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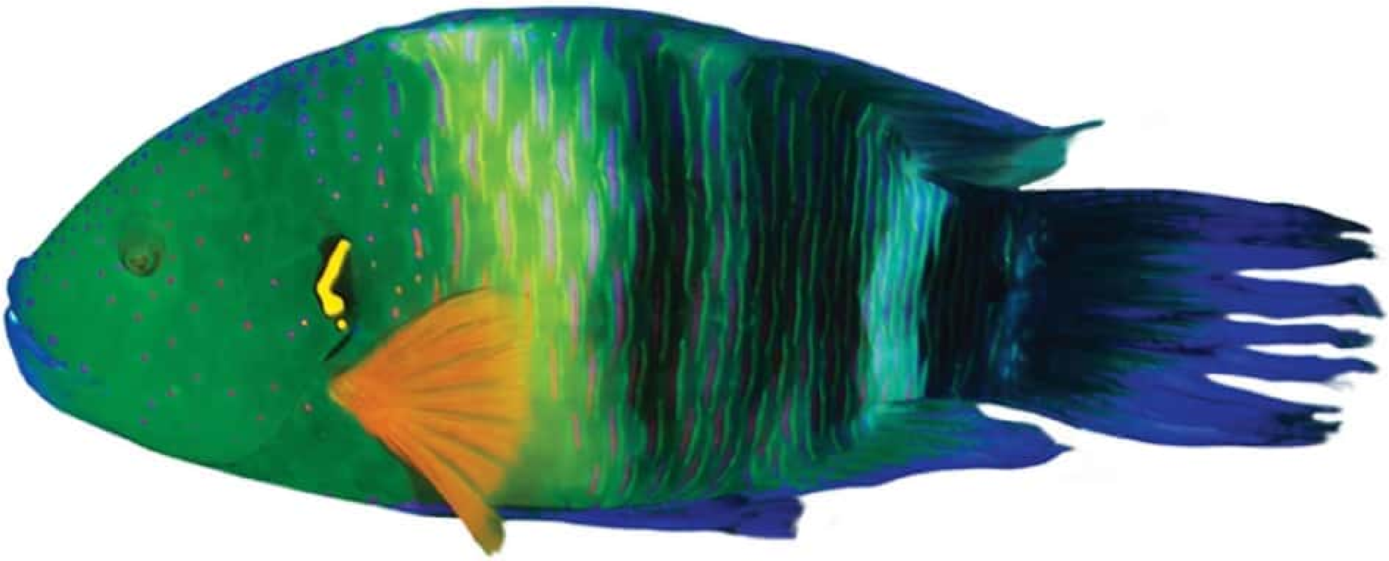

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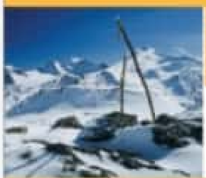
CHAPTER 1

Methods of Science

TheBIGIdea
What processes do scientists use when they do scientific investigations?



1.1 Case Study
- What is the relation between independent variables and dependent variables?
- How is scientific inquiry used in a real-life scientific investigation?

1.2 Saruq Al-Hadid Study
- How is scientific inquiry used in a real-life scientific investigation in modern discovery?

2

PAGE KEELEY SCIENCE PROBES

Desert Descriptions

Deserts are one of the seven major land biomes. [illegible] to any of the characteristics that can describe a desert.

- ☐ **A.** Earth's driest ecosystem
- ☐ **B.** Can be hot during the day and cold at night
- ☐ **C.** Can be very cold all the time
- ☐ **D.** Has soil that holds water
- ☐ **E.** Has plants that can store water
- ☐ **F.** Has plants with large leaves
- ☐ **G.** Can be near an ocean
- ☐ **H.** Only found in subtropical areas
- ☐ **I.** Are always sand-covered
- ☐ **J.** Lizards, bats, birds, and snakes live there.

Explain your thinking in the space below. Describe what makes a desert different from other biomes.

2018

Methods of Science

TheBIGIdea

There are no right or wrong answers to these questions. Write student generated questions produced during the discussion on chart paper and return to them throughout the chapter.

PAGE KEELEY SCIENCE PROBES

The Scientific Method

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Guiding Questions

AL Where do scientists perform scientific investigations?	*Students might be familiar with the idea of investigations that occur in laboratories. The picture might cause students to realize that investigations are often conducted in natural settings.*
OL What is a scientific investigation?	*Students are likely to know that a scientific investigation is one that tests an explanation for an observation by using experiments or gathering evidence from observations. Scientists share methods and results from investigations with other scientists. Results can then be checked using the exact same methods.*
BL How do scientists come up with scientific investigations?	*Scientists might make observations about the natural world that they would like to test. They might also read the results of studies and decide to verify those results.*

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Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.

* Sometimes people aren't sure what will happen because they don't know everything that might be having an effect.

* Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments

* Sometimes similar investigations give different results because of unexpected differences in the things being investigated, the methods used, or the circumstances in which the investigation is carried out, and sometimes just because of uncertainties in observations.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1
Case Study

1 Scientific inquiry is a process that uses a set of skills to answer questions or to test ideas about the natural world.

2 A scientific law is a rule that describes a pattern in nature. A scientific theory is an explanation of things or events that is based on knowledge gained from many observations and investigations.

3 Facts are measurements, observations, and theories that can be evaluated for their validity through scientific investigation. Opinions are personal views, feelings, or claims about a topic that cannot be proven true or false.

4 Scientists worldwide use the International System of Units because their work is easier to confirm and repeat by their peers.

5 Measurement uncertainty occurs because no scientific tool can provide a perfect measurement.

6 Mean, median, mode, and range are statistical calculations that are used to evaluate sets of data.

7 The independent variable is the factor a scientist changes to observe how it affects a dependent variable. A dependent variable is the factor a scientist measures or observes during an experiment.

8 Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

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Scientific Theories

Find Out What Students Think

Students might think that ...

... a scientific theory is just an educated guess that is not backed up by much information. While an everyday theory is generally an educated guess, a scientific theory is an explanation that is based on knowledge gained from many observations and scientific investigations. Before something becomes a scientific theory, it must be fully supported by scientific evidence.

Discussion

Tell students that the theory of plate tectonics states that Earth's crust is divided into plates that move very slowly in relation to each other. **Ask:** How do you think the theory of plate tectonics is different from the theory that your favorite sports team will win their next game if they practice hard? Form small discussion groups. After a set time limit, let students present some of their ideas. Students might correctly state that the theory of plate tectonics is a scientific theory, so it must be supported by many scientific investigations over many years. The theory that their team will win is a guess based on their experience or general observation that practice usually improves performance.

Promote Understanding

Activity Perform this activity to help students understand how evidence is used to construct a scientific theory.

1. Use trusted scientific sources to find a variety of evidence that supports the theory of plate tectonics. Print or copy each piece of evidence and make sure that the source information is on each piece. Include one or two from unreliable sources.
2. Form small student groups. Hand out two or three pieces of information to each group. Make sure that each group has different information. Save some pieces of evidence for the end of the activity.
3. Instruct students to determine whether each piece of information is from a trusted scientific source. Tell them to disregard questionable evidence and summarize the information from their trusted sources.
4. Have a student from each group present their summary. Work as a class to develop a statement that explains all of the information presented. This will be the "theory."
5. Share the "new" evidence that you withheld. Have a student read each piece of information. Have the class determine whether the new information fits with the "theory," or whether it causes them to reexamine and alter the "theory."

The International System of Units

Find Out What Students Think

Students might think that ...

... scientists in different countries use different units of measurement. They might be aware that in the United States we use feet, inches, and miles to make measurements, while people in other countries use meters, centimeters, and kilometers. Since we use different measurements in our everyday lives, students might think this extends to scientists. They might not be aware that an International System of Units (SI) was adopted to make it easier for scientists worldwide to share information.

Discussion

Ask: Why do you think that we measure things in centimeters and meters in the classroom when you probably measure things in inches and feet at home? Form small discussion groups and then have students present their answers and supporting evidence. Students might conclude correctly that scientists measure things using the metric system, while U. S. non-scientists mainly use the standard, or English, system. Some students might know that the metric system is part of an international system of units.

Promote Understanding

Activity Have students perform this activity to discover how difficult communication would be if scientists worldwide used different measuring systems.

1. Form small student groups. Provide half with metersticks and half with yardsticks.
2. Instruct them to measure each person's height in their group. Record each measurement and whether the student is male or female.
3. Make a blank data table using chart paper or the board. Label a column "*Girls*" and the other "*Boys.*" When students finish measuring, have them record their data in the table. Remind students to include the units.
4. **Ask:** Can we find the average heights of boys and girls by adding the numbers in each column and dividing by the total number of entries? **No. Some of the measurements are in inches and some are in centimeters.**
5. **Ask:** What do we need to do to find the averages? **Convert inches to centimeters, or convert centimeters to inches.**
6. **Ask:** How could we have made data analysis easier? **Everyone could have used the same units when measuring.**

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A Controlled Experiment
Identifying Variables and Constants

To solve the mystery of the Iceman, scientists used observation, hypothesis formation, prediction, hypothesis testing, and other tools of scientific inquiry. In some cases, the scientists used controlled experiments. Have students read the material on this page, to learn about the components of a controlled experiment. Then ask these questions.

Guiding Questions

AL What kind of process did scientists use to solve the mystery of the Iceman?	*Scientists used the process of scientific inquiry to solve the mystery. Scientific inquiry can include observation, forming hypotheses, making predictions, and carrying out controlled experiments.*
OL What are the two types of variables in a controlled experiment, and how do they relate to each other?	*The two types of variables are independent and dependent variables. An independent variable is a factor that you want to test. A dependent variable is the factor that is measured during the experiment that might be affected by the independent variable.*
BL An investigator tests the effect of temperature on the rate that a body decays. What are the independent and dependent variables in the experiment?	*Temperature is the independent variable and the rate of decay is the dependent variable.*

Teacher Notes

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> An inference is a logical explanation of observations based on past experiences.

Inference: Based on its construction, the ax is at least 4,000 years old.
Prediction: If the ax is at least 4,000 years old, then the body found near it is also at least 4,000 years old.
Test Results: Radiocarbon dating showed the man to be 5,300 years old.

> After many observations, revised hypotheses, and tests, conclusions often can be made.

Conclusion: The Iceman is about 5,300 years old. He was a seasonal visitor to the high mountains. He died in autumn. When winter came the Iceman's body became buried and frozen in the snow, which preserved his body.

Figure 9 This ax, and dagger and sheath were found with the Iceman's body.

An Early Conclusion

Konrad Spindler was a professor of archeology at the University of Innsbruck in Austria when the Iceman was discovered. Spindler estimated that the ax, shown in **Figure 9**, was at least 4,000 years old based on its construction. If the ax was that old, then the Iceman was also at least 4,000 years old. Later, radiocarbon dating showed that the Iceman actually lived about 5,300 years ago.

The Iceman's body was in a mountain glacier 3,210 m above sea level. What was this man doing so high in the snow- and ice-covered mountains? Was he hunting for food, shepherding his animals, or looking for metal ore?

Spindler noted that some of the wood used in the artifacts was from trees that grew at lower elevations. He concluded that the Iceman was probably a seasonal visitor to the high mountains.

Spindler also hypothesized that shortly before the Iceman's death, the Iceman had driven his herds from their summer high mountain pastures to the lowland valleys. However, the Iceman soon returned to the mountains where he died of exposure to the cold, wintry weather.

The Iceman's body was extremely well preserved. Spindler inferred that ice and snow covered the Iceman's body shortly after he died. Spindler concluded that the Iceman died in autumn and was quickly buried and frozen, which preserved his body and all his possessions.

6 Chapter 1

More Observations and Revised Hypotheses

> Scientific investigations often lead to new questions.

When the Iceman's body was discovered, Klaus Oeggl was an assistant professor of botany at the University of Innsbruck. His area of study was plant life during prehistoric times in the Alps. He was invited to join the research team studying the Iceman.

Upon close examination of the Iceman and his belongings, Professor Oeggl found three plant materials–grass from the Iceman's shoe, as shown in **Figure 10**, a splinter of wood from his longbow, and a tiny fruit called a sloe berry.

Over the next year, Professor Oeggl examined bits of charcoal wrapped in maple leaves that had been found at the discovery site. Examination of the samples revealed the charcoal was from the wood of eight different types of trees. All but one of the trees grew only at lower elevations than where the Iceman's body was found. Like Spindler, Professor Oeggl suspected that the Iceman had been at a lower elevation shortly before he died. From Oeggl's observations, he formed a hypothesis and made some predictions.

Oeggl realized that he would need more data to support his hypothesis. He requested that he be allowed to examine the contents of the Iceman's digestive tract. If all went well, the study would show what the Iceman had swallowed just hours before his death.

Observations: Plant matter near body, to study—grass on shoe, splinter from longbow, sloe berry fruit, charcoal wrapped in maple leaves, wood in charcoal from 8 different trees—7 of 8 types of wood in charcoal grow at lower elevations.
Hypothesis: The Iceman had recently been at lower elevations before he died because the plants identified near him grow only at lower elevations.
Prediction: If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations just before he died.
Question: What did the Iceman eat the day before he died?

Figure 10 Professor Oeggl examined the Iceman's belongings along with the leaves and grass that were stuck to his shoe.

Lesson 1 Case Study 7

An Early Conclusion

Radiocarbon dating and observations of the Iceman's artifacts indicated that the Iceman was a 5,300 year-old shepherd. Scientists initially hypothesized that the Iceman lived at lower elevations but traveled into the mountains with his herds in summer. For some reason, he had returned to the high mountains in autumn and died of exposure. Have students read about the evidence that led to this early conclusion and then ask these scaffolded questions.

Guiding Questions

AL What are the many things that scientists originally thought the Iceman could have been doing in the high mountains?
The Iceman could have been hunting for food, prospecting for metal ore, or shepherding his animals.

OL How did the Iceman's ax and other artifacts help scientists to learn more about the age of the Iceman?
Scientists could see by the construction of the ax that it was at least 4,000 years old. Radiocarbon dating of the wood on the ax showed that it was 5,300 years old. The wood used in the ax and other artifacts was from trees at a lower elevation, so scientists knew it was not likely that the Iceman lived in the high mountains.

BL How could the state of the Iceman's body help scientists to understand how he died?
Any signs of injury would indicate that he might have died from a fight. An absence of injury would indicate that he died from exposure or an illness.

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More Observations and Revised Hypotheses

The research team working on the Iceman mystery included a botanist named Klaus Oeggl. Professor Oeggl learned a lot about the Iceman by studying plant matter near the body. Have students read about Professor Oeggl's findings and then ask these scaffolded questions.

Guiding Questions

AL What does a professor of botany study?	*A professor of botany studies plants.*
OL What types of plant matter at the Iceman site did Professor Oeggl study?	*Professor Oeggl studied grass from the Iceman's shoe, wood from his long bow, sloe berry fruit, and charcoal wrapped in maple leaves.*
BL Why was it important for Professor Oeggl to know about the modern-day plants that grow in the Alps as he worked to solve the Iceman mystery?	*By knowing where current plants grow, the professor could get an idea of the range of the different plants and infer where prehistoric plants grew. This would help him to determine where the Iceman had lived.*

Visual Literacy: More Observations and Revised Hypotheses

Professor Oeggl's observations about the plant material near the Iceman led him to form a hypothesis and prediction. Have students read the material written in the notebook on this page. Then ask these questions.

Ask: What led Professor Oeggl to hypothesize that the Iceman had been at lower elevations before he died? *The plants identified near the Iceman grew at lower elevations.*

Hypothesis: The Iceman had recently been at lower elevations before he died because the plants identified near him grow only at lower elevations.

Prediction: If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations before he died.

Ask: What prediction did Professor Oeggl make? *He predicted that if he could show that plants that grew at lower elevations were in the Iceman's digestive tract, then the Iceman was at lower levels before he died.*

Differentiated Instruction

Middle School Boy Have students work together to write and perform a play about future humans investigating the mysterious Middle School Boy of the early 21st century. Differentiate the act as follows:

AL **Portraying Future Generations** Have AL students act as future humans, discovering the artifacts and hypothesizing to whom they belonged.

