Chapter 1

The Practice of Science

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Chapter 1 • Lesson 1

Standards: SC.6.N.1.1, SC.6.N.1.3, SC.6.N.1.5

Scientific Investigation

Key Words • observation • investigation • data • experiment • hypothesis

Getting the Idea

Have you ever asked a question about something in nature? Scientists ask questions all the time. But the questions they ask may be different from yours. In this lesson you will learn about the questions scientists ask. You will also learn how they find answers to those questions.

Observations and Questions

You notice things around you when you see, hear, feel, taste, smell, and touch. An **observation** is information gathered with your senses. Once you make an observation, you may get curious and start asking questions. So do scientists.

Suppose you wonder if playing music changes how plants grow. Every day after school, you play your favorite music for six plants growing on your bedroom windowsill. Six similar plants on your brother's windowsill get no music. You make sure all the plants get the same amount of sunlight and water. After a month, you measure the growth of each plant. Now you are ready to figure out what you learned. You have asked and answered a question. You have carried out a scientific investigation. An **investigation** is a close study of something to answer a question about it.

Kinds of Investigations

An investigation can simply be observing something or recording an event. For example, you might observe which trees lose their leaves first as fall approaches. Perhaps a construction crew is digging a basement or a foundation near you. You might observe the layers of rock that have been uncovered. If you are lucky, you might get to watch a solar or a lunar eclipse.

You might also collect samples as part of an investigation. For example, you might gather the falling leaves to make sure you have identified the trees correctly. You might chip off pieces of the rock layers and identify them.

All the pieces of information that you gather during an investigation are called **data** (singular, *datum*). Often data are measurements or other numbers.

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Some investigations are experiments. An **experiment** is a carefully controlled test to answer a scientific question. Playing music for one group of plants and not for another is an experiment. You must control all the conditions in an experiment. Then you will know what causes changes.

Suppose no one waters the plants in your brother's room. The plants in your room grow about 10 centimeters during your study. Your brother's plants grow only 4 centimeters. You do not know why your plants grew faster. Was it because of the music? Or was it because of the water? In a good study, both groups must have the same conditions. In this study, both groups of plants must get the same amount of water. Only one thing can be different—the music. Then you can be more sure you are measuring the effects of the music.

Some investigations are not experiments. They may be surveys in which you ask questions and write down the answers. They may be studies in which you make observations in a laboratory. They may be field studies, in which you work outside instead of in a lab. They may be studies in which you use models instead of observing real objects or events. (You will learn more about using models in science in Lesson 6.) The type of investigation you should choose depends on the question you are trying to answer. For example, suppose you want to know how different amounts of light affect the growth of tomato plants. To answer that question, you should do a controlled experiment. But to find out about the feeding habits of mockingbirds, you should do a field study. You cannot control conditions outside in a natural setting.

Forming and Testing Hypotheses

Scientists learn about the world by asking and answering questions. Every investigation begins with a question. A **hypothesis** is a possible answer to a scientific question. Scientists use what they already know to form a hypothesis. Then they conduct an investigation to test the hypothesis.

Think again about your plant investigation. First, you asked the question, "Does playing music change how plants grow?" What hypothesis would you form about music and plant growth? Think about what you already know about plants. You know they need sunlight and water to grow. You might form the hypothesis that playing music has no effect on plant growth.

Did You Know?

Albert Einstein was one of the world's greatest scientists. He said, "The important thing is not to stop questioning."

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The table below shows some scientific questions. The table gives one hypothesis for each question. The hypothesis is a possible answer to the question. To find out if the hypothesis is true, you could conduct an investigation or an experiment.

Scientific Questions and Hypotheses

Scientific Question	Hypothesis
Which fertilizer—X or Y—will cause tomato plants to produce more tomatoes?	Tomato plants given fertilizer Y will produce more tomatoes than plants given fertilizer X.
What effect does the size of a parachute have on how fast an object falls?	The larger the parachute, the more slowly the object falls.
How does salt affect water's boiling point?	If salt is added to water, then the boiling point will increase.

How Scientists Learn

Scientists use what they already know to form hypotheses and plan investigations. They use creativity, too. *Creativity* is the ability to think of new ideas and ways of doing things. Scientists use creativity all the time. They use it to think of good questions to ask. They use it to design experiments and other investigations. They also use it when they figure out what the results of their investigations mean. Creativity in science does not mean making things up. It means thinking about observations and data in a new way.

Scientists make observations and collect as much data as possible. Then, they study the information. They use logical reasoning to figure out what their data mean and decide if their hypothesis is correct. A scientist may find out that a hypothesis is not correct. But, he or she has still learned something important. The information gathered during any investigation adds to scientific knowledge. It can also lead to new investigations.

Discussion Question

What is the difference between a hypothesis and a guess?

