SECTION 2.5 INTRODUCTION

2.5 Revise Your Explanation

◀ *1 class period**

How Does an Inclined Plane Do Its Job?

Overview

Students review what they have learned about how an inclined plane works and revise their explanations of how an inclined plane makes it easier to lift a weight. They share their explanations, and together the class creates a recommendation they all agree on. Finally, the class reads about the concept of work and thinks about how it applies to the inclined plane and ties everything together with an example of choosing one of two different ramps to lift something.

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

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Scientists often work together and then share their findings. Sharing findings makes new information available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	Students share their explanations with the class to help revise and refine their final explanations.
Scientists must keep clear, accurate, and descriptive records of what they do so they can share their work with others and consider what they did, why they did it, and what they want to do next.	Students use the records they kept during the *Learning Set* to revise their former explanations.
Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations.	Students construct claims as part of their explanations.
Explanations are claims supported by evidence, accepted ideas, and facts.	Students revise their explanations based on the science knowledge and experiences from the previous section.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
When the forces exerted on an object are unbalanced, the speed and/or direction of the object will change, otherwise there is no change in motion.	Students should use the concept of forces in their explanations.
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance.	Students use the concept of mechanical advantage in their revised explanations.
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley	Students apply the concept of mechanical advantage to the problem of choosing a ramp to lift a heavy object. Students should also update their previous explanations to include the wedge and the screw.
Work only occurs when a force exerted on a moving object is applied in or opposite to the object's direction of motion.	Students should be able to describe the concept of work qualitatively in class discussion.

Homework Options

Reflection

- **Science Content:** You have screws with threads close together and screws with threads wide apart. Both types are equally long. Which type do you have to turn more to drive in? Which type requires more work to drive in? *(You have to turn the screws with the closer threads more to drive them in. Students might include ideas about work.)*
- **Science Process:** What evidence did you use in your revised explanation? What new science knowledge did you use? *(Students should have used the differences in force and the differences in distance measured as evidence. They should have used the concepts of mechanical advantage and the tradeoff of force and distance in their explanations. Students should have included information about wedges and screws to back up general statements of machines, or included claims about screws and wedges.)*

SECTION 2.5 IMPLEMENTATION

PBIS

◀ *1 class period**

2.5: Revise Your Explanation:

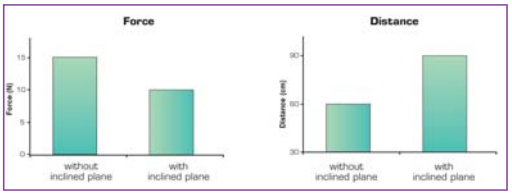
How Does an Inclined Plane Do Its Job?

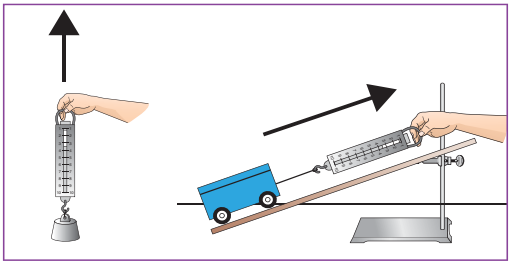
2.5 Revise Your Explanation

How Does an Inclined Plane Do Its Job?

Explanation

Machines can transform a small applied force into a large force. The trade-off is that the smaller force must be applied over a longer distance to do the same task. The force-distance trade-off is the mechanical advantage of machines. There is an advantage to using a machine. The advantage is that you have to apply less force through a longer distance than without a machine.





The mechanical advantage of a machine can be seen clearly in graphs that show the relationship between force and distance. The graphs shown are similar to the graphs that you created in class when you investigated the inclined plane. These two graphs show the results when a weight was moved from the floor to the top of a table that was 60 cm high. First it was lifted straight up. Then an inclined plane was used. The first graph compares the amount of force applied to move the weight. Without an inclined plane, 15 N of force were required to move the weight. Using an inclined plane, only 10 N of force were needed.

The advantage of using the inclined plane was that less force was needed to move the weight. What was the trade-off? Without the inclined plane, the force was applied through a distance of 60 cm. However, using the inclined plane to move the weight, the force was applied through 90 cm. The trade-off for using the inclined plane was that the force had to be applied through a longer distance.

MBT 58

Project-Based Inquiry Science

Explanation

10 min.

Lead students through reading and review some of the concepts with them.

