SECTION 4.3 INTRODUCTION

4.3 Explore

What Simple Machines are Combined to Make Complex Machines?

◀ *1 class period**

Overview

Students apply what they have learned to identify and describe simple machines that make up complex machines. They describe the mechanical advantage of each simple machine and the complex machine. Students are then introduced to the idea of mechanical energy and the conservation of energy.

*A class period is considered to be one 40 to 50 minute class.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley.	Students should be able to apply what they have learned to identify and describe complex machines in terms of simple machines.
Energy cannot be created nor can it be destroyed, it can only be changed from one form to another through energy transformations.	Students should be able to state that energy cannot be created or destroyed, but can be transferred from one object to another and transformed from one type to another.

Homework Options

Reflection

- **Science Content:** Describe how energy is transferred or transformed when lifting the cart and 1-kg mass up 20 cm. *(Students should be able to describe how they have to use their energy to move the cart and mass. Their energy is transferred to the cart and mass and transformed into kinetic energy and potential energy.)*

Preparation for Answer the Big Question

- **Science Process:** Create a design plan to move the crate up the cliff using the class's criteria and constraints as a guide. *(The purpose of this homework is to have students come prepared with ideas for a design plan to discuss in their groups.)*

NOTES

SECTION 4.3 IMPLEMENTATION

◀ *1 class period*

4.3 Explore

What Simple Machines are Combined to Make Complex Machines?

5 min.

Introduce the section.

4.3 Explore

What Simple Machines are Combined to Make Complex Machines?

You investigated how simple machines can help to move big things. You also learned that it often takes two or more simple machines, combined together into a complex machine, to get big jobs done. In the last section, you read about how simple machines can be combined to make complex machines. Now, you are going to revisit some more of the machines that you may have seen at the construction site or in the video. You will also think about some machines that you are familiar with from everyday life. Working with your group, you are going to identify the simple machines that make up each machine and describe how they work together.

Procedure

For each machine pictured at left and on the next page, answer the following questions:

1. What is the machine designed to do?
2. List all of the simple machines you see that make up the complex machine. What is the mechanical advantage of each simple machine?
3. Make a list of other simple machines that you think might make up the complex machine but you cannot see in the picture. Describe what you think each of them might do and what you think their mechanical advantage is.
4. What is the mechanical advantage of the complex machine?
5. What is the name of the machine?

MBT 104

Project-Based Inquiry Science

Engage

Remind students of the construction site they visited and/or the construction video they saw. Ask students what their favorite machine was, why, and what simple machines they think it is composed of. Record a few of the students' ideas.

Then let students know that they will be identifying and describing simple machines that make up complex machines like those they saw.

Procedure

20 min.

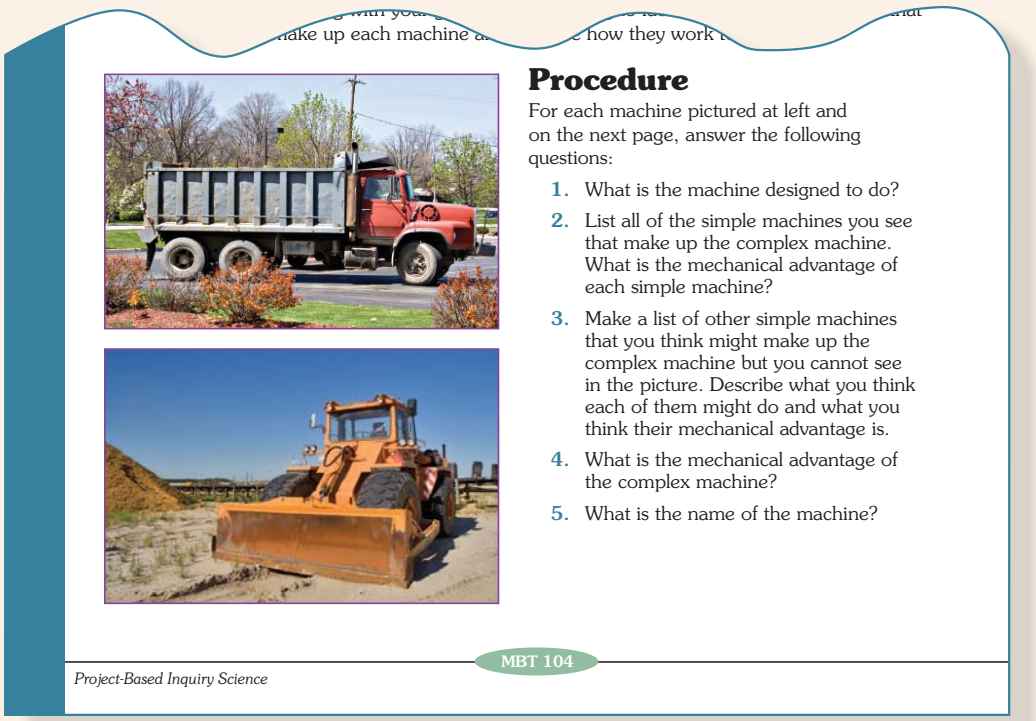
Have groups answer the questions to identify and describe the simple machines that make up the complex machines shown. Then hold a class discussion.