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Lesson Review

1. Which of these is an experiment?

   A. a controlled study of the effect of temperature on the growth of bean plants

   B. a survey to collect data on students' exercise habits

   C. observations of bacteria under a microscope

   D. a study of how blue jays build their nests

2. What do scientists collect during a scientific investigation?

   A. technology

   B. hypotheses

   C. data

   D. questions

3. What is the **best** definition of hypothesis?

   A. a question

   B. an observation

   C. a possible answer to a scientific question

   D. a question that can be answered

4. What do you do first in a scientific investigation?

   A. collect data

   B. gather materials

   C. form a hypothesis

   D. ask a question

5. When scientists come up with new ideas and ways of doing things, they use

   A. technology.

   B. creativity.

   C. data.

   D. questions.

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Standards: SC.6.N.1.1, SC.6.N.1.2, SC.6.N.1.4

Designing and Conducting an Experiment

Key Words • hypothesis • data • experiment • variable • independent variable • dependent variable • procedure • conclusion • trial

Getting the Idea

A scientific experiment is one way to answer a question. The experiment can show if a hypothesis is correct. There are many kinds of experiments. But all of them have some things in common.

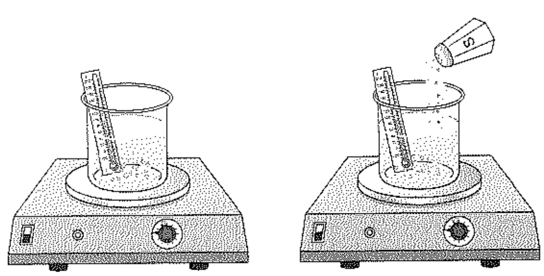
Before the Experiment

In the last lesson, you learned that scientists ask questions. Then they think of possible answers. They use what they already know to think of answers that make sense. A possible answer to a scientific question is called a **hypothesis**. A good hypothesis can be tested. Testing usually includes collecting **data**, or information. Data can be measurements or observations. One way to gather data is to do an experiment. An **experiment** is a carefully controlled study.

Parts of an Experiment

Experiments include variables. A **variable** is something that can change, or vary. In an experiment, scientists investigate how changing one thing causes something else to change. Scientists are careful to change just one variable at a time. Then they know that any effects they observe are caused by that variable.

Suppose that you want to find out how salt changes the boiling point of water. The boiling point is the temperature at which water boils. You decide to use two beakers that are exactly the same. You pour the same amount of water into each beaker. The water in each beaker starts at the same temperature. You will add salt to one of the beakers, as shown below. Your variables are the amount of salt, the amount of water, and the starting temperature of the water. You want to be sure that only the amount of salt is different. The other variables must stay the same.



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Every experiment has two main variables. The **independent variable** is the variable that is changed in an experiment. In this experiment, the independent variable is the amount of salt added to the water. The **dependent variable** is the variable that changes as a result of changes in the independent variable. The dependent variable is the boiling point of the water. You will add salt to one of the beakers. Then you will find out if adding salt changes the boiling point.

Your scientific question might be: How does adding salt to water change its boiling point? You state a hypothesis, or a possible answer to your question. A good hypothesis tells how changing the independent variable may change the dependent variable. Your hypothesis might be: Adding salt to water will make the water boil at a higher temperature. Your experiment will tell you if your hypothesis is correct.

Doing an Experiment

When you design an experiment, you must decide what steps to follow. The written, step-by-step plan for an experiment is called a **procedure**. This plan helps you decide what materials you will need. It also lets other people review your work. They can repeat the experiment to check the results. For your experiment, your procedure might have these steps:

1. Use two beakers of the same size. Label one "no salt" and the other "salt."
2. Add 250 mL of water to each beaker.
3. Measure 10 mL of salt. Add the salt to the beaker labeled "salt." Stir the water.
4. Place each beaker on a hot plate. Heat each beaker until the water starts to boil. Use a thermometer to measure the boiling temperature in each beaker. Record each boiling temperature.

At the end of the experiment, you analyze the data. You study your data carefully to figure out what they mean. Suppose you find that the water with salt boils at a higher temperature. Then you know the results support your hypothesis. The water with salt has a higher boiling point.

Now you are ready to draw a conclusion. A **conclusion** is a statement about what you think data mean. It indicates whether or not the results support the hypothesis. In this experiment, your conclusion might be: Adding salt to water causes the water to boil at a higher temperature. In this case, the results support your hypothesis.

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After the Experiment

Suppose the data did not support your hypothesis. That would *not* mean your experiment was a failure. You would still have learned something. You could do other experiments. For example, you could try adding different amounts of salt. All your experiments will give you new information.