△ Guide

First summarize the mechanical advantage of machines. Point out the graphs depicted on page 58 that show the force-distance tradeoff. This segment reviews what students have learned about mechanical advantage using concrete examples. Emphasize that these examples demonstrate how to use evidence to support claims about mechanical advantage.

NOTE: The second image on page 58 shows a small force arrow for the vertical lift and a large force arrow for the lift along the inclined plane. These are reversed. The vertical lift requires more force and should have a larger force arrow than the lift along the inclined plane.

TEACHER TALK

"Machines can change the amount and/or direction of a force. Someone investigated moving a cart up an inclined plane and obtained the data shown in the graphs on page 58. What do these graphs say? What claims can you make from them?"

NOTES

How would you write a conclusion for this investigation? You would need to describe what the data show. In general, you found that less force was needed to move the weight when using an inclined plane than to lift it straight up. You also needed to apply the force through a longer distance when using an inclined plane. You might write a conclusion like the following: "When using an inclined plane to move a weight, less force is applied. However, the force is applied through a greater distance than when lifting the weight straight up."

You can use the data from the investigation as evidence to support the conclusion. What is the evidence to support the claim that when an inclined plane was used, *less force* was applied? The data show that when using the inclined plane a force of 10 N of force was applied. When lifting straight up, 15 N of force was applied. A force of 10 N is less than 15 N, so this evidence supports your claim.

Now look at the second part of the conclusion. The claim states that when the inclined plane was used, the force was applied through a *greater distance* than when you lifted the weight directly. What is the evidence to support this claim? In the data, when the inclined plane was used, the weight moved 90 cm. When lifting straight up, the weight moved only 60 cm. A distance of 90 cm is greater than 60 cm, so this evidence supports the claim that the distance was greater using the inclined plane.

Revise Your Explanation

Look at the explanations you have created so far for inclined planes. Work with your group to revise your explanation. When you revise an explanation, you should consider any new information you have. You just read an explanation about using an inclined plane. In the last section, you also read about other simple machines that are a variation of an inclined plane. Revise your explanation about using an inclined plane to include the screw and the wedge.

Make sure when you revise one part that the whole explanation still makes sense. If you think an additional claim and explanation is needed based on what you have just learned, spend time in your group working on that too. Use a new *Create Your Explanation* page for each explanation you develop.

Communicate

Share Your Explanation

When you are finished, share your new explanations with the class. Discuss each explanation to make sure it is clear and complete.

Revise Your Explanation

10 min.

Have groups revise their explanations.

Communicate: Share Your Explanation

10 min.

Have a discussion of groups' explanations with the class.

Get Going

Ask students to revise their explanations to include mechanical advantage, the inclined plane, the wedge, and the screw. Give students a time frame to complete their work and let them know that they will be sharing their results with the class.

Guide

Once groups have revised their explanations, ask each group to read their explanation. Consider recording the revised explanations on the same poster or overhead slide where you recorded the original explanations.

META NOTES

Students may also include information about how to calculate the mechanical advantage and/or what it means for the mechanical advantage to be greater than 1 (applied force reduced, distance applied for increases).

Next, ask students if there are any big differences between the claims in the different explanations. Help them develop claims that they all agree on. Consider coming up with a class explanation. Ask them what evidence they should use in the class explanation. Record the class explanation on the poster or transparency.

◇ Evaluate

Before moving on, check that students' claims include: a less-steep incline requires less force; using less force requires that you apply the force over a longer distance, a description or claim about the wedge and the screw.

Example explanation: Machines can change the amount and direction of a force. This is described by the mechanical advantage, which is a tradeoff between the amount of force you have to apply and the distance you have to apply that force. If the machine increases the force you apply then you need to apply the force over a longer distance. This is supported by the data we collected for the inclined plane. We measured the applied force and the distance we had to move a filled cart to a height of 20 cm. The less steep the incline, the smaller the force we needed to apply, but we had to apply it over greater distances. We also learned that the wedge, used to cut or separate things, has a greater mechanical advantage as the blade width decreases. We learned that the screw has a mechanical advantage greater than 1 and that the more threads there are on the screw per length, the greater the mechanical advantage.

NOTES

PBIS

*Learning Set 2 • **How Can a Machine Change a Force?***

work: when a force acts on an object and the object moves a distance in the direction of the force, then work has been done.

machine: a device that helps you do work more easily with it than without it.

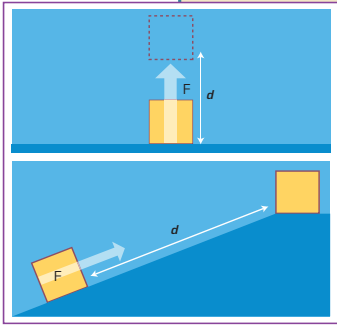
What is Work?

