UNIT 1

v 1.0

Teacher Edition

# EVIDENCE & ITERATION IN SCIENCE

SCIENTIFIC THINKING FOR ALL : A TOOLKIT

This book is part of the *Scientific Thinking for All: A Toolkit* curriculum that is a high school adaptation of the University of California, Berkeley, "Big Ideas" course titled Sense and Sensibility and Science https://sensesensibilityscience.berkeley.edu/. It was developed by professors Saul Perlmutter, John Campbell, and Robert MacCoun and represents a collaboration among physics, philosophy, and psychology. Scientific Thinking for All: A Toolkit was developed by curriculum developers and researchers at the Lawrence Hall of Science, University of California. The initiative is a cooperation between Nobel Prize Outreach (NPO) and Saul Perlmutter. This work is supported by a consortium of funders including Kenneth C. Griffin, the William and Flora Hewlett Foundation, the John D. and Catherine T. MacArthur Foundation, the Gordon and Betty Moore Foundation, and The Rockefeller Foundation.

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# SCIENTIFIC THINKING FOR ALL
## A TOOLKIT

### COURSE DESCRIPTION

**Scientific Thinking for All: A Toolkit** is a high school curriculum designed to equip students with scientific tools and ideas for using and evaluating information. For example, conceptual scientific tools include modeling and strategies for probabilistic reasoning. Such conceptual tools can be used to interpret evidence, identify uncertainty, manage trade-offs, and develop iterative solutions. Students learn these ideas in the context of real issues at the intersection of science and society, ranging from medical treatments to land use.

The seven-unit curriculum is divided into three major sections, each emphasizing different scientific tools. In Section 1, *Tools for Investigating the World*, students are introduced to the nature of science as an iterative process based on observation and measurement and use modeling to represent and predict specific aspects of the world. In Section 2, *Tools for Evaluating Data*, students evaluate different types of evidence for causation, discuss appropriate inferences and sources of uncertainty, and identify errors due to human bias. In Section 3, *Applying Science to Everyday Life*, students use techniques that encourage effective decision-making and consider science as a lens through which to understand the world.

### COURSE DRIVING QUESTION

**How do scientific tools and scientific thinking help people address complex challenges?**

## UNIT 1

# EVIDENCE & ITERATION IN SCIENCE

## UNIT SUMMARY

In this unit, students are introduced to essential concepts in science in the context of issues related to technology and society. Students explore the nature of **scientific evidence** as they examine issues related to water quality and accessibility. They learn how advances in scientific tools and technology have enhanced human observations and provided more accurate and precise measurements **(human senses and scientific tools and technology)**. Timelines from the history of scientific thought illustrate the use of such evidence in the iterative process of science, resulting in the development of scientific theories and a growing body of scientific knowledge. An attitude of **scientific optimism** has led scientists and others to persist despite obstacles, failures, and missteps, improving human understanding of a shared external reality that has resulted in ongoing **scientific advancements**. Case studies model **science as a human endeavor** that is accomplished by individuals and teams of people working together to utilize prior work, replicate studies, and contribute new ideas.

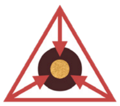
## UNIT DRIVING QUESTION

**How do people use evidence and iteration of ideas to construct scientific explanations that are relevant to everyday issues, such as water quality?**

## PRIMARY CONCEPTUAL TOOL

**Multiple Lines of Evidence**

# KEY CONCEPTS & PROCESS SKILLS



## MULTIPLE LINES OF EVIDENCE

Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.

## SENSES AND INSTRUMENTATION

- New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.
- Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.

## SCIENTIFIC ADVANCEMENT

- The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.
- Scientific optimism enables scientists to solve difficult problems over time.

## SCIENCE AS A HUMAN ENDEAVOR

Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

# KEY CONCEPTS & PROCESS SKILLS

While each activity focuses primarily on one or two of these concepts, these concepts are addressed in multiple places throughout the unit. You can see where in the unit each of these Key Concepts and Process Skills is addressed in the following table.

| UNIT 1 : KEY CONCEPTS & PROCESS SKILLS | ACTIVITY 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence. | X | | | | X | X | | | | |
| New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data. | | X | X | X | X | X | | X | | X |
| Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence. | | X | | X | | X | | | | |
| The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error. | | | X | | X | | X | X | X | X |
| Scientific optimism enables scientists to solve difficult problems over long periods of time. | | | | | | | | X | X | X |
| Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science. | | | X | X | X | | X | X | X | X |

## UNIT 1

# EVIDENCE & ITERATION IN SCIENCE

## UNIT OVERVIEW

| ACTIVITY TITLE AND SUMMARY | KEY CONCEPTS & PROCESS SKILLS | GUIDING QUESTION |
|---|---|---|
| **1. Skipton's Water**<br>CARD-BASED INVESTIGATION<br>Students are introduced to a fictional scenario about providing clean drinking water for a town. They make a decision based on available information. They are then provided with additional data and revisit their decision. Students discuss the role of evidence in decision-making. The concepts of relevance, accuracy, and reliability of evidence are introduced. | • Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.<br>• NGSS Connection: Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | **What role can evidence play in decision-making?** |
| **2. Validating Measurements**<br>LABORATORY<br>Students conduct an investigation into one water quality indicator: pH. They measure pH values, using different techniques, and compare their pH values in order to validate their results. They apply the concepts of accuracy and reliability of data. As a class, they discuss the role of human senses and other scientific tools in gathering data and validating results. | • New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br>• Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.<br>• NGSS Connection: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. | **How do people collect information about the physical world?** |

# UNIT OVERVIEW (CONTINUED)

| ACTIVITY TITLE AND SUMMARY | KEY CONCEPTS & PROCESS SKILLS | GUIDING QUESTION |
|---|---|---|
| **3. Scientific Advancement**<br>CARD-BASED INVESTIGATION<br><br>Students explore the development of scientific explanations over time. They investigate two timelines from the history of science. First, they organize the likely sequence of three events in one timeline. Then they place these events in a larger timeline containing multiple events in the development of the topic. Students discuss the role of evidence and advances in scientific tools and techniques in the development of scientific thinking. | • New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br>• The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.<br>• NGSS Connection: Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | **What role does new technology play in the development of scientific ideas over time?** |
| **4. Testing Local Water**<br>FIELD TRIP<br><br>Students utilize a smartphone app (such as HydroColor, an app that measures turbidity) to gather water quality data of a local water body, such as a lake. They compare the data collected from their scientific tool to the data collected by their senses. The class discusses how the use of new technologies can enhance the contribution of nonscientists to data collection. | • New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br>• Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.<br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science. | **How can technology improve people's ability to collect information about the natural world?** |

| ACTIVITY TITLE AND SUMMARY | KEY CONCEPTS & PROCESS SKILLS | GUIDING QUESTION |
|---|---|---|
| **5. Iteration of Ideas**<br>READING<br>Students read several case studies of modern scientists and others working to address global water issues. They examine how each case study illustrates particular unit concepts including multiple lines of evidence, the validation of data through human senses and scientific technology, iteration, and scientific advancement. The case studies illustrate how scientific knowledge is a result of human endeavor. | • New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br>• Scientific knowledge and explanations are based on evidence and are strengthened by multiple lines of relevant, accurate, and reliable evidence.<br>• The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.<br>• NGSS Connection: Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | **What is the role of evidence and iteration in developing scientific knowledge?** |
| **6. Claims and Evidence**<br>COMPUTER SIMULATION<br>Students use a computer simulation to gather evidence and evaluate claims about the water quality of Skipton's Lake Timtim. They use multiple lines of evidence to support or refute their claims. The class discusses how new evidence can lead to a re-evaluation and revision of ideas. Based on the evidence, students make a recommendation to Skipton's city council about whether to use Lake Timtim as a water source for Skipton. | • Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.<br>• New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br>• Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.<br>• NGSS Connection: Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | **How can evidence be used to support or refute a claim?** |

# UNIT OVERVIEW (CONTINUED)

| ACTIVITY TITLE AND SUMMARY | KEY CONCEPTS & PROCESS SKILLS | GUIDING QUESTION |
|---|---|---|
| **7. Evidence and Explanations**<br>CARD-BASED INVESTIGATION<br><br>Students further investigate the use of multiple lines of evidence to support or refute a scientific explanation, using the context of cholera outbreaks in 19th-century London. They compare their thinking about cholera transmission to three widely held explanations of the time. Students receive Evidence cards and evaluate which explanation is most substantiated by the evidence. They brainstorm investigations that could provide additional evidence. | • The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br><br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science. | **What is the role of evidence in evaluating scientific explanations?** |
| **8. Science Is a Human Endeavor**<br>VIDEO<br><br>Students watch a video segment on how scientific research may lead to possible solutions for water scarcity and improvements in water conservation. The contributions of individuals and teams from many nations and cultures to the field of science is highlighted. The concept of scientific optimism is formally introduced. Students begin to discuss the role of advances in science and technology in solving global problems. | • Scientific optimism enables scientists to solve difficult problems over long periods of time.<br><br>• New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br><br>• The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br><br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science. | **What role does scientific optimism play in the development of scientific solutions?** |

# UNIT OVERVIEW (CONTINUED)

| ACTIVITY TITLE AND SUMMARY | KEY CONCEPTS & PROCESS SKILLS | GUIDING QUESTION |
|---|---|---|
| **9. Water Quality Design Challenge**<br>LABORATORY<br><br>Students work together to design and build simple water-filtration devices. They test their filtered water for turbidity, pH, and simulated contaminants (red food dye). They collaborate with other groups to share results and improve their designs. The process illustrates unit concepts such as iteration, collaboration, and science as a human endeavor. | • The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br><br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.<br><br>• Scientific optimism enables scientists to solve difficult problems over long periods of time.<br><br>• NGSS Connection: Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). | **How can you utilize the processes of iteration and collaboration to construct a device to improve water quality?** |
| **10. Solutions Through Scientific Optimism**<br>PRESENTATION<br><br>Students brainstorm solutions for addressing global needs for clean and accessible water. They then read about some of the most common proposed solutions to global water needs and identify connections to some key ideas of the unit. Students select a community to represent and research specific aspects of its water needs. They propose a plan for addressing those water needs and communicate an aspect of their proposal by creating a public service announcement. They revisit decisions made in Activity 1 and elsewhere in the unit. | • New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.<br><br>• The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.<br><br>• Scientific optimism enables scientists to solve difficult problems over long periods of time.<br><br>• Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.<br><br>• NGSS Connection: Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). | **How are key scientific ideas reflected in modern solutions to regional water issues?** |

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ACTIVITY 1

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CARD-BASED INVESTIGATION

ACTIVITY 1

# Skipton's Water

## ACTIVITY SUMMARY

**Students are introduced to a fictional scenario about providing clean drinking water for a town. They make a decision based on available information. They are then provided with additional data and revisit their decision. Students discuss the role of evidence in decision-making. The concepts of relevance, accuracy, and reliability of evidence are introduced.**

ACTIVITY TYPE

CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS

2

## KEY CONCEPTS & PROCESS SKILLS

Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS


## VOCABULARY DEVELOPMENT

**accuracy**
closeness of a measured value to a true or standard value

**contaminant**
(assumed prior knowledge)
any physical, chemical, biological, or radiological substance in water (as defined by the U.S. Safe Water Drinking Act)

**data**
(assumed prior knowledge)
information gathered from an experiment or observations

**evidence**
information that helps support or refute a claim or leads to the development of a new claim

**relevant**
(assumed prior knowledge)
closely connected to the idea or question being considered

**reliable**
able to be reproduced consistently

**trade-off**
an exchange of one valued outcome for another by giving up something that is a benefit or advantage in exchange for another benefit that may be more desirable

## BACKGROUND INFORMATION

Background information is intended to provide instructional support to the teacher and is not intended to be shared with students. In some cases, it may provide information that can give away the problem that students are being asked to consider in the activity. Be sure to review an activity in its entirety before communicating background information with your class.

### Shared External Reality

One of the basic assumptions of science is a shared external reality. This is the idea that there is a shared external reality that affects everyone, even when people disagree about what that is. For example, new species of organisms, such as fish or bacteria, are discovered and described almost every year. These organisms exist in a shared external reality, whether or not they are known to people or whether all people believe in their existence.

See Teaching Step 7 for another example of shared external reality.

## MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.1 "Developing Communication Skills" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- VISUAL AID 1.3 "Understanding Conceptual Tools" (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 1 Build Understanding item 3

FOR EACH GROUP OF FOUR STUDENTS

- SET OF 16 DATA CARDS (provided in two sets: 1–8 and 9–16)

FOR EACH STUDENT

- STUDENT SHEET 1.1 "Plan for Skipton's Water"
- STUDENT SHEET 1.2 "Evaluating Data"
- STUDENT SHEET 1.3 "Writing Frame: Evidence and Trade-Offs" (OPTIONAL)
- STUDENT SHEET 1.4 "Unit Concepts and Skills" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)

## PLANNING AHEAD

**Activity 4, Testing Local Water**, is a field trip that involves visiting a local water body such as a lake or large pond that is optically deep (has a water depth where the light reflection from the bottom does not influence the light leaving the surface). The field trip also requires the use of smartphones with a turbidity app installed, which will only work onsite if there is a signal. You may wish to begin preparing for this activity by identifying a local site; providing students with permission slips; having students download the app; arranging transportation for the class; and organizing a teacher substitute, if necessary. If you are not able to arrange for a field trip or have other challenges completing the activity as written, see Activity 4, Advance Preparation, for alternatives.

**Activity 9, Water quality Design Challenge**, requires numerous everyday materials, such as 500 mL plastic bottles. Review the materials list for Activity 9. Calculate the amount of materials needed based on the number of class periods and group size you have. Make a plan to gather materials.

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Elicit students' prior knowledge about water by constructing a class concept map about water.**

- Students may have personal experience with and prior knowledge of issues related to the use of water in society, such as lack of water availability due to dry wells or contamination of drinking water. Engaging students about their experiences can create a stronger foundation for learning. Support students, particularly those with varied life experiences, in sharing their prior knowledge of and personal experiences with this issue. Specifically validate funds of knowledge (not just textbook knowledge, but also family or cultural insights, practices, and personal histories) by eliciting students' observations and experiences as assets to building understanding. Throughout this course, encourage students to respond to any topics or questions that arise to which they feel a personal connection—during small-group or class discussions, when students respond to relevant Build Understanding items, and when they write reflections in their science notebooks.
- Elicit student prior knowledge about water by first brainstorming a list of key words or ideas associated with water. Ask, What do you know about water? What words do you associate with water when you think about water in science or the use of water in society? Students may describe familiarity with ideas and words related to water use (such as *drinking* and *swimming*), words related to states of water (such as *snow* or *ice*), words related to bodies of water (such as *rivers* and *ocean*) and words related to water treatment (such as *filtration* or *boiling*).
- Use the brainstormed word list to construct a concept map about water based on student thinking. Concept maps demonstrate students' understanding of connections between topics. You will revisit this concept map in the last activity of the unit, so consider posting it or otherwise maintaining access to it for later use.
- Depending on your student population, you may find it helpful to provide a starting list of terms that can be included in the concept map or provide the beginning of an incomplete concept map to spark students' responses. Terms that may help students get started include: drinking, swimming, showering, cleaning, cooking, water quality, clean water, pollution, ice, rain, snow, precipitation, groundwater, rivers, lakes, freshwater, saltwater, water treatment, filtration, boiling, tap water, wells.

2 **Introduce the unit focus on water by reading the Student Book introduction.**

- Read the introduction to Activity 1 in the Student Book, either as a class or individually. Connect students' prior knowledge and ideas about water to the information provided in the Student Book introduction. Student ideas most likely included a greater breadth of topics related to water than is addressed in the introduction. Point out that the introduction highlights the particular focus of this unit.
- As a class, work together to add additional information from the introduction to the concept map. A sample concept map is provided here:


## PROCEDURE SUPPORT (30–40 MIN)

3 **Present the scenario of Skipton found in Procedure Part A.**

- Part A has students make a decision about the town of Skipton. The scenario presented in Step 1 can be shared with the class in multiple ways: Read it aloud to the class (using a storytelling approach), have individual students read a paragraph aloud to the class while others follow along with the text, or have students read it individually or cooperatively in their groups of four.

- Depending on your student population, use oral storytelling to support diverse learners in decoding scientific ideas and constructing meaning and ask questions about the main points of the scenario to ensure comprehension. Students can refer to the text in the Student Book as needed.

- Aspects of the nature of scientific evidence (with regard to accuracy and reliability) are brought up in Build Understanding and do not need to be introduced here. For now, allow students to use a working definition of evidence, to be followed up after the procedure.

- Provide each student with a copy of Student Sheet 1.1, "Plan for Skipton's Water," and Student Sheet 1.2, "Evaluating Data." After students discuss their thinking with their groups, each student can record their own ideas on Student Sheets 1.1 and 1.2—there does not need to be agreement among group members.

- On Student Sheet 1.1, students record:
  - their initial decision about the proposal.
  - evidence that supports their decision.
  - any questions they have.

- On Student Sheet 1.2, students record:
  - whether the evidence is relevant to the decision.
  - whether the evidence supports or refutes the use of the Mizu River.

- Depending on your student population and the emphasis on other science standards such as claims, evidence, and reasoning, you may wish to ask students to also describe how the evidence supports their decision (reasoning).

- Sample student responses for both student sheets are located at the end of this activity.

**4 When students are ready for Procedure Step 4, provide the class with Data cards.**

- Provide students with Cards 1–8 from the set of 16 Data cards.

> TEACHER'S NOTE: Do not provide students with all 16 cards in Step 4. Cards 9–16 are provided in Student Book Procedure Step 9 (see Teaching Step 5).

- Have student groups work together to share their ideas. You may wish to use Visual Aid 1.1, "Developing Communication Skills," to help guide student interactions. The Developing Communication Skills Visual Aid is a tool to help students effectively participate in class discussions by providing sentence starters that students can use to initiate a conversation and express their ideas.

**5 When students are ready for Procedure Step 8, provide the remaining Data cards 9–16.**

Students record updated recommendations (even if it remains the same), additional evidence that supports their decisions, and any new questions they have.

6 **Procedure Step 12 asks students to share their decision-making and evidence with the class.**

- You may wish to call on individuals or groups to share their decision-making and evidence with the class. Alternatively, have students indicate with a show of hands whether they initially thought Skipton should use water from the Mizu River, what they decided after receiving the first sets of Data cards, and what they decided after receiving the second set of Data cards.

- Ask, How can people with access to the same set of evidence sometimes still disagree? Have students who came to different decisions share the evidence that supported their thinking. They may recognize that disagreement is more likely when people value different pieces of information differently; for example, some people may be more concerned about potential water contaminants when residents of a community become ill.

- Ask, Were you able to revise your thinking based on new evidence? Why or why not? Discuss the role of scientific data in decision-making and project what kinds of future outcomes or evidence could change minds. Students may recognize that it is difficult to change one's mind when one is already heavily invested in a decision.

7 **Introduce the concept of a shared external reality.**

- Introduce the idea of **shared external reality**. This is the idea that there is a shared external reality that affects everyone, even when people disagree about what that is. For example, a poisonous berry will make people sick whether or not they believe it is poisonous. The poison in the berry is part of a shared external reality. Even when people do disagree, they are only able to talk about that disagreement in the context of some shared agreement. For example, in a disagreement about whether the berry is poisonous, people can agree that it is a berry, that it is possible to eat it, that poisonous things cause sickness, etc. This background of agreement is what makes disagreement about details meaningful.

- Skipton's water quality is part of a shared external reality. Discuss whether having only partial evidence initially affected the actual water quality of Skipton's tap water. Point out that, whether people agree on its quality or not, water can still cause illness if it is contaminated. Science can provide tools and techniques to understand water quality more accurately.

- Another example of shared external reality is provided in the Teacher Background Information.

- Ask, Is there a shared external reality even when data is incorrect? Or when people disagree about the importance of evidence? Highlight the variability in interpretations of the cloudiness of the water and how that influenced the most likely explanations for the sickness of Skipton residents. Skipton's water quality was the same (existed in a shared external reality) whether or not tests detected the presence of contaminants, or whether people valued evidence differently.

- Students may have varied ideas about the concept of a shared external reality based on family or cultural insights, practices, and personal histories. Acknowledge funds of knowledge as assets to building understanding. Encourage students to respond to this topic or questions that arise from it by sharing their ideas during small-group or class discussions, or by writing reflections in their science notebooks.

- Guide students to the understanding that science is based on the idea of a knowable shared external reality and that the process of scientific investigation is to gather data on that reality.

## SYNTHESIS OF IDEAS (10–15 MIN)

**8 Review the concepts of accuracy and reliability of data, using Build Understanding items 1 and 2.**

- Have students respond to Build Understanding items 1 and 2 and provide guidance as needed. You may wish to discuss the experiences of Skipton residents. Everyone but the residents who had cloudy water were likely to rely on test results. People's personal experience of their tap water could influence whether they thought the tests were accurate. Residents who got sick might consider their observations to be more accurate than the tests because they indicate that something was not right about the water.

- Support students, particularly English learners (ELs), in sensemaking and language acquisition by reviewing the terms accuracy and reliability and supporting the construction of a word wall. You may want to model a sample response as a class to help scaffold student understanding. You may want to extend Build Understanding item 2 by introducing additional examples of accuracy and reliability. For instance, some water bottles have a mark to indicate the amount of liquid they contain, such as 1 liter. Students could measure the amount of water in a bottle by using scientific equipment, such as graduated cylinders or beakers, to investigate if the mark is accurate. Taking repeated measurements could provide reliability. This type of experimental design is reproducible, since other students could use the same method to get similar results.

**9 Review the role of evidence in the activity.**

- In Build Understanding item 3, students are introduced to a formal definition of *evidence*, which is a central concept in the unit. Clarify with students the difference between evidence, information, and a claim. **Evidence** is information that helps support or refute a claim or leads to the development of a new claim. Information, such as observations or raw data, is not evidence until it has been interpreted for the purpose of supporting or refuting a claim. In general, a **claim** is a statement that asserts something is true. In science, scientists make claims based on experimental results or other evidence. Students will further explore the concept of a claim in Activity 6, "Claims and Evidence," when a formal definition of claim is provided in the Student Book introduction.

- If the topic comes up, distinguish evidence from opinion. Explain that evidence is a set of observations that supports a claim. In contrast, an opinion is a view that someone takes about a certain issue based on their own judgment. An opinion might not be based on evidence. An informed opinion might be based on evidence; however, another person may have a different opinion based on the same evidence.

**10 Introduce the concept of trade-offs.**

- Introduce the idea that decisions about solutions to scientific and engineering problems often involve trade-offs. In Build Understanding item 3, students make a decision about Skipton's use of water from the Mizu River. The units of this course include issues that relate to science and/or engineering, which may lead to decisions about the best solutions for solving problems. Decision-making in the context of trade-offs includes the following key ideas:
  - Decisions often involve trade-offs.
  - Identifying trade-offs involves analyzing evidence.

  The concept of trade-offs will be used throughout the units of this course, especially as part of the decision-making focus of the course.

- The Scoring Guide: Evidence and Trade-Offs (E&T) assesses students' understanding of these concepts. This Scoring Guide can be shared with students to help them develop a response and to communicate what is expected of them. The item-specific Scoring Guide, however, is not intended to be shared with students. Its purpose is to guide teachers while scoring a specific prompt, such as Build Understanding item 3 in this activity.

- A **trade-off** is a desirable outcome given up to gain another desirable outcome. In a decision involving trade-offs, something positive (or desirable) is given up to gain another positive (or desirable) outcome. Since many decisions involve trade-offs, students should understand that a perfect choice that maximizes all goals is often not possible. It is possible, however, to recognize and analyze the trade-offs associated with each decision.

- Provide an example of a trade-off. For example, when choosing to purchase a disposable or reusable water bottle, there are several benefits and trade-offs to consider. A consumer who chooses the disposable water bottle may want a cheap option that doesn't need to be cleaned or maintained. Disposable bottles are also easily shared with others, since they are not expected to be returned. However, in choosing the disposable water bottle, the consumer is contributing to environmental problems, such as increased energy use and higher amounts of solid waste in landfills if the bottle is not recycled. A consumer choosing to purchase a reusable water bottle may do so to save money over time, to save bottles from ending up in a landfill, and—by their example—to encourage others to purchase reusable bottles. However, this option has trade-offs as well, such as the increased upfront cost of the reusable bottle and the need to clean and maintain the bottle. Neither choice is ideal, and both choices have positives and negatives. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision.

- Develop some examples of trade-offs in students' lives by brainstorming with the class a list of decisions they make every day that involve trade-offs. Choose one and talk through the associated trade-offs of deciding one way or another. This practice will familiarize students with ways to identify and consider trade-offs in this and subsequent activities.

