optional – to model units of energy)	1 bag per class
(Optional, as a props): Lamp with incandescent light bulb, bicycle or picture of bicycle	**1 per class**

Time Required: 2-3 sessions

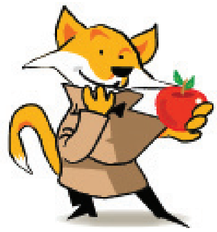
Session 1: Construct spool racer, discuss and map energy increase and decreases for spool racer

Session 2: Introduce "intended" and "unintended" energy transfers, identify energy transfers and transformations in every day situations, debrief

Session 3: Model energy efficiency

Connection to *Maine Learning Results (MLR)*, *Benchmarks for Science Literacy (BSL)* and *Science for All Americans (SFAA)*:

- People have invented ingenious ways of deliberately bringing about energy transformations that are useful to them.
  BSL (SFAA) 8C/M8** (6-8)
- Energy is required for technological processes such as taking apart, putting together, moving around, and communicating.
  BSL (SFAA) 8C/M7** (6-8)
- Use examples of energy transformations from one form to another to explain that energy cannot be created or destroyed.
  MLR D3 (6-8) i



Teaching The Lesson

Engage

1 Construct a spool racer and develop its energy map.

Provide each pair of students with a copy of Student Handout 4.1: Building a Rubber Band-Powered Spool Racer and the materials to construct a spool racer. Assist students as needed in the construction of their racers.

Alternatively, use the following video clip from the PBS program ZOOM to show students how to construct the racers but keep in mind some of the materials used in this lesson differ slightly than those shown in the clip:

http://www.teachersdomain.org/asset/phy03_vid_zsplcar/

Have students practice making their spool racers go. Students may need to spend some time adjusting the parts of their racer to get them to move.

Ask students to create an energy map in their scientists' notebooks that identifies the energy source(s), energy receiver(s), and energy forms.

Using students' input, construct an energy map similar to the one below for the spool racer on the board:

Energy Source		Energy Receiver/Source		Energy Receiver/Source		Energy Receiver/Source		Energy Receiver/Source
hand	→	rubber band (twisted)	→	spool	→	floor	→	air

Note: *Students may also include the sun and/or the food the person ate as an energy source/receiver. At this point, some may not include the interaction between the spool and its parts or the spool and the floor. Friction is discussed later in the lesson.*

2 Explore how the amount of energy available at the source and intended receiver changes as transfers and transformations occur.

Call the class together. Pose the following:

- *How does the amount of energy available at the source compare to the energy available at the intended receiver?*

Students begin to consider how the amount of energy available at the beginning of an interaction at the source compares to that available to make things happen at the end and that not all energy input results in energy output. Students will likely respond that not all of the energy available in the beginning of the interaction is available to keep making things happen for the intended purpose. Ask students how we know – what evidence do we have? (Students may say that the spool racer slows down and doesn't keep going on forever but may not offer up any explanations as to why.)

6

3 Demonstrate adding energy increases and decreases to maps.

Discuss how energy increases and decreases could be added to an energy map by asking students how the amount of energy available would change as energy is transferred and transformed in the spool racer.

A sample of how this might be noted in a map is shown below:

Energy Source		Energy Receiver	
rubber band	elastic (stored mechanical) →	spool	mechanical/ motion →
decrease in elastic energy		*increase* in or mechanical/ motion energy	

Reiterate that when interactions occur, energy is being transferred from a source to a receiver. The source is decreasing in some forms of energy and the receiver is increasing in some forms of energy.

Select another example, such as the lamp/incandescent light bulb example below, to map for students by writing the top portion of the map on the board.

Energy Source		**Energy Receiver**	
electrical outlet (power plant)	**electrical** →	lamp (incandescent light bulb)	**light** → **and** **heat** →
decrease in electrical energy		*increase* in thermal and radiant energy	

Ask for student input how to note changes in energy in this example. Students should say that "decrease in electrical energy" should be added below "electrical outlet/power plant" and "increase in thermal and radiant energy" (heat/light) should be added below "lamp/bulb."