When a force acts on an object and the object moves a distance in the direction of the force, scientists say that **work** has been done. You did work when you lifted the weight straight up. You also did work when you pulled the weight up the inclined plane.

But you will probably be surprised to learn that when you pushed on the heavy bucket and it did not move, scientists would say that you did not do any work. You may have tried hard, but the bucket did not move. According to the scientific definition of work, it does not matter how hard you push or pull on an object. If the object does not move, no work has been done.

Work is being done.

No work is done.



Science definitions are often different and more exact than the way you use words in everyday conversation. Work is one of those words that has a different meaning scientifically than it has when you use it in everyday conversation. You might talk about "working hard on an assignment" or "working with others to get something done." In everyday terms, that means you tried hard and did things together. From a scientific point of view, there was only work being done if what you were doing was moving something from one place to another.

The inclined plane made it easier for you to do work. One function of a **machine** is to help you do work more easily. However, a machine does not change the *amount* of work that is done. It only changes the force that is required to do the work. You did the same amount of work to lift the weight straight up as you did to pull it to the same height up the ramp. You used less force to pull the weight up the ramp than you did to lift it straight up. However, you had to apply this lesser force over a greater distance. The amount of work done when a force is applied to move an object depends on two things:

- the amount of force needed
- the distance over which that force is applied

These are the two things that are traded off when using a machine.

What is Work?

10 min.

Introduce and discuss the concept of work with the class.

META NOTES

There is more information about work in the *Understanding for Teachers* segment at the front of this *Learning Set*.

△ Guide

Emphasize that scientists use the word *work* differently from its everyday use. In science, the work done by a force is equal to the amount of force parallel (or anti-parallel) to the path the objects moves over multiplied by the distance it moves over.

Then provide examples. For the inclined plane, the work done by the applied force is the force you apply to the object parallel to the incline plane multiplied by the distance you move the object. When you lift a box,

META NOTES

You may want to mention that the when you push an object up an incline friction does negative work on the object because it points opposite to the direction of motion of the box.

META NOTES

You may also want to note that the ideal mechanical advantage is found when you take the output distance divided by the distance the object moved in the desired direction. For the actual mechanical advantage, one uses the output force divided by the input force.

the work done is the force you apply upward multiplied by the distance you lifted the box. These are the two things that are part of the tradeoff when you use a machine. Note, however, that if you carry a heavy box for 20 minutes but don't move it anywhere, you do no work.

TEACHER TALK

"Did you do more work when you lifted the weight straight up than when you lifted it along the inclined plane? Remember, we're using the word work in the special scientific sense. What about when you pull up on a weight without actually lifting it? Do you do a lot of work then?"

◇ Evaluate

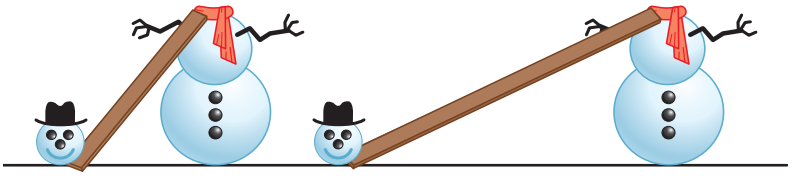
Make sure students understand mechanical advantage, work, and what it means for the force doing work to be in or opposite to the direction of motion.

NOTES

Reflect

It is winter and you have a "snow day." School is cancelled. You and your friends are building a snowman. You roll a huge snowball for the bottom, and another big snowball for the middle. As you and your friends try to add the head, you realize that the snowball is too heavy and the body of the snowman is too tall for you to lift the head to the top. You ask your friends, "Now what do we do?" Your best friend remembers something about machines he learned in science class that could save the day. What do you think he remembered?

You remember your work with machines in science class. How can you use the information about inclined planes to move the head to the top of the snowman? You find two boards to choose from, a long one and a short one. Draw a diagram that shows the board you choose and how you will use it to get the head of the snowman on the top of the snowman.



What's the Point?

Scientists are always trying to understand why things function the way they do. They make the best explanations they can as they investigate. But scientists are constantly learning more. They revise their explanations to make them more accurate and complete as they add to what they know. You had a chance to do the same thing.

You also read that work is done when a force acts on an object and the object moves for a distance in the direction of the force. A machine helps you do work more easily than you can without a machine. However, it does not change the amount of work you do. It only changes the force you need to apply to move an object.