BL **Portraying Scientists** Have BL students act as future scientists, using the artifacts to investigate and report conclusions about Middle School Boy.

Teacher Toolbox

Fun Fact

Radiocarbon Dating Radiocarbon dating examines the amount of carbon-14 that is in organic remains, such as wood or bone. Carbon-14 is a radioactive isotope that fo when cosmic radiation interacts with carbon in Earth's atmosphere. Plants take up carbon-14 and the nonradioactive carbon-12 when they perform photosynthesis. Each type of carbon is passed to anim when they eat plants. Carbon-12 and carbon-14 are als passed to animals when they eat other animals. Organi stop taking in carbon-12 and carbon-14 when they die. Carbon-12 does not change, but carbon-14 decays at a constant rate within the remains of the organism. There scientists can examine the ratio of carbon-14 atoms to carbon-12 atoms in the remains to determine an organi approximate age.

Activity

Examining Plant Parts Professor Oeggl learned about the Iceman by examining plant materials at the discovery si Bring in a variety of parts from different plants, such as leaves, twigs, and bark. Form small student groups and provide magnifying lenses to each group. Instruct each group to write a series of observations about each plan part and to draw sketches. Have students classify the p parts into different groups, based on their physical similarities.

Careers in Science

Archaeologist An archaeologist carefully recovers and studies artifacts from ancient civilizations. Archaeologis help us to understand the history of human culture. Archaeologists generally study anthropology, history, ancient languages, art, art history, and theology. Archaeologists work on digs all around the world, as w in museums, government agencies, and universities.

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Experiment to Test Hypothesis

The research teams provided Professor Oeggl with a tiny sample from the Iceman's digestive tract. He was determined to study it carefully to obtain as much information as possible. Oeggl carefully planned his scientific inquiry. He knew that he had to work quickly to avoid the decomposition of the sample and to reduce the chances of contaminating the samples.

There is more than one way to test a hypothesis. Scientists might gather and evaluate evidence, collect data and record their observations, create a model, or design and perform an experiment. They also might perform a combination of these skills.

Test Plan:
- Divide a sample of the Iceman's digestive tract into four sections.
- Examine the pieces under microscopes.
- Gather data from observations of the pieces and record observations.

His plan was to divide the material from the digestive tract into four samples. Each sample would undergo several chemical tests. Then, the samples would be examined under an electron microscope to see as many details as possible.

Professor Oeggl began by adding a saline solution to the first sample. This caused it to swell slightly, making it easier to identify particles using the microscope at a relatively low magnification. He saw particles of a wheat grain known as einkorn, which was a common type of wheat grown in the region during prehistoric times. He also found other edible plant material in the sample.

Oeggl noticed that the sample also contained pollen grains in the digestive tract of the Iceman. To see the pollen grains more clearly, he used a chemical that separated unwanted substances from the pollen grains. He washed the sample a few times with alcohol. After each wash, he examined the sample under a microscope at a high magnification. The pollen grains became more visible. Many more microscopic pollen grains could now be seen. Professor Oeggl identified these pollen grains as those from a hop hornbeam tree.

Describe

List the main ideas from this section in the lines below.

Analyzing Results

Professor Oeggl observed that the hop-hornbeam pollen grains had not been digested. Therefore, the Iceman must have swallowed them within hours before his death. But, hop hornbeam trees only grow in lower valleys. Oeggl was confused. How could pollen grains from trees at low elevations be ingested within a few hours of this man dying in high, snow-covered mountains? Perhaps the samples from the Iceman's digestive tract had been contaminated. Oeggl knew he needed to investigate further.

Error is unavoidable in scientific research. Scientists are careful to document procedures and any unanticipated factors or accidents. They also are careful to document possible sources of error in their measurements.

Procedure:
- Sterilize laboratory equipment
- Prepare saline slides
- View saline slides under electron microscope. Results: no hop-hornbeam pollen grains
- Add digestive tract sample to one slide
- View this slide under electron microscope. Result: hop-hornbeam pollen grains present.

Further Experimentation

Oeggl realized that the most likely source of contamination would be Oeggl's own laboratory. He decided to test whether his lab equipment or saline solution contained hop-hornbeam pollen grains. To do this, he prepared two identical, sterile slides with saline solution. Then, on one slide, he placed a sample from the Iceman's digestive tract. The slide with the sample was the experimental group. The slide without the sample was the control group.

Controlled experiments contain two types of variables.

Dependent Variable: amount of hop-hornbeam pollen grains found on slide
Independent Variable: digestive tract sample on slide

The independent variable, or the variable that Oeggl changed, was the presence of the sample on the slide. The dependent variable, or the variable Oeggl tested, was whether hop-hornbeam pollen grains showed up on the slides. Oeggl examined the slides carefully.

Analyzing Additional Results

The experiment showed that the control group (the slide without the digestive tract sample) contained no hop-hornbeam pollen grains. Therefore, the pollen grains had not come from his lab equipment or solutions. The sample from the Iceman's digestive tract was closely re-examined. All of the samples contained the same hop-hornbeam pollen grains. The Iceman had indeed swallowed the hop-hornbeam pollen grains.

Without a control group, it is difficult to determine the origin of some observations.

Control Group: sterilized slide
Experimental Group: sterilized slide with digestive tract sample

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Experiment to Test Hypothesis

Describe Answer: Answers may vary.

Professor Oeggl performed careful observations on the digestive tract of the Iceman to determine the kinds of plants he had eaten. Have students read the professor's experimental procedure and answer these questions.

Guiding Questions

AL What was the professor looking for when he examined pieces of the Iceman's digestive tract? *The professor was looking for plant materials that the Iceman had eaten.*

OL What procedures did the professor use when examining the digestive tract? *He divided the tract into four samples, added saline to the first sample, and examined it using an electron microscope at low magnification. Then he used a chemical to separate unwanted substances in the sample, applied alcohol, and examined it using an electron microscope at a higher magnification.*

BL Why wasn't the examination of the Iceman's digestive tract a controlled experiment? *Sample answer: The professor did not have a control digestive tract to compare to the Iceman's digestive tract.*

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Analyzing Results / Further Experimentation /

Analyzing Additional Results

When Professor Oeggl found pollen in the sample of the Iceman's intestines, he performed an experiment to make sure the pollen was not simply contamination from his laboratory. His results showed that the pollen had indeed been swallowed by the Iceman. Have students review Professor Oeggl's procedures and the interpretation of his results. Then ask these questions.

Guiding Questions

AL What kind of contamination did Professor Oeggl think might have happened?	*He thought his sample might have been contaminated by pollen floating around his lab.*
OL What procedures did Professor Oeggl use to test for error?	*He sterilized lab equipment. Then he prepared and viewed a control slide containing just saline to verify that no pollen was present. He also prepared and viewed samples of the Iceman's intestines and found pollen. He re-examined the samples and still found the pollen.*
BL Why was it important for the professor to identify the types of pollen that were found in the Iceman's digestive system?	*By knowing the types of pollen, he could determine where the plants that produced the pollen grew, which could then help determine where the Iceman had traveled before he died.*

Visual Literacy: Analyzing Results

The procedure to find the source of the pollen was a controlled experiment. Have students study the notes on this page related to the procedure and answer these questions.

Without a control group, it is difficult to determine the origin of some observations.

Control Group: sterilized slide
Experimental Group: sterilized slide with digestive tract sample

Ask: What were the control and experiment groups in the error analysis? *The control group was the sterilized slide; the experimental group was the sterilized slide with the digestive tract sample.*

Procedure:
- Sterilize laboratory equipment.
- Prepare saline slides.
- View saline slides under electron microscope.

Results: no hop-hornbeam pollen grains.
- Add digestive tract sample to one slide.
- View this slide under electron microscope. Result: hop-hornbeam pollen grains present.

Ask: What was the conclusion of the error analysis? *The laboratory was not contaminated, so the Iceman must have ingested the pollen.*

Differentiated Instruction

Iceman Comics

Have students create a graphic novel that illustrates the discoveries made by Professor Oeggl as he investigated the mystery of the Iceman. Differentiate the activity as follows.

BL **Summarizing the Story** Have students summarize the information about Professor Oeggl's observations and experiments in their graphic novel.

AL **Making More Stories** Have students use the information they gained about Professor Oeggl and his techniques to create a graphic novel about his further adventures.

BL **Illustrating the Story** Have students use mainly pictures and brief descriptions to illustrate the discoveries of Professor Oeggl.

Teacher Toolbox

Careers in Science

Archaeobotanist An archaeobotanist studies the remains of plants that lived thousands or even millions of years ago. Archaeobotanists study fossilized plants or plant remains such as pollen, that has been trapped in sediment. Archaeobotanists need a good background in chemistry, physics, mathematics, statistics, as well as plant biology and ecology.

Reading Strategy

Linking Specifics and Generalities Have students work in pairs to revisit **Figure 2** in **Lesson 1** of this chapter, which shows the steps of a scientific inquiry. Have students discuss how the investigations related to the Iceman match up with each general scientific inquiry step. Encourage students to record their ideas in their science journal.

Fun Fact

Tracing the Origins of the Chinese Clay Army A life-sized army made entirely of clay, containing 8,000 soldiers, horses, and 200 chariots stands guard over the tomb of the first emperor of China. This army is 2,200 years old, and archaeologists have long wondered where the figures were made. Now scientists are grinding up small pieces of the terracotta soldiers and horses to examine pollen samples embedded in the clay. Scientists have already determined that the horses and soldiers have different types of pollen, so they were likely made at different places. In fact, the mystery of the origin of the horses might be solved. The pollen found in the horse figures matches tree pollen in soils near the tomb. This indicates that the horses were probably made nearby. Scientists have still not determined where the soldiers were made.

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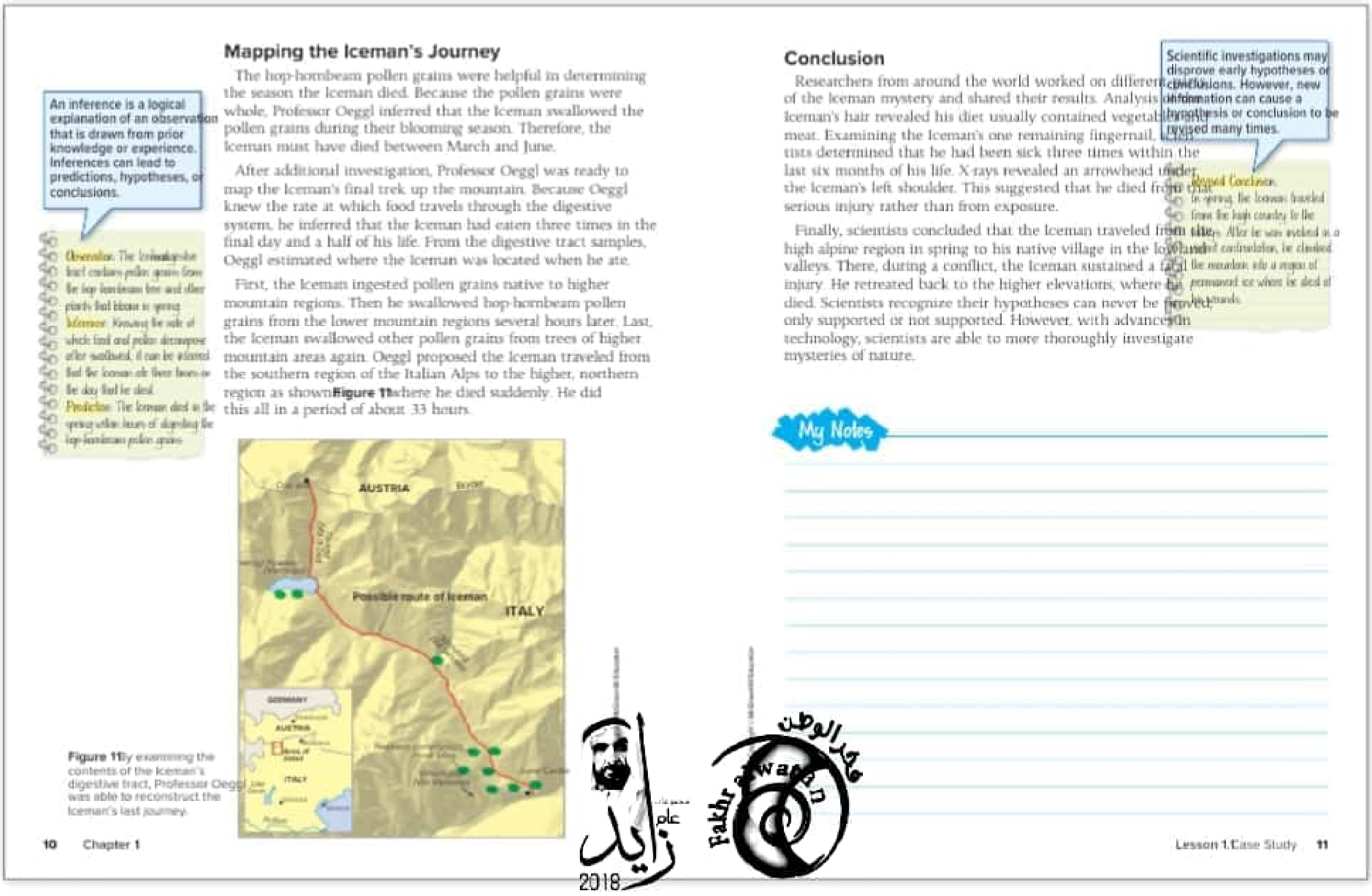

Mapping the Iceman's Journey

An inference is a logical explanation of an observation that is drawn from prior knowledge or experience. Inferences can lead to predictions, hypotheses, or conclusions.

The hop-hornbeam pollen grains were helpful in determining the season the Iceman died. Because the pollen grains were whole, Professor Oeggl inferred that the Iceman swallowed the pollen grains during their blooming season. Therefore, the Iceman must have died between March and June.

After additional investigation, Professor Oeggl was ready to map the Iceman's final trek up the mountain. Because Oeggl knew the rate at which food travels through the digestive system, he inferred that the Iceman had eaten three times in the final day and a half of his life. From the digestive tract samples, Oeggl estimated where the Iceman was located when he ate.

First, the Iceman ingested pollen grains native to higher mountain regions. Then he swallowed hop-hornbeam pollen grains from the lower mountain regions several hours later. Last, the Iceman swallowed other pollen grains from trees of higher mountain areas again. Oeggl proposed the Iceman traveled from the southern region of the Italian Alps to the higher, northern region as shown **Figure 11** where he died suddenly. He did this all in a period of about 33 hours.

Figure 11 By examining the contents of the Iceman's digestive tract, Professor Oeggl was able to reconstruct the Iceman's last journey.

Conclusion

Scientific investigations may disprove early hypotheses or conclusions. However, new information can cause a hypothesis or conclusion to be revised many times.

Researchers from around the world worked on different parts of the Iceman mystery and shared their results. Analysis of the Iceman's hair revealed his diet usually contained vegetables and meat. Examining the Iceman's one remaining fingernail, scientists determined that he had been sick three times within the last six months of his life. X-rays revealed an arrowhead under the Iceman's left shoulder. This suggested that he died from that serious injury rather than from exposure.

Finally, scientists concluded that the Iceman traveled from the high alpine region in spring to his native village in the lowland valleys. There, during a conflict, the Iceman sustained a fatal injury. He retreated back to the higher elevations, where he died. Scientists recognize their hypotheses can never be proved, only supported or not supported. However, with advances in technology, scientists are able to more thoroughly investigate mysteries of nature.

My Notes

10 Chapter 1 | Lesson 1 Case Study 11

Mapping the Iceman's Journey

An inference is a logical explanation based on the information that is available to the scientist. After Professor Oeggl gathered information from the Iceman's digestive system, he was ready to make inferences, or provide an explanation, of the Iceman's final journey.