- Build Understanding item 3 applies the concepts of evidence and trade-offs. A writing frame can support diverse learners, particularly ELs, in decoding scientific ideas, constructing meaning, sense-making, and language acquisition. This strategy, which has been deemed effective for ELs, was built on and adapted from strategies for English-proficient learners. In this activity, use Student Sheet 1.3, "Writing Frame—Evidence and Trade-Offs" as a scaffold for students to write their responses to Build Understanding item 3. A sample student response can be found at the end of this activity

- You can use Visual Aid 1.2, "Scoring Guide: Evidence and Trade-Offs (E&T)" to assess Build Understanding item 3. Point out the scoring levels (0–4) and review the criteria for each score. Explain that the scores are based on the quality of students' responses and reflect student growth over time. The scores do not correspond to letter grades. A Level 3 response is complete and correct. A Level 4 response signifies that the student has both achieved and exceeded the acceptable level of response. At first, many students will write Level 2 responses, and they should strive to achieve Level 3 or Level 4 responses. Let students know that you would like them to improve by at least one level as they progress through the unit. As a class, discuss what a Level 4 response to Build Understanding item 3 would include. You may develop a Level 4 exemplar as a class or share with students the Level 4 responses from the provided sample responses. To help students better understand the three levels, discuss how they are different and ask students for ideas about how to improve from Level 2 to Level 3 and from Level 3 to Level 4. A sample Level 4 response is included in Sample Responses to Build Understanding and on Student Sheet 1.3.

**11 Highlight opportunities for metacognition here and throughout the unit.**

- Connections to Everyday Life item 4 provides an opportunity for students to practice metacognition— thinking about and understanding one's own thought processes. Research has found that students show greater improvements in their learning when they are given opportunities to determine and evaluate their own learning.

- Highlight these opportunities here and throughout the unit. Ask, In what ways could knowing about your thinking process influence your decision-making skills? Encourage students to share their ideas. Some students may note that being more aware of their own thinking may make them more likely to be more open to limitations in their thinking or make them more likely to change their minds. They may also enhance their skills at communicating their ideas.

**12 Review the idea that scientific knowledge and explanations are strengthened by multiple lines of relevant, accurate, and reliable evidence.**

- Use Student Sheet 1.1 to discuss comments and questions that students had about the evidence.

- Address the quantity and quality of evidence as a factor in their decision-making. Having multiple lines of evidence strengthens an argument and having evidence that is relevant, accurate, and reliable makes the argument more convincing. In science, knowledge and explanations are developed as a result of many people producing relevant, accurate, and reliable evidence. When evaluating evidence, scientists consider the source, quality, and quantity of the evidence available.

- Ask, Do you have enough information to know for sure (that is, with 100% confidence) whether Skipton's water was contaminated with Cryptosporidium? Discuss how the evidence can lead to an inference, a conclusion based on evidence and reasoning vs. explicit data.
- Highlight the idea that scientific knowledge can change over time as more evidence is gathered. Discuss what effect this may have on decision-making.

**12 Introduce the conceptual tool of multiple lines of evidence.**

- Use Build Understanding item 5 to discuss the role of **multiple lines of evidence** as a tool in a student's scientific toolkit. The scientific toolkit is intended to be a set of conceptual tools that can be applied to everyday life. Students will add conceptual tools to their toolkit with each new unit. Depending on your student population, use Visual Aid 1.3, " Understanding Conceptual Tools" to review the use of the word tool—an implement used to carry out a particular function. The word is commonly used to refer to construction tools such as hammers, levels, and tape measures. In a science classroom, examples of scientific tools include beakers, graduated cylinders, and microscopes; in this unit, scientific tools and technology are used to gather evidence. In this course, students consider conceptual tools, such as multiple lines of evidence, as a way of exploring the application of science to everyday life.
- As students build understanding about the importance of having multiple lines of evidence in a scientific argument or explanation, they will build a conceptual tool about this idea in their minds and develop skills to utilize it at various points in the unit. You may wish to use Student Sheet 1.4, "Unit Concepts and Skills," to help students organize their learning. This course organizer is designed to help students reflect on their understanding of the conceptual tool, consider how they have used it to analyze problems throughout the unit, and how it may influence their decisions about unit topics.
- While a sample completed course organizer is provided in this activity, students will not be able to complete it at this time; the ideas in the sample response will be built over the course of the unit. At the end of this activity, students can add information about the role of multiple lines of relevant, accurate, and reliable evidence in supporting an explanation. The Skipton scenario is an example of when students had an opportunity to analyze information related to this idea, as well as make a decision.

## EXTENSION (10 MIN)

**13 Use the Extension as an opportunity for advanced learning.**

Students can connect the scenario to the source of water in their own community. They can research local water sources and treatment, as well as any recent news about the local water supply, prior to sharing their findings with one another. Alternatively, you can pre-select the research and share it with the class.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

**The Build Understanding and Connections to Everyday Life questions are intended to guide your understanding. Some of these questions may be discussed with a partner, be part of a class discussion, or require an individual written response. Your teacher will guide you as to how these questions will be used in your class.**

1. **How did Skipton's residents' observations of the water compare with the results of water-quality tests?**

   *Some residents observed some cloudiness in their tap water, while the water-treatment tests of water quality met national standards.*

2. **In Skipton, many of the water quality tests, such as pH, did not indicate any change in water quality over time. Scientific explanations depend on relevant, accurate, and reliable data.**

   - **Data is relevant if it is closely connected to or related to the idea or question being considered. For example, your body temperature and how you feel are both relevant to whether you are well. The price of a thermometer is not relevant to your health.**
   - **Data is considered reliable if it can be reproduced consistently. For example, if you take your temperature at three different times and each time it is 100°F, your temperature data is reliable.**
   - **Accuracy is the closeness of a measured value to a true or standard value. For example, your parent feels your forehead and says you have a fever. When you take your temperature with a thermometer, it shows a reading of 101°F. Based on data from both human senses and a scientific tool, your temperature data is accurate.**

   **Were the Skipton water quality test results reliable, accurate, both, or neither? Explain your reasoning.**

   *The tests were repeated multiple times, so the tests could be considered reliable. Yet people got sick, probably from the water. So that means that tests were probably not accurate.*

## ③ E&T Scoring Guide

**You found out more about the town of Skipton's decision from the Data cards. Did you agree with the town's decision about water from the Mizu River?**

**Support your answer with at least three pieces of evidence from this activity and identify the trade-offs of your decision. Evidence is information that helps support or refute a claim or leads to the development of a new claim. A trade-off is an exchange of one valued outcome for another by giving up something that is a benefit or advantage in exchange for another benefit that may be more desirable.**

Following is a sample student response, which can also be found on Student Sheet 1.3, Sample. Student Response at the end of this activity.

### LEVEL 4 RESPONSE

*I agree with Skipton's decision to get water from the river. The town has already saved a lot of money. Water quality tests do not show any change, and cloudiness levels meet standards for water quality. While some residents have gotten sick, there is no evidence that it is from the drinking water. The trade-off of my decision is that if the Cryptosporidium is in the water, more people may get sick. Some people might not think saving money is worth the risk.*

### LEVEL 3 RESPONSE

*I agree with Skipton's decision to get water from the river. The town has saved money, the water quality tests haven't changed, and the cloudiness levels meet standards. The trade-off of my decision is that there might be Cryptosporidium in the water.*

### LEVEL 2 RESPONSE

*I agree with Skipton's decision to get water from the river. The water quality tests are okay, but people might get sick.*

### LEVEL 1 RESPONSE

*I agree with Skipton's decision to get water from the river because river water is clean and good for you.*

## CONNECTIONS TO EVERYDAY LIFE

④ **In this activity, the Skipton scenario provided an opportunity to conduct a thought experiment by testing ideas about drinking water without doing additional experiments or your own research. This is a common approach used in many fields of study prior to doing real-world work. What are some situations in your daily life where it might be useful for you to conduct thought experiments?**

*Sometimes I think about what might happen if I don't study for a test (how it might affect my grade), what would happen if my team wins a game (how it would affect us getting into league championships), and what my month might look like if I spend most of my money at the beginning of the month (what I could or couldn't do with my friends).*

⑤ **In this activity, you began to investigate the role of multiple lines of evidence in supporting or refuting an idea. Consider what role evidence plays in your own decision-making. Imagine that your friend just told you that caffeinated energy drinks are great for breakfast because they help kids focus. On days when she stays up late and doesn't have an energy drink for breakfast, she sometimes falls asleep in class. Did she provide enough evidence for you to choose having an energy drink for breakfast? Explain why or why not.**

*No, I hate energy drinks, so the evidence she gave isn't enough for me. I would want data from more kids than just her because everyone is different. The drink might have a different effect on different people. If she experimented with having and not having the drink and had data that showed how often she stayed awake in both situations, that would provide more evidence that might convince me.*

### REFERENCES

World Wildlife Fund. (2022). Water scarcity overview. Retrieved from https://www.worldwildlife.org/threats/water-scarcity#:~:text=As%20a%20result%2C%20some%201.1,and%20other%20water%2Dborne%20illnesses

## DATA CARD 1

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**Many residents report that their tap water looks and smells fine.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 2

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**Repeated bacterial tests of the water do not indicate any changes in water quality.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 3

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**The pH tests of the water do not indicate any changes in water quality.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 4

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**Many residents enjoy drinking fresh orange juice at breakfast.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 5

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**Some residents have recently complained that their tap water is cloudy, not clear.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 6

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**A few residents are worried about the quality of their drinking water.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 7

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**Sales of bottled water have increased.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 8

The town of Skipton decided to move forward with using water from the Mizu River for residential use. Two months have passed.

**The city has already saved $500,000.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 9

One month later:

**Numerous tests of the water do not indicate any changes in water quality.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 10

One month later:

**Residents of one area of Skipton have observed increased water cloudiness over a period of two weeks.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 11

One month later:

**The water has undergone multiple additional measurements of cloudiness beyond those required by law, and the water meets national treatment standards.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 12

One month later:

**Thousands of town residents have experienced stomach upset and diarrhea over a period of several weeks.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 13

One month later:

**A stool sample of a sick patient contains *Cryptosporidium. Cryptosporidium* is a microscopic parasite that causes watery diarrhea. It can be found in water, food, soil, or on surfaces that have been contaminated with the feces of humans or animals infected with the parasite.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 14

One month later:

***Cryptosporidium* cannot be detected by most standard tests of water quality.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 15

One month later:

**Reusable water bottles are on sale at local stores.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

## DATA CARD 16

One month later:

***Cryptosporidium* cannot be killed with chlorine at the concentrations used in routine water treatment.**

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 1

**STUDENT SHEET 1.1** | **PLAN FOR SKIPTON'S WATER** | **NAME**

| | MY DECISION | EVIDENCE SUPPORTING MY DECISION | QUESTIONS I HAVE |
|---|---|---|---|
| INITIAL PROPOSAL | | | |
| AFTER DATA CARDS 1–8 | | | |
| AFTER DATA CARDS 9–16 | | | |

| | MY DECISION | EVIDENCE SUPPORTING MY DECISION | QUESTIONS I HAVE |
|---|---|---|---|
| INITIAL PROPOSAL | *Yes, use water from Mizu River for 2 years.* | *Saves money.*<br>*Water is clear and has no odor.*<br>*The pH is in the right range.*<br>*Low level of microbes.*<br>*Water will be treated with chlorine.* | *Will there be enough water for the 2 years?*<br>*Will the water be tested for other factors?*<br>*Is the water from Lake Timtim clean?* |
| AFTER DATA CARDS 1–8 | *Yes, keep using water from Mizu River.* | *Tap water looks and smells fine.*<br>*Bacterial and pH tests of water show no change.*<br>*City saved $500,000.* | *Who is deciding that the water looks and smells fine?*<br>*Exactly how is this being determined?* |
| AFTER DATA CARDS 9–16 | *Yes, keep using water from Mizu River.* | *No other tests indicate any change in water quality.*<br>*Water meets national treatment standards.*<br>*Conducting more water quality tests for cloudiness than required by law.* | *What else could be making people sick?*<br>*Why is the water cloudy?* |