Even when the data support your hypothesis, you should repeat the experiment. You should follow exactly the same procedure. Each repetition of an experiment is called a **trial**. Conducting several trials lets you check your results. If you do an experiment just once, you cannot be sure that the same results will occur again. Doing several trials helps make sure your data can be trusted.

Scientists repeat their experiments many times. Each time, they follow exactly the same procedure. They do this to test their results. If the results of several trials are different, then something may be wrong with the experiment. There may be extra variables. Or errors may have been made in measuring. If an experiment cannot be repeated, the conclusion may not be true.

Other scientists should be able to test the results, too. If they repeat the experiment, they should make the same observations. They should get the same results. Results that many scientists can find again and again are the basis for valid scientific conclusions. That is one reason why communicating, or sharing, results is an important part of science.

You and your classmates often conduct the same experiments. Sometimes different scientists, too, try to answer the same question. They may conduct experiments using similar procedures and tools. When the scientists share their results, they may find that their results are the same. If different scientists get the same results, they know their conclusions are most likely correct.

Now suppose the scientists get and share different results. If different scientists get different results, they know their conclusions may be incorrect. In this case, they probably need to go back and repeat the investigation. If they did not share their results, they might not know this. Sharing, discussing, and comparing results is an important part of any scientific investigation.

Discussion Question

Why is it important to change only one variable in an experiment?

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Lesson Review

1. What is the main purpose of an experiment?

   A. to test a hypothesis
   B. to form a hypothesis
   C. to ask a question
   D. to prove that a hypothesis is correct

2. Which sentence is correct?

   A. An experiment should have only one variable.
   B. An experiment begins with drawing a conclusion and ends with asking a question.
   C. Doing an experiment includes recording data and drawing a conclusion.
   D. You can make up an experiment as you go along.

3. A student sets up an experiment to see how sunlight affects how tall a plant grows. She gives two identical plants the same amount of water every day, but she puts one plant in sunlight and the other plant in shade. Which of the following is the dependent variable?

   A. plant location
   B. amount of water given to each plant
   C. time of year
   D. plant height

4. A student is conducting an experiment to see how a watering schedule affects the growth of grass. He conducts the experiment two times. His data are different each time, and he comes to two different conclusions. What should he do next?

   A. forget about the entire investigation
   B. get different kinds of plants and start over
   C. repeat the experiment carefully one or more times
   D. change the results so that they match

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Standard: SC.6.N.1.1

Organizing and Analyzing Data

Key Words • data table • line graph • *x*-axis • *y*-axis • interval • prediction • bar graph • circle graph

Getting the Idea

In the last lesson, you learned how to carry out a scientific investigation. Once you have collected data in your experiment or study, you are not done. You still need to organize and understand the data. When you share your results, you may want to describe your data with more than words. You can make tables and draw graphs to organize and display the data clearly. Tables and graphs can help the reader or listener understand data. These visual displays make it easier to see patterns in the data.

Using Data Tables

A **data table** is a chart made up of rows and columns in which scientists record data. Data tables are used to organize and display information such as measurements. Data tables can also show words that describe observations. An example is shown below.

Suppose your class has a pet guinea pig. It was two months old when you got it. You and the other students weigh the guinea pig and measure its length. You do this every week for six weeks. You record and organize the data in the table shown.

Guinea Pig's Weekly Growth

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Weight (N)	5	7	8	9	10	10
Length (cm)	20	24	28	30	30	30

Using Line Graphs

A **line graph** is a visual display that uses a line on a grid to relate two variables. For example, the graph may show how a variable changes over time. A line graph has two scales called *axes* (singular: *axis*). Each axis shows values for one variable. The ***x*-axis** is the horizontal or bottom edge of a graph. The ***y*-axis** is the vertical or left edge of a graph. Within a graph, a point is plotted at each place where the values of the two variables intersect. Then a line is drawn to connect all the points.

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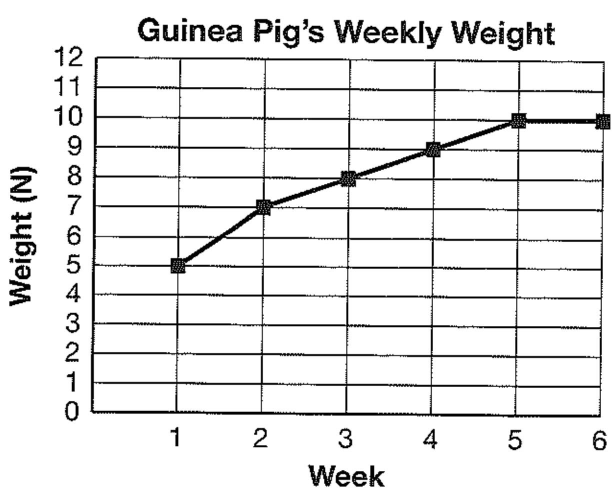
To start making a line graph, draw a horizontal line and a vertical line. The lines should meet at a right angle. The horizontal x-axis usually shows the independent variable. Recall that the independent variable is the variable that is changed in an experiment. Time is often shown on the x-axis. The vertical y-axis shows the dependent variable. The dependent variable is the variable that changes as a result of changes in the independent variable.

