Objective 1

The student will demonstrate an understanding of the nature of science.

My Notes

Through scientific investigations, you should be able to demonstrate an understanding of the nature of science.

What is "the nature of science"?

The nature of science is just a way of looking at the world around us. Science is a process of trying to answer questions based on evidence. Scientists make observations and measurements to gather evidence during their investigations. Without thinking about it, we use the same processes that scientists use.

We do? How?

When we ask questions about our world, we are thinking like scientists. Let's say that you are in gym class and are about to run a 400-meter race. What question might you ask?

How long will it take me to run 400 meters?

Good question! Now you need to find the answer. How can you do that?

Can I run the 400 meters and have someone time me?

That will work. You just made a plan to answer your question. What do you think the answer will be?

I think I can run 400 meters in 60 seconds.

Good! You just made a hypothesis. When we investigate questions, we usually try to predict the answer first. It's called making a *hypothesis*. A hypothesis is a reasonable prediction that can be tested. What is your hypothesis? And, by the way, why did you say 60 seconds?

Well, I know I can run 100 meters in 12 seconds. But I would have to run at a little slower pace to go 400 meters.

Great job! You used data to make your hypothesis. That's thinking like a scientist. After you run the 400 meters, you can check to see whether your hypothesis was correct.

O.K., so I've made a hypothesis about the 400 meters. Am I ready to run?

Yes, and we need to measure your time. Let's say you run and it takes you 72 seconds. Now you have some data.

But what if I was just really slow that day?

That's a very good point. If we want to be more sure of our data, we should repeat the investigation several times. For example, you might run the 400 meters three times during each gym class for one week. You could record your time for each run in a data table like the one below.

Remember!

A hypothesis is stated so that it can be tested by observation or investigation.

400-meter Run Times

Day	Time (s)			Average Time (s)
	Run 1	Run 2	Run 3	
Monday	72	73	72	72
Tuesday	71	73	72	72
Wednesday	73	72	70	72
Thursday	70	71	72	71
Friday	73	71	71	72

Now what am I supposed to do with the run times in my table?

You now have enough data to draw a *conclusion*. A conclusion involves looking at your data and comparing it to your hypothesis. Your hypothesis was that you could run the 400 meters in 60 seconds. Study the data in the table. What did you learn?

My results don't agree with my hypothesis! So the investigation failed, right?

Not at all! We still learn something important when the results of an investigation do not support the hypothesis. For instance, you learned that your 400-meter run time is about six times greater than your 100-meter run time. You didn't know that until you did the investigation.

O.K., that's a good everyday example. What about when we do science experiments?

Well, before we begin an experiment, what is the first thing your teacher always reminds you about?

Lab safety, right?

Yes! The first rule of scientific experimentation is to be safe.

Wait! Can I show you the poster our lab group made that shows some of the important safety rules?

Sure, let's see it.

Laboratory Safety Rules

1. Know the location of all safety equipment (eye wash, fire extinguisher, fire blanket, fire alarm) and the correct route to leave the lab in case of an emergency.
2. Tie back loose clothing and hair. Wear all required safety equipment for a lab (goggles, apron, gloves, etc.) at all times unless you are told to remove them.
3. Do not taste, smell, or handle any material in the laboratory unless told to do so.
4. Never run, push, or play in the laboratory.
5. Handle lab equipment with care and use the proper tools.
6. Report any accident or equipment problem to the teacher immediately.

That's a great list of important safety rules. I'm sure your teacher will tell you about special safety issues related to the specific experiments you do. And you should also be familiar with the safety symbols used in the lab.

Now we are ready to experiment. What would you like to investigate?

My Notes

When I walk home on sunny days, it seems like I feel warmer when I wear black clothes than when I wear white clothes. Can we do an experiment to find out whether black clothes really gain more heat?

Sure! So let's put our experimental problem in the form of a question that can easily be tested. How about stating it like this: Will a black T-shirt gain more heat in sunlight than a white T-shirt will?

Next you will need to make a hypothesis. What prediction can you make about what will happen in your experiment?

