CHAPTER 1

The Nature of Science

1 The Methods of Science

TEKS 1(A), 1(B), 2(A), 2(B), 2(C), 2(D), 2(E), 3(A), 3(C)

What You'll Learn

- how scientists solve problems
- why scientists use variables
- how to compare and contrast science laws and theory

Before You Read

When you hear the word *scientist*, what comes to mind? Brainstorm some words that describe a scientist. Write them on the lines below.

Focus →
Highlight each heading that is a question. Use a different color of marker to highlight the answers to the questions.

Read to Learn

What is science?

Science is not just a subject in school. Science is a way of studying the world. The word *science* comes from a Latin work that means "knowledge." Science is a way to learn or gain knowledge by observing and investigating.

Scientific inquiry is a process for asking questions and investigating the world. Science uses scientific inquiry to form explanations that can be tested. Those explanations can also be used to make predictions about the world.

What are the major categories of science?

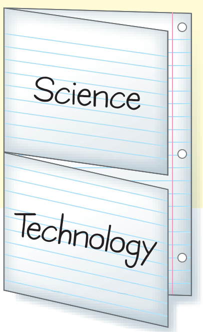
Science covers many different topics. Life science is the study of living things. Earth science is the study of Earth and space. Physical science is the study of matter and energy. In this book, you will study mainly physical science. You will also learn how these three main categories sometimes overlap.

How does science change over time?

Scientific explanations help explain the natural world. Scientists investigate and use technology to get new information. Sometimes, this new information causes scientific explanations to change. The model of the atom has changed over time. Scientists once thought an atom was the smallest particle. We now know that atoms are made up of protons and neutrons surrounded by a cloud of electrons. Because science changes, scientists still study the atom today.

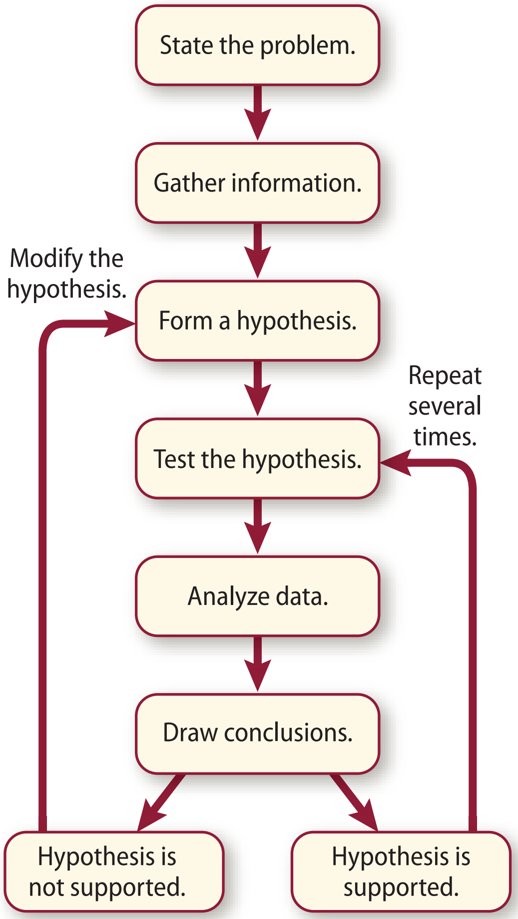
FOLDABLES® Study Organizer

Understand Main Ideas
Make the following Foldable to help you organize your notes about Science and Technology. Fill it in as you read the chapter.



Scientific Methods

A **scientific method** is a set of steps used in an investigation. Scientists follow steps similiar to those listed below when doing an investigation. These steps guide the scientist. Some steps may be repeated. Other steps may be skipped. The flowchart below shows six common steps found in various scientific methods.



Think it Over

1. **Draw Conclusions** Why might steps in scientific methods be skipped or changed?

Take a Look

2. **Interpret** Why are there two arrows leading to different parts of the chart at the bottom?

Stating a Problem Many scientific investigations begin with a question about how or why something happens in nature. The problem is stated as a "how" or "why" question.

Scientists once asked why objects fall to Earth, what causes day or night, or how electricity can be generated. Some of the answers to these questions lead to more questions. For example, once scientists knew what caused day and night, they wanted to know why Earth rotates.