Guiding Questions

AL What is an inference?	*An inference is a logical explanation of an observation that is drawn from prior knowledge or experience.*
OL What inference did the professor make after studying the plant evidence in the Iceman's digestive system?	*Knowing the rate at which food and pollen decompose after swallowing, the professor inferred from the plant evidence that the Iceman ate three time on the day he died.*
BL What can you infer about pollen after reading all of the evidence about the Iceman?	*Sample answer: I can infer that pollen is specific to a species of plant and can remain identifiable for thousands of years*

Visual Literacy: Figure 11

Figure 11 shows the hypothesized final journey of the Iceman, from a low alpine valley to the high mountain region where he was found. Professor Oeggl used evidence from pollen in the Iceman's digestive system to create this map. Have students study the map and answer these questions.

Ask: What do the green spots on the map represent? *The green spots represent areas that contain the types of plants that produced the pollen found in the Iceman's digestive system.*

Ask: Where did the Iceman's last journey likely begin? What evidence led to your conclusion? *The journey began in the alpine valley near the current Juval Castle. There was evidence of pollen from plants that grew only in this region.*

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Conclusion

Research on the Iceman and the artifacts surrounding him helped scientists to understand how he died. Scientific inquiry often occurs over years and years, as different scientists test different hypotheses and adjust old conclusions. The story of the Iceman shows that science is an active discipline that assembles many pieces of information to obtain the most accurate conclusion possible.

Guiding Questions

AL How did scientists solve the mystery of the Iceman?	*Many scientists studied artifacts, tested different hypotheses, and analyzed data to come up with the most logical conclusion.*
OL What evidence in 2002 led scientists to revise previous conclusions about the Iceman?	*A radiological investigation revealed an arrowhead under the Iceman's left shoulder, indicating that he had died from an injury and not exposure.*
BL Do you think that the mystery of the Iceman has been completely solved? Explain.	*Sample answer: No. Scientists might discover even more evidence that will help them to revise their conclusion to make it more accurate.*

Teacher Notes

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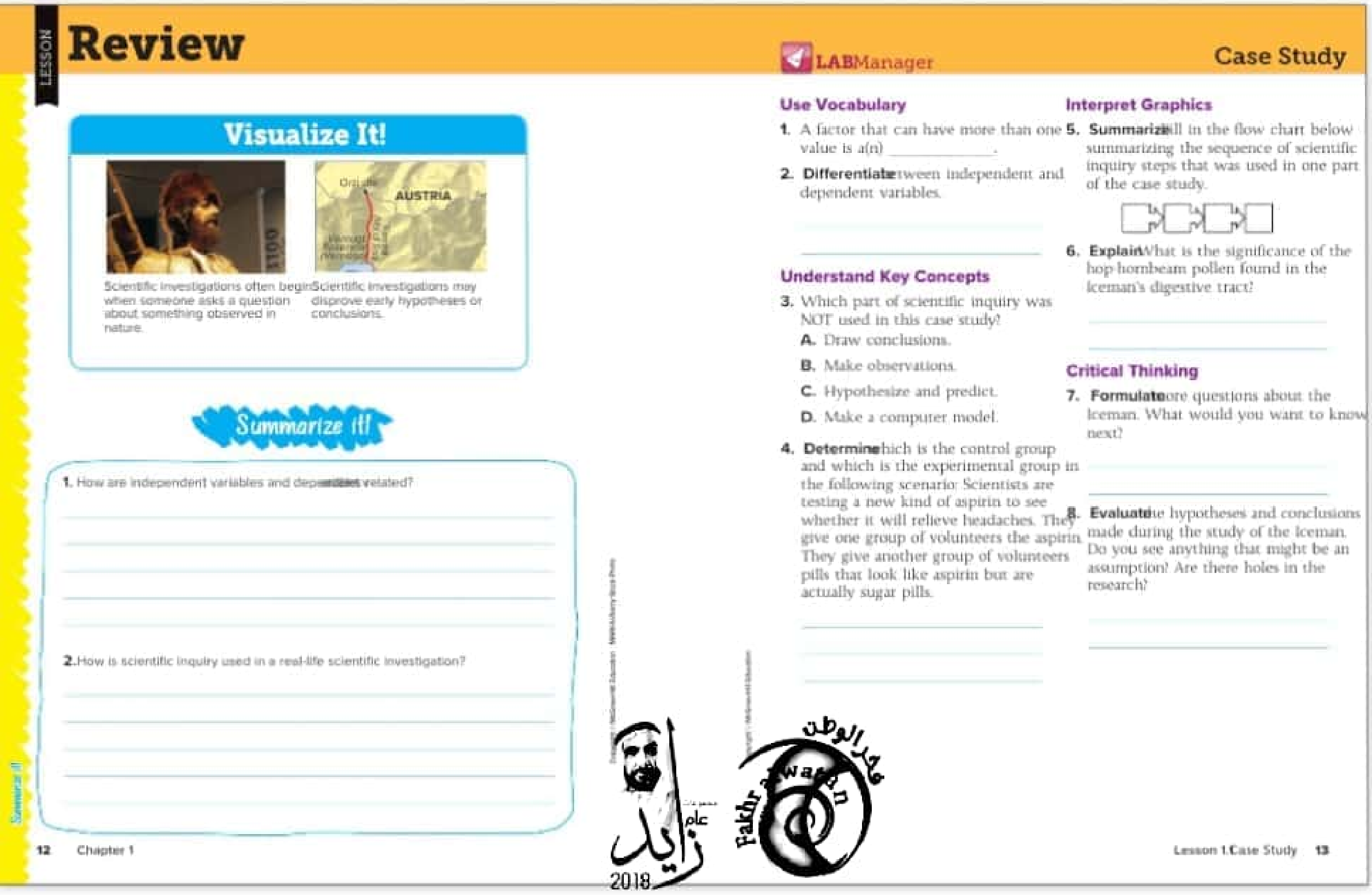
LESSON

Review

Visualize It!

Scientific investigations often begin when someone asks a question about something observed in nature.

Scientific investigations may disprove early hypotheses or conclusions.

Summarize it!

1. How are independent variables and dependent variables related?

2. How is scientific inquiry used in a real-life scientific investigation?

LABManager — Case Study

Use Vocabulary

1. A factor that can have more than one value is a(n) ________.
2. **Differentiate** between independent and dependent variables.

Understand Key Concepts

3. Which part of scientific inquiry was NOT used in this case study?
   A. Draw conclusions.
   B. Make observations.
   C. Hypothesize and predict.
   D. Make a computer model.
4. **Determine** which is the control group and which is the experimental group in the following scenario: Scientists are testing a new kind of aspirin to see whether it will relieve headaches. They give one group of volunteers the aspirin. They give another group of volunteers pills that look like aspirin but are actually sugar pills.

Interpret Graphics

5. **Summarize** Fill in the flow chart below summarizing the sequence of scientific inquiry steps that was used in one part of the case study.
6. **Explain** What is the significance of the hop-hornbeam pollen found in the Iceman's digestive tract?

Critical Thinking

7. **Formulate** more questions about the Iceman. What would you want to know next?
8. **Evaluate** the hypotheses and conclusions made during the study of the Iceman. Do you see anything that might be an assumption? Are there holes in the research?

12 Chapter 1

Lesson 1 Case Study 13

Summarize it!

- The *independent variable* is the factor a scientist changes to observe how it affects a *dependent variable*. A dependent variable is the factor a scientist measures or observes during an experiment.
- Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

Use Vocabulary

1 variable

2 The independent variable is the factor a scientist wants to test. The dependent variable is the factor a scientist observes or measures during an experiment. A scientist changes the independent variable to observe how it affects a dependent variable.

Understand Key Concepts

3 **D.** Make a computer model.

4 The control group is the group given sugar pills. The experimental group is the group given aspirin.

Interpret Graphics

5 Sample answer: Observation-The construction of the ax indicates that it is at least 4,000 years old; Prediction-If the ax is 4,000 years old, the body found is at least 4,000 years old; Test Result-Radiocarbon dating showed that the ax was 5,300 years old; Conclusion- The Iceman died around 5,300 years ago.

6 The hop hornbeam blooms from March to June and it only grows in lower elevations. Because the hop hornbeam was still intact in the Iceman's stomach, he had to have died in the spring when the hop hornbeam blooms.

Critical Thinking

7 Sample answer: Who shot the Iceman with the arrow? Why was the Iceman shot?

8 Sample answer: There is an assumption that he died from an injury instead of exposure to the elements. Could both have been a factor in his death? A hole in the research is who shot the arrow and why.

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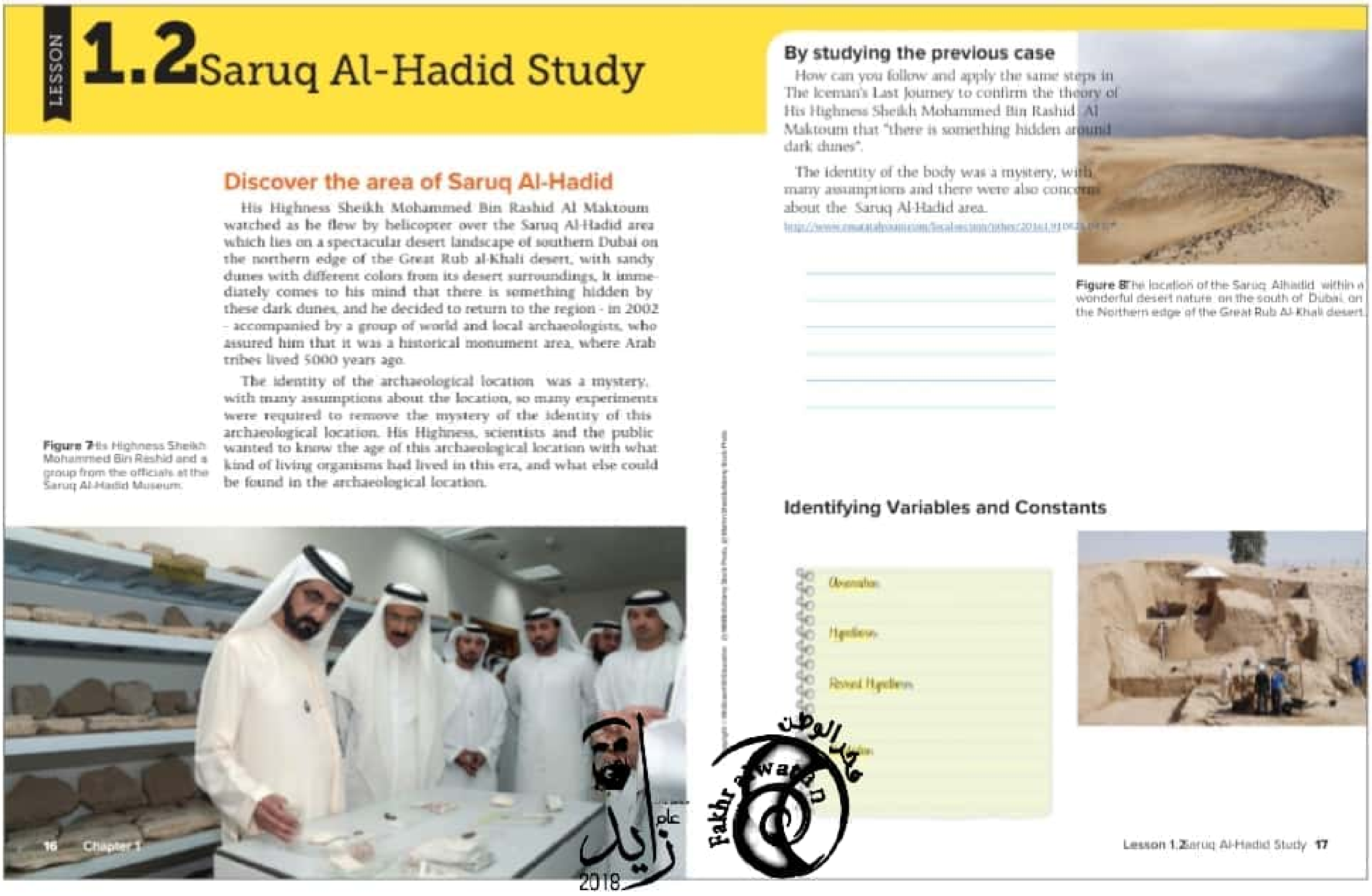

LESSON

1.2 Saruq Al-Hadid Study

Discover the area of Saruq Al-Hadid

His Highness Sheikh Mohammed Bin Rashid Al Maktoum watched as he flew by helicopter over the Saruq Al-Hadid area which lies on a spectacular desert landscape of southern Dubai on the northern edge of the Great Rub al-Khali desert, with sandy dunes with different colors from its desert surroundings, It immediately comes to his mind that there is something hidden by these dark dunes, and he decided to return to the region - in 2002 - accompanied by a group of world and local archaeologists, who assured him that it was a historical monument area, where Arab tribes lived 5000 years ago.

The identity of the archaeological location was a mystery, with many assumptions about the location, so many experiments were required to remove the mystery of the identity of this archaeological location. His Highness, scientists and the public wanted to know the age of this archaeological location with what kind of living organisms had lived in this era, and what else could be found in the archaeological location.

Figure 7 His Highness Sheikh Mohammed Bin Rashid and a group from the officials at the Saruq Al-Hadid Museum.

By studying the previous case

How can you follow and apply the same steps in The Iceman's Last Journey to confirm the theory of His Highness Sheikh Mohammed Bin Rashid Al Maktoum that "there is something hidden around dark dunes".

The identity of the body was a mystery, with many assumptions and there were also concerns about the Saruq Al-Hadid area.

Figure 8 The location of the Saruq Alhadid within a wonderful desert nature on the south of Dubai, on the Northern edge of the Great Rub Al-Khali desert.

Identifying Variables and Constants

Observation

Hypothesis

Revised Hypothesis

16 Chapter 1

Lesson 1.2 Saruq Al-Hadid Study 17

An Early Conclusion

Radiocarbon dating and observations of the Saruq Al-Hadid artifacts indicated that the Saruq Al-Hadid was a 5,300 year-old shepherd. Scientists initially hypothesized that the Saruq Al-Hadid was gust a kaind of sand but they discover its the Way of Iron. For some reason, it was covered and he shainging in the wither it make this area come out Have students read about the evidence that led to this early conclusion and then ask these scaffolded questions.

Guiding Questions

AL	What are the many things that scientists originally thought about Saruq Al-Hadid	*diffrent answer*
OL	How did the Saruq Al-Hadid other artifacts help scientists to learn more about the age of the Saruq Al-Hadid?	*scientists could see by the construction of the Iron Swords that it was at least 4,000 years old. Radiocarbon dating of the Iron on the Swords showed that it was 5,300 years old. The Iron used in the Swords and other artifacts was from Iron at a lower elevation, so scientists knew it was not likely that the Saruq l-Hadid lived in this place.*
BL	How could the state of the objects help scientists to understand how the place begain	*from the web said*

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More Observations and Revised Hypotheses

The research team working on the Iceman mystery included a botanist named Klaus Oeggl. Professor Oeggl learned a lot about the Iceman by studying plant matter near the body. Have students read about Professor Oeggl's findings and then ask these scaffolded questions.

Guiding Questions

AL What does a professor of botany study?	*A professor of botany studies plants.*
OL What types of plant matter at the Iceman site did Professor Oeggl study?	*Professor Oeggl studied grass from the Iceman's shoe, wood from his long bow, sloe berry fruit, and charcoal wrapped in maple leaves.*
BL Why was it important for Professor Oeggl to know about the modern-day plants that grow in the Alps as he worked to solve the Iceman mystery?	*By knowing where current plants grow, the professor could get an idea of the range of the different plants and infer where prehistoric plants grew. This would help him to determine where the Iceman had lived.*

Visual Literacy: More Observations and Revised Hypotheses

Professor Oeggl's observations about the plant material near the Iceman led him to form a hypothesis and prediction. Have students read the material written in the notebook on this page. Then ask these questions.

Ask: What led Professor Oeggl to hypothesize that the Iceman had been at lower elevations before he died? *The plants identified near the Iceman grew at lower elevations.*

Hypothesis: The Iceman had recently been at lower elevations before he died because the plants identified near him grow only at lower elevations.

Prediction: If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations before he died.