 SAMPLE STUDENT RESPONSE B

| | MY DECISION | EVIDENCE SUPPORTING MY DECISION | QUESTIONS I HAVE |
|---|---|---|---|
| INITIAL PROPOSAL | *Yes, use water from Mizu River for 2 years.* | *Saves money.*<br>*Water is clear and has no odor.*<br>*The pH is in the right range.*<br>*Low level of microbes.*<br>*Water will be treated with chlorine.* | *Will there be enough water for the 2 years?*<br>*Will the water be tested for other factors?*<br>*Is the water from Lake Timtim clean?* |
| AFTER DATA CARDS 1–8 | *No, stop using water from Mizu River.* | *Some residents have cloudy tap water.*<br>*Some residents worried about water quality.* | *What is making the tap water cloudy?*<br>*What other water quality tests could be conducted?*<br>*Who is deciding?* |
| AFTER DATA CARDS 9–16 | *No, stop using water from Mizu River.* | *Thousands of people have stomach upset and diarrhea.*<br>*Stool sample of a sick patient contains Cryptosporidium, a parasite that causes diarrhea.* | *Why wasn't the water tested more often?*<br>*Why weren't other water quality tests done?*<br>*What would prove if there is a parasite in the water?* |

STUDENT SHEET 1.2 | EVALUATING DATA | NAME

| | IS THE DATA RELEVANT? | | DOES IT PROVIDE EVIDENCE THAT SUPPORTS OR REFUTES USING WATER FROM MIZU RIVER? | |
|---|---|---|---|---|
| DATA | YES | NO | SUPPORTS | REFUTES |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |

STUDENT SHEET 1.2 | EVALUATING DATA | NAME SAMPLE STUDENT RESPONSE

| | IS THE DATA RELEVANT? | | DOES IT PROVIDE EVIDENCE THAT SUPPORTS OR REFUTES USING WATER FROM MIZU RIVER? | |
|---|---|---|---|---|
| DATA | YES | NO | SUPPORTS | REFUTES |
| 1 | X | | X | |
| 2 | X | | X | |
| 3 | X | | X | |
| 4 | | X | - | - |
| 5 | X | | | X |
| 6 | X | | | X |
| 7 | | X | - | - |
| 8 | X | | X | |
| 9 | X | | X | |
| 10 | X | | | X |
| 11 | X | | X | |
| 12 | X | | | X |
| 13 | X | | | X |
| 14 | X | | | X |
| 15 | | X | - | - |
| 16 | X | | | X |

STUDENT SHEET 1.3 | WRITING FRAME: EVIDENCE & TRADE-OFFS | NAME

THERE IS A LOT OF DISCUSSION ABOUT THE ISSUE OF

MY DECISION IS THAT

MY DECISION IS BASED ON THE FOLLOWING EVIDENCE:

FIRST,

SECOND,

THIRD,

THE TRADE-OFF(S)

PEOPLE WHO DISAGREE WITH MY DECISION MIGHT SAY THAT

STUDENT SHEET 1.3 | WRITING FRAME: EVIDENCE & TRADE-OFFS | NAME SAMPLE STUDENT RESPONSE

THERE IS A LOT OF DISCUSSION ABOUT THE ISSUE OF

*whether to get water from the Mizu River.*

MY DECISION IS THAT

*the town should not get water from the river.*

MY DECISION IS BASED ON THE FOLLOWING EVIDENCE:

FIRST,

*many residents are worried and have complained about their water.*

SECOND,

*some people have become sick from Cryptosporidium, which can be found in water.*

THIRD,

*Cryptosporidium cannot be detected by most water quality tests.*

THE TRADE-OFF(S)

*is that it will cost the city more money.*

PEOPLE WHO DISAGREE WITH MY DECISION MIGHT SAY THAT

*the Cryptosporidium could have been a result of contaminated food or another source.*

STUDENT SHEET 1.4 | UNIT CONCEPTS AND SKILLS | NAME

| UNDERSTAND | | ANALYZE |
|---|---|---|
| CONCEPT | DESCRIPTION | UNIT EXAMPLE(S) |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?

| UNDERSTAND | | ANALYZE |
|---|---|---|
| **CONCEPT** | **DESCRIPTION** | **UNIT EXAMPLE(S)** |
| *Multiple lines of evidence* | *Scientific explanations are supported by multiple lines of relevant, accurate, and reliable evidence* | *Skipton's water source*<br>*use of Lake Timtim* |
| *Data from human senses + scientific tools and technology* | *Evidence can be the result of data from human senses + scientific tools and technology* | *Odor and appearance of water samples, pH data, turbidity data* |
| *Validation* | *Evidence from different sources can be used to validate each other* | *pH data from multiple methods*<br>*different water quality indicators* |
| *Scientific advancement* | *Scientific knowledge develops over time due to new evidence, better experimental methods, collaboration, + trial and error* | *Evidence of water on planet Mars, development of microscope and relationship to understanding role of microbes in infectious disease* |
| *Iteration* | *Scientific ideas and processes are continuously re-evaluated and revised* | *Julius Lucks, water quality design challenge* |
| *Science a human endeavor* | *Science is done by people* | *Pastor McCathern, LeeAnne Walters, Africa Flores, Julian Lucks, Marilou Sison-Mangus* |
| *Scientific optimism* | *People keep working to solve problems using science* | *Dr. Daniel Fernandez and team, Hugo Streeter, Dr. Peter Weiss-Penzias, Dr. Sara Baguskas, Steve Jenkins and Xeros team* |

**WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?**

*Whether to move Skipton's water supply, whether to get water from Lake Timtim, how to design a water-treatment device, how to address local water quality and availability.*

| COMMUNICATION | SENTENCE STARTERS |
|---|---|
| **to better understand** | One point that was not clear to me was...<br>What if we tried...<br>I have an idea. We could try... |
| **to disagree** | I see your point, but what about...?<br>Another way of looking at this is...<br>I'm still not convinced that... |
| **to challenge** | How do you reach the conclusion that...?<br>What makes you think that...?<br>How does it explain...? |
| **to look for feedback** | What would help me improve...<br>Does it make sense, what I said about...? |
| **to provide positive feedback** | One strength of your idea is...<br>Your idea is good because... |
| **to provide constructive feedback** | The argument would be stronger if...<br>Another way to do it would be...<br>What if you said it like this...? |

**MAKE SURE YOUR RESPONSE:**

- uses relevant evidence, concepts, and process skills to compare multiple options in order to make a choice.
- takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

| LEVEL | DESCRIPTION |
|---|---|
| **Level 4**<br>**Complete and correct** | The student provides a clear and relevant choice with appropriate and sufficient evidence, including BOTH of the following:<br>• a thorough description of the trade-offs of the decision<br>• reasons why an alternative choice was rejected (if applicable) |
| **Level 3**<br>**Almost there** | The student provides a clear and relevant choice with appropriate and sufficient evidence, BUT one or both of the following are insufficient:<br>• the description of the trade-offs<br>• reasons why an alternate choice was rejected (if applicable) |
| **Level 2**<br>**On the way** | The student provides a clear and relevant choice, BUT the evidence is incomplete. |
| **Level 1**<br>**Getting started** | The student provides a clear and relevant choice BUT provides reasons that are subjective or inaccurate. |
| **Level 0** | The student's response is missing, illegible, or irrelevant. |
| **X** | The student had no opportunity to respond. |

### WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue when arguments may include judgments based on nonscientific factors.

### WHAT TO LOOK FOR:

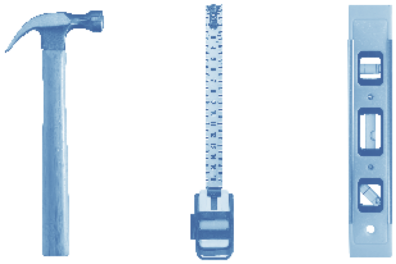
- Response uses relevant evidence, concepts, and process skills to compare multiple options in order to make a choice.
- Response takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 4**<br>**Complete and correct** | The student provides a clear and relevant choice with appropriate and sufficient evidence, including BOTH of the following:<br>• a thorough description of the trade-offs of the decision<br>• reasons why an alternative choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of whether they agree or disagree with the town's choice.<br>• a clear, thorough description of at least three pieces of evidence that are relevant to and support their position.<br>• a clear, thorough description of at least one appropriate trade-off. |
| **Level 3**<br>**Almost there** | The student provides a clear and relevant choice with appropriate and sufficient evidence, BUT one or both of the following are insufficient:<br>• the description of the trade-offs<br>• reasons why an alternate choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of whether they agree or disagree with the town's choice.<br>• at least three pieces of evidence that are relevant to and support their position.<br>• at least one appropriate trade-off.<br>• descriptions of evidence and trade-offs may be unclear or insufficient. |

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
| --- | --- | --- |
| **Level 2**<br>**On the way** | The student provides a clear and relevant choice, BUT the evidence is incomplete. | **The student's response includes:**<br>• a clear description of whether they agree or disagree with the town's choice.<br>• at least one piece of evidence that is relevant to their decision.<br>**And may include:**<br>• at least one trade-off<br>**However, evidence is less than three pieces and/or trade-off is missing or unclear.** |
| **Level 1**<br>**Getting started** | The student provides a clear and relevant choice BUT provides reasons that are subjective or inaccurate. | **The student's response includes:**<br>• a clear description of whether they agree or disagree with the town's choice.<br>**However, evidence is subjective, inaccurate, or irrelevant and/or trade-off is missing or unclear.** |
| **Level 0** | The student's response is missing, illegible, or irrelevant. | |
| **X** | The student had no opportunity to respond. | |

## VISUAL AID 1.3 | UNDERSTANDING CONCEPTUAL TOOLS

### CONSTRUCTION TOOLS



### SCIENTIFIC TOOLS

### SCIENTIFIC TOOLS + TECHNOLOGY

### CONCEPTUAL TOOLS

ACTIVITY 2

# Validating Measurements

LABORATORY

## ACTIVITY 2

# Validating Measurements

## ACTIVITY SUMMARY

**Students conduct an investigation into one water quality indicator: pH. They measure pH values, using different techniques and compare their pH values in order to validate their results. They apply the concepts of accuracy and reliability of data. As a class, they discuss the role of human senses and other scientific tools in gathering data and validating results.**

ACTIVITY TYPE
LABORATORY

NUMBER OF 40–50 MINUTE CLASS PERIODS
2

## KEY CONCEPTS & PROCESS SKILLS

1. New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.

2. Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS

SENSES & INSTRUMENTATION

## VOCABULARY DEVELOPMENT

### control

(assumed prior knowledge)

standard of comparison for checking or verifying the results of an experiment; results of the experiment are compared with the control in order to see if the variable changed in the experiment caused any effect

### pH

(assumed prior knowledge)

a measure of how acidic or basic a solution is; the pH scale measures the relative concentration of hydrogen ions (H+), utilizing a scale where 1–6 is classified as acidic, 7 as neutral (neither acidic nor basic), and 8–14 is classified as basic

### turbidity

a measure of the clarity of water that indicates the presence of suspended particles such as soil or algae

### validation

process of determining the accuracy of a measurement

## BACKGROUND INFORMATION

### Scientific Validation

When using scientific tools, scientists must check how much each instrument differs from the standard at the start and end of an experiment (and sometimes in the middle of the experiment, if it is a long-term experiment). For example, tape measures can stretch, so their accuracy should be checked at the beginning and end of an experiment. If a person visually assessed something, such as the behavior of an organism, it must be a repeatable observation. The observation process must be validated for the same result to be consistently obtained—for example, by detailing exactly the behavior observed and how it is recorded. If more than one person collects data, it is essential to validate, at regular intervals, that everyone is collecting data in the same way; otherwise, certain items are recorded more frequently or less frequently as different people focus on different aspects or provide more detail or less detail. If several people participate in a visual assessment, it is important to validate their ability to interpret an item in the same way—for example, the taste and color differences in fruit or other foods.

# MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 2 Build Understanding item 5
- 6-8 CUPS OF BOILING DISTILLED WATER
- LARGE HEAD OF RED CABBAGE
- LARGE GLASS CONTAINER
- KNIFE
- STRAINER
- BLENDER (OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

- 100 mL BEAKER OF RED-CABBAGE JUICE
- DROPPER BOTTLE OF HOUSEHOLD AMMONIA
- DROPPER BOTTLE OF DISTILLED WATER
- DROPPER BOTTLE OF HOUSEHOLD VINEGAR
- CUP OF DRINKING WATER SAMPLE
- pH PAPER WITH pH SCALE
- pH METER WITH PROBE
- CUP OF WATER
- EMPTY CUP
- PAPER TOWEL

FOR EACH PAIR OF STUDENTS

- 5 SMALL BEAKERS, LABELED A–E (or empty petri-dish bases or a tray with multiple wells, such as a SEPUP tray)
- 10 mL GRADUATED CYLINDER
- SHEET OF WHITE PAPER
- DROPPER
- STIR STICK

FOR EACH STUDENT

- SAFETY GOGGLES
- LAB COAT
- STUDENT SHEET 1.3 "Writing Frame: Evidence and Trade-Offs" (OPTIONAL)
- STUDENT SHEET 2.1 "Data Tables" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)

Chop the cabbage into small pieces until you have about 4 cups of chopped cabbage. Place the cabbage in a large beaker or other glass container and add boiling water to cover the cabbage. Allow at least 10 minutes for the color to leach out of the cabbage. Alternatively, you can place about 4 cups of cabbage in a blender, cover it with boiling water, and blend it. Filter out the plant material to obtain a purplish-colored liquid (the exact color depends on the pH of the water). Using distilled water, this liquid should have a pH of about 7. Depending on your number of teaching periods and your class size, you may require additional red-cabbage juice. Each pair of students will need approximately 20 mL of this liquid.

Each pair of students will use approximately 25 mL of each of the 4 liquids. Based on your class size and number of periods, determine the amount of liquid you will require for the activity. Label the beakers A–E. Empty petri-dish bases, or a tray with multiple wells (such as a SEPUP tray), can be substituted for the beakers.

Note that the activity can be modified to address the availability of materials in your classroom. If you do not have access to pH meters, have students skip Procedure Steps 15 and 17.

## SAFETY NOTE

**Remind students to make observations using only sight and smell and to not eat or drink any chemicals.**

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Brainstorm water quality indicators as a class.**

- Remind students of how the scenario of Skipton raised the issues of water accessibility and water quality. Some residents observed cloudiness, a possible indicator of contaminants. Ask, What are other indicators of water quality? Elicit students' thinking and make a list of student responses. Students may be aware of smell, appearance (color, clarity), salinity, temperature, oxygen levels, the possible presence of microbes, and the possibility of chemical contaminants. They may also identify pH, which was raised in the Skipton scenario.

2 **Have students read the Introduction in the Student Book.**

- Review the use of **pH** and **turbidity** as water quality indicators.
- If students are completely unfamiliar with pH, refer to "Scientific Review: pH" found at the end of the Student Book activity to review basic concepts about pH.
- Discuss the concept of **validation**, a process of determining the accuracy of a measurement. For example, a weighing scale can be validated by measuring the weight of several objects of known weights to determine if the scale is accurate. Students may have had experience with this if they had to use a scientific balance that provided inaccurate measurements. Scientific tools can be validated by comparing measurements taken with the tool with other reliable values, such as those made with other instruments or even by human senses or by using known values to determine the tool's accuracy.

## PROCEDURE SUPPORT (30 MIN)

3 **Review classroom safety expectations.**

- Remind students to wear lab coats and goggles and to follow all classroom safety rules. Review the Safety Note in the Student Book and the proper method for smelling chemicals in science by wafting, as described in Procedure Step 2.

4 **Students make observations of each of the four liquids.**

- Students begin by using their senses to gather data. They are able to make observations of odor and appearance and are asked to make pH predictions.
- Discourage students from trying to research the pH of each liquid in advance. A goal of this procedure step is to determine the data that can be gathered by human senses, as well as its limits.

5 **Students measure pH, using red-cabbage juice in Procedure Part B.**

- If students are not familiar with the term control, remind them that a **control** is a standard of comparison for checking or verifying the results of an experiment. Comparing the experimental results with the control allows them to see if the variable they changed in the experiment caused any effect.
- In this unit, laboratories and card-based investigations use hands-on materials to support student learning. Certain student populations—including girls, gender non-conforming students, and English learners (ELs)—often take on roles in which they do not directly engage with hands-on materials, such as recorder and observer. Incorporate strategies to ensure that all students participate over time. For example, in activities like this one in which students conduct the investigation in groups of four, one strategy is to assign roles (such as group leader, recorder, observer, and timekeeper) ahead of time and then rotate them periodically. Another strategy is to create specific groupings of four that might encourage greater participation. Decide which strategy you will use to best support your student population.
- Students can record their lab results in a science notebook. Alternatively, you may wish to provide copies of Student Sheet 2.1, "Data Tables," which contains all the data tables to be completed during the procedure. Sample student responses to all the data tables are shown on Student Sheet 2.1 found at the end of this activity.
- You may wish to review the color variation described in Table 2.3. Violet is a deeper shade of purple that contains slightly more blue than red.

**6 Students measure pH using pH paper in Procedure Part C.**

- Different commercially available pH papers have different color scales. Review the color scale of the pH paper being used in your classroom as needed. You may wish to develop a common language to refer to each color on the scale—for example, pH 7 is spring green, while pH 8 is grass green.

- To support color-blind students, consider using a pH paper that does not utilize red/green contrast but instead uses intensities of a single color, such as green. Or install a smartphone app that helps identify colors for those with color blindness and allow students to use the app as needed. Be sure there is good lighting to examine the pH paper.

- Students can use the information in Table 2.3 or in the Scientific Review to determine whether each liquid is acidic, basic, or neutral.

**7 Students measure pH, using pH meters, in Procedure Part D.**

- If you have pH meters available, have students use them to measure the pH of each liquid. Methods to calibrate and measure pH with pH meters can vary, so provide appropriate direction to your students as needed.

- You may want to discuss how the accuracy of scientific technologies such as pH meters are dependent on their calibration. A miscalibrated meter can result in inaccurate data.

**8 Students compare their pH measurements.**

- In Table 5, students compare their predicted and measured pH readings for the four liquids. They should see some consistency in their readings, leading to reliability, and recognize that they gathered more accurate data by using the pH meters.

- Discuss variability in students' observations of color and how this may have affected their pH readings. Review the idea that scientific data can require the interpretation of observations and that part of the process of science is constructing methods to reduce such variability. Variability is reduced by validation measurements and by ensuring the accuracy and reliability of data.

- Students validated the measurement of pH by comparing different pH measuring techniques: red-cabbage juice, pH paper, and pH meters. These techniques let students perceive phenomena more completely, precisely, reliably, and accurately than senses alone.

## SYNTHESIS OF IDEAS (10–15 MIN)

9 **Discuss the role of human senses in validating results from scientific tools.**

- Use Build Understanding items 1–4 to discuss the usefulness and limits of human senses for gathering data.
- Students' predicted pH values may vary widely from the measured values. Some phenomena, such as pH level, are not directly perceivable by human senses alone, only by instruments such as pH strips or pH meters. Ask, How can people be confident that they are observing real differences in pH levels when pH cannot be directly seen by people? What could increase your confidence level in such measurements? Students should respond that multiple measurements from scientific tools, such as pH meters, can be used to validate pH. More complete scientific explanations, such as understanding the mechanism behind a phenomenon, can result in increased confidence levels.
- Ask, In what situations are scientific tools used to validate data from human senses? Think about everyday situations in which data gathered by your senses requires you to get more detailed information from scientific tools. Sample responses may include temperature, weight, height (or length), distance, time, speed, heart rate, altitude, etc.

10 **Relate the concept of pH to the Skipton scenario.**

- Build Understanding item 5 applies the concept of pH to the Skipton scenario.
- You can use Visual Aid 1.2, "Scoring Guide: Evidence and Trade-Offs (E&T)" to assess Build Understanding item 5. A sample Level 4 response is included in Sample Responses to Build Understanding and on Student Sheet 1.3.

## EXTENSION (10 MIN)

11 **Use the Extension as an opportunity for advanced learning.**

Students can find out more about their local water quality by researching publicly available information provided by local water authorities. Most public water authorities have an annual report of local water quality that can be accessed online or is mailed to local residents. Data is likely to include both biological and inorganic measurements, unregulated contaminants, and disinfection byproducts. Facilitate students' research by providing the name(s) of your local water authority and/or provide website links for students to get more information about local water quality.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

① **Explain how using pH probes (or pH paper) did or did not validate the use of red-cabbage juice as a pH indicator. Support your answer with evidence from your experimental results.**

HINT: Consider how similar or different the resulting pH values were for each tested liquid.

*The pH paper validated the use of the red-cabbage juice because we had similar pH values for all 4 liquids. For example, the vinegar had a pH of 3–6 based on the dark red color of the cabbage juice, and it had a pH of 3, using the pH paper.*

② **Scientific explanations depend on relevant, accurate, and reliable data.**

a Compare the pH measurements you made, using different tools. Describe how accurate your measurements of pH were in this activity.

*The pH data were accurate with a specific range, as measured by the different techniques. The pH readings may vary because people can see and identify colors, such as dark pink vs. red, differently.*

b Compare your pH measurements with those of other groups. Based on your comparisons, describe how reliable your measurements of pH were in this activity.

*The pH data was reliable because almost all the groups measured the pH within a range of 1 when using the pH paper and the pH meter. The pH data based on the cabbage juice was less reliable because people had very different results.*

③ **What does this activity tell you about data from human senses vs. scientific testing?**

*pH cannot be observed by human senses and needs scientific testing to be measured. Different techniques can contribute to increased reliability and accuracy.*

④ **Beginning in the 1920s, electrochemical probes, such as the one shown here, began to be used to measure pH more accurately. Advances in technology have resulted in miniature devices that can test pH inside living cells. Why would these technologies be preferred over color indicators such as pH paper and cabbage juice?**

*These new technologies provide more precise pH measurements that are more reliable and accurate. They can also be used to measure the pH of more materials than color indicators.*

⑤ **E&T Scoring Guide**

**Levels of pH decrease as temperature increases: a 10°C (50°F) increase in temperature will reduce the pH by 0.2. In order to reduce energy use and save money, a factory sited along the Mizu River in Skipton releases treated wastewater back into the river at a temperature of 27°C (80°F) and a pH of 6.3. The average temperature of the river is 18°C–24°C (65°F–75°F) in the summer and 2°C–7°C (35°F–45°F) in the winter. The factory supervisor calculates that as the water cools, it will result in an acceptable pH.**

**Should the local government require additional treatment of the wastewater before it is released? Support your answer with at least three pieces of relevant evidence from this activity and identify the trade-offs of your decision.**

HINT: You may want to first review the introduction and Scientific Review for this activity.

### LEVEL 4 RESPONSE

*The government should require that the wastewater be treated more before being released. The pH of drinking water is expected to be within a range of 6.5–9, and the company is releasing it at 6.3, which is lower than drinking water standards. Also, the ideal pH range for aquatic organisms such as snails is higher (over 7). Even though the pH of the water might go up as the water cools, it is still going into the river as being too acidic. The trade-off is that treating the water will use more energy and cost more money. People who disagree with my decision might say that the difference in pH from 6.3 to 6.5 is quite small, and the water will be diluted once it is released into the river.*

### LEVEL 3 RESPONSE

*The government should require that the wastewater be treated more before being released. The water being released is at pH 6.3 and 27°C, which is too low a pH for aquatic organisms and hotter than the warmest average temperature of the river. Even though the pH might go up as the water cools, it shouldn't go into the river if it is that different from the river water. The trade-off is that treating the water more will cost more.*

#### LEVEL 2 RESPONSE

*The government should require that the wastewater be treated more before being released. The pH is still higher than the river water. The trade-off is it will be more expensive.*

#### LEVEL 1 RESPONSE

*The government should require that the wastewater be treated more before being released because it might hurt the environment.*

## CONNECTIONS TO EVERYDAY LIFE

6. **Rita makes a recipe using a large glass measuring cup that holds up to 3 cups of liquid. Her final dish never turns out quite right. Explain how she could validate the accuracy of her measuring tool.**

   *Rita could use a different measuring cup, such as a 1-cup container, and fill it up 3 times to compare it to the amount measured by using the large measuring cup. She could then determine if it is accurately measuring 3 cups.*

7. **Suppose you are using a thermometer to track the temperature in your home, but you suspect it is not working. How could you validate its temperature reading?**

   *You could compare it to data from your own senses (does the room feel warm or cold), place the thermometer in boiling water to see if it reads 100°C (212°F), place it in a glass of ice water to see if it reads 0°C (32°F), or use it to take your body temperature 37°C (98.6°F).*

### REFERENCES

Fondriest Environmental, Inc. (2013, November 19). pH of water. Fundamentals of Environmental Measurements. Retrieved from https://www.fondriest.com/environmental-measurements/parameters/water quality/ph/

| STUDENT SHEET 2.1 | DATA TABLES | NAME |
|---|---|---|

## PART A

### TABLE 2.1: OBSERVATIONS

| LIQUID | APPEARANCE | ODOR | PREDICTED pH |
|---|---|---|---|
| A. DISTILLED WATER | | | |
| B. DRINKING WATER | | | |
| C. AMMONIA | | | |
| D. VINEGAR | | | |

## PART B

### TABLE 2.2: TESTING pH WITH RED-CABBAGE JUICE

| LIQUID | FINAL COLOR | APPROXIMATE pH RANGE | ACIDIC, BASIC, OR NEUTRAL? |
|---|---|---|---|
| A. DISTILLED WATER | | | |
| B. DRINKING WATER | | | |
| C. AMMONIA | | | |
| D. VINEGAR | | | |
| E. CONTROL (CABBAGE JUICE) | | *7* | *neutral* |

TABLE 2.3 IS AN INFORMATIONAL TABLE FOUND ONLY IN THE STUDENT BOOK.