4 Practice identifying energy increases and decreases (changes).

Have students work in groups of 4. Ask students to review the energy maps they made for the interaction stations. Explain that they are to select 3 station maps to discuss and identify the energy increases and energy decreases. Tell students they need to be prepared to share with the class a specific example of how energy was increasing and decreasing between any two parts of an interaction.

(Remember that for these examples, students have already identified the energy sources, energy receivers, and forms of energy involved in the transfers.)

Have students take turns reporting out specific examples of energy increases and decreases.

> **Note:** *Recognizing that energy sources decrease in some forms of energy and that energy receivers increase in some forms of energy will most likely be intuitive to students. This exercise is intended to stimulate students' thinking about what happens to the amount of energy in sources and receivers in a semi-quantitative way. It is important as students begin to transition into considering why it appears that energy is "lost" as it is transferred from an energy source to an energy receiver.*

Explore

5 Develop the idea of using energy for intended effects.

Have the lamp with the incandescent light bulb available for this discussion. Consider having the energy maps for the incandescent light bulb available for students as a reference.

Ask students: *How do people want energy used when an incandescent light is turned on? In other words, what was the incandescent light bulb created to do? What energy transfers are desired?* Students should recognize that the light bulb was designed to emit light. The desired or engineered transfers involve electrical energy from the power plant being transferred to the light bulb. Electrical energy from the power plant is transformed into radiant (light) energy in the light bulb.

Ask students: *Are there any transfers and transformations that are undesirable or unwanted in the incandescent light bulb?* Students should notice that heat transfers also occur and these are unintended. Mention to students that often energy is transferred to objects or places or transformed into other forms that are unintended.

Energy transfers are often challenging to detect and/or control. In the case of the incandescent light bulb, the "unintended" effect is fairly obvious for us to observe; we can feel the incandescent light bulbs becoming noticeably warm. Consider demonstrating this effect. Other types of light bulbs, compact fluorescent light (CFL) bulbs, for example, have been engineered to reduce the amount of heat that is given off. Tell students that energy in the form of heat is almost always one of the transformations that occurs in an interaction and is one that is generally unintended for a variety of reasons. Ask students why heat would be an "unintended" transfer. Students may suggest that heat can cause mechanical devices to "overheat," damage parts, and cause a device to malfunction. Students may not recognize that heat is not "desired" or "useful" in most instances in the sense that it cannot easily be transformed to another form; heat tends to dissipate into the surrounding environment making it quite challenging if not virtually impossible to "repurpose."

6 Identify the energy transfers and transformations in everyday situations including those in common household devices.

Distribute to each pair of students one of the descriptions of an everyday energy interaction listed on the Teacher Resource 4.1, a piece of chart paper, and a marker. Ask students to affix the example to the top of the chart paper or write the example at the top of their chart paper with a marker. Instruct students to create energy maps that identify as completely as possible the:

- energy source(s)
- energy receiver(s)
- energy transfer(s)
- forms of energy
- increases and decreases of energy

(Optional) Students may prefer to use index cards or self-stick notes to organize these multi-step, more complex energy interactions. Students can write the names of the objects or devices specific to their situation on the index cards or self-stick notes. Each student pair would need approximately 10-15 index cards or self-stick notes. Students may also find using a set of precut energy words found on Student Resource 4.2: Energy Map Words helpful. Make sure students understand that the task is not to "match up" or necessarily use all the words but rather use them to construct draft maps without having to erase or cross out. Using them may make it easier to reorganize their thinking. When students are ready to construct the final version of their maps, they may choose to fasten the manipulatives to the chart paper instead of writing the words with a marker.