Ask: What prediction did Professor Oeggl make? *He predicted that if he could show that plants that grew at lower elevations were in the Iceman's digestive tract, then the Iceman was at lower levels before he died.*

Differentiated Instruction

Middle School Boy Have students work together to write and perform a play about future humans investigating the mysterious Middle School Boy of the early 21st century. Differentiate the act as follows:

AL Portraying Future Generations Have AL students act as future humans, discovering the artifacts and hypothesizing to whom they belonged.

BL Portraying Scientists Have BL students act as future scientists, using the artifacts to investigate and report conclusions about Middle School Boy.

Teacher Toolbox

Fun Fact

Radiocarbon Dating Radiocarbon dating examines the amount of carbon-14 that is in organic remains, such as wood or bone. Carbon-14 is a radioactive isotope that f when cosmic radiation interacts with carbon in Earth's atmosphere. Plants take up carbon-14 and the nonradioactive carbon-12 when they perform photosynthesis. Each type of carbon is passed to anim when they eat plants. Carbon-12 and carbon-14 are als passed to animals when they eat other animals. Organi stop taking in carbon-12 and carbon-14 when they die. Carbon-12 does not change, but carbon-14 decays at a constant rate within the remains of the organism. Ther scientists can examine the ratio of carbon-14 atoms to carbon-12 atoms in the remains to determine an organi approximate age.

Activity

Examining Plant Parts Professor Oeggl learned about the Iceman by examining plant materials at the discovery s Bring in a variety of parts from different plants, such as leaves, twigs, and bark. Form small student groups and provide magnifying lenses to each group. Instruct each group to write a series of observations about each pla part and to draw sketches. Have students classify the p parts into different groups, based on their physical similarities.

Careers in Science

Archaeologist An archaeologist carefully recovers and studies artifacts from ancient civilizations. Archaeologis help us to understand the history of human culture. Archaeologists generally study anthropology, history, ancient languages, art, art history, and theology. Archaeologists work on digs all around the world, as w in museums, government agencies, and universities.

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An Early Conclusion

More Observations and Revised Hypotheses

More Observations and Revised Hypotheses

Analyzing Results

Figure 9 These artifacts and remains were found at the location of the Saruq Al-Hadid.

Figure 10 The archeologist examined a collection of artifacts found at the location of the Saruq Al-Hadid.

Saruq Al-Hadid.

Mapping the saruq Al-Hadid

An inference is a logical explanation based on the information that is available to the scientist. After Professor James gathered information from the Saruq Al-Hadid , he was ready to make inferences, or provide an explanation, of the Irelation ship betwwen the Saruq Al-Hadid and the wider world .

Guiding Questions

AL	What is an inference?	*An inference is a logical explanation of an observation that is drawn from prior knowledge or experience.*
OL	What inference did the professor make after studying the animals evidence in the artfacts that found in the area?	*Knowing the rate at which food and pollen decompose in the artifacts , the professor inferred from the animal evidence that the warkers have these kind of food.*
BL	What can you infer about pollen after reading all of the evidence about the Saruq Al-Hadid ?	*Sample answer:*

Visual Literacy: Figure 11

Figure 11 shows the hypothesized final journey of the Iceman, from a low alpine valley to the high mountain region where he was found. Professor Oeggl used evidence from pollen in the Iceman's digestive system to create this map. Have students study the map and answer these questions.

Ask: What do the green spots on the map represent? *The green spots represent areas that contain the types of plants that produced the pollen found in the Iceman's digestive system.*

Ask: Where did the Iceman's last journey likely begin? What evidence led to your conclusion? *His journey began in the alpine valley near the current Juval Castle. There was evidence of pollen from plants that grew only in this region.*

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Conclusion

Research on the Saruq Al-Hadid and the artifacts surrounding it helped scientists to understand how the place grow . Scientific inquiry often occurs over years and years, as different scientists test different hypotheses and adjust old conclusions. The story of the Saruq Al-Hadid shows that science is an active discipline that assembles many pieces of information to obtain the most accurate conclusion
possible.

Guiding Questions

AL How did scientists solve the mystery of the Saruq Al-Hadid?	*Many scientists studied artifacts, tested different hypotheses, and analyzed data to come up with the most logical conclusion.*
OL What evidence in 2002 led scientists to revise previous conclusions about the Saruq Al-Hadid ?	*A radiological investigation revealed an arrowhead under the Saruq Al-Hadid left shoulder, indicating that he had relation shap between it and the wider world*
BL Do you think that the mystery of the Saruq Al-Hadid has been completely solved? Explain.	*Sample answer: No. Scientists might discover even more evidence that will help them to revise their conclusion to make it more accurate.*

Teacher Notes

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CHAPTER **1** Study Guide

Chapter Study Guide

TheBIGIdea
Scientists use the process of scientific inquiry to perform scientific investigations.

Key Concepts Summary | **Vocabulary**

1.1 Case Study: The Iceman's Last Journey

- The **independent variable** is the factor a scientist changes to observe how it affects a **dependent variable**. A dependent variable is the factor a scientist measures or observes during an experiment.
- Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

variable
independent variable
dependent variable

Use Vocabulary
Each of the following sentences is false. Make each sentence true by replacing the italicized term with the correct vocabulary term.

1. A(n) *description* ________ is an interpretation of observations.
2. The *means* ________ are the numbers of digits in a measurement that you know with a certain degree of reliability.
3. The act of watching something and taking note of what occurs is a(n) *inference*. ________
4. A *scientific theory* ________ is a rule that describes a pattern in nature.

Writing in Science
5. **Write** a five-sentence paragraph explaining why the International System of Units (SI) is an easier system to use than the English system of measurement. Be sure to include a topic sentence and a concluding sentence in your paragraph.

Math Skill
Use Numbers
6. Convert 152.5 kg to grams.

7. Convert 89.7 cm to millimeters.

22 Chapter Study Guide | Chapter Study Guide 23

Key Concepts Summary

Study Strategy: Sentence Scramble

Most students enjoy playing games, which make games an ideal tool forstudying. Many games, like the sentence-scramble game described below,can be adapted to the classroom.

1. Tell students to choose five different Key Concept statements from thischapter.
2. Have students make a chart like the one below. In the first column,they should scramble the words of the five Key Concept statements they chose.
3. Ask students to exchange charts with a partner. Students should unscramble the sentence in the first column and write it in the second column.

Example:

Scrambled Sentence	Corrected Sentence
evaluate that mean statistical median sets mode and range are calculations are used to of data	Mean, median, mode, and range are statistical calculations that are used to evaluate sets of data.

Vocabulary

Study Strategy: Self-Assessment

It is important for students to know how to identify concepts and terms on which they should focus when they study. Having students work in pairs to quiz each other can help students do this. Students can use this activity to find out how well they know this chapter's vocabulary.

4. Have students form pairs. Each partner will take turns reading the definitions of the chapter's vocabulary from the Glossary.
5. The partner will then try to identify the term that matches that definition.
6. Tell students that if they did not correctly identify a term, they should write it down in their Science Journals. Next to each term they did not correctly identify, they should write the term's definition. They can use a chart like the one below.

Example:

Terms to Study	Definition
scientific law	a rule that describes a pattern in nature
variable	

Levels of Question: L1 Concepts L2 Application L3 Text-Dependent Reading L4 Science Performance Assessment L5 Integration of Content and Process Standards

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CHAPTER 1 Review

Understand Key Concepts

1. Which best describes an independent variable?
   - A. It is a factor that is not in every test.
   - B. It is a factor the investigator changes.
   - C. It is a factor you measure during a test.
   - D. It is a factor that stays the same in every test.

Critical Thinking

2. **Predict** what would happen if every scientist tried to use all the skills of scientific inquiry in the same order in every investigation.

5. **Assess** the role of measurement uncertainty in 3 investigations.

4. **Evaluate** the importance of having a control group in a scientific investigation.

The BIG Idea

5. What process do scientists use to perform scientific investigations? List and explain three of the skills involved.

My Notes

24 Chapter Review

Understand Key Concepts

1 C. Make a model.

2 D. range

3 B. It is a factor the investigator changes

Critical Thinking

4 Sample Answer: Scientific progress would slow down because scientific testing would contain unnecessary steps.

5 Sample Answer: Because measurement uncertainty is unavoidable, it must be correctly communicated to others and managed.

6 The control group reveals whether the experimental observ tions are a result of changing a variable or not.

Review

7 scientific inquiry; devising a testable hypothesis-If the hypothesis is not testable, it is of little value. devising an experiment to test the hypothesis-If the experiment is not well thought out, the results might have little value. drawing reasonable conclusions-If the conclusions do not make reasonable inferences from the data, they have no value.

8 The pink dye is an indicator that gives scientists a reference point to measure. The movement of the pink dye shows the movement of the ice.

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CHAPTER 2

Technology and the Design Process

TheBIGIdea

How do people use tools and materials to modify or create technologies?

LESSON **2.1 Tools of Technology**
- How are science and technology connected?
- What technological resources are needed to create new technologies?

LESSON **2.2 Materials and Their Properties**
- How are materials selected for a designed product?
- Why are materials modified to change their properties?
- How are materials classified?

LESSON **2.3 The Design Process**
- What is the design process?
- How can different solutions be tested and compared?

LESSON **2.4 Technology Systems**
- How are subsystems different than systems?
- What is the difference between open-loop systems and closed-loop systems?
- How are automatic controls different than manual controls?
- What is life cycle analysis?

26

Science and SOCIETY

Stretch of the Imagination

The Incredible Stretching Putty

During World War II, when natural resources were scarce and needed for the war effort, the U.S. government asked an eng to develop an inexpensive alternative to synthetic rubber. While researching the problem and looking for solutions, the engineer dropped boric aci into silicone oil. The result of mixing these two substances created a product that could bounce and stretch in all directio The product was called silicone bouncing putty.

The engineer also discovered that when strong pressure is applied to the substance, it reacts like a solid and breaks apa Even though the combination was versatile, the U.S. governm decided the new substance wasn't a good substitute for synt rubber.

A few years later, a business person and a toy-store owner the putty's potential as a toy. In 1949 it was sold through a toy store catalog for the first time. The silicone bouncing putty outsold all toys except for crayons.

The putty can be used for more than child's play. People use it to make impressions of newspaper print or com Its sticky consistency makes it good for cleaning computer keyboards and removing small specks of lint from fabrics. Athletes strengthen their grip by squeezing it over and over.

It's Your Turn!

RESEARCH Determine how other people have used the silicone bouncing putty. Then as a group, brainstorm other uses for this substance.

Chapter 2 Technology and the Design Process 27

Technology and the Design Process

TheBIGIdea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL What are some ways you use technology?	*Possible answers may include smartphones to watch videos or to listen to music or e-reader or a tablet to read books. Use this question to help students develop a greater awareness for how technology impacts individuals at home, in school, and at work.*
OL What do you think of when you hear the word technology?	*Possible answers may include computers, hybrid cars, artificial limbs, or GPS systems as technology. Use this question to assess student understanding of the meaning of technology.*
BL Why does technology keep changing?	*Possible answer may include that people come up with new ideas to do something different. Use this question to help students consider the forces that drive new designs in technology.*

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Explore Activity

How can you use magnetism?

Prep: *5 min* **Class:** *15–20 min*

Purpose
To distinguish between science and technology

Materials
Per team of 3 students: variety of magnets

Before You Begin
Assemble a variety of magnets, such as refrigerator magnets, small horseshoe-shaped, or bar magnets, and devices that use magnets such as a compass. There should be enough magnets that each team can observe and use several different shapes.

Guide the Investigation

- Have students use pairs of magnets to determine what materials the magnets will and won't stick to.
- Encourage students to brainstorm ways in which magnets can accomplish tasks. Students may begin with ways that magnets are already used and then come up with ideas of their own.

Think About This
Students may not know the answers to all questions. Encourage them to hypothesize.

1. The knowledge that metals can be pulled into the shape of a wire or bent into different shapes without breaking.
2. The inventions are all based on the scientific principle of magnetism. The use of the magnets is a product of creativity.

Teacher Notes

OL On Level AL Approaching Level BL Beyond Level

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Energy

How would you define energy? The word *energy* comes from the ancient Greek word *energos*, which means active. You probably have used the word *energy* in the same way. When you say you have a lot of energy, what does thi **Energy**s *the ability to cause change*. For example, you use energy when you change the speed of a bicycle by pedaling faster or when you put on the brakes. The energy in a thunderstorm produces lightning, shown in **Figure 7** which lights up the sky and produces thunder that can rattle windows.

Energy does not usually exist naturally in a form humans can directly use. For example, coal is a source of energy, but the coal has to be processed. Technology makes it possible to find and release the energy in the coal, and then put that energy to work. Technologists are always looking for new and better ways to use energy resources.

Figure 7 The temperature of a lightning bolt is five times hotter than the surface of the Sun.

Reading Check

9. What is energy?

Describe

List the main ideas from this section in the lines below.

36 Chapter 2

LESSON **2.1** Review

Visualize It!

Technology was developed because people had ideas they turned into useful devices.

Resources are used to create the products and services we want and need. Without resources, science and technology would not advance.

Companies buy resources needed to create new technology. They hire people with the knowledge and skill to make products.

Summarize it!

1. How are science and technology connected?

2. What technological resources are needed to create new technologies?

Lesson 2.1 Tools of Technology 37

Energy

Write the word *energy* on the board or chart paper. Have students skim the paragraphs to find the definition. Push a chair to change its position. Explain that energy was used to change the position of the chair. Direct student attention to **Figure 7** and have them read the caption. Discuss the energy released by a lightning bolt and the change it can cause when it strikes a tree or building.

Guiding Questions

AL	What is an example of energy?	*fire*
	Reading Check What is energy?	*the ability to cause change*
BL	Why is it important to find new technologies to use energy resources?	*Energy resources usually need to processed in order for humans to use it. Humans consume so much energy, finding efficient and clean ways to provide this energy is important.*

Describe Answers Student answers will vary.

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Science and Technology
- Technology Resources

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Tools of Technology

Use Vocabulary

1. **Define** resource in your own words.

2. The ability to do work is ________.

3. **Use the term** technology in a sentence.

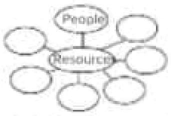
Understand Key Concepts

4. Which material resource is found in a plastic toy?
   - A. manufactured materials
   - B. processed materials
   - C. raw materials
   - D. synthetic materials

5. **Discuss** how one technology has changed in your lifetime.

Interpret Graphics

6. **Summarize** Copy and fill in the graphic organizer listing the resources needed for technology.



7. **Explain** why the type of resource shown below is important in developing new technology.

Critical Thinking

8. **Infer** Why is skill important when creating technology?

9. **Infer** What could happen if no one understood the science behind a technology they used?

My Notes

38 Chapter 2

Use Vocabulary

1. A resource is something that gives help to a system Information can be a resource.

2. energy

3. Technology is anything and everything we design and use to get things done.

Understand Key Concepts

4. D. synthetic materials

5. Accept all reasonable answers. Possible answer: Television has changed in my life time. The TV signals used to be sent as analog; now they are digital. TV sets used to be big and heavy because of the picture tube. Now TVs are lighter and thin

Interpret Graphics

6. information, tools/machines, capital, energy, materials, time

7. The image represents capital or money. Capital is needed to buy other resources and to hire people

Critical Thinking

8. Skilled people make better use of resources (less time, less wasted materials, etc.), and the products they produced are of better quality.