## PART C

### TABLE 2.4: TESTING pH WITH pH PAPER

| LIQUID | PAPER COLOR AFTER TESTING A LIQUID* | pH | ACIDIC, BASIC, OR NEUTRAL? |
|---|---|---|---|
| A. DISTILLED WATER | | | |
| B. DRINKING WATER | | | |
| C. AMMONIA | | | |
| D. VINEGAR | | | |

*varies based on pH paper used

## PART D

### TABLE 2.5: TESTING AND COMPARING pH WITH pH PROBES

| LIQUID | PREDICTED pH | pH FROM CABBAGE JUICE | pH FROM pH PAPER | pH FROM pH METER |
|---|---|---|---|---|
| A. DISTILLED WATER | | | | * |
| B. DRINKING WATER | | | | |
| C. AMMONIA | | | | |
| D. VINEGAR | | | | |

*not measurable with probe

STUDENT SHEET 2.1 | DATA TABLES | NAME SAMPLE STUDENT RESPONSE

## PART A

### TABLE 2.1: OBSERVATIONS

| LIQUID | APPEARANCE | ODOR | PREDICTED pH |
|---|---|---|---|
| A. DISTILLED WATER | *clear, colorless* | *none* | *7* |
| B. DRINKING WATER | *clear, colorless* | *none* | *7* |
| C. AMMONIA | *clear, colorless* | *strong, pool-water smell* | *10* |
| D. VINEGAR | *clear, colorless* | *sharp, sour* | *4* |

## PART B

### TABLE 2.2: TESTING pH WITH RED-CABBAGE JUICE

| LIQUID | FINAL COLOR | APPROXIMATE pH RANGE | ACIDIC, BASIC, OR NEUTRAL? |
|---|---|---|---|
| A. DISTILLED WATER | *violet* | *7* | *neutral* |
| B. DRINKING WATER | *violet / blue* | *7 - 8* | *neutral / slightly basic* |
| C. AMMONIA | *green* | *12 - 14* | *basic* |
| D. VINEGAR | *pink / dark red* | *1 - 3* | *acidic* |
| E. CONTROL (CABBAGE JUICE) | *purple* | *7* | *neutral* |

TABLE 2.3 IS AN INFORMATIONAL TABLE FOUND ONLY IN THE STUDENT BOOK.

## PART C

### TABLE 2.4: TESTING pH WITH pH PAPER

| LIQUID | PAPER COLOR AFTER TESTING A LIQUID* | pH | ACIDIC, BASIC, OR NEUTRAL? |
|---|---|---|---|
| A. DISTILLED WATER | *bright spring green* | *7* | *neutral* |
| B. DRINKING WATER | *grass green* | *8* | *neutral / slightly basic* |
| C. AMMONIA | *dark forest green* | *13* | *basic* |
| D. VINEGAR | *bright orange* | *2* | *acidic* |

*varies based on pH paper used

## PART D

### TABLE 2.5: TESTING AND COMPARING pH WITH pH PROBES

| LIQUID | PREDICTED pH | pH FROM CABBAGE JUICE | pH FROM pH PAPER | pH FROM pH METER |
|---|---|---|---|---|
| A. DISTILLED WATER | *7* | *7* | *7* | * |
| B. DRINKING WATER | *7* | *7 - 8* | *8* | *8.1* |
| C. AMMONIA | *10* | *12 - 14* | *13* | *11.2* |
| D. VINEGAR | *4* | *1 - 3* | *2* | *2.4* |

*not measurable with probe

STUDENT SHEET 1.3 | WRITING FRAME: EVIDENCE & TRADE-OFFS | NAME

THERE IS A LOT OF DISCUSSION ABOUT THE ISSUE OF

MY DECISION IS THAT

MY DECISION IS BASED ON THE FOLLOWING EVIDENCE:

FIRST,

SECOND,

THIRD,

THE TRADE-OFF(S)

PEOPLE WHO DISAGREE WITH MY DECISION MIGHT SAY THAT

THERE IS A LOT OF DISCUSSION ABOUT THE ISSUE OF

*water quality.*

MY DECISION IS THAT

*the wastewater should be required to be treated more before being released.*

MY DECISION IS BASED ON THE FOLLOWING EVIDENCE:

FIRST,

*the pH of drinking water is expected to be within a range of 6.5–9, and the company is releasing it at 6.3, which is lower than drinking water standards.*

SECOND,

*the ideal pH range for aquatic organisms such as snails is higher (over 7).*

THIRD,

*even though the pH of the water might go up as the water cools, it is still going into the river as being too acidic.*

THE TRADE-OFF(S)

*is that treating the water will use more energy and cost more money.*

PEOPLE WHO DISAGREE WITH MY DECISION MIGHT SAY THAT

*the difference in pH from 6.3 to 6.5 is quite small, and the water will be diluted once it is released into the river.*

### WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue when arguments may include judgments based on nonscientific factors.

### WHAT TO LOOK FOR:

- Response uses relevant evidence, concepts, and process skills to compare multiple options in order to make a choice.
- Response takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 4**<br>**Complete and correct** | The student provides a clear and relevant choice with appropriate and sufficient evidence, including BOTH of the following:<br>• a thorough description of the trade-offs of the decision<br>• reasons why an alternative choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their decision about requiring additional water treatment.<br>• a clear, thorough description of at least three pieces of evidence that are relevant to, and support their position, including evidence from the activity (not in the question prompt).<br>• a clear, thorough description of at least one appropriate trade-off. |
| **Level 3**<br>**Almost there** | The student provides a clear and relevant choice with appropriate and sufficient evidence, BUT one or both of the following are insufficient:<br>• the description of the trade-offs<br>• reasons why an alternate choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their decision about requiring additional water treatment.<br>• at least three pieces of evidence that are relevant to, and support their position.<br>• at least one appropriate trade-off.<br>• descriptions of evidence and trade-offs may be unclear or insufficient. |

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 2**<br>**On the way** | The student provides a clear and relevant choice, BUT the evidence is incomplete. | **The student's response includes:**<br>• a clear description of their decision about requiring additional water treatment.<br>• at least one piece of evidence that is relevant to their decision.<br>**And may include:**<br>• at least one trade-off<br>**However, evidence is less than three pieces and/or trade-off is missing or unclear.** |
| **Level 1**<br>**Getting started** | The student provides a clear and relevant choice BUT provides evidence that is subjective, inaccurate, or irrelevant. | **The student's response includes:**<br>• a clear description of their decision about requiring additional water treatment.<br>**However, evidence is subjective, inaccurate, or irrelevant and/or trade-off is missing or unclear.** |
| **Level 0** | The student's response is missing, illegible, or irrelevant. | |
| **X** | The student had no opportunity to respond. | |

ACTIVITY 3

# Scientific Advancement

CARD-BASED INVESTIGATION

ACTIVITY 3

# Scientific Advancement

## ACTIVITY SUMMARY

**Students explore the development of scientific explanations over time. They investigate two timelines from the history of science. First, they organize the likely sequence of three events in one timeline. Then they place these events in a larger timeline containing multiple events in the development of the topic. Students discuss the role of evidence and advances in scientific tools and techniques in the development of scientific thinking.**

ACTIVITY TYPE
CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
1–2

## KEY CONCEPTS & PROCESS SKILLS

1 New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.

2 The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.

3 Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS

SHARED REALITY

SENSES & INSTRUMENTATION

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

## VOCABULARY DEVELOPMENT

**scientific advancement**
the progress of science toward more accurate, reliable, and complete explanations of phenomena

## BACKGROUND INFORMATION

### Scientific Advancement

The process of science is a way of building knowledge about the universe. Those ideas are initially tentative, but as they cycle through the process of science, they are tested and retested in different ways, resulting in increasing confidence in these ideas. Through this same iterative process, ideas are modified, expanded, and combined into more accurate explanations. For example, a few observations about inheritance patterns in garden peas can—through the work of many different scientists—be built into the broad understanding of genetics offered by science today. In this way, scientific knowledge is constructed, and there is scientific advancement in human understanding of the natural world.

## MATERIALS & ADVANCE PREPARATION

FOR EACH GROUP OF FOUR STUDENTS

- 2 SETS OF TIMELINE CARDS

FOR EACH STUDENT

- STUDENT SHEET 3.1A OR 3.1B "Timeline Dates"
- STUDENT SHEET 3.2 "Timeline Analysis"
- STUDENT SHEET 1.4 "Unit Concepts and Skills" (OPTIONAL)

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Discuss the graph in the introduction of the Student Book.**

- Have students carefully examine the graph in the activity's introduction, which shows outbreaks due to different sources of drinking water contamination over time. If needed, review how to examine the data provided in the graph to look for trends in the sources of drinking water contamination over time.
- First, have students make observations about patterns in the graph. They should notice that over time, the number of outbreaks with unidentified and parasitic causes decreased, while the number of outbreaks due to bacteria (including *Legionella*) and multiple causes increased, with bacteria (including *Legionella*) outbreaks trending up. The number of bacteria (non-*Legionella*) outbreaks appeared to stay steady over time. There was no discernible pattern in viral or chemical outbreaks.
- Ask, What do you think this graph might look like today? Based on the trends in the graph, current outbreaks due to bacteria (including *Legionella*) may be higher, while parasitic outbreaks may be less.
- Ask students to focus on the period of 1971–83 by covering the rest of the graph with their hands. Ask what trends they would have predicted solely on that data. Students should observe that there were consistently high levels of bacteria (non-*Legionella*) and increasing parasitic outbreaks. Predictions made for this time period lead to different predictions than ones based on more current information.
- Use the graph to point out that there are changes in data over time, and they can result in observations of different patterns. In a similar way, scientific ideas can change over time as new scientific tools and technology and new observations lead to more complete and revised explanations. In this activity, students will examine two timelines from the history of science to look for relationships between new observations as a result of advances in scientific tools and the development of scientific ideas.
- One of the timelines is on the topic of water on the planet Mars, and the other is on the imaging used to examine microscopic aspects of water. With the Mars timeline, emphasize the importance of water for life; scientists have used the presence of water as an indicator of possible life on other

planets. With the imaging timeline, highlight how understanding potential water contaminants is linked to the scientific tools and technology that allow for more detailed examination of components of water.

TEACHER'S NOTE: While these timelines further develop a unit focus on human senses and scientific tools and technology and are broadly related to water, they diverge from the primary focus on water quality. These timelines provide documented examples from the history of science that illustrate some of the key unit ideas.

2 **Review the idea of a timeline by constructing a personal timeline.**

- Explain that in this activity, students will organize events from the history of science into a timeline. If needed, use the following simple example to model how to construct a timeline by putting events in chronological order. Have students put the following (or similar) events in order:

  I ate solid foods.

  I went to middle school.

  I started kindergarten

  I was born.

  I started high school.

- Note that the events can first be ordered and then dates added to determine if the sequence is correct. Students will be doing something similar in this activity to investigate how scientific ideas develop over time.

## PROCEDURE SUPPORT (30 MIN)

3 **Pairs of students explore a timeline from the history of science.**

- Facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support. Consider how to best adapt the activity to the needs of your particular student population. Students who need more time processing language (such as students with dyslexia) can be provided with a set of the cards in advance of the day's activity. Alternatively, you can place a set of cards in order for a class to model the process and then assign students to the other set (or work through ordering both sets together as a class). Cue students to look for words that may help determine sequence, such as first or the concept that a tool had to be invented before it was used.