Since I seem to feel warmer when I wear black clothes, I predict that the black T-shirt will gain more heat. Does that sound good?

That sounds reasonable. Now we need to plan an experiment to test the hypothesis. First we need to decide what equipment to use.

Obviously, we need two T-shirts—one black and one white. And we need a thermometer or temperature probe to measure temperature. Let's see. Have I forgotten anything?

You want the shirts to be identical except for color. Also, you need something to measure the length of time the shirts are in the sun.

If we need to measure time, won't we need a watch?

Good choice. I think those materials will work. Now we need to use them to test the hypothesis.

First we need to identify the *variables*. Variables are the values or quantities that change (vary) during an experiment. Which variable will we measure to see whether sunlight makes the black T-shirt gain more heat?

The temperature. We think it will go up, right?

That's right. In our experiment, temperature is the *dependent* (responding) *variable*. We observe the dependent variable to see whether it changes (responds) during the experiment.

Another important variable is the *independent* (manipulated) *variable*. This is the variable that we change on purpose (manipulate) to try to get a response out of the dependent variable. What is the independent variable in our T-shirt experiment?

Isn't the independent variable the color of the T-shirts?

That's right.

But what if something else makes one T-shirt gain more heat than the other? For example, what if one T-shirt gets more sunlight than the other?

You're really thinking like a scientist now! We need to make sure that all the other possible variables are the same for both T-shirts. The other variables are called *controlled variables* (constants), because we want to keep them the same (controlled) for both T-shirts.

We can start by folding the T-shirts into squares the same size and putting them in the sun side by side. This way they will have equal areas exposed to the sunlight. They will also need to be in as close to the same environment as possible.

I think we also need to make sure the T-shirts are in the sun for the same amount of time. Are we going to control the time?

Yes, you're right. We can shade both shirts until we are ready to start the experiment. Then we can take temperature readings of both shirts at the start and after 15 minutes and after 30 minutes.

Let's summarize the design of our experiment:

1. My question: "Will a black T-shirt gain more heat in the same amount of time in sunlight than a white T-shirt?"
2. My hypothesis: "The black T-shirt will gain more heat than the white T-shirt."
3. The variables:
    - Independent variable: color of T-shirt (white versus black)
    - Dependent variable: temperature change of T-shirts
    - Controlled variables: size of T-shirts, time T-shirts are in sunlight
4. The materials:
    - 2 thermometers
    - 2 T-shirts the same size, one black and one white
    - Watch
    - Piece of cardboard to use as a shade
5. The procedure:
    a. Fold T-shirts into 20 cm squares and lay them on a flat surface in the sun. Cover them with a piece of cardboard.
    b. Place a thermometer inside the fold of each T-shirt.
    c. Remove the cardboard shade and record temperature of each T-shirt at 0, 15, and 30 minutes.

O.K., now I'll make a data table for our temperature measurements. Once I've done that, are we ready to start the experiment?

Yes, let's do it. You can read the temperatures, and I'll record them in the data table.

Here's what the data table looks like after the experiment is finished:

T-Shirt Temperature (°C)

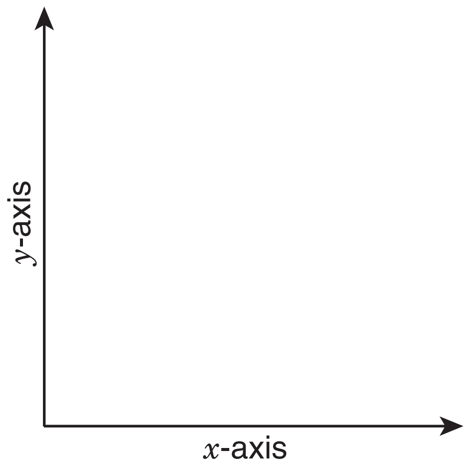
T-Shirt Color	Time (min)		
	0	15	30
Black	32	35	37
White	32	33	35

Are there other ways to show our results?