Make certain that students recognize that the interactions involve multiple transfers – some of which may be difficult to observe or detect. Students should identify as many as they can. Remind students that an energy receiver can become an energy source in a multi-step, complex interaction. Circulate among pairs of students as they are working, listen to their ideas, and address questions.

After pairs complete their energy maps, give each pair one red and one green marker. Instruct students to underline the "intended" effects in green and the "unintended" effects in red.

Reflect And Discuss

7 Debrief students' energy maps.

Have students post their maps. Discuss with students the patterns that they notice in the maps. Students should be able to identify heat as an undesired effect in virtually all of the examples. Mechanical/motion (observable by sound) and light are also sometimes a common "undesired" effect.

Tell students that they will continue to investigate "undesired" and "unintended" effects in future lessons as these are at the heart of thinking about efficient energy use. Instruct students to leave their maps up so that they can be referred to in future activities.

8 Engage students in a "quick write."

Ask students to refer to and consider the energy transfer maps they created in this lesson. Post the prompts below on the black/white board or on an overhead and ask students, individually and their scientists' notebooks, to do a quick write about the following:

- *Can energy "disappear?"*
- *Can energy be created?*

Provide reasoning and specific examples to support your answer.

Briefly discuss students' ideas.

> **Note:** *The idea here is not necessarily to have students come to an agreement or definitive answer to the prompts, but rather to surface students' ideas. The two prompts are phrased similarly to the First Law of Thermodynamics which states "energy cannot be created or destroyed." Many students have heard this idea and can recite it, but struggle when pushed to explain the scientific ideas behind the statement. Students may say that energy cannot be created or destroyed but do they really believe it? This idea is counterintuitive. As students look back at their energy maps and discuss everyday energy interactions, it appears that some energy gets "used up" or is "lost." For now, it is acceptable to leave students with some uncertainty, putting the focus on getting ideas out to stimulate thinking.*

9 Discuss the energy changes in a ball-floor interaction.

Show students a tennis ball. Hold it out as if it were going to be dropped. Ask students if the ball has energy. Students should recognize that the ball has potential energy. More specifically, students may recognize that the ball has gravitational potential energy due to its position and elastic energy (stored mechanical) due to its materials. Students may refer to their forms of energy cards if they are having difficulty deciding whether or not the ball has energy.

Ask students to suggest some ways the potential energy of the ball could be transformed to kinetic energy. (Students may say that the ball could be thrown, dropped, hit with another object, etc.)

Say to students: *Let's say that right now the ball has 100 units of energy that can be used to make something happen (in this case, bounce the ball). If energy cannot be created or destroyed, how many units of energy are available to make something happen ("bounce")?* (Students should recognize that 100 units are available.) *If all of 100 units were transferred to the ball as it is bounced, how high do you think the ball would bounce?* (Help students recognize that if all of the energy is transferred to the ball, the ball would bounce as high as its release height.) Ask students to predict how high the ball will bounce when it is released and then drop the ball as students observe what happens.

Discuss with students why the ball does not bounce back to the same height at which it was dropped by focusing on the energy transfers and transformations that occur. Students should recognize that part of the 100 available units of energy was transferred to the floor as heat and part of the 100 units of energy available was transferred to the ball for the bounce and sound. Some of the energy also goes into temporarily changing the shape of the ball. As the ball hits the floor, the floor "pushes" back, squashing the ball into a new shape. The molecules of the ball are stretched apart in some places and squeezed together in others. The molecules in the ball collide and rub across each other. How much stretching and squeezing of the molecules in a ball depends its material.

> **Note:** *Students may be interested in learning more about how ball's bounce using the Exploratorium's Sport! Science: Why Do Balls Bounce? which features photographs by MIT professor Dr. Harold Edgerton. Dr. Edgerton used stroboscopic photography to find out more about how things work.* http://www.exploratorium.edu/sports/ball_bounces/ballbounces2.html

Make certain that students recognize that the ball demonstration is an oversimplified model but one that can help in understanding what happens to available energy as it is transferred.