9. People would not have the knowledge needed to maintain or improve the technology.

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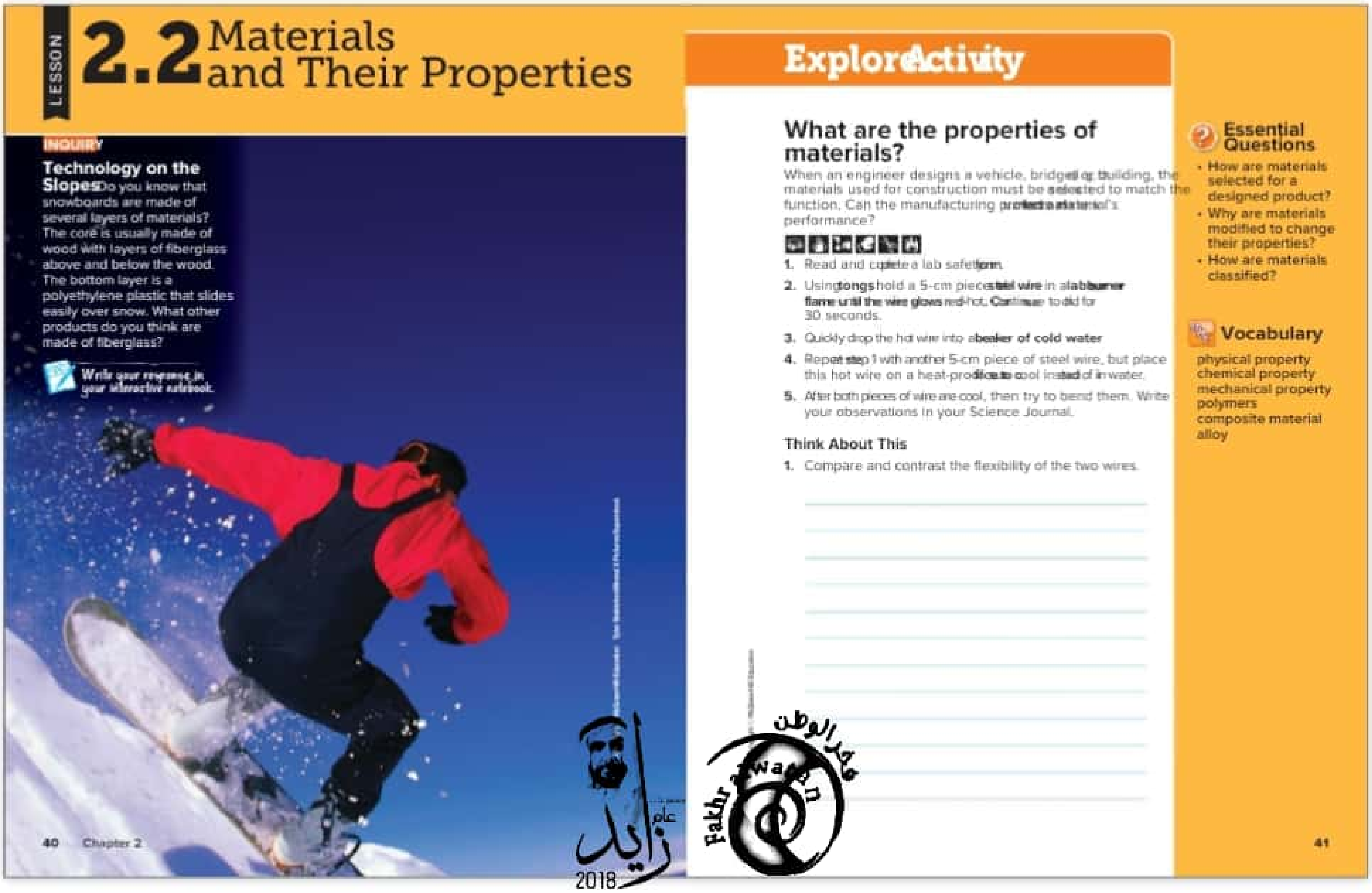

LESSON 2.2 Materials and Their Properties

INQUIRY

Technology on the Slopes Do you know that snowboards are made of several layers of materials? The core is usually made of wood with layers of fiberglass above and below the wood. The bottom layer is a polyethylene plastic that slides easily over snow. What other products do you think are made of fiberglass?

Write your response in your interactive notebook.

40 Chapter 2

Explore Activity

What are the properties of materials?

When an engineer designs a vehicle, bridge, or building, the materials used for construction must be selected to match the function. Can the manufacturing process affect a material's performance?

1. Read and complete a lab safety form.
2. Using tongs, hold a 5-cm piece of steel wire in a lab burner flame until the wire glows red-hot. Continue to hold for 30 seconds.
3. Quickly drop the hot wire into a beaker of cold water.
4. Repeat step 1 with another 5-cm piece of steel wire, but place this hot wire on a heat-proof [illegible] to cool instead of in water.
5. After both pieces of wire are cool, then try to bend them. Write your observations in your Science Journal.

Think About This

1. Compare and contrast the flexibility of the two wires.

Essential Questions

- How are materials selected for a designed product?
- Why are materials modified to change their properties?
- How are materials classified?

Vocabulary

physical property
chemical property
mechanical property
polymers
composite material
alloy

41

INQUIRY

About the Photo **Technology on the Slopes** Snowboards are built with different properties based on the type of snowboarding the rider wants. The snowboard designs are tested and adjusted to achieve the desired results. Explain that humans are essential in making sure technology works efficiently. Have students answer the following questions.

Guiding Questions

AL **Why does the snowboard slide over the snow?**	*A combination of gravity and the smooth polyethylene plastic surface allow the snowboard to easily slide over the snow. Use this question to begin discussion of the physical properties of the snowboard and the snow.*
OL **What other products do you think are made of fiberglass?**	*Possible answers: bathtubs, car bodies, outdoor furniture*
BL **What considerations do you think are made when choosing material for a snowboard?**	*Possible answer: friction reduction, durability, flexibility, density, hardness. Use this question to help students analyze the importance of materials in the design of a product.*

LABManager

All the labs for this lesson can be found in the Student Resource Handbook and the Activity Lab Workbook.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Associations

Associating words with images can help students understand and recall scientific words.

1. Write the word physical on the board or chart paper. Hold up a pencil. **Ask:** **What are some physical characteristics of this pencil?** hard, yellow, smooth

   Explain that these characteristics are called properties because they belong to the object, but in a different way then we think of a person owning a house. Use a few examples comparing the two uses of the term.

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When thinking about a material's physical, chemical, or mechanical properties, remember that the properties describe the characteristics of the material.

2. Have students add the lesson's vocabulary words to their Science Journal. Remind them to write the definition after each word as they read the lesson.

Teacher Notes

Explore Activity

What are the properties of materials?

Prep: *5 min* **Class:** *15 min*

Purpose
To investigate how metals may respond to fast and slow temperature change.

Materials
lab burner, tongs, several beakers of ice water, 18-gauge steel wire

Guide the Investigation

- Point out that both wire pieces are heated to the same temperature, so the only variable is the rate at which they cool. Remind students that heating metals to high temperature and then allowing them to cool occurs in engines and heating elements.
- **Ask students** what happened to the atoms in the metal as it was heated. *The atoms began to move faster and their relationship to each other changed and weakened.*
- **Ask students** why cooling quickly might not restore the flexibility to the metal wire. *The heated atoms were not given time to return to their original stable position.*

Think About This

1. Before heating, both wires were somewhat flexible. After being heated, then cooled, the wire that cooled slowly was still somewhat flexible. However, the wire that was cooled quickly became brittle and snapped easily *when bent.*

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FOLDABLES

Make a six-door book. Label the tabs as shown. Use your book to summarize the properties and applications of each material.

Types of Materials

Materials can be classified by how they originated. Some organic materials, such as wood and cotton, come from living things. Inorganic materials, such as metal and rocks, come from mineral deposits. Each material type has unique properties that make it useful in a wide range of applications.

Wood

One of the most common materials used by humans is wood from trees. Wood is used to build houses, make toys and furniture, and to provide fuel.

Polymers

Polymers *are natural or manufactured materials composed of long chains of small, repeating molecules* **monomers**. Proteins are an example of a natural polymer. One example of a manufactured polymer is plastics. By changing the number, type, and position of the monomer in a polymer, the properties of the polymer change. Such changes can result in a nearly infinite number of polymers, each with a unique set of chemical and physical properties. Some polymers are shown in **Figure 10**.

Word Origin

monomer from Greek *mono*, means one and *meros* means part

Reading Check

3. Why are there so many types of polymers?

Plastics

Many widely used products are made of polymers commonly called plastic. Plastics are usually lightweight, strong, waterproof, and inexpensive. Plastics are used in toys, computer hardware, and containers. Some plastics are clear, some melt at high temperature, and some are flexible. Melting temperature, clarity, and flexibility are properties of plastic that relate to the composition of the polymer.

Figure 10 These products are made from different types of polymers.

44 Chapter 2

Composites

The bodies of automobiles once were made entirely of metal. An automobile with a metallic body was heavy and rusted easily. With the advancement of polymer technology, automobile bodies are now made from a type of polymer called composites. A **composite material** *is a mixture of two or more materials—one layered in the other.* The new material is better than the original materials would have been on their own. The composite's ingredients provide the correct physical properties, and a binder or glue holds them together. Composite materials are used to make automobile bodies strong, lightweight, and rust resistant. Composites are used to make other products, such as boats, and sports equipment.

Key Concept Check

4. Why would automobile manufactures want to use composite materials instead of metal for automobile bodies?

Alloys

An **alloy** *is a mixture of two or more metals.* Alloys are used when the properties of a metal need to be improved for an application. Alloys can be produced to improve the hardness, strength, density, or durability of the metal. One example, stainless steel, is a mixture of iron, chromium, and nickel. The mixture retains the strength of iron but is corrosion resistant. This makes stainless steel useful inside the human body to replace or repair broken bones, as shown in **Figure 11**.

Key Concept Check

5. What are possible advantages of an alloy over a pure metal?

Figure 11 Stainless steel can be used inside the human body because it does not react with body fluids. The broken thigh bone has a surgically-attached pin to help the bone heal.

Lesson 2.2 Materials and Their Properties 45

Types of Materials

Write *organic* and *inorganic* on the board. Have students identify materials that fit in both categories. Create a chart on the interactive whiteboard as the materials are identified. Compare and contrast the properties of selected items.

Word Origin

monomer

Ask: What two Greek words make up the word *monomer*? *Mono means one and meros means part.* Together, what do these two Greek words mean? *one part*

Wood and Polymers

Direct student attention to **Figure 10** and have them read the caption. Have students identify the items. After students read the two paragraphs, discuss with them what makes polymers different. Use the questions below to assess students' comprehension.

Guiding Questions

AL What are some uses for wood?	*Possible answers: build houses, make toys and furniture, make pencils*
OL What is the relationship between polymers and monomers?	*Polymers are made up of repeating molecules called monomers.*
Reading Check Why are there so many types of polymers?	*Changing the number, type, and position of the monomer changes the properties of the polymer. Such changes can result in a large number of different polymers.*

Plastics

Plastics are widely used for many products because they have desirable properties. They can be lightweight, waterproof, strong, and inexpensive. Transparency, melting temperature, and flexibility are properties of plastics that relate to the composition of the polymer. Have students read the paragraph and identify the properties of plastic. Then have students identify products in the classroom made from plastic.

Guiding Questions

AL What type of material is plastic?	*a polymer*
OL What are three properties of plastic?	*melting temperature, clarity, flexibility*
BL What defines the properties of a particular plastic?	*composition of the polymer that makes up the plastic*

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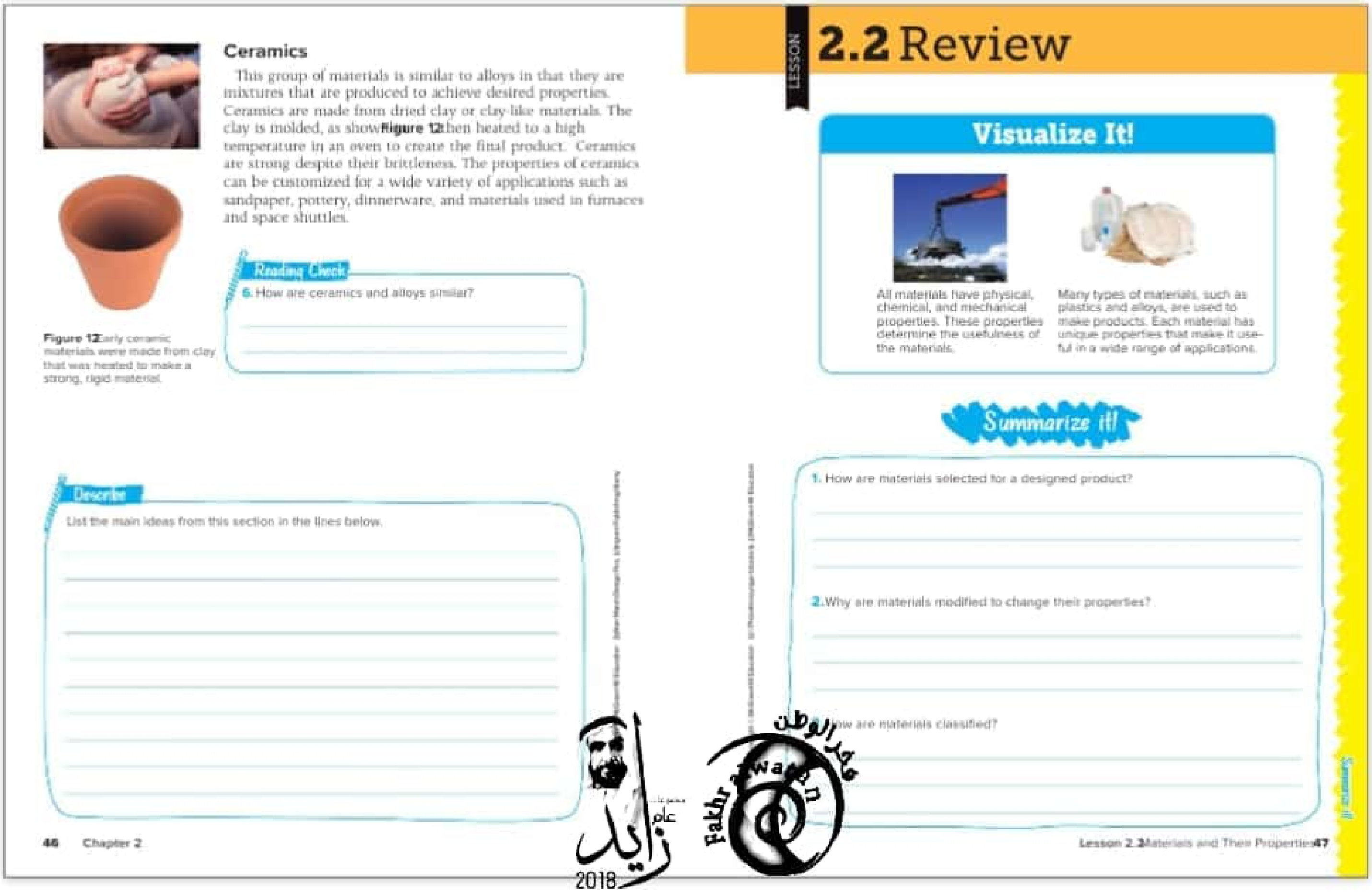

Ceramics

This group of materials is similar to alloys in that they are mixtures that are produced to achieve desired properties. Ceramics are made from dried clay or clay-like materials. The clay is molded, as shown **Figure 12** then heated to a high temperature in an oven to create the final product. Ceramics are strong despite their brittleness. The properties of ceramics can be customized for a wide variety of applications such as sandpaper, pottery, dinnerware, and materials used in furnaces and space shuttles.

Figure 12 Early ceramic materials were made from clay that was heated to make a strong, rigid material.

Reading Check

6. How are ceramics and alloys similar?

Describe

List the main ideas from this section in the lines below.

46 Chapter 2

LESSON

2.2 Review

Visualize It!

All materials have physical, chemical, and mechanical properties. These properties determine the usefulness of the materials.

Many types of materials, such as plastics and alloys, are used to make products. Each material has unique properties that make it useful in a wide range of applications.

Summarize it!

1. How are materials selected for a designed product?

2. Why are materials modified to change their properties?

3. How are materials classified?

Lesson 2.2 Materials and Their Properties 47

Ceramics

Have students read the paragraph and caption **Figure 12**. Then have students share their experiences with making ceramics or familiarity with ceramic products. Have students identify the physical properties of ceramics.

Guiding Questions

AL What materials make up ceramics?	*dried clay or clay-like materials*
Reading Check How are ceramics and alloys similar?	*Ceramics and alloys are both mixtures designed to produce desired properties.*
BL What process causes the clay to change from a material that can be molded to a material that is strong and rigid?	*heating the clay*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which key concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties
- Mechanical Properties
- Types of Materials

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Materials and Their Properties

Use Vocabulary

1. A(n) ______________ is a characteristic that determines how a material reacts to forces.

2. **Define** alloy in your own words.