META NOTES

Having students make connections between what they are learning and everyday items or experiences helps them to see the importance and relevance of science in our society, and makes the learning experience more meaningful to the students.

META NOTES

Students are applying what they have learned to identify and describe how simple machines work together to form a complex machine. Students should also be able to describe the mechanical advantage. This is similar to what they did in the last section. At this point students should not need much guidance. If they do, you may want to review some of the main ideas of the Unit.



make up each machine a… how they work t…

Procedure

For each machine pictured at left and on the next page, answer the following questions:

1. What is the machine designed to do?
2. List all of the simple machines you see that make up the complex machine. What is the mechanical advantage of each simple machine?
3. Make a list of other simple machines that you think might make up the complex machine but you cannot see in the picture. Describe what you think each of them might do and what you think their mechanical advantage is.
4. What is the mechanical advantage of the complex machine?
5. What is the name of the machine?

MBT 104

Project-Based Inquiry Science

△ Guide and Assess

Ask groups to answer the five questions for each of the six images shown and let them know that a class discussion will follow. Then have groups get started.

Monitor groups' progress and refer them to their previous investigations and the previous section. Help students identify the simple machines by asking them questions such as:

- How does this machine move the object? What types of simple machines move the object in that way?
- How does the machine change the direction of force? What types of simple machines change the direction of force in that way?
- What is the tradeoff? Is the distance over which the force is applied increased? If so, what happens to the force needed to move the object?

△ Guide

Hold a class discussion.

When groups are done, begin a class discussion on their responses to the six images. Encourage groups to discuss what was the same and different about their responses for a given image.

△ Guide and Assess

Students may not have the same responses as those listed below. Guide students to the core ideas listed.

META NOTES

You may want to have each group present to the class their responses for a given image.

Picture 1: Dump Truck

1. The machine is designed to carry, move, and unload large amounts of material.
2. The wheels that help drive the load around are wheels and axles. A lever is used to raise and lower the bed of the truck, and the bed of the truck becomes an inclined plane when it is raised to help unload the materials. The mechanical advantage of the wheel and axle is to decrease the force we need to apply to move the material. The mechanical advantage of the lever is to decrease the amount of force we need to apply to move the bed of the truck and it changes the direction of the force. And the mechanical advantage of the inclined plane is to decrease the amount of force needed to unload the material from the truck.
3. Other simple machines that you may not see are pulleys (fan belt, timing belt under the hood), levers (involved perhaps with the pistons), wheels and axles (e.g., steering wheel, gears). All of these decrease the amount of force needed to be applied.
4. The overall mechanical advantage of this complex machine is that it decreases the amount of force needed to be applied.
5. This machine is a dump truck.

Picture 2: Bull Dozer

1. The machine is designed to lift and move material.
2. The wheels that help move the load are wheels and axles. A lever is used to raise and lower the front end, a wedge is at the base of the front end to help push the scoop under the material, but it does not dig like a shovel. The mechanical advantage of the lever is to reduce the amount of force needed. The mechanical advantage of the wedge is to change the direction of the force to help push the material upward.
3. Other simple machines that you may not see are pulleys (fan belt, timing belt under the hood), levers (involved perhaps with the pistons), wheels and axles (e.g., steering wheel, gears). All of these decrease the amount of force needed to be applied.

META NOTES

The main simple machines in a conveyor belt are gears a type of wheel and axle. Unfortunately it is not easy to see this in the image so students may only list the inclined plane.