10 Revisit the idea: *Can energy disappear? Can energy be created?*

Explain to students that these two questions are challenging to answer just by doing investigations in the classroom. Energy is difficult to measure quantitatively with tools available in classrooms. Tell students that scientists have considered these questions and through very careful experimentation using precise tools and methodologies have concluded that energy can neither be created nor destroyed. It can only be converted among various forms. This idea is known as the First Law of Thermodynamics. This law is also known as the Law of Conservation of Energy and essentially means that energy in = energy out. The energy "score" is always equal.

Have students revisit the energy maps of everyday energy interactions. Point to some of the maps and ask students: *How can we have increases and decreases of energy going on at the same time? Do these energy maps support or contradict the First Law of Thermodynamics?* Have students discuss their ideas in small groups before debriefing their ideas as a full group. (Students should recognize these energy maps do not contradict or confirm the Law of Conservation of Energy but rather show the way energy was moving from object to object. What is challenging is for people to observe, measure, and account for where energy is coming from and where all of it is going.)

11 Model energy transfers using dry beans.

Reinforce the conservation idea by doing some "bean counting" to depict energy transfer and transformations using the spool racers students constructed. Distribute a paper cup with 20 beans to each pair of students. Begin by reviewing the Law of Conservation of Energy — no energy is created or destroyed in the interactions of the spool racer. This means that the exact amount of energy decrease in the rubber band shows up as an energy increase somewhere else.

12 Model this increase and decrease by asking students to imagine that the twisted rubber band has 20 units of elastic (stored mechanical/motion) energy. After the spool racer is released, the rubber band has 0 units of elastic (stored mechanical) energy. How much energy would you expect to be transferred to the spool racer, moving it forward? Let's say 2 units of energy goes toward moving the spool racer forward (mechanical/motion energy) and 18 of units are transferred to the racer's parts, floor, and surrounding air as heat. Ask students to show how energy is transferred/transformed by moving the representative number of beans into smaller piles. Remind students that what is important to remember is that the Law of Conservation of Energy tells that all of the units of energy are accounted for – what goes in is equivalent to what goes out.

12 Introduce the idea of energy efficiency.

Ask students for suggestions on how to change their spool racers to make them go a greater distance using the same number of rubber band twists. Students may suggest a number of things that they could do such as adding tape to the edges of the spool, warming up the rubber band, adding additional washers to the band, etc. Ask students to imagine that their modifications made the spool racer go further on the same number of twists. Ask students what they might say about the way the improved racer uses its available (potential/elastic/stored mechanical) energy. Help students develop the idea that the improved racer is more "energy efficient" than the first because it "does more" with the same amount of energy.

The twisted rubber band in the second version could transfer its 20 units of energy differently, perhaps transferring 3 units of energy toward moving the spool racer forward (as motion or mechanical energy) and 17 units to the spool racers, floor, and surrounding air as heat and sound.

(Optional) Tell students that energy efficiency is often expressed as the following ratio:

$$\text{efficiency} = \frac{\text{energy output}}{\text{Energy input}} \times 100\%$$

For the car examples:

$$10\%\ \text{efficient} = \frac{\text{2 energy units (“intended” energy output)}}{\text{20 energy units (energy input)}} \times 100\%$$

$$15\%\ \text{efficient} = \frac{\text{3 energy units (“intended” energy output)}}{\text{20 energy units (energy input)}} \times 100\%$$

(Optional) Use a bicycle or other familiar device to provide students with additional practice in accounting for changes in energy using their beans. Use a bicycle as a prop, if available. Have students use 20 beans to represent the bicyclists' breakfast. (Note: One could use this as an opportunity to connect with nutrition.) Ask students where the energy could go besides moving the bicycle and its rider forward? Have students examine the bicycle, paying particular attention to the flow of energy through the bicycle's parts. Ask students what could slow the bicycle/person down? As students make suggestions, have students set aside a representative number of beans. For example, students could set aside 3 beans for a low amount of air in the tires, 4 beans for riding on a rough road, 5 beans for the rider sitting upright on the bike instead of tucking the body in, etc. Calculate the efficiency of the bicycle based on how many beans students have left at the end.