3. **Use the term** physical property in a complete sentence.

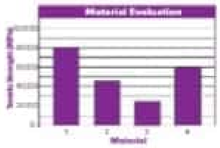
Understand Key Concepts

4. Which does NOT have modified properties?
   - A. alloys
   - B. ceramics
   - C. metals
   - D. polymers

5. **Explain** how you would classify a material that contains a mixture of three metals.

Interpret Graphics

6. **Analyze** Tensile strength is a measure of the amount of pulling stress an object can withstand before it breaks. Using the graph, which material should be considered for a product that must have the highest tensile strength?



7. **Summarize Information** Copy the graphic organizer below to give examples of the various properties used to select materials.

Properties	Examples
Physical properties	
Chemical properties	
Mechanical properties	

Critical Thinking

8. If you were designing a skyscraper in an earthquake zone, what properties would the building materials need?

My Notes

48 Chapter 2

Use Vocabulary

1. mechanical properties

2. Alloys are mixtures of two or more metals.

3. Possible answer: Physical property is a characteristic that can be observed or measured without changing identity of the material.

Understand Key Concepts

4. C.metals

5. The mixture would be classified as an alloy because an alloy is a mixture of two or more metals.

Interpret Graphics

6. material 1

7.

Properties	Examples
Physical properties	Possible answers: conductivity, density, melting point, solubility
Chemical properties	Possible answers: ability to burn, ability to rust
Mechanical properties	Possible answers: strength, elasticity, hardness, fatigue

Critical Thinking

8. The materials would need strength to support the weight of the structure and flexibility to withstand the forces generated by the earthquake.

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LESSON 2.3 The Design Process

INQUIRY

It takes a team. Developing any new product or process requires contributions from many people. Teamwork is a part of any problem-solving or design activity. Why do you think teamwork is important?

Write your response in your interactive notebook.

50 Chapter 2

Explore Activity

How can you build a better mousetrap?

New inventions are often the results of someone having a problem with existing technology. For example, baiting a mouse trap and disposing of a dead mouse are messy and unpleasant. Because of this, someone invented a disposable mouse trap with built-in bait. In this activity, you will identify a problem with an existing device and invent a better one.

Procedure

1. Think about simple objects, such as a can opener, eyeglasses, pen, scissors, or eating utensils. What is something you wish the object would do or would do better? List your ideas in your Science Journal.
2. Select one object that you think you could improve. Draw a diagram of how you would change or add to the design to improve the product.

Think About This

1. Would people be willing to buy your new product? Why or why not?
2. Is there any product that cannot be improved? Explain.
3. What steps do you think would you have to take before you build and sell your invention?

Essential Questions

- What is the design process?
- How can different solutions be tested and compared?

Vocabulary

design process
problem statement
criteria
constraints
brainstorming
Pugh Chart
prototype

51

INQUIRY

About the Photo It takes a team. Have students discuss times when teamwork is needed. Make a connection with the teamwork needed in sports to the importance of teamwork in solving problems or creating a new product or in certain jobs, like firefighting. Ask the following questions.

Guiding Questions

AL	What is teamwork?	*Use this question to begin discussion on how teamwork involves several individuals sharing ideas.*
OL	Why do you think teamwork is important?	*People have different ideas and see things differently.*
BL	What advantage does teamwork have over individual problem solving?	*Use this question to help students think about the advantages of having a team share and critique ideas.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Compound Words

Compound words are formed by combining two words that form a new meaning when placed together.

1. Write the word *brainstorming* on the board or chart paper. **Ask: What two words do you find in the word brainstorming?** brain and storming
2. Circle brain and underline storming. **Ask: What is the meaning of brain?** organ that controls human systems and thought **Ask: What is the meaning of storming?** something that occurs with great force **Ask: What do you think the word brainstorming means?** when a lot of thinking occurs by one of more people
3. Explain that brainstorming is a process where individuals spend time developing and sharing ideas to solve problems or create a plan of action.
4. Have students add the lesson's vocabulary words to their Science Journal. Remind them to write the definition after each word as they read the lesson.

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Explore Activity

How can you build a better mousetrap?

Prep *none* **Class** *20 min*

Purpose
To have students identify a problem and a possible solution.

Materials per team
paper, pencils or pens

Before You Begin
Ask students what it means to build a better mousetrap. Students should say that it means making an existing product better. Display a simple object, such as a can opener. Ask students how they might improve the design to make it easier to use, more efficient, or to do something more than it already does.

Guide the Investigation

- To get students thinking about what they might improve, have them think about objects they don't enjoy or have a hard time using.
- Encourage students to think about ordinary things that they take for granted and how they might be improved.
- Challenge students to come up with ideas that are different from anything they've seen before. Help them understand the possibility for invention is all around them.

Think About This

1. Answers will vary. If the students have developed an idea that is much better than the existing product and not too expensive, it might be easy to sell it. If it's not useful by a lot of people or too expensive, people are less likely to buy it.
2. Answers will vary. Students should recognize that almost everything can be improved in some way. Help students see that an improvement could be something that benefits the environment or makes it easier to produce, but leaves the object just as useful.
3. **Key Concept** Students should recognize that they would have to consider things like what material they would use, where they would get it, how much it would cost to buy the materials, what tools they would need to make it, what kind of skill people would need to make it, how long it would take, and how it would be packaged.

Teacher Notes

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Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Creativity and Design Factors

Society often creates the need for a new product. For example, the insulin pump like the one shown in **Figure 13** was developed so that people with diabetes would not have to give themselves daily insulin injections.

Creativity is the ability to make new things or to think of new ideas. It plays a large role in designing products. Other design factors include engineering, appearance, cost, and efficiency. Cost sometimes dictates the appearance of a product. For example, a laptop computer that is thin and sleek may cost more to make than a larger, heavier laptop. Cost is also related to efficiency. Efficiency is the ability to achieve a desired result with as little effort and waste as possible. A more efficient manufacturing process produces a product more quickly and at less cost.

Figure 13 The insulin pump has improved the quality of life for many people.

Reading Check

1. Why is efficiency important in designing a product?

52 Chapter 2

The Role of Creativity

When you look at your mp3 player, do you ever wonder who thought of this product? Just about everything you see started as an idea in someone's mind. The design of all new processes and products begins with an idea. Creativity often leads to ideas that are original and imaginative. Some ideas can help solve a problem or meet a need, while others are not practical.

Reading Check

2. Why is creativity an important design factor?

The Role of Engineering

An engineer turns an idea into a product. Engineers attempt to design a product that works well, is durable, reliable, and easy to maintain. Engineers might also consider how a product relates to the human body. This is called ergonomics. Clothes are more comfortable, playgrounds are safer, the computer keyboard in **Figure 14**, and other tools are easier to use when designers think about how these things will fit the people who use them.

Reading Check

3. Why do products come in different designs?

The Role of Appearance

A product's appearance is often important to the purchaser. Clothing, cars, and even electronic devices are designed to appeal to many different tastes. Many people enjoy using products that they consider attractive.

The same food can be served on a paper plate or on a fine china plate. Yet many people think food tastes better when eaten from an attractive china plate than when eaten from a paper plate. A larger laptop might work just as well as a smaller sleeker laptop. The sleeker design, however, is often perceived as having greater quality. Everyone has a slightly different idea about what is attractive. That's one reason why products often come in varying designs.

Figure 14 This ergonomically designed computer keyboard is more comfortable and easier to use than traditional keyboards.

Lesson 2.3 The Design Process 53

Explain
Creativity and Design Factors

Write *creativity* on the board or chart paper. Have students define creativity. Direct student attention to **Figure 13** and read the caption. Have students consider the creativity and problem solving needed when designing a product such as the insulin pump.

Guiding Questions

AL What is efficiency?	*the ability to achieve a desired result with as little effort and waste as possible*
Reading Check Why is efficiency important in designing a product?	*Efficiency can reduce the cost of a product because materials are not being wasted.*
BL What role can cost play in a product's design?	*It can determine the appearance of a product.*

The Role of Creativity

Have students identify a creative product or idea. Discuss if the product or idea solves a problem or meets a need. Talk about the imagination needed for the initial idea and why the product or idea is considered creative. Have students read the paragraph and caption for **Figure 14**.

Guiding Questions

Reading Check Why is creativity an important design factor?	*New products start with an idea from someone.*
BL How can creativity affect the design of a product?	*It can produce a design that is original and imaginative.*

The Role of Engineering

Explain to students that there are many types of engineers. Engineering careers include, but not limited to, chemical, aeronautical, civil, and electrical. Direct student attention to **Figure 14** and read the caption. Discuss how this product's design is different from standard keyboards. Have students read the paragraph and respond to the questions.

Guiding Questions

OL What three qualities do engineers strive for in the design of a new product?	*durability, reliability, and ease of maintenance*
BL Why might some consider ergonomics a positive design feature?	*Possible answer: Since it relates to the human body, it would be a more comfortable product to use.*

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Figure 15 The Wright brother's first powered flight lasted only 12 seconds.

Designing Products

When you watch a movie on a DVD, do you wonder how or why the DVD technology was developed? Every product you see started as an idea. Taking an idea and turning it into a product takes a lot of work.

Improving on Old Ideas

Improving old ideas is an important part of technology. An old idea can be enhanced because of advancements in science and technology. In 1903 the airpl**Figure 15**was built by the Wright brothers. It flew three meters above the ground and for a distance of about 39 meters. Aircraft technology advanced in response to World War I. Today, passenger airplanes can fly almost anywhere on Earth at speeds of 800 km/h or more, and at altitudes of thousands of meters.

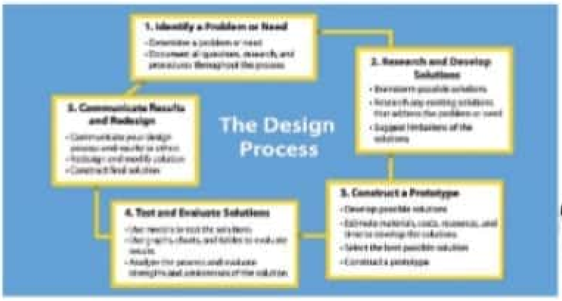
Visual Check

4. Which step evaluates the strengths and weaknesses of the solution?

The Design Process

How do scientists and engineers work together to create technological solutions? Scientific methods, careful planning, and testing are some of the strategies scientists and engineers use to answer questions or solve problems. The design process is also a strategy. Th**design process***a series of steps used to find solutions to specific problems.* Problem solving using these steps can be repeated as often as needed as sh**Figure 16.**

Figure 16 The design process can be thought of as a circular flowchart.



Identifying a Problem or a Need How do scientists and engineers begin when they need to find a solution to a pro First, they must clearly define the problem. The problem must be specific enough that a solution is possible. For example, it would be useless to define the problem as, "Design an improved animal carrier." This definition of the problem is too broad. Is this carrier for a cat, a bird, or some other animal? Each animal requires a different type of carrier. The problem statement does not provide enough informat**problem statement** *statement that clearly defines a problem to be solved.* A problem statement for the animal carrier might be, "Design a carrier for cats weighing up to 5 kg. The carrier must fit under an airline seat. The carrier must cost no more than AED 75." This statement tells you exactly what is required. A poorly worded statement results in wasted time and effort.

FOLDABLES

Make a vertical half-fold book and label it. Use your book to summarize the steps used in the design process.

The Design Process

Criteria and Constraints After the problem has been identified, criteria are usually iden**Criteria** (singular, criterion) *are the standards by which the product will be evaluated.* For example, in designing the cat carr**Figure 17**the **weight** of the cat is a criterion. These criteria may be included in the problem statemen**Constraints***re limitations put on the design of the product from outside factors, such as cost, efficiency, environmental impact, or availability of materials.* Constraints are generally determined at the beginning of a project. Otherwise scientists or engineers might waste their time working on a product that cannot be used. Sometimes, criteria and constraints may change as the product develops.

Key Concept Check

Why is it important to have a detailed problem statement?

Reading Check

5. Explain the difference between criteria and constraints.

Science Use v. Common

weight

Science Use gravitational force exerted on an object

Common Use measurement that indicates how heavy a person or thing is

Figure 17 Even a simple product such as this pet carrier is designed to address specific criteria and constraints.

Designing Products

Emphasize that every product began with an idea, some which seemed impossible to achieve at the time, others to address a practical need.

Improving on Old Designs

Direct student attentio**Figure 15**nd read the caption. Have students read the paragraph. Discuss how one idea can impact the future in ways not imagined at the time.

Guiding Questions

AL Why is improving on old ideas an important part of technology?	*Possible answers: It's always good to find better ways to accomplish tasks. Improvements can save money, resources, time and reduce long-term impacts on health and/or environment.*
OL Why can old ideas be improved?	*Old ideas can be improved because advancements have been made in science and technology.*

The Design Process

Have students read the paragraph. Draw att**Figure 16**. Read through and discuss each step in the design process.

Guiding Questions

AL What is the design process?	*a series of steps used to find solutions to specific problems*
OL What are some of the tools that scientists and engineers use to create solutions?	*scientific method, planning, testing, design process*
Visual Check Which step evaluates the strengths and weaknesses of the solution?	*Step 4–Test and Evaluate Solutions*

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Describe

List the main ideas from this section in the lines below.

Research Information and Develop Solutions Before engineers begin work on the animal carrier, they need to know if other people have worked on the same or a similar problem. Researching solutions that have been tried, those that have failed, and solutions that have worked is a good starting point. This research could save time and lead to a better solution. After the research is completed, engineers often brainstorm possible solutions. **Brainstorming** *a problem-solving technique that involves individuals contributing ideas without the fear of being criticized.*

Key Concept Check

7. What is involved in finding solutions to problems?

Brainstorming allows people to openly and creatively talk about all aspects of the problem and develop possible solutions. Most problems have more than one solution. Some solutions may be less costly, more efficient, or easier to produce. Of the different solutions, how do engineers decide which solution to develop?

Visual Check

8. Which jacket would be the best choice?

Pugh Charts Have you ever had to choose between more than one option, such as which jacket to buy? How do you decide which jacket is best? If you look at the positive and negative features of each jacket, you select your jacket using a set of criteria and constraints. You can use a Pugh Chart to help you select your jacket. A **Pugh Chart** *is a method used to compare options or solutions.* A Pugh Chart used to select a jacket may look similar to Table 3.

Table 3
Pugh Chart: Jacket Criteria

Jacket	Cost	Color	Warmth	Length	Total
Jacket 1	+1	+1	+1	–1	+2
Jacket 2	0	0	0	0	0
Jacket 3	–1	+1	0	–1	–1

56 Chapter 2

Construct a Prototype Once a possible solution has been selected, a prototype must be made. A **prototype** *is a full-scale model that is used to test a new product.* Engineers often construct a prototype. When an aircraft company designs a new airplane, they build several airplanes for testing. Those tests are evaluated and the airplane is changed as necessary before full-scale manufacturing begins.

Key Concept Check

9. Why is it important to test a solution?

Testing and Evaluating Solutions In all stages of the design process, the design must be tested and reviewed. Did the solution meet all the criteria and constraints? Testing and evaluating the solution allows the engineer to find and correct problems. Sometimes the design is changed. For example, an engineer designing an airplane may learn about a new technology that will improve the original idea before the airplane is built. Ideas are always being refined. After evaluation and testing, one solution will be chosen as the best.

Redesigning Your Solution Does a new product work the way it should? Does it meet all the criteria and constraints? After being evaluated, most designs change because new information and ideas are revealed during the testing and evaluating processes. If a new solution is proposed, many of the design steps are repeated.

My Notes

Lesson 2.3 The Design Process 57

Research Information and Develop Solutions

Have students read to find out why it is important to research solutions to an identified problem. Discuss how brainstorming helps to facilitate problem-solving.