- Provide each pair of students with the three cards from either Timeline cards Set 1 or Timeline cards Set 2 as identified in the following table. Students are asked to place the cards in the correct sequence and to describe their reasoning. A sample response is provided.
- Guide students to see the connections between events in the timelines. Ask students to examine the three cards in their timeline to identify an example of a technological innovation, an observation made using the technical innovation, and an explanation derived from the observation. A sample response for each timeline is provided in the following table.
- Provide students with the remaining cards in their sets for them to sequence. Some students may find it helpful to have a set of cards that can be annotated to show how one idea leads to another or to use highlighters to annotate the student sheet to differentiate among an example of a technological innovation, an observation made using the technical innovation, and an explanation derived from the observation. Point out that the cards highlight only certain events in the history of science and are not comprehensive in terms of all the work that has led to scientific thinking on these topics.

| | SET 1: WATER ON MARS | SET 2: IMAGING |
|---|---|---|
| PROVIDE STUDENTS: | CARDS B, G, AND I | CARDS C, K, AND B |
| **Correct sequence (oldest to youngest)** | CARD B *Scientists Gustav Kirchhoff and Robert Bunsen invented the spectroscope, an instrument for observing light spectra. It can be used to determine the composition of an object.*<br>CARD I *Astronomers William Huggins and Pierre Janssen pointed a spectroscope at Mars and observed absorption lines (light spectra) consistent with water on Mars. They inferred that there was water on Mars.*<br>CARD G *New scientific models by planetary scientists indicate that between 30%–99% of water on Mars is incorporated as ice into minerals in the planet's crust, while the remaining fraction of water evaporates into space.* | CARD C *Italian physicist Giovanni Amici invented the oil-immersion microscope, which could magnify objects 6,000 times.*<br>CARD K *German scientist Robert Koch used an oil-immersion lens and a condenser to see bacteria cells. He was able to prove that infectious diseases such as tuberculosis, typhoid, and anthrax are each caused by specific microbes.*<br>CARD B *Molecular biologist Elizabeth English and her team used live-cell imaging (a way of seeing living cells by using time-lapse microscopy) to update knowledge of the life cycle of Cryptosporidium.* |
| **Reasoning** | *The spectroscope had to be invented before it could be used to observe Mars. New models of water on Mars had to occur after older ones.* | *The first observations had to happen before later ones. Then, each improvement in the microscope allowed people to see smaller and smaller things.* |

- After students have ordered the cards, discussed their thinking with their partners, and recorded their ideas in their science notebooks, hand out Student Sheet 3.1a or 3.1b, "Timeline Dates" (depending on which card set students examined). Students can use this student sheet to correct their sequence, as required. Students may find it helpful to annotate the timeline with notes or highlights to compare their proposed order with the sequence of historical events.

| | TIMELINE 1: MARS | TIMELINE 2: IMAGING |
|---|---|---|
| **Technological innovation** | *invention of spectroscope* | *microscope* |
| **Observations made, using the technical innovation** | *spectra indicating water on Mars* | *observations of bacteria and protozoa* |

- In Procedure Part B, students are asked to think through the logic of how each event built on previous events and to develop their sense of the iterative and cumulative advancement of science through new tools, new observations, and revised explanations. You may wish to have pairs of students with the same Timeline sets work together if they are finding Procedure Part B challenging.

- Hand out Student Sheet 3.2, "Timeline Analysis." Ways in which students may identify the different events as contributing to scientific advancements are described in the sample responses to Student Sheet 3.2 found at the end of the activity.

**4 Have students work in groups of four to compare different timelines.**

- Have pairs join another pair who investigated a different timeline. Students share the most important aspects of their timelines by sharing their responses to Student Sheet 3.2. They should be able to explain where in their timeline:
  - a new scientific tool or experiment led to a new observation.
  - an observation led to a new idea.
  - an explanation was revised based on new evidence.
  - an idea was later rejected or updated.

- With the class, revisit the concept of a shared external reality by pointing out that 200 years ago, some of the images described in the timeline could not be seen because the technology had not yet been invented. Ask, Does that mean that these aspects of the physical world did not exist? Review the idea that the planets and microbes existed before they were observed and described.

## SYNTHESIS OF IDEAS (20 MIN)

**5 Class discusses what the timelines reveal about scientific advancement**

- The term **scientific advancement** is formally defined in Build Understanding item 3. You can use Build Understanding item 3 to formatively assess students' understanding of scientific advancement.

- Support students in their understanding of scientific advancement as needed by asking questions such as:

  - Did anyone find cases in which scientists got something wrong? How do you know they got it wrong? Students may identify different events. For example, some people thought there were artificial canals constructed on Mars by intelligent beings. Later, scientists revealed that the pattern of artificial canals was an optical illusion from flaws in the telescope lenses.

  - How did the scientists realize they had gotten something wrong? In some cases, new tools and techniques, such as space rovers, provided evidence in the form of new observations, such as images of Mars' surface.

  - Does scientific advancement occur when ideas are later shown to be incorrect? Emphasize that the advancement of scientific knowledge occurs through continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error. This means that errors and mistakes are a part of the process of science, and scientific processes are intended to eventually identify those errors through new lines of evidence.

- Summarize elements of scientific advancement—how new scientific tools and technology make new observations possible beyond those from earlier instruments or human senses; how these new observations inform the revision of ideas; how additional evidence can help evaluate explanations that have gone awry and enable scientists to revise and improve their ideas to be accurate, reliable, and complete.

- Note that some students may raise issues about how unethical, immoral, or even illegal actions have been taken in the name of scientific progress. Support students in sharing their knowledge of such issues. Validate students' points of view by eliciting students' observations, experiences, and knowledge as assets to building understanding.

- You may wish to have students revisit Student Sheet 1.4, "Unit Concepts and Skills," and add information about the concept of scientific advancement.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

1. **Consider the following ways in which scientific ideas are revised:**

   - **introduction of new evidence**
   - **improved methods of data collection and experimentation**
   - **collaboration with others**
   - **trial and error**

   **Which of these were represented in the timeline you investigated? Support your answer with examples from your timeline.**

   Student responses will vary based on the assigned timeline.

   *In the Mars timeline, new evidence was collected when Cassini observed pale spots with his telescope, improved methods of data collection occurred when the rover Curiosity landed on Mars, and collaboration occurred when two scientists worked together to invent the spectroscope.*

   *In the imaging timeline, new evidence was collected when Leeuwenhoek described organisms he observed with his microscope, improved methods of data collection occurred as microscopes improved, and scientists collaborated on the development of the Mesolens.*

2. **Explain how new scientific tools and techniques can lead to new insights and questions.**

   *New scientific tools and techniques can provide new data about things that might be unknown, such as cells or microbes. The data can challenge previously held ideas or raise new questions. Making sense of new data can lead to providing more evidence for existing explanations or create new ideas to investigate.*

3. **Scientific advancement is the progress of science toward more accurate, reliable, and complete explanations of phenomena. Did the timeline you investigated represent scientific advancement? Support your response with at least three examples from your timeline.**

   Student responses will vary based on the assigned timeline.

   *The Mars timeline represented scientific advancement because there has been more evidence and understanding about water on Mars. Data from telescopes, spectroscopes, and rovers all provided evidence that there is water on Mars. This data was collected over hundreds of years.*

   *The imaging timeline represented scientific advancements because both the technology and the scientific ideas built on each other over time. The first microscopes provided evidence of living things unseen by human senses, and later improvements in microscopes helped identify the role of microbes in disease. Today, modern scientific technology is providing information about microbes inside host organisms.*

## CONNECTIONS TO EVERYDAY LIFE

4. **Today, people and teams around the world are able to easily communicate. What impact do you think this has on the speed of scientific discovery and technological innovation? Explain your thinking.**

*I think it has increased the speed of discovery and innovation. People from different parts of the world can work together online to share observations and ideas.*

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### SET 1: CARD A

The former Soviet Union successfully launched the first spacecraft, *Sputnik 1*, in orbit around Earth.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD B

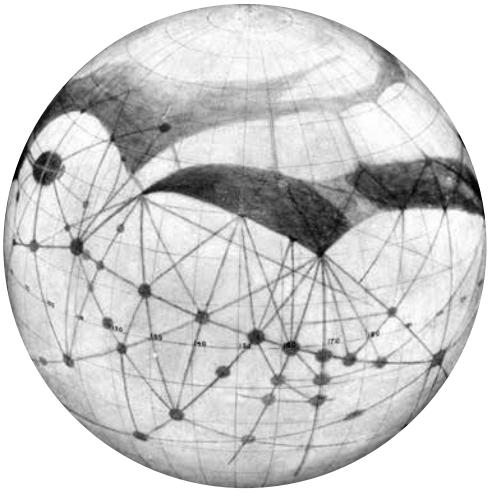
Scientists Gustav Kirchhoff and Robert Bunsen invented the spectroscope, an instrument for observing light spectra. It can be used to determine the composition of an object.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD C

American amateur astronomer Percival Lowell studied Mars for 15 years, making intricate drawings of the planet's surface. He conclud-ed that there were multiple nonnatural fea-tures on the surface, including artificial canals.

Percival Lowells' drawing of canals on Mars



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD D

The U.S. National Aeronautics and Space Administration (NASA) spacecraft *Mariner 4* took pictures as it passed by Mars, showing ice caps but no canals. Scientists became more confident that Mars had polar ice caps but no canals.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD E

NASA landed *Sojourner*, the first robotic rover, on the surface of Mars. It gathered and sent back data on the planet's surface.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 1: CARD F

French astronomer Camille Flammarion researched the Martian canals and argued that they were constructed to transport water over the entire planet. He suggested the presence of the canals indicated a form of life on Mars that might be more advanced than humans.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 1: CARD G

New scientific models by planetary scientists indicate that between 30%–99% of water on Mars is incorporated as ice into minerals in the planet's crust, while the remaining fraction of water evaporates into space.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 1: CARD H

Dutch eyeglass maker Hans Lipperhey built the first telescope.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 1: CARD I

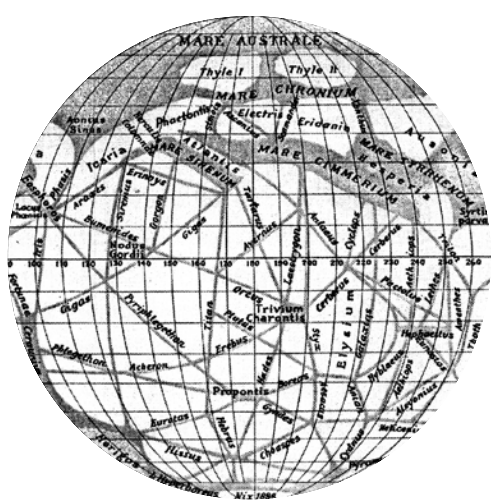
Astronomers William Huggins and Pierre Janssen pointed a spectroscope at Mars and observed absorption lines (light spectra) consistent with water on Mars. They inferred that there was water on Mars.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 1: CARD J

Italian astronomer Giovanni Schiaparelli used a 22-centimeter telescope to create the first detailed map of Mars, including linear features he called *canali*, which is Italian for *channels*. Later observers of his maps mistranslated *canali* as *canals*, instead of *channels*.

Giovanni Schiaparelli's map of canals on Mars




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD K

Italian mathematician Giovanni Domenico Cassini observed pale spots on the poles of Mars through his telescope. He inferred that Mars has polar ice caps made of frozen water.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD L

English astronomers Joseph Edward Evans and Edward Maunder conducted visual experiments with telescopes. They demonstrated that with a poor-quality telescope, certain features, such as craters, appear to connect to form lines. They argued that the observations of Martian canals were due to an optical illusion.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 1: CARD M

*Curiosity*, a fourth U.S. rover, landed on Mars. It used a laser spectrometer to gather data on the chemical and mineral composition of the surface and found gravel deposits like those found in streambeds on Earth. NASA scientists concluded that there had been an ancient streambed with a vigorous flow of water on Mars.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD A

American physician Dr. Ernest Edward Tyzzer used a light microscope to observe and describe *Cryptosporidium* in the intestinal tissue of mice.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD B

Molecular biologist Elizabeth English and her team used live-cell imaging (a way of seeing living cells by using time-lapse microscopy) to update knowledge of the life cycle of *Cryptosporidium*.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD C

Italian physicist Giovanni Amici invented the oil-immersion microscope, which could magnify objects 6,000 times.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD D

After its original identification in animals, the first human cases of *Cryptosporidium* were not reported until almost 70 years later.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD E

Electron microscopy was used to determine that *Cryptosporidium* parasites live inside the cells of host organisms, such as humans.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

### SET 2: CARD F

Dutch scientist Antonie van Leeuwenhoek wrote to the Royal Society of London reporting his discovery of little animals (bacteria and protozoa). English scientist Robert Hooke was asked by the Society to confirm Leeuwenhoek's findings. He did so, leading to wide acceptance of Leeuwenhoek's discoveries.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD G

Dutch opticians Hans Janssen and his son Zacharias are credited with inventing the first compound microscope—a microscope that uses more than one lens. This microscope could magnify objects 20–30 times its original size. This was not enough magnification to observe the tiny microbes that can cause disease.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD H

Genome sequencing (a way of determining an organism's DNA sequence) was used to determine that *Cryptosporidium* obtains all its nutrients from its host.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD I

English scientist Robert Hooke improved the design of the existing compound microscope by adding a light and using three lenses. This illuminated and enlarged the specimens. He observed many things, including cork (which has a regular shape he called cells).