Reflect

10 min.

Have students diagram and solve the question and then discuss it.

△ Guide

Discuss the *Reflect* scenario with the class.

TEACHER TALK

"Imagine you are building a big snowman. The bottom parts are so tall that you have to stretch your arms to reach the top. The head is big and heavy, and you can't get it on top of the snowman. You've decided to use an inclined plane. There are two boards to choose from, a short one and a long one. You need to describe which one will you use? Why? And draw a diagram of how it will be used and the forces involved."

META NOTES

It is important for students to update their class *Project Board* as they go through each *Learning Set*. Whenever you feel that the students have acquired ample new information, you should have the class update their *Project Board*.

The ramps are essentially the same as the inclined planes they used in their investigation. Emphasize that they should consider the mechanical advantage of the steep and less-steep ramps.

Have students draw diagrams and explain which of the boards would make it easiest to move the head to the top of the snowman. Groups should discuss their responses and pick out their best response for the class discussion.

△ Guide

Hold a class discussion on groups' the answers. Ask groups to discuss the similarities and differences responses.

Next, update the *Project Board*, focusing on *What are we learning?* and *What is our evidence?*

TEACHER TALK

"So what can we add to the *Project Board*? What have we learned? What evidence do we have for it?"

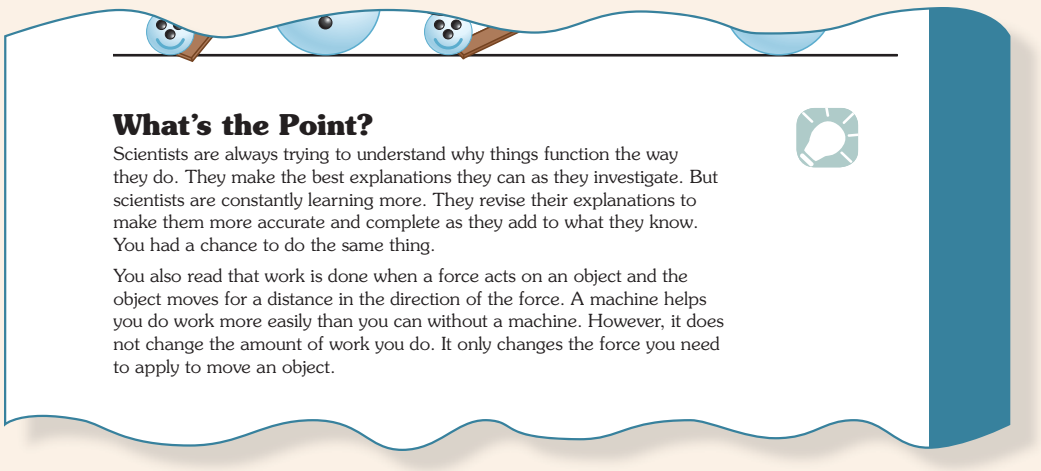
◇ Evaluate

Students should have their class explanation for machines and mechanical advantage written in column 5. They should include a description of work

What's the Point?

less than 5 min.

If needed, summarize mechanical advantage, making explanations, and work.



If needed summarize mechanical advantage, making explanations, and work.

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance.	**ASK:** What is the mechanical advantage of machines useful for? **LISTEN:** It helps us to move objects that would otherwise be difficult to move.
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley.	**ASK:** What is the mechanical advantage of a screw with close threads? **LISTEN:** Students should recognize that it is easier to drive a screw that has close, "less-steep" threads, but that you must turn the screw farther to drive it in.
Work only occurs when a force exerted on a moving object is applied in or opposite to the object's direction of motion.	**ASK:** How much work did you do when you pulled on the weight without lifting it? How much work was done when we pushed on the bucket and it didn't move? **LISTEN:** No work was done.
Explanations are claims supported by evidence, accepted ideas, and facts.	**ASK:** What were the parts of your revised explanations? What additional information did you have to add to your explanations? **LISTEN:** Students should be able to break them down into claims, evidence, and science knowledge—or accepted ideas and facts. Information about wedges and screws should be provided.

Teacher Reflection Questions

- What difficulties did students have with the concepts of work and mechanical advantage? What can you do to help them grasp these concepts?
- How do you expect students to apply what they've learned to the Unit challenge? What specific concepts do you think will be most useful for the challenge?
- What issues came up when you led the class through creating a class explanation? What can you do to encourage collaboration between classmates?

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