Guiding Questions

Key Concept Check What is involved in finding solutions to problems?	*collecting information on solutions to similar problems, original thought and creativity*
OL Which jacket would be the best choice?	*jacket 1*
Visual Check Answer:	*jacket 1*

Construct a Prototype

Read the definition for prototype and discuss the importance of having prototypes. Remind students that prototypes are physical models. Have students read the text and guide their understanding using the following questions.

Guiding Questions

AL What is a prototype?	*a full-scale model that is used to test a new product*
OL Why is it important to build a prototype?	*Building a prototype will give the engineers opportunity to change the product before full-scale production.*

Testing and Evaluating Solutions

Remind students that testing and evaluating are step 4 of the design process. Have students read the text. Discuss the importance of prototype testing. Assess student understanding of the concept by asking the following questions.

Guiding Questions

Key Concept Check Why is it important to test a solution?	*Testing a solution allows the engineer to find and correct problems with the design.*
BL Why does having a consistent testing procedure improve the quality and cost of a product?	*Consistent testing procedure reduces the amount of time production has to remake a new product.*

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Key Concept Chec

10. What are the steps of the design process?

Communicate Resultse the testing and the evaluations are completed, the results must be communicated. Scientists and engineers write reports and produce presentations for other scientists, engineers, government agencies, private industries, and the public. The reports provide details of the design process, summaries of the data, and final conclusions. Scientists and engineers include recommendations for further research in their reports. Scientists and engineers usually publish their most important findings. By communicating their results, other scientists or engineers have the opportunity to duplicate the work or to continue the work of others.

Full-Scale Productionce all of the problems in the design are resolved, manufacturing facilities, such as the one shown in **Figure 18**, may be created to manufacture the new product. The proposed product has undergone careful evaluation and testing, but the evaluation process does not stop when full-scale production begins. The materials that are used to make the product must be tested throughout the manufacturing process to assure that a quality product is produced.

Figure 18A product, such as this jumbo jet, is manufactured in quantity only after its entire design process is completed.

58 Chapter 2

LESSON

2.3 Review

Visualize It!

The design of new products begins with an idea. Engineers take ideas and turn them into products.

The design process is a series of steps used to find solutions to problems. Prototypes are often used to test solutions.

Summarize It!

1. What is the design process?

2. How can different solutions be tested and compared?

Lesson 2.3 The Design Process 59

Communicate Results

Have students read the text. Have students identify what information might be shared when communicating results. Use the following questions to guide understanding.

Guiding Questions

AL What step comes after a design solution meets all criteria and constraints tests?	*The results are communicated to other scientists and engineers.*
OL What tasks are included in communicating results?	*writing reports and producing presentations for others*
BL Why is communicating results an essential part of the design process?	*Communicating results allows other scientists to replicate and possibly improve on the original work.*

Full-Scale Production

Direct attention to **Figure 18** and read the caption. Review the steps taken in the design process before full-scale production occurs. Have students read the text and answer the questions.

Guiding Questions

AL When does full-scale production begin?	*after all problems in a design have been resolved*

Key Concept Chec What are the steps of the design process?	*The steps include defining the problem, collecting information, developing possible solutions, building a model, testing the solution, evaluating the solution, redesigning the solution and communicating results.*
BL Why is it important to continue the evaluation process after full-scale production begins?	*It is important to ensure that materials used in production continually meet established standards and the product functions as intended over longer periods of time.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an ima**Ask: Which Key Concept does each image relate to?**

Summarize It!

The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties
- Mechanical Properties
- Types of Materials

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The Design Process

Use Vocabulary

1. **Define** *brainstorming* in your own words.

2. A method used to compare options or solutions is a ________.

3. **Use the term** *prototype* in a sentence.

Understand Key Concepts

4. **Explain** the influence engineering has on a design.

5. Which step in the design process has the engineer building a model for testing?
   - **A.** identify a problem
   - **B.** test a solution
   - **C.** construct a prototype
   - **D.** redesign a solution

6. **Arrange** Solve the problem of a river flooding annually by putting the following steps in order: a) investigating the river's source and its geography; b) build a model dam; c) create several designs of dams; d) write a problem statement; e) test the model; f) select the most promising dam design; g) redesign the model.

Interpret Graphics

7. **Organize Information** Copy and fill in the graphic organizer below to list the steps in the design process.

The Design Process
Define the Problem

Critical Thinking

8. **Explain** Why does the design process have so many steps?

Science & SOCIETY

Bigger, Higher, Faster

Should there be a limit to the size and speed of a roller coaster?

If you've been to an amusement park recently, you know that roller coasters are taller and faster than ever. The thrill of their curves and corkscrews make them popular. However, the increasingly daring roller coaster designs have raised concerns about safety.

A 30-story high roller coaster will drop you downhill at speeds nearing 160 km/h. The excitement of such a high-velocity coaster is undeniable; but skeptics argue that, even with safety measures, accidents on roller coasters will be more frequent and more severe.

Supporters of new rides say that injuries and deaths are rare when you consider the hundreds of millions of annual riders. They also note that most accidents or deaths result from breakdowns or foolish rider behavior, not from bad design.

Designers emphasize that riders are governed by Newton's laws of motion. Factors such as the bank and tightness of the curve are carefully calculated according to these laws to safely balance the forces on riders.

The designers can't account for riders who don't follow instructions. The forces on a standing rider might be quite different from those on a seated rider who is strapped in properly.

Roller coasters are here to stay, but with accidents increasing, designers and riders of roller coasters must consider both safety and thrills.

It's Your Turn! **RESEARCH AND DESIGN** Research the history of roller coasters. Then design your own roller coaster on a poster. Compare your design with your classmates' designs.

Use Vocabulary

1. Possible answer: The design process is a series of steps used to find solutions to problems.

2. Pugh Chart.

3. Possible answer: A prototype is a model of a new product used for testing.

Understand Key Concepts

4. Engineering makes sure the product works well, is durable and reliable, and easy to maintain.

5. C. construct a prototype

6. d, a, c, f, b, e, g

Interpret Graphics

7. Research information; Develop possible solutions; Build a prototype; Test and evaluate solutions; Redesign your solution and communicate results

Critical Thinking

8. The design process requires taking a specific series of steps to get the job done. The steps in the process might change, depending on the project. Building a new product from scratch, for example, would require more steps than improving on an already existing product.

Science and SOCIETY

Bigger, Higher, Faster

Background Information

Roller coasters originated in 15th century Russia in the form of iced chutes that were navigated on a block of ice with a straw seat. The first true roller coaster was built in St. Petersburg in 1784, and "Russian Mountains" appeared in Paris in 1804. Safety was not a concern. Injuries seemed to be more an enticement than a deterrent to riding them.

One of the first American coasters was a coalmine railway in Pennsylvania. People discovered that the fast downhill ride was exciting and would pay to ride it after the morning coal runs were finished.

The great roller coaster era began at the end of the 1800s when trolley companies started to build amusement parks at the end of their rail lines to attract customers on the weekends. The first roller coasters were low-speed gravity railways.

Thrill rides like Coney Islands' Flip-Flap and the Loop-the-Loop actually took riders through a 360-degree vertical loop. They were uncomfortable and dangerous but extremely popular until today's high speed coasters replaced them. Space Age engineering and Disneyland launched the modern coaster era. Tubular steel structure and nylon wheels made true looping coasters possible. The only limit to modern coaster design is the ability of the human body to endure G forces.

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Before You Read

Call on students to learn what they know about roller coasters.

Ask: What do you like about roller coasters? *Answers will vary. Students might say they like the thrill and speed of the ride. Others might like the twists and turns.*

Ask: What do you dislike about roller coasters? *Answers will vary. Some students might say they dislike the height of the hills. Some might say the ride is too short.*

After You Read

Call on students to discuss what they have learned about roller coasters.

Ask: What is the downside to having a high-velocity roller coaster? *A possibility exists that people will get injured. The accident rate could increase.*

It's Your Turn Have students work in pairs in researching the history of roller coasters. Have a class discussion on how technology has changed roller coasters over the years. The same pair of students also can design their roller coaster. When presenting their roller coaster, have students discuss the safety issues. Simulation web sites are available where students can design and test their roller coasters.

Teacher Notes

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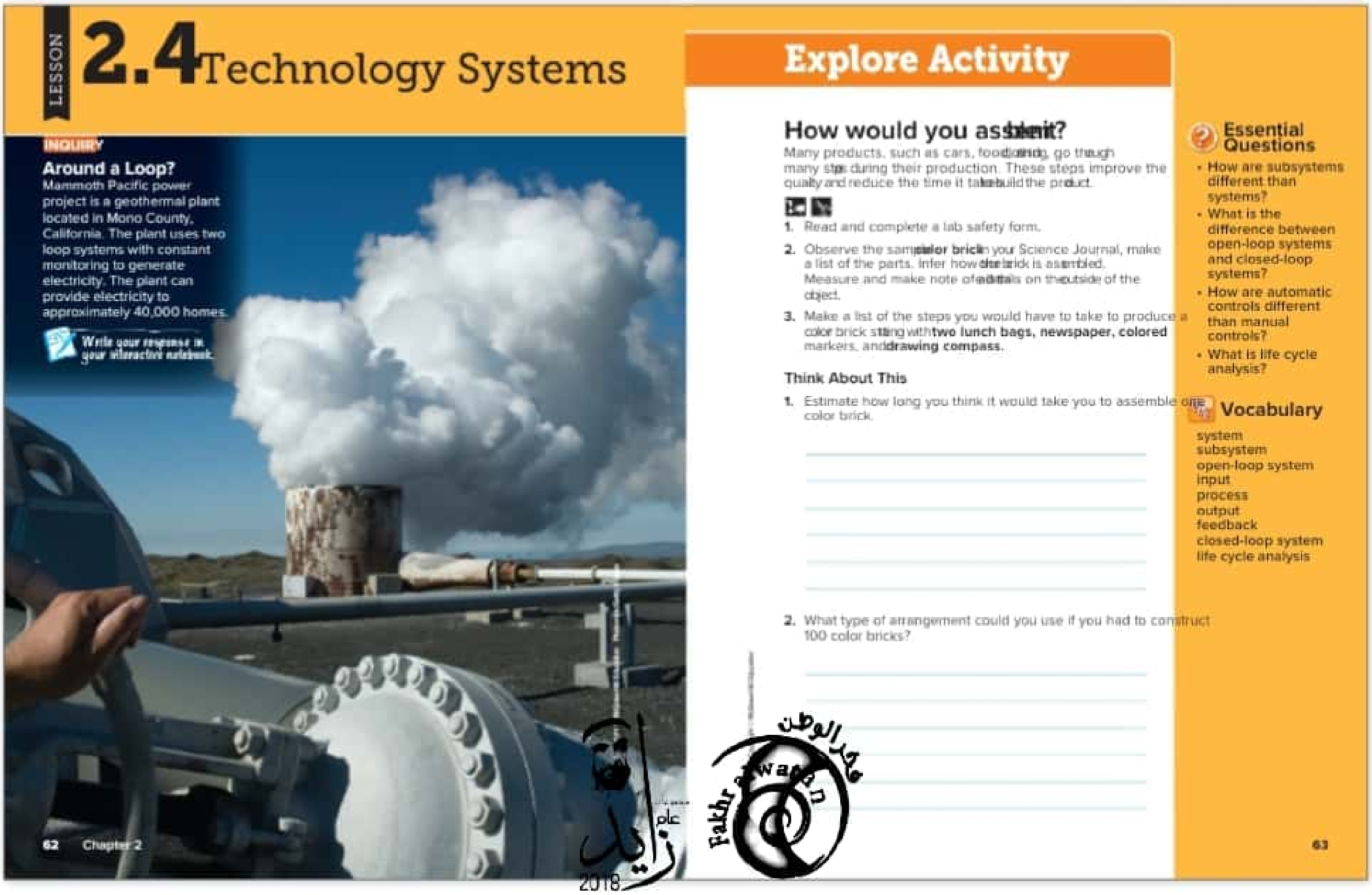

INQUIRY

About the Photo **Around the Loop?** The Mammoth Pacific power project is a geothermal power plant that converts thermal energy held in underground water reservoirs to electrical energy.

Guiding Questions

AL What is meant by *around a loop?*	*something that begins at one point, goes around, and ends at the same place*
OL What do you think goes around the loop at the power plant?	*water*
BL What is the purpose of the loop system?	*to convert the water's energy into electricity*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Visualization

Words become easier to recall and remember if a visual image can be attached to the meaning of the word.

1. Write the word *feedback* on the board or chart paper. **Ask:** **What two words do you find in the word feedback?** *feed* and *back*. Feedback is something that is given back after information is considered. **Ask:** **How does the word "feed" in this term compare to "feed" as in food?** Possible answer: *Both uses mean to give something. In science it is a response to give information. With food, it is the act of giving food to a living thing.*
2. Write *input* and *output* on the board. **Ask:** **Look at the words *input* and *output*. What am I asking for when I ask for your input on a project?** Possible Answer: *help or to share ideas with the project.* **What do I mean when I say we need a lot of output today?** Possible answer: *a lot of work has to be done.* Encourage students to make pictures of words in their minds to help remember and understand word meanings.

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Explore Activity

How would you assemble it?

Prep: *20 min* **Class:** *15 min*

Purpose
To have students think about systems and subsystems, which produce a product.

Materials per team
a color brick
Alternative: You may assign larger teams so that you only need to make a couple of color bricks, or have students help you make samples.

Before You Begin
Prepare a sample color block for each team. Draw three one-inch circles and three two-inch circles on the flat sides of a paper lunch bag. Color the circles in four different colors (red, blue, yellow, and green). Draw five half-inch wide lines on the bottom of the bag. Fill a second bag with crushed newspaper. Insert the open end of that bag into the colored bag to form a brick.

Guide the Investigation
- Encourage students to draw the color brick first. Have them turn it around and specifically describe what is on each surface.
- Allow students to take the brick apart to see how it is constructed. Then have the students reassemble the brick.
- Have students think about the order in which they would produce a color brick. Then have students list the exact steps they would take.

Think About This
1. Students should guess at least 15 minutes. Share with students how long it took you to construct the samples.
2. **Key Concept** Answers will vary, but students should say that it would be easier if one person did each of the tasks, such as drawing the circles the right size, filling the circles with color, drawing the lines, filling the bag with newspaper, and assembling the two bags together.

Teacher Notes

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Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Understanding Systems

Scientists study different things in nature. Some study how the human body works, while others study how planets move around the Sun. What do these things have in common? They are systems. When we talk about a system, we are talking about an organized way of doing something. A **system** is *a group of parts that work together in an organized way.*

Figure 19 Cars are just one part of the transportation system.

When you see buses, trains, cars, and airplanes, you see ways of getting from one place to another. They are part of the transportation system. One part of the transportation system is shown in **Figure 19.**

Understanding how systems work is an important part of technology. The field of system analysis studies the interactions among the parts in a system.

Reading Check

1. What is a system?

Types of Systems

There are many different types of systems around you. Have you studied about the human body systems? Your body digests food through the organs of your digestive system. When you send a text message to a friend, you are using a communication system.

FOLDABLES

Use one sheet of paper to make a book with at least nine tabs. Write each highlighted term on a tab. Write the definition inside.

Systems are not found only in science. In mathematics you use different systems to solve addition, subtraction, division, and word problems. In social studies you study our system of government. Our country has formed many governmental, legal, and educational subsystems to carry out the basic ideas of our system of freedom and democracy.

Subsystems

All systems are made up of other systems. For example, you are part of your school system. Your school is part of the educational system–cluster , sector , ministry.

Subsystems *are smaller systems that exist within larger systems.* A subsystem usually cannot function properly without its surroundings. For example, the jet engine is one of many subsystems of an airplane. However, some systems can be both a **distinct** system and a subsystem. The airplane is a system, but it is also a subsystem of the transportation system. The car is another subsystem of the transportation system. The car has subsystems, such as the engine and the electrical system.

Academic Vocabulary

distinct

(adjective) distinguishable to the eye or mind as discrete; separate

Technological systems turn ideas, facts, and principles into the things that we want and need. This is done through the skilled use of people, information, capital, tools, machines, materials, energy, and time.

Key Concept Check

2. How are subsystems related to systems?

Figure 20 The students within a classroom are a subsystem within their school.