Yes, we can make a graph. Graphs can make data easier to read and compare. What kind of graph would you suggest? A pie graph, a bar graph, or a line graph?

Let's see. We are comparing the two T-shirts at equal times. How about a bar graph?

Yes, a bar graph would help us see the temperature difference between the two colors very easily. Bar graphs compare two variables that do not affect each other, such as the T-shirt colors. The bars for the two variables being compared are placed side by side at points along the *x*-axis. The scale for the values is placed on the *y*-axis.

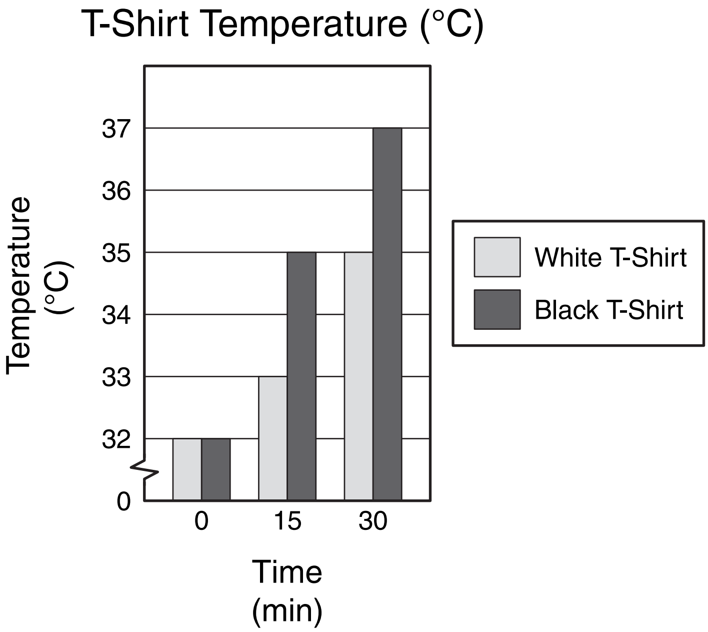


Remember!

Different types of graphs are used to show different relationships between data.

- Pie graphs show percentages.
- Line graphs show continuous change.
- Bar graphs compare two measured variables.

My Notes



Wow! The graph does make it easier to see the results. What now?

Now that we have results, we can reach a conclusion. Remember, the data may or may not support the hypothesis you made. Was your hypothesis supported by the data?

Yes, the temperature of the black T-shirt was greater. But what if somebody doesn't agree with the data or my conclusion?

That's a very important question. A scientific conclusion doesn't become accepted until more investigation is done. Experiments are usually repeated, or the data are checked with other research. This is called verifying scientific data.

So we can use data to see whether someone is making a false statement about something they have done or maybe a product they are selling?

That's exactly right. Advertising has good examples of this. Sometimes products are advertised with claims that are not supported by scientific results. It is important for buyers to be able to look at the data and come to their own conclusions. If there are no data, or if a poor investigation produced unreliable data, then the advertising claims may not be true.

Here, I have a cookie package in my backpack. The label on the back gives information about the cookies. What does the label tell us?

Oatmeal Cookies

Nutrition Information

Serving size: 28 g
(about 3 cookies)

Calories:	128
Protein:	2 g
Fat:	5 g
Carbohydrate:	19 g
Fiber:	1 g
Sugar:	7 g

The label names the product and shows how much product is in one serving (serving size). The energy (in Calories) and mass (in grams) of each nutrient in one serving is also shown.

How could this information be useful?

Let's say the cookie company produces a TV commercial that shows a man eating the oatmeal cookies. The man says four servings of the cookies supply all the protein he needs each day. Is this statement true? Let's check it out.

How do I know whether the advertisement's claim is true or false?

According to its website, the Food and Drug Administration (FDA) recommends that the diet of an adult man should contain 56 grams of protein per day.