Scientists might want to solve a particular problem. For example, NASA scientists needed to find a way to protect the instruments and crew onboard the space shuttle.

Think it Over

3. **Research** List two places where you might find information on the development of the space shuttle.

Researching and Gathering Information It is important to study a problem before any testing is done. Sometimes someone has already solved a similar problem. NASA scientists gathered information about melting points and other properties of various materials that might be used. They also performed tests on newly created materials.

Forming a Hypothesis A **hypothesis** is a possible explanation for a question or problem based on what you know and what you observe. A scientist who forms a hypothesis must be certain it can be tested. NASA scientists knew that a certain ceramic material had been used to protect the nose cones of guided missiles. They hypothesized that a ceramic material might also protect the space shuttle.

Testing a Hypothesis Some hypotheses are simply tested by making observations. Building a model may be the best way to test a hypothesis. Scientists may also use an experiment to test a hypothesis. The **experiment** looks at how one thing affects another under controlled conditions. NASA scientists built model space shuttles and covered them with various materials. They tested the models in simulated re-entry environments to see which material gave the best protection.

Think it Over

4. **Define** What are the two kinds of variables that are tested in experiments?

Variable An experiment usually has at least two variables. A **variable** is a factor that can cause a change in the results of an experiment. Suppose you set up an experiment to see which fertilizer makes plants grow biggest. First, you need to think of all the factors that can make a plant grow bigger. These might include the type of plant, amount of sunlight, amount of water, type of soil, and amount of fertilizer.

In this experiment, the amount of growth is one variable. It is a **dependent variable** because its value changes according to the changes in other variables. The other variable is the amount of fertilizer. The **independent variable** is changed to see how it affects the dependent variable.

Types of Variables	
Dependent Variable	changes according to the changes of the independent variable
Independent Variable	the variable that is changed to test the effect on the dependent variable
Constant	a factor that does not change when other variables change
Control	the standard by which the test results can be compared

Constants and Controls To keep an investigation fair, all other factors must be the same. A **constant** is a factor in an experiment that does not change. In the fertilizer experiment, the constants are the amount of water and sunlight the plants get and the temperature at which the plants are kept. These are the same for all plants tested. Three plants get different amounts of fertilizer, which is the independent variable.

A **control** is used to compare the results of the experiment. One plant is a control and does not get any fertilizer, but does get the same sunlight, water, and temperature as the other plants. Suppose after several days that the control plants grow between 2 and 3 cm. If the unfertilized plant grows only 1.5 cm, you might infer that the greater growth of the fertilized plants was caused by the fertilizer.

Analyze the Data An important part of any experiment is recording observations and organizing information. All results and observations should be recorded during an experiment. Many important discoveries have been made from unexpected results. The information or data should be organized into an easy-to-read table or graph. Later in this chapter, you will learn how to show your data.

Understanding what the data and observations mean is also important. The data must be organized logically. Poorly organized data may lead to a wrong conclusion. Scientists share their data through reports and meetings. Scientists may disagree about certain data, no matter how well the data is presented.

Drawing Conclusions Scientists look at their data and decide if the data support the hypothesis. If the data is the same after many experiments, the hypothesis is supported. If the hypothesis isn't supported, scientists may change it or the experiment.

Sometimes others don't agree with the conclusions, so they design new experiments to test the hypothesis. In time, data will support a valid hypothesis.

Being Objective Scientists must avoid a bias. A **bias** occurs in an experiment when a scientist expects something to happen and lets this influence how the results are viewed. Scientists try to reduce bias whenever they can by doing the experiment many times and keeping careful notes about observations. Also, other scientists repeat the same experiment to see if they get the same results.

GET IT?

5. **Identify** What is the purpose of a control in an experiment?

Think it Over

6. List two reasons why data must be organized.

GET IT?

7. **Explain** why a scientist must be unbiased.

Think it Over

8. **Classify** Give an examples of qualitative and quantitative data.

Student-Driven Scientific Inquiry

You will conduct investigations and experiments as you learn science. Some lab assignments include a series of steps to follow. Other investigations will be designed by you. When you plan an investigation, you should choose the appropriate equipment and supplies.

How is data collected?

When you perform an investigation, you will gather data—information gained from observations. The data might be qualitative or quantitative data. Qualitative data are descriptions of what we see, hear, feel, and smell. Quantitative data contain numbers. Quantitative data come from taking careful measurements.