4. The overall mechanical advantage of this complex machine is that it decreases the amount of force needed to be applied and changes the direction of the force.
5. This machine is a bull dozer.

Picture 3: Conveyer Belt

1. The machine is designed to move material to different locations.
2. There are wheels and axles that make up the gears in a conveyer belt. The mechanical advantage of the gears in this situation is to redirect the force. There is also an inclined plane in the image whose purpose is to redirect the force and decrease the force. (You might note that the angle of the inclined plane is probably optimized so that the box also does not topple over).
3. Students may think that other machines may be involved like a lever or a pulley to place the boxes on the conveyor belt.
4. The overall mechanical advantage of this complex machine is that it redirects the amount of force needed.
5. This machine is a conveyor belt.

Picture 4: Snow Plow

1. The machine is designed to move material.
2. The wheels that help move the load are wheels and axles. A lever is used to raise and lower the front end, a wedge is at the base of the front end to help push the scoop under the snow, and then redirect the snow upward, and then it is then pushed to the side. The mechanical advantage of the lever is to reduce the amount of force needed. The mechanical advantage of the wedge is to change the direction of the force to help push the material upward.
3. Other simple machines that you may not see are pulleys (fan belt, timing belt under the hood), levers (involved perhaps with the pistons), wheels and axles (e.g. steering wheel, gears). All of these decrease the amount of force needed to be applied.
4. The overall mechanical advantage of this complex machine is that it redirects the force needed to be applied to move the snow and it reduces the force we need to apply.
5. This machine is a snow plow.

Picture 5: Roller Coaster

1. The machine is designed to lift and move people.
2. The wheels that help move the load are wheels and axles. An inclined plane is used to help lift the people. The mechanical advantage of the inclined plane is to reduce the amount of force needed. The mechanical advantage of the wheel and axle is to redirect the force.
3. Other simple machines that you may not see are pulleys and wheels and axles, used to run the car. The wheel and axle may be part of the motor or gear system which could be used to change the size of forced needed to be applied, the pulleys might be part of a belt system whose advantage may just be to redirect a force.
4. The overall mechanical advantage of this complex machine is that it decreases the amount of applied force needed and it changes the direction of the force.
5. This machine is a roller coaster.

Picture 6: Bicycle

1. The machine is designed to move a person.
2. The wheels and gears are wheels and axles to help reduce and redirect the applied force. The gears might be thought of as a pulley when the chain is looped over them that help to redirect the force. The pedals are attached to a lever that turns a pulley to reduce the applied force needed and redirect it.
3. Other simple machines that you may not see are screws used to hold the bike together which redirect the force. There are levers to switch gears and brake, that reduce the applied force needed and redirect it.
4. The overall mechanical advantage of this complex machine is that it decreases the amount of force needed to be applied, and changes the direction of the force.
5. This machine is a bicycle.

After discussing each image, emphasize that complex machines (sometimes called compound machines) are made up of two or more simple machines that work together and that all machines have mechanical advantage.

Reflect

10 min.

Have students design and discuss a complex machine for completing an everyday job.

META NOTES

Having students apply what they have learned to their own life experiences makes the learning process more meaningful for the students.

META NOTES

There are many possible extensions to this. You could extend this to have students create a poster of their machine as homework. You could have students build a model. You could have students build a prototype of the machine.




Reflect

Think of a task that you do everyday. It may be washing the dishes, cleaning your room, or carrying your backpack. Design a complex machine, made up of at least two simple machines that could help you do the job more easily. Make a drawing of your machine and name it. Write a brief description of each simple machine in your complex machine. What is the mechanical advantage of each? Explain what the mechanical advantage of your complex machine is and how it makes getting the job done easier for you.

What's the Point?

It is important to carefully observe combinations of simple machines. When you observe a machine's parts and watch how it works you can find the simple machines in the complex machine. By looking at each part of the machine, it is easier to figure out how the machine actually helps do work. Then it is possible for mechanical advantage to be determined. Mechanical advantage, the trade-off of force for distance, is different for all machines and makes it easier to move large, heavy objects.

○ Engage

Begin by asking students what are some everyday physical tasks that they do that they wish they had some machine for so that the tasks were not so difficult. Record students' ideas.