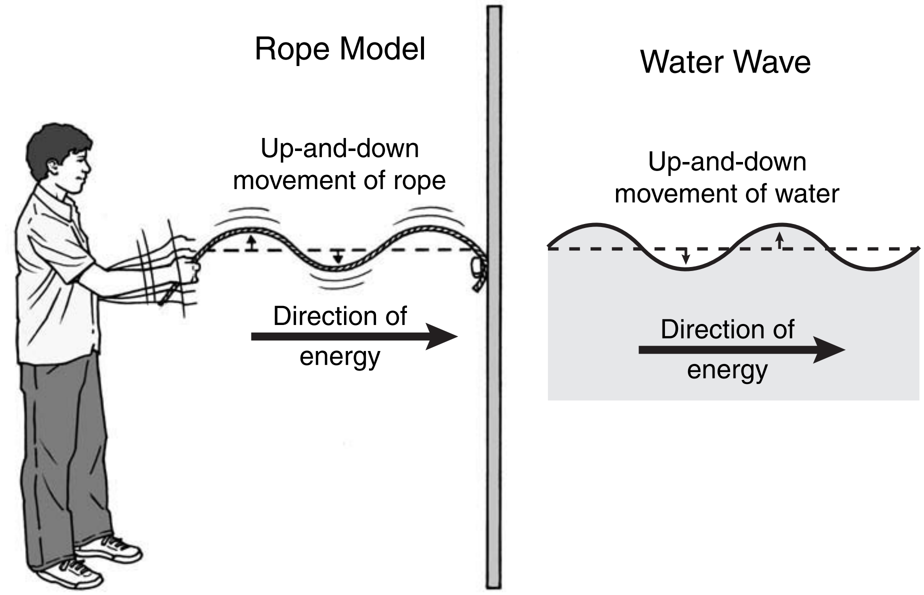
The label says that each serving (3 cookies) supplies 2 grams of protein. So four servings would contain only eight grams of protein (2 g × 4 = 8 g). But according to the FDA, he needs 56 grams per day. This would mean that he still needs 48 more grams of protein (56 g – 8 g = 48 g). So the man in the advertisement is making a false statement.

We've looked at data in tables, graphs, and on labels. What's another way that we can gain information to help us understand the things and events that we observe?

Observations may lead us to discover patterns in the natural world. From these patterns we can form *models*. A model is a description or representation of something that cannot be directly observed. What's a natural pattern you can think of that might be modeled?

How about wave patterns on water?

That's a good example. Let's say data show that water is moved up and down by a passing wave. To model this, we might tie a piece of rope at one end and swing it up and down on the other end. The energy passing through the rope models the way energy passes through the water.



Using this model, we can show what will happen to the wave if we add more energy. To do this, we swing the rope up and down with more energy. This makes the rope travel higher. We can see from the model that water waves will get higher if the wind blows harder.

That's pretty neat! Do models work for everything?

No. Models help us, but they also have limitations. For example, the rope model above does not tell us how a water wave will act when it reaches the shore. When a wave reaches shallow water, its shape changes. This causes a wave to "break," or fall forward. We can't easily model this using a rope. Models must be examined and tested before we can know how well they represent real-world situations.

So with good data and accurate models we can make predictions about our world?

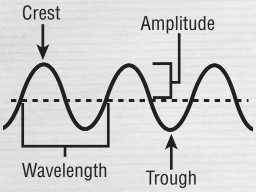
Yes, that's an important part of science. Data and models often show trends or patterns that allow us to predict events. From a trend or pattern, we can make a reasonable guess about data we haven't measured yet.

Remember!

A wave is a disturbance that transfers energy from one place to another.

Remember!

Parts of a Wave



For example, let's look back at our T-shirt experiment. In our experiment the black T-shirt's temperature increased 5°C and the white T-shirt's temperature increased 3°C in 30 minutes.

My Notes

How does that help us make a prediction?

We might use the data to make a prediction about the temperature change in a black-and-white striped T-shirt. We could predict that under the same experimental conditions, the temperature of the black-and-white T-shirt would increase 4°C in 30 minutes.

Of course, predictions do not always prove true. In another experiment the black-and-white striped T-shirt may not increase in temperature 4°C in 30 minutes. But based on our data, we can reasonably expect the result we have predicted.