Accuracy and Precision You will often collect data several times in one investigation. If your measurements are close to one another, they are considered to be precise. If your measurements are close to a real or accepted value, they are considered to be accurate. By practicing your skills in the lab, you can make accurate and precise measurements.

Organizing Data When working in the lab, it is important to stay organized. Many scientists use notebooks to record observations. Data tables are used to record data. Some investigations take several days. Using a notebook keeps data together and keeps information from getting lost.

How should resources be used?

In the lab, it is important to conserve resources. Choose reusable supplies whenever possible. Take only enough material to complete your investigation. And when an investigation is finished, follow your teacher's instructions to dispose of materials. Recycle materials whenever possible to reduce waste and reduce the amount of resources used.

Using Reusable Equipment Using disposable supplies might sound convenient, but it creates trash. Instead, try to use materials that can be reused. For example, use washable glassware instead of plastic cups.

Consider a school that has 200 students in 10 classes all doing the same lab. If each two-person lab team used one disposable cup, that's 100 cups that get thrown away. If they had used beakers instead, there would be much less trash. Recycling materials conserves many kinds of resources.

Applying Math

9. **Calculate** how many cups would be used in the school had 450 students doing the lab working in teams of three.

Using Small Amounts When conducting an investigation, the smallest amount of all resources should be used. This is especially true when doing chemistry experiments. Chemicals can be costly. In addition, disposing of chemicals can be costly and difficult.

Disposing of Waste Responsibly Even when you use reusable materials and only a small amount of supplies, there is still waste. Properly disposing of waste is important. Laboratory waste can harm environments and pollute air, land, and water. Local governments often have rules for waste disposal. Following guidelines for waste disposal helps to reduce pollution.

How are laboratory investigations conducted safely?

When you conduct lab procedures, you will be warned of safety hazards. Some labs have special warnings. Others use safety symbols. A safety symbol is a logo designed to alert you to a specific danger. The table below lists common safety symbols found in physical science labs.

Think it Over

10. Explain why using small quantities is important.

Take a Look

11. Compare What is the difference between the symbol with the flames and the one with flames behind a "no" symbol?

Laboratory Safety Symbols

Symbol	Hazard	Precaution
	Special disposal procedures need to be followed.	Follow your teacher's instructions.
	Objects that can burn skin by being too hot or too cold	Use proper protection or equipment when handing.
	Use of tools or glassware that can easily slice or puncture skin	Practice common-sense behavior and follow guidelines for use of the tool.
	Possible danger to respiratory tract from fumes	Work where there is good ventilation. Wear a mask. Never smell fumes.
	Possible danger from electrical shock or burn	Double-check setup with teacher. Check condition of wires and apparatus.
	Substances that can irritate the skin or respiratory tract	Wear dust mask and gloves. Practice extra care when handling materials.
	Chemicals that can react with and destroy tissue	Wear goggles, gloves, and an apron.
	Open flame may ignite flammable chemicals, loose clothing, or hair.	Avoid open flames and heat when using flammable chemicals.
	Open flame in use; may cause fire.	Tie back hair and loose clothing. Follow teacher's instructions on lighting and extinguishing flames.

Think it Over

12. Explain What information should be found on a chemical's MSDS?

Think it Over

13. Infer Why would a scientist include their methods when they publish their findings?

Completing Lab Safety Forms Before working in the lab, read the entire procedure carefully. Take note of safety symbols and warnings. Fill-out a lab safety form and have it approved by your teacher. If there are any accidents while you are in the lab, contact your teacher immediately.

Understanding the MSDS Chemical manufacturers produce information about the chemicals they produce. This information includes safety hazards, special first-aid procedures, and chemical storage instructions. The information is on a Material Safety Data Sheet (MSDS). The MSDS for each chemical used in the lab should be kept near the chemicals. Before conducting an investigation that uses chemicals, find and read the MSDS for each chemical.

Evaluating Scientific Explanations

Scientists analyze and evaluate scientific explanations. Recall that science is always changing. It grows and changes because of new discoveries and technology. Scientists sometimes disagree. This can lead to new research and discoveries.

How do you make informed decisions about science? You must analyze, evaluate, and critique scientific explanations.