△ Guide

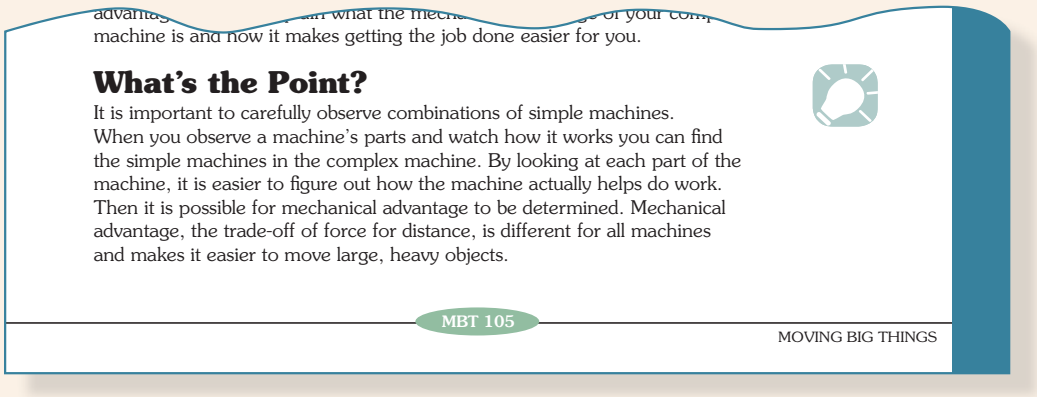
Let students know that they are going to design a complex machine to help them complete one of their everyday tasks. Let students know that they will need to make a drawing of their machine and name it. They will also need

to write a brief description of each simple machine that makes up their complex machine, and their mechanical advantage. They will also have to describe the mechanical advantage of their complex machine and how it makes getting the job done easier.

△ Guide and Assess

Assess students' progress and guide students as needed. Ask students questions such as how the simple machines work together to complete the task and how they change the amount of force that the student needs to apply. You might also want to ask questions about the tradeoff between the applied force and the distance it needs to be applied through.

Then hold a brief class discussion on some of the students' machines.


machine is and how it makes getting the job done easier for you.

What's the Point?

It is important to carefully observe combinations of simple machines. When you observe a machine's parts and watch how it works you can find the simple machines in the complex machine. By looking at each part of the machine, it is easier to figure out how the machine actually helps do work. Then it is possible for mechanical advantage to be determined. Mechanical advantage, the trade-off of force for distance, is different for all machines and makes it easier to move large, heavy objects.

MBT 105

MOVING BIG THINGS

What's the Point?

0 to 5 min.

Point out that all complex machines are made up of the six simple machines and that looking at each part of the machine makes it easier to figure out how the machine helps do work.