Discuss ways to improve the efficiency of the bicycle. As students make suggestions (pumping up the tires, lubricating the chain, etc.) have them move a representative number of beans into the “available” pile. Recalculate the efficiency.

13 Bring the lesson to a close.

Explain that in the next few lessons they will be examining energy efficiency in different contexts including those on a much larger scale (looking at the energy transfers and efficiency on large-scale situations). Students will also relate efficiency to energy conservation practices.

Extension

Students may:

- review the How Stuff Works "Elements of Physics: Energy Exchanges" online video clip http://videos.howstuffworks.com/hsw/10794-elements-of-physics-energy-exchanges-video.htm focusing on the last minute of the 3 minute clip. Consider *Why is it important that cars have cooling systems?*
- learn about infrared images. View an image that has been heated by friction from the road: http://coolcosmos.ipac.caltech.edu/cosmic_games/what/img10.html or view an image of someone rubbing their hands together: http://www.youtube.com/profile?user=nutscode&view=videos (worldofwarmth.com)
- 14 consider the energy transfers in this 2003 Rube Goldberg Honda advertisement. What are the desired and undesired effects? http://autorepair.about.com/od/glossary/a/honda_rube.htm
- learn how artist Vollis Simpson creates kinetic sculptures and whirligigs using bearings in all of his spinning pieces so that they move smoothly. Try the investigation featured on the Science Museum of Minnesota's website: http://www.thinkingfountain.org/f/friction/friction.html
- find out how energy is measured: http://www.uwsp.edu/cnr/wcee/keep/Mod1/Whatis/energymeasures.htm
- find out more about how a particular device works. Websites such as How Stuff Works (www.howstuffworks.com) or print resources like David Macaulay's *The Way Things Work* can be useful. Be aware that depending on the device and the resource, this information may overwhelm or confuse students as they consider energy transfers.
- play energy conversion dominoes described on describe on pages 5-7 of School's Power Naturally Lesson #4: www.powernaturally.org/Programs/pdfs_docs/4_PV-games.doc Some of the dominoes would need to be modified to reflect the forms of energy introduced to students in *Energy for Maine*. Substitute devices that would be unfamiliar to students with more familiar ones, but make sure examples include a variety of energy forms.

- take the Design Squad Challenge. Build a car that goes really far, really fast. The challenge: use a rubber band as the power source and the car can only have two wheels. http://pbskids.org/designsquad/projects/rubber_band_car.html

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives will come to interested schools, free of charge, to guide and support the concepts in lesson and have several programs that supplement concepts in this lesson:

- Electricity and the Environment including Icebreaker with comparison of CFL and incandescent light bulbs. Students become aware of electricity in our awareness session. They make electricity from an apple in the Apple Battery experiment and then learn how electricity is made in the real world. Next, with MEEP's PV Fan and Mini-Wind Turbine activities, they make electricity from renewable resources. These activities can be combined with the Great Energy Debate and Energy Jeopardy in a full-day workshop.

More information can be found on the MEEP website: www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

KEEP's Website:
http://www.uwsp.edu/cnr/wcee/keep/Mod1/Rules/EnConversion.htm

Spool Racers:
http://www.pbs.org/saf/1103/teaching/teaching3.htm
http://www.teachersdomain.org/asset/phy03_vid_zsplcar/

Teach Engineering Activity: Energy Conversions
http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml

Urban Heat Islands: An Introduction to Energy Transfer and Transformation by Kate Porter, Cornell Science Inquiry Partnerships, Cornell University (NSF) http://csip.cornell.edu