- Analyze—break down the scientific explanation into parts
- Evaluate—study closely the scientific explanation; consider what you already know; look at the scientific methods used to support the explanation
- Critique—review and consider the merits and faults of the explanation and its parts

How do you evaluate published scientific information?

When you read about new scientific discoveries or explanations, you should ask yourself "How were these conclusions reached?" Can you find the empirical evidence used to come to the conclusion? See if you can understand the logical reasoning used to draw conclusions.

When scientists publish their findings, they explain their methods. They may use experimental testing in controlled investigations. Or they may use observational testing, gathering data from observations. When evaluating scientists' findings, be sure to examine all sides of scientific evidence. Watch out for unsupported conclusions or bias.

How do you evaluate promotional materials?

When you read advertisements for products and services you might see scientific claims. Use the same skills you would use when you read scientific information. First, analyze the claims in the promotional materials. What are the specific claims they make? Then, evaluate the scientific claims. What evidence is presented? Do they reference scientific investigations? Where does their evidence come from? Finally, critique the claims. Do the claims make sense? Or do they seem biased? Or false? Often, logical reasoning and your life experiences are all you need to evaluate promotional materials.

Visualizing with Models

Sometimes, scientists cannot see everything they are testing. They might be studying something too large or too small to see. It might even take too much time to see completely. In these cases, scientists use models. A **model** represents an idea, event, or object to help people better understand it. A model may be a physical object such as a scaled-down version of the space shuttle. A model can also be represented by a drawing on paper or by a computer program.

Models in History Models have been used throughout history. Lord Kelvin, a scientist who lived in England in the 1800s, was famous for making models. To model his idea of how light moves through space, he put balls in a bowl of jelly. He asked people to move the balls with their hands. Kelvin's work explaining heat and temperature is still used today.

What are high-tech models?

Scientific models don't have to be something you can touch. Many scientists use computers to build models. Computer models are used to solve difficult mathematical equations. NASA uses computers in experiments with space flights to solve equations that are too hard or would take too long to solve by hand.

Another type of model is a simulator. A simulator can create the conditions found in real life. For example, a flight simulator is a model of an airplane. It can help a pilot pretend to be flying a plane. The pilot can test different ways to solve problems. The simulator reacts the same way a real plane does when it flies, but there is no danger to either the pilot or a plane.

Think it Over

14. Explain What are models?

Think it Over

15. List three differences between a flight simulator and a real airplane.

Scientific Theories and Laws

A scientific **theory** is a way of explaining things or events based on what has been learned from many observations and investigations. When these observations and investigations have been repeated many times and support the hypothesis, then the hypothesis becomes a theory. New information in the future may change the theory.

A **scientific law** is a statement about what happens in nature and seems to be true all the time. A law explains what will happen under certain conditions, but it does not explain why or how it happens. Theories are used to explain how and why laws work. Gravity is an example of a scientific law. The law of gravity says that any one mass will attract another mass. To date, no experiments have been done that prove this law is not true.

Think it Over

16. Restate What is a scientific law?

The Limitations of Science

Science is used to explain many things about the world. However, science cannot explain everything. Questions about emotions or values are not questions science can answer. A survey of peoples' opinions would not prove that these opinions are true for everyone. Scientists make predictions when they perform experiments. Then these predictions are tested and verified by using a scientific method.

After You Read

Mini Glossary

bias: what is expected changes how the results are viewed

constant: a condition in an experiment that does not change

control: a standard in an experiment against which the results are compared

dependent variable: the condition in an experiment that results from the changes made to the independent variable

experiment: an investigation that tests a hypothesis bycollecting information under controlled conditions

hypothesis: an explanation for a question or a problem that can be tested

independent variable: in an experiment, the condition that is tested

model: anything that represents an idea, event, or object to improve understanding

scientific law: a statement about what happens in nature that seems true all the time

scientific method: the steps a scientist follows when performing an investigation

theory: an explanation that is supported by a large body of scientific evidence obtained from many different investigations and observations

variable: a quantity that can have more than a single value

Review

1. Read the terms and their definitions in the Mini Glossary. Write a sentence explaining how bias can influence an experiment.

2. Complete the chart below to organize the information you have learned in this section. Put the following steps for scientific methods in order.

Analyze the data	**Test the hypothesis**	**State the problem**
Draw conclusions	**Gather information**	**Form a hypothesis**