NOTES

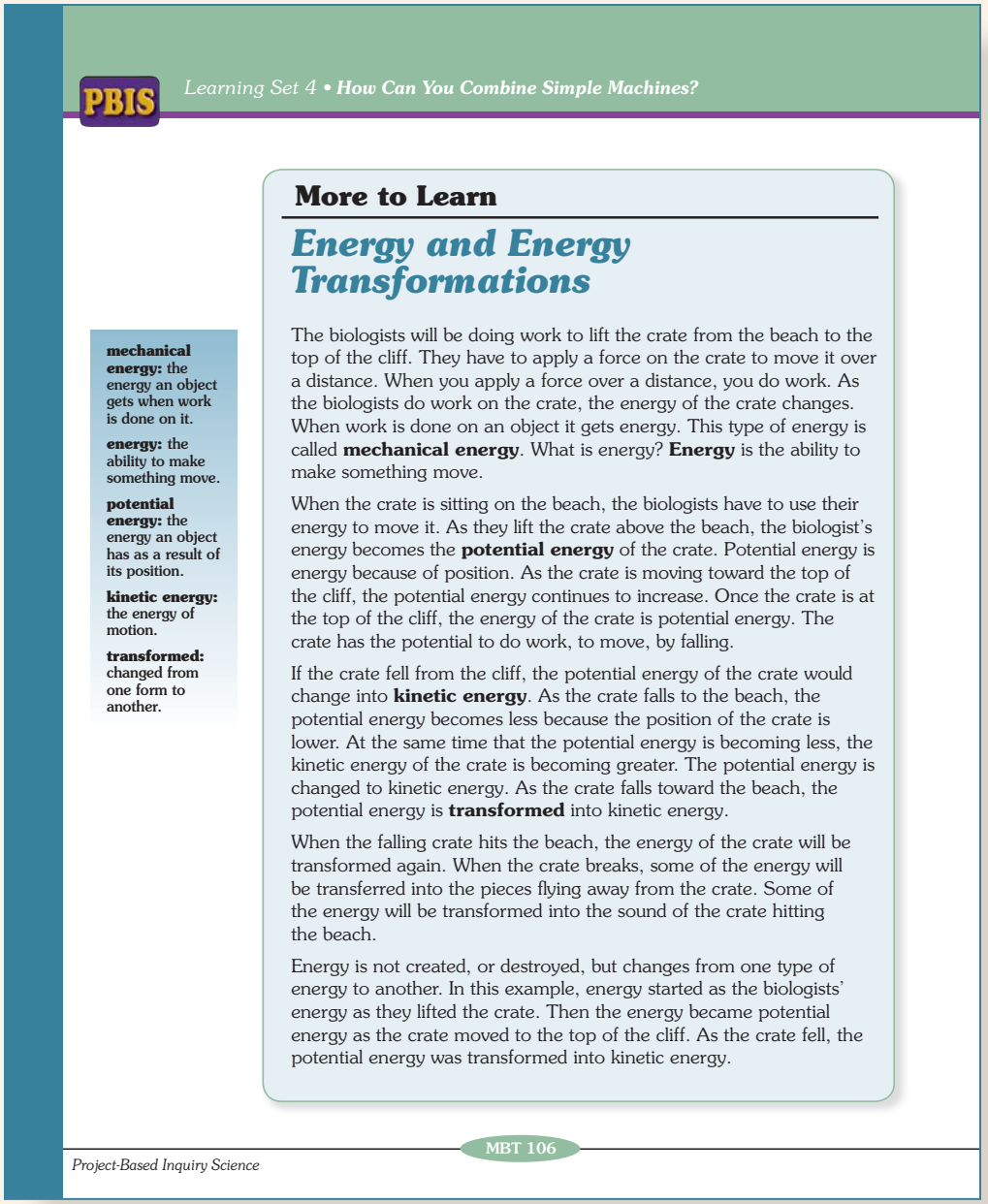
More to Learn

10 min.

Introduce students to the ideas of energy transfer, transformation, and conservation.

META NOTES

This segment is designed to provide students with information that is commonly discussed when discussing machines. However, it is not the intent to provide students with a robust understanding of energy. The concepts of energy transfer, transformation, and conservation are the focus of a different unit in PBIS.



PBIS Learning Set 4 • How Can You Combine Simple Machines?

More to Learn

Energy and Energy Transformations

mechanical energy: the energy an object gets when work is done on it.

energy: the ability to make something move.

potential energy: the energy an object has as a result of its position.

kinetic energy: the energy of motion.

transformed: changed from one form to another.

The biologists will be doing work to lift the crate from the beach to the top of the cliff. They have to apply a force on the crate to move it over a distance. When you apply a force over a distance, you do work. As the biologists do work on the crate, the energy of the crate changes. When work is done on an object it gets energy. This type of energy is called **mechanical energy**. What is energy? **Energy** is the ability to make something move.

When the crate is sitting on the beach, the biologists have to use their energy to move it. As they lift the crate above the beach, the biologist's energy becomes the **potential energy** of the crate. Potential energy is energy because of position. As the crate is moving toward the top of the cliff, the potential energy continues to increase. Once the crate is at the top of the cliff, the energy of the crate is potential energy. The crate has the potential to do work, to move, by falling.

If the crate fell from the cliff, the potential energy of the crate would change into **kinetic energy**. As the crate falls to the beach, the potential energy becomes less because the position of the crate is lower. At the same time that the potential energy is becoming less, the kinetic energy of the crate is becoming greater. The potential energy is changed to kinetic energy. As the crate falls toward the beach, the potential energy is **transformed** into kinetic energy.

When the falling crate hits the beach, the energy of the crate will be transformed again. When the crate breaks, some of the energy will be transferred into the pieces flying away from the crate. Some of the energy will be transformed into the sound of the crate hitting the beach.

Energy is not created, or destroyed, but changes from one type of energy to another. In this example, energy started as the biologists' energy as they lifted the crate. Then the energy became potential energy as the crate moved to the top of the cliff. As the crate fell, the potential energy was transformed into kinetic energy.

MBT 106

Project-Based Inquiry Science

Engage

Begin by connecting work to the challenge, then you will connect energy to work.