Understanding Systems

Write the term *system* on the board or chart paper and read its definition. Have students read the three paragraphs and answer the questions. Direct student attention to **Figure 19** and read the caption. Have students speculate on the parts that make up the transportation system.

Guiding Questions

AL What does a technology system do?	*Turns ideas into the things we want and need*
Reading Check What is a system?	*collection of structures, cycles, and process that relate to and interact with each other*
BL What is the field of systems analysis?	*The field of system analysis studies the interactions among the parts of a system.*

Types of Systems

Point out that there are many different types of systems. Ask students to explain how a system works in sports—a football play for example, or soccer players moving the ball down the field to make a goal. Have students read the paragraphs and then ask the following questions.

Guiding Questions

AL What is an example of a system?	*Possible answers: mathematics, human body*
OL How is a text message part of a communication system?	*Possible answer: It makes a connection between two points. It travels through a system of wireless technology.*
BL In what way is the federal government a system?	*Possible answer: Several different individuals, departments, and branches of government work together to accomplish established goals.*

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Subsystems

Discuss how each classroom is a subsystem of the school, and how each school in a district is a subsystem of that school district. Have students read the three paragraphs. Use the questions below to assess their understanding of subsystems.

Guiding Questions

OL **Key Concept Check** How are subsystems related to systems?	*Subsystems are smaller systems within a larger system.*
BL How does a distinct system relate to a subsystem?	*A distinct system, such as an airplane, has several systems that only function as part of that system. But a distinct system also is a subsystem, such as an airplane being a subsystem of the transportation system.*

Academic Vocabulary

distinct

Ask: If I say that I see a distinct star in the night sky called the North Star, what do I mean? *The North Star is very visible and separate from the other stars in the sky.*

Ask: What other things might be distinct? *Possible answers: an idea, an animal in the distance, a person walking down the hall*

Differentiated Instruction

AL **Systems** Form teams of 2 to 3 students. Have each team create a poster using an online poster making application. Have students find a picture of a local bus Students should then create a diagram of the subsyste that are a part of that business, including suppliers, customers, and employees. Students may recognize th some local businesses are a subsystem of a large corporation. Print and display the posters in the classr

BL **Input, Process, Output** Form small groups. Have each group develop explanations of two open-loop systems not name them. The input, process, and output of each open-loop system must be described. Have groups exchange descriptions and attempt to identify each open-loop system. Each group should choose its favor description to share for the class to identify.

Teacher Toolbo

Teacher Demo

Open-Loop Systems Remind students that open-loop systems have three parts: input, process, and output. H up a pen. Explain that you are thinking about writing a to someone who does not have email. Discuss how w a letter is an open-loop system. **Ask: What is the input?** *using the ink pen to write a letter* **Ask: Why is a pen a part of an open-loop system?** *The pen is used as a resource or inpu to write the letter* **Ask: What is the output?** the letter; Ask students to identify and explain three open-loop syste

Reading Strategy

Graphic Organizers Draw a three concentric circle graph organizer on the board and have students copy it. Use system students are familiar with (such as a school sys to show how systems are made up of subsystems. Ha student groups draw a similar graphic organizer and illustrate systems organization.

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Open-Loop Process

Have students read the text, followed by asking the first guiding question. Help students understand how different products and different technologies involve different processes. Assess student understanding by asking the remaining two questions.

Guiding Questions

OL What is a process?	*conversion of ideas or activities into products by using machines and labor*
Visual Check: If you were making buttons for your school team, what information would you place in each section of your open-looped system?	***Input:*** *pictures, slogan, paints and brushes or paste, blank buttons.* ***Process:*** *paint or paste picture and slogan on each button.* ***Output:*** *completed buttons to distribute.*
BL When might an output become the input for another system?	*Possible answer: when the output from one system becomes an idea or component for another system. For example, a hen laying eggs and the egg as an ingredient in a recipe.*

Visual Literacy: Open-Loop Systems

Use **Figure 27** and the questions below to help students think about open-loop systems.

Ask: Which part of the open-loop system is the conversion of an idea into a product? *process*

Ask: During which part of an open-loop system is the actual product available from the system? *output*

Differentiated Instruction

AL **Open-Loop Systems** Divide students into small groups. Provide chart paper and markers for each group. Assign one of the following topics to each group: water systems, home entertainment systems, home appliances, vehicles, and personal banking system. Each group should use the markers to create an input–process–output diagram to explain its assigned open-loop system. Display chart p

BL **Creating a Closed-Loop System** In groups of five students with each group identifying a closed-loop sys Have the group illustrate how the system uses feedba control the outcome of the system. Have each group s their illustration and explanation.

Teacher Toolbox

Fun Fact

Telephone Operators Today our communication systems are closed-loop systems. Feedback provides callers wi call waiting, call forwarding, and voice mail. In the early 1900s an open-loop system controlled phone connecti Operators managed a switchboard containing some 20 phone lines. The operators worked first by answering and then plugging an incoming call into the phone line the person being called. As phone service grew, city operators handled as many as 600 calls an hour.

Reading Strategy

Summarizing Have students write a summary of an open-loop system and a summary of a closed-loop sys Form student pairs. Have them compare their summar and add illustrations to their written work.

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Closed-Loop Systems

When you make an effort to control the quality of the output of an open-loop system, you need to get information about your product or output. If you knew that your posters were offending students, what would you do? You would change your posters to correct the problem. The information that you received about your posters is feedb **Feedback** *the part of the system that measures and controls the outcome of the system*. Feedback serves as a bridge between what you want to do (input) and what you are actually doing (process). Feedback closes the loop to make the system a closed-loop system, as sh **Figure 22**

A **closed-loop system** *system that has a way of automatically controlling or measuring its output*. Can you think of examples of closed-loop systems? The heater in a fish tank warms the water in the tank. The heater shuts off when the water reaches the right temperature. If it did not shut off, the fish might not survive because the water could become too hot.

Complex systems have many layers of feedback and control.

Key Concept Chec

6. What is the difference between an open-loop system and a closed-loop system?

Visual Check

7. Why is it important to know if a system is effective?

Figure 22 closed-loop system adds a method of measuring the effectiveness of the system.

Controlling Systems

In order for a system to function properly, it must have some type of control. Controls are any part of a system that can be adjusted. For example, the heater on the fish tank has a control to set the water temperature. The heater turns on and off in order to maintain the correct temperature.

Controls can be either manual or automatic. A **manual control** *a device that requires a human operator*. An example of a manual device is crosswalk signal. In order to cross the street safely, you first push the crosswalk button. The button then turns on the crosswalk signal which allows you to cross the street safely.

An **automatic control** *device that can be programmed and then continues to operate without human intervention*. The thermostat in your home is an automatic control. Once you set the temperature, the thermostat maintains the temperature without your involvement. Feedback and control systems are important to keep systems running smoothly with little human involvement.

Key Concept Chec

8. What is the difference between manual controls and automatic controls?

Interactions of Systems

Most manufacturing companies do not have all the resources they need to make their products. They depend on other companies to produce these resources. For example, the automotive industry relies on many different companies for the various parts to make an automobile. A rubber company makes tires for the auto company. The automotive manufacturer is one system and the rubber company is another system. The output of the rubber company is tires, which becomes the input for the automotive company.

Science Use v. Common

temperature

Science Use the measure of the average kinetic energy of the particles in a material

Common Use measurement that indicates how hot or cold something is

Closed-Loop Systems

Have students read the text. Review the examples of closed-loop systems in the reading. Have students identify the control in each system. Emphasize that feedback controls the outcome of a closed-loop system. Use the guiding questions to assess student understanding.

Guiding Questions

AL What is feedback?	*the part of the system that measures and controls the outcome of the system*
Visual Check What is the difference between an open-loop system and a closed-loop system?	*The closed-loop system has feedback.*
Key Concept Check Why is it important to know if a system is effective?	*Only with feedback information can a product or system be fixed or improved.*

Visual Literacy: Closed-Loop Systems

Use **Figure 22** and the questions below to help students think about closed-loop systems.

Ask: Why is feedback important to a closed-loop system? *It measures and controls the outcome of the system.*

Ask: How is the output of a closed-loop system controlled? *It is automatically controlled by feedback.*

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Controlling Systems

Discuss the need for control for any system to function properly. Have students identify the system's control. Have students read the paragraphs. Assess student understanding by asking the following questions.

Guiding Questions

AL What are controls?	*any part of a system that can be adjusted*
Key Concept Check What is the difference between manual controls and automatic controls?	*A manual control needs a user to operate whereas the automatic control can operate without human intervention.*
BL What role do automated controls have in closed-loop systems?	*They keep the system running by providing constant feedback and control.*

Science Use v. Common Use

temperature

Ask: **How is the scientific use meaning of temperature similar to the common use meaning of temperature?** *Possible answer: One measures a level of kinetic energy in the particles in a material, the other measures the effect of kinetic energy.*

Interactions of Systems

Have students read the text. Draw a Venn diagram on the board showing how the systems of a rubber company and the automobile industry interact. Ask the questions below to guide student understanding.

Guiding Questions

OL What limits what a system can do?	*available resources, limitations, components*
BL What makes the interaction of systems complex?	*Possible answer: The number of components/variables in the system*

Differentiated Instruction

AL **Understanding Feedback** Have students compare a heating system in a vehicle where the occupants manu change the inside temperature by turning a dial with a heating system that automatically adjusts to a preset temperature. Provide the following graphic organizer fo students to illustrate and explain each system.

Controlling the Inside Temperature of a Vehicle	
Manual Control	Automatic Control

BL **Life Cycle Analysis** Form groups of four or five. Prese each group with a commonly used throw-away produc such as an empty water bottle, paper plate, or plastic f container. Have each group chart the life cycle of the product. Have groups share their information with the c

Teacher Toolbox

Teacher Demo

Fun Facts

Life Cycle Facts The life cycle of a product starts with ra materials and ends with product disposal. This cycle includes manufacturing, maintenance, and distribution. The cycle of commonly used products can vary from a month to hundreds of years. The life cycles of a few common products are shown below.

- Aluminum can 200–500 years
- Batteries 100 years.
- Disposable Diapers 500–600 years
- Cotton cloth 1–5 months
- Paper bag 1 month
- Plastic Water Bottle 700 years
- Tin cans 50–100 years

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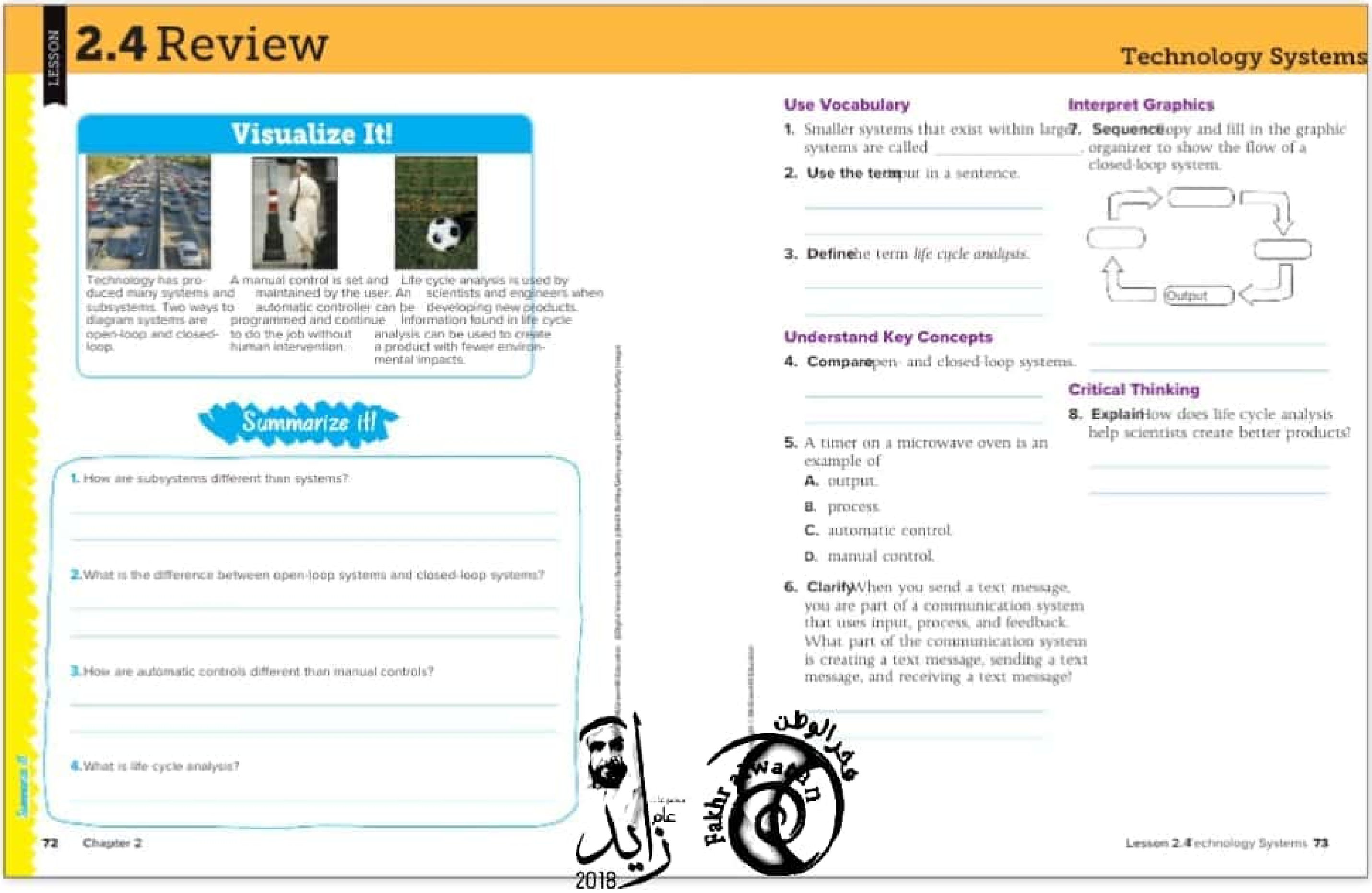
LESSON **2.4 Review**

Technology Systems

Visualize It!

Technology has produced many systems and subsystems. Two ways to diagram systems are open-loop and closed-loop.

A manual control is set and maintained by the user. An automatic controller can be programmed and continue to do the job without human intervention.

Life cycle analysis is used by scientists and engineers when developing new products. Information found in life cycle analysis can be used to create a product with fewer environmental impacts.

Summarize It!

1. How are subsystems different than systems?
2. What is the difference between open-loop systems and closed-loop systems?
3. How are automatic controls different than manual controls?
4. What is life cycle analysis?

72 Chapter 2

Use Vocabulary

1. Smaller systems that exist within larger systems are called ______.
2. **Use the term** input in a sentence.
3. **Define** the term *life cycle analysis*.

Understand Key Concepts

4. **Compare** open- and closed-loop systems.
5. A timer on a microwave oven is an example of
   A. output.
   B. process.
   C. automatic control.
   D. manual control.
6. **Clarify** When you send a text message, you are part of a communication system that uses input, process, and feedback. What part of the communication system is creating a text message, sending a text message, and receiving a text message?

Interpret Graphics

7. **Sequence** Copy and fill in the graphic organizer to show the flow of a closed-loop system.

Critical Thinking

8. **Explain** How does life cycle analysis help scientists create better products?

Lesson 2.4 Technology Systems 73

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which key concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Understanding Systems
- Diagramming Systems
- What is a Life Cycle

Use Vocabulary

1. subsystems

2. Sample answer: Input can be the ideas, which is used at the beginning of a process.

3. Life cycle analysis is a method of estimating the environmental impact of a product throughout its life.

Understand Key Concepts

4. An open-loop system does not include a way to measure or control its product; it includes input, process, and output. A closed-loop system adds feedback about the end product.

5. D. manual control

6. Input: creating a text message; process-sending the text message; output-receiving the text message

Interpret Graphics

7. In a clockwise manner: input; process; feedback

Critical Thinking

8. Life cycle analysis helps scientist by providing information on the resources and their environmental impact.

LABManager

Design and Build a Useful Product This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

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