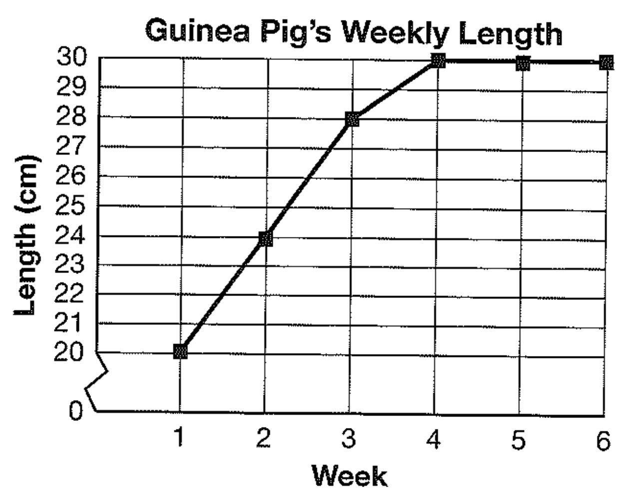
In your class investigation, the independent variable is time, measured in weeks. There are two dependent variables—weight and length. Since you have two dependent variables, you will need to make two graphs. You can follow the steps below to make a line graph.

Steps for Making a Line Graph

- Draw the horizontal and vertical axes.
- Put the independent variable on the x-axis. In your investigation, this is time, or the number of weeks. Decide on the **interval**, or equal division of the graph's axis. Your interval is 1 week.
- Put the dependent variable on the y-axis. For your first graph, this is weight. You can use an interval of 1 N. For the second graph, the dependent variable is length. You can use an interval of 1 cm.
- Plot the data. This means making a mark or point for each matched pair of numbers. For example, the first matched pair of numbers for the weight graph is (1, 5). It represents a time (week 1) and a weight (5 N). This pair of numbers gets plotted as a point on the graph.
- Connect the data points with a line.
- Write a title for the graph. Use both variables in your title.

The graphs below show the data from the table on page 20. They show how the guinea pig changed over the six weeks.





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You can use the graphs on page 21 to help you analyze the data and see patterns. Then you can draw conclusions. You can see that the guinea pig got longer for three weeks. It also got heavier for four weeks. After week 5, the guinea pig did not get longer or heavier. By then, it was three months old. Based on this information, you draw a conclusion. You conclude that the guinea pig was full-grown when it was about three months old.

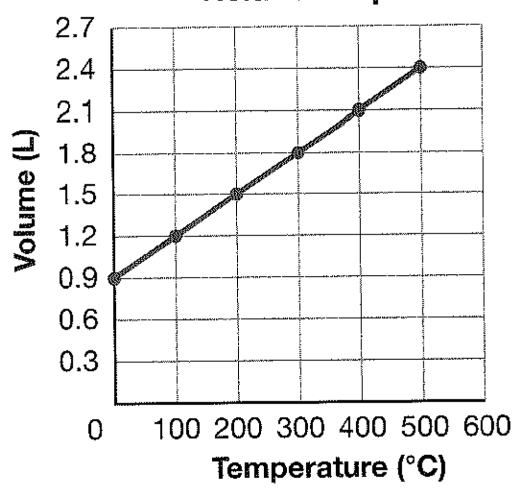
Showing Trends in Data

Data from an investigation can be organized and displayed in many ways. Writing, making tables, and drawing graphs are some ways scientists organize and show data. Sometimes one way makes it easier to analyze the data and spot trends than another way. Compare the table and graph below.

Volume–Temperature Relationship

Temperature (°C)	Volume (L)
0	0.9
100	1.2
200	1.5
300	1.8
400	2.1
500	2.4

Volume–Temperature Relationship



Line graphs can show trends in data more clearly than data tables do. Both the graph and the table show how the volume and temperature of a gas are related. As the temperature of the gas increases, its volume also increases. It is easier to see this trend on the graph than in the table.

You can use graphs to make predictions. A **prediction** is a statement about what is likely to happen in the future. The volume-temperature graph is a straight line. This line shows a constant rate of change. Each 100°C increase in temperature causes a 0.3 L increase in volume. The data in the table stop at 500°C. But you can make the line on the graph longer. You can extend it to 600°C. Then you can predict that the volume of the gas at that temperature will be 2.7 L.

Did You Know? Extending the line on a graph to make a prediction is called *extrapolation*. Looking between two points on a line and predicting a value is called *interpolation*.

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