TEACHER TALK

"So far we have learned that when a force acts on an object and the object moves a distance in the direction (or opposite the direction) of the force, then work has been done. Work is a quantity calculated by the amount of force in the line of motion multiplied by the distance the object moves.

How can we determine the amount of work the biologists will need to do to move the crate up the cliff? *(The crate can be moved at a constant speed up the cliff, so the force needed to move the crate is equal to the weight. Note however, that a force greater than the weight is needed to get the crate moving. The approximate amount of work the scientists will need to do is equal to the weight of the crate times the height of the cliff.)*

Will machines reduce the amount of work? *(No, they can never reduce it, there is a tradeoff between reducing the force and increasing the distance. Ideally the work done by a machine is the same as without the machine, realistically more work is done by the machine.)*"

META NOTES

Kinetic friction or the force of friction between two objects interacting by sliding over each other is an example of a force that does work opposite to the motion and does not have the ability to move the object. This type of friction always does negative work and transforms mechanical energy (kinetic energy) into thermal energy.

Then connect work and energy.

TEACHER TALK

"When work is being done on an object, the object moves. If it moves it has energy—motion energy. The energy of motion has a special name—it is called kinetic energy. Kinetic energy is a type of mechanical energy. For example, once the crate begins to move upward it has kinetic energy.

When work is done on an object, the object may also store energy because of its location. Stored energy due to where an object is located is called potential energy. Potential energy is a type of mechanical energy too. For example, as the crate increases its distance above the ground, it increases its potential energy. An object above the ground has potential energy because it has the potential to do work. It has the potential to move because the force of gravity is acting on it and it has the potential to fall.

So whenever work is done on an object, the object has mechanical energy. And mechanical energy is the ability to do work or the ability to move something (or stop something from moving)."

Then describe how energy is transferred and transformed.

META NOTES

You might want to let students know that Einstein's theory of relativity states that mass (matter) is just a type of energy and can be transformed into other types of energy. This has been proven many times.

TEACHER TALK

"Imagine the crate just reaching the top of the cliff. What type of energy does it have? *(Potential energy.)*

Imagine that the rope breaks and the crate falls. What happens to the potential energy as the crate falls? *(The potential energy decreases.)*

What happens to the motion of the crate? *(The crate speeds up as it falls down.)*

The crate speeds up as it falls down and it increases in its kinetic energy (which is proportional to how fast the object is going). So the falling crate is losing potential energy and gaining kinetic energy. It turns out that the potential energy is being transformed into kinetic energy as the crate falls.

Just as the crate reaches the beach it no longer has potential energy, just kinetic energy. As the crate hits the beach that kinetic energy is transformed into the energy used to break the crate, move the sand out of the way, make the noise, and warm up the surroundings. *(Eventually all the energy ends up as thermal energy.)*"

Then discuss conservation of energy.

TEACHER TALK

"It turns out that the energy can never be created nor can it be destroyed. It can be transformed. It can be transferred. But it cannot be made or taken away. All the energy in the entire universe is all the energy there will ever be. When a quantity doesn't change, scientists call it conserved. Energy is conserved."

Then ask students to describe what happens in terms of work and energy when they push a book across their desk. As they push the book, they are doing work on the book (and friction is doing work on the book, but opposite to the book's motion). The book moves so it has kinetic energy. Where did that energy come from? It came from the students pushing it. They transferred energy to the book. In the process, they transformed some of the potential energy stored in them to move their hand, which transferred energy to the book to move the book.

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
Energy cannot be created nor can it be destroyed, it can only be changed from one form to another through energy transformations.	**ASK:** Describe what happens to the energy of the crate as it falls from the cliff, and when it crashes into the beach. **LISTEN:** Students should describe how the crate had potential energy that decreases as the crate falls, but this energy is transformed into kinetic energy as it speeds up. So the crate doesn't gain or lose energy—the energy stays the same. Just before the crate hits the beach, it only has kinetic energy. When the crate crashes into the beach, all the energy is transformed to other kinds of energy used to push away the sand, warm up the surroundings, make sound, etc.

Teacher Reflection Questions

- What difficulties did students have with the concepts of energy?
- What evidence do you have that students collaborated within their groups and built on each other's ideas?
- How did you manage the *More to Learn* segment on energy? What ideas do you have for next time?

NOTES