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD J

English biologist Brad Amos led a team of researchers in designing the Mesolens, a giant microscope objective lens—about the length and width of a human arm—for use by computers. It is used to produce new images of microscopic parasites.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD K

German scientist Robert Koch used an oil-immersion lens and a condenser to see bacteria cells. He was able to prove that infectious diseases such as tuberculosis, typhoid, and anthrax are each caused by specific microbes.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD L

Dutch scientist Antonie van Leeuwenhoek invented a microscope that could enlarge an image 400 times. He made the first observations of protozoa and bacteria, helping to disprove the idea of spontaneous generation.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

## SET 2: CARD M

Greek philosopher Aristotle described spontaneous generation as the idea that living organisms can form from nonliving things.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 3

| STUDENT SHEET 3.1A | TIMELINE DATES: WATER ON MARS (SET 1) | NAME |
|---|---|---|

| | | |
|---|---|---|
| CARD H | 1608 | Dutch eyeglass maker Hans Lipperhey built the first telescope. |
| CARD K | 1666 | Italian mathematician Giovanni Domenico Cassini observed pale spots on the poles of Mars through his telescope. He inferred that Mars has polar ice caps made of frozen water. |
| CARD B | 1860 | Scientists Gustav Kirchhoff and Robert Bunsen invented the spectroscope, an instrument for observing light spectra. It can be used to determine the composition of an object. |
| CARD I | 1867 | Astronomers William Huggins and Pierre Janssen pointed a spectroscope at Mars and observed absorption lines (light spectra) consistent with water on Mars. They inferred that there was water on Mars. |
| CARD J | 1877 | Italian astronomer Giovanni Schiaparelli used a 22-centimeter telescope to create the first detailed map of Mars, including linear features he called *canali*, which is Italian for *channels*. Later observers of his maps mistranslated *canali* as *canals*, instead of *channels*. |
| CARD F | 1892 | French astronomer Camille Flammarion researched the Martian canals and argued that they were constructed to transport water over the entire planet. He suggested the presence of the canals indicated a form of life on Mars that might be more advanced than humans. |
| CARD C | 1895 | American amateur astronomer Percival Lowell studied Mars for 15 years, making intricate drawings of the planet's surface. He concluded that there were multiple nonnatural features on the surface, including artificial canals. |
| CARD L | 1903 | English astronomers Joseph Edward Evans and Edward Maunder conducted visual experiments with telescopes. They demonstrated that with a poor-quality telescope, certain features, such as craters, appear to connect to form lines. They argued that the observations of Martian canals were due to an optical illusion. |
| CARD A | 1957 | The former Soviet Union successfully launched the first spacecraft, *Sputnik 1*, in orbit around Earth. |
| CARD D | 1965 | The U.S. National Aeronautics and Space Administration (NASA) spacecraft *Mariner 4* took pictures as it passed by Mars, showing ice caps but no canals. Scientists became more confident that Mars had polar ice caps but no canals. |
| CARD E | 1997 | NASA landed *Sojourner*, the first robotic rover, on the surface of Mars. It gathered and sent back data on the planet's surface. |
| CARD M | 2012 | *Curiosity*, a fourth U.S. rover, landed on Mars. It used a laser spectrometer to gather data on the chemical and mineral composition of the surface and found gravel deposits like those found in streambeds on Earth. NASA scientists concluded that there had been an ancient streambed with a vigorous flow of water on Mars. |
| CARD G | 2021 | New scientific models by planetary scientists indicate that between 30%–99% of water on Mars is incorporated as ice into minerals in the planet's crust, while the remaining fraction of water evaporates into space. |

## TIMELINE DATES: IMAGING (SET 2)

NAME

| | | |
|---|---|---|
| CARD M | 4th c. | Greek philosopher Aristotle described spontaneous generation as the idea that living organisms can form from nonliving things. |
| CARD G | 1595 | Dutch opticians Hans Janssen and his son Zacharias are credited with inventing the first compound microscope—a microscope that uses more than one lens. This microscope could magnify objects 20–30 times its original size. This was not enough magnification to observe the tiny microbes that can cause disease. |
| CARD I | 1665 | English scientist Robert Hooke improved the design of the existing compound microscope by adding a light and using three lenses. This illuminated and enlarged the specimens. He observed many things, including cork (which has a regular shape he called cells). |
| CARD L | 1673 | Dutch scientist Antonie van Leeuwenhoek invented a microscope that could enlarge an image 400 times. He made the first observations of protozoa and bacteria, helping to disprove the idea of spontaneous generation. |
| CARD F | 1678 | Dutch scientist Antonie van Leeuwenhoek wrote to the Royal Society of London reporting his discovery of little animals (bacteria and protozoa). English scientist Robert Hooke was asked by the Society to confirm Leeuwenhoek's findings. He did so, leading to wide acceptance of Leeuwenhoek's discoveries. |
| CARD C | 1840 | Italian physicist Giovanni Amici invented the oil-immersion microscope, which could magnify objects 6,000 times. |
| CARD K | 1877 | German scientist Robert Koch used an oil-immersion lens and a condenser to see bacteria cells. He was able to prove that infectious diseases such as tuberculosis, typhoid, and anthrax are each caused by specific microbes. |
| CARD A | 1907 | American physician Dr. Ernest Edward Tyzzer used a light microscope to observe and describe *Cryptosporidium* in the intestinal tissue of mice. |
| CARD D | 1976 | After its original identification in animals, the first human cases of *Cryptosporidium* were not reported until almost 70 years later. |
| CARD E | 1986 | Electron microscopy was used to determine that *Cryptosporidium* parasites live inside the cells of host organisms, such as humans. |
| CARD H | 2004 | Genome sequencing (a way of determining an organism's DNA sequence) was used to determine that *Cryptosporidium* obtains all its nutrients from its host. |
| CARD J | 2016 | English biologist Brad Amos led a team of researchers in designing the Mesolens, a giant microscope objective lens—about the length and width of a human arm—for use by computers. It is used to produce new images of microscopic parasites. |
| CARD B | 2022 | Molecular biologist Elizabeth English and her team used live-cell imaging (a way of seeing living cells by using time-lapse microscopy) to update knowledge of the life cycle of *Cryptosporidium*. |

STUDENT SHEET 3.2 | TIMELINE ANALYSIS | NAME

| | TIMELINE : |
|---|---|
| **A new scientific tool or experiment that led to a new observation** | |
| **An observation that led to a new idea** | |
| **An explanation was revised based on new evidence** | |
| **An idea that was later rejected or updated** | |

| STUDENT SHEET 3.2 | TIMELINE ANALYSIS | NAME SAMPLE STUDENT RESPONSE |
|---|---|---|

Students are expected to provide only a single response in each row.
This table provides more than one correct sample response.

| | **TIMELINE :** *Mars* |
|---|---|
| **A new scientific tool or experiment that led to a new observation** | • *Lipperhey built the first telescope, which allowed Cassini to observe pale spots on Mars through his telescope*<br>• *invention of the spectroscope led astronomers to observe absorption lines that indicated water on Mars*<br>• *development of first spacecraft eventually led to pictures of Mars showing ice caps but no canals* |
| **An observation that led to a new idea** | • *Cassini's observations of pale spots on the poles of Mars led to the idea that Mars has polar ice caps made of frozen water*<br>• *astronomers' observations of absorption lines of Mars led to the idea that there was water on Mars*<br>• *telescope observations produced detailed map of Mars, which led to the (false) idea that there was a network of canals built by life on Mars*<br>• *rover landed on Mars and found gravel deposits, leading to idea of ancient streambeds on Mars* |
| **An explanation was revised based on new evidence** | • *idea of Martian canals was revised based on astronomers' experiments showing that the canals were an optical illusion*<br>• *idea of water on Mars was revised as more evidence about the planet's surface, including photos and samples, revealed that water is present as ice in minerals in the planet's crust* |
| **An idea that was later rejected or updated** | • *Flammarion's idea that there was a network of water canals built by life on Mars* |

| STUDENT SHEET 3.2 | TIMELINE ANALYSIS | NAME | SAMPLE STUDENT RESPONSE |
|---|---|---|---|

Students are expected to provide only a single response in each row.
This table provides more than one correct sample response.

| | TIMELINE : *Imaging* |
|---|---|
| **A new scientific tool or experiment that led to a new observation** | • *invention and improvement of microscope led to identifying first cork cells*<br>• *microscope that could enlarge 400x led to first observations of protozoa and bacteria*<br>• *microscope led to describing Cryptosporidium in mice*<br>• *electron microscopy led to idea that Cryptosporidium parasites live inside cells of hosts* |
| **An observation that led to a new idea** | • *observation of little animals led to idea of microscopic organisms such as bacteria and protozoa*<br>• *observations of bacteria cells led to idea that infectious diseases are each caused by specific microbes* |
| **An explanation was revised based on new evidence** | • *idea about how Cryptosporidium lives in hosts was revised based on new imaging*<br>• *idea about how Cryptosporidium gets its food was revised based on electron microscopy* |
| **An idea that was later rejected or updated** | • *idea of spontaneous generation*<br>• *updated knowledge of the life cycle of Cryptosporidium* |

ACTIVITY 4

# Testing Local Water

FIELD TRIP

ACTIVITY 4

# Testing Local Water

## ACTIVITY SUMMARY

**Students utilize a smartphone app (such as HydroColor, an app that measures turbidity) to gather water quality data of a local water body, such as a lake. They compare the data collected from their scientific tool to the data collected by their senses. The class discusses how the use of new technologies can enhance the contribution of nonscientists to data collection.**

ACTIVITY TYPE
FIELD TRIP

NUMBER OF
40–50 MINUTE
CLASS PERIODS
2

## KEY CONCEPTS & PROCESS SKILLS

1 New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.

2 Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.

3 Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

CONCEPTUAL TOOLS

SENSES & INSTRUMENTATION

SCIENCE AS A HUMAN ENDEAVOUR

## MATERIALS & ADVANCE PREPARATION

FOR THE CLASS

- ACCESS TO A LOCAL WATER BODY (such as a lake)

FOR THE TEACHER

- VISUAL AID 4.1 "World Health Organization Drinking Sample Water Standards"

FOR EACH GROUP OF FOUR STUDENTS

- 18% GRAY-SCALE CARD
- DISTILLED WATER SAMPLE (in clear container)

FOR EACH PAIR OF STUDENTS

- pH PAPER WITH pH SCALE
- SMARTPHONE WITH HYDROCOLOR (or similar) APP

FOR EACH STUDENT

- PLASTIC SANDWICH BAG (OPTIONAL)

**As first stated in Advance Preparation, Planning Ahead for Activity 1, this activity is a field trip that involves visiting a local water body, such as a lake. In order to use the app, it is necessary to have a site that:**

- is optically deep (has a water depth where the light reflection from the bottom does not influence the light leaving the surface).
- has a pier or other outcropping to access water at depth.
- has connectivity. If there is no signal or service, the app will not work at the site.

Prepare for this activity by identifying a local site; providing students with permission slips; having students download the app; arranging transportation for the class; and organizing a teacher substitute, if necessary. Practice using the app prior to conducting the activity with the class. You may wish to have students place phones in sealed sandwich bags and only remove them as needed to avoid any accidents.

Depending on the availability of materials, you may also wish to have students take additional water quality measurements, such as dissolved oxygen or nitrogen. If you have access to turbidity meters or turbidity tubes, you may wish to take measurements using them to compare to the measurements taken on the HydroColor app. You may also choose to bring back water samples for students to examine under a microscope to look for the presence of both beneficial and harmful living organisms as water quality indicators. Modify the activity as needed to address your local environment and access to materials.

**If you are not able to arrange for a field trip or have other challenges completing the activity as written, you may wish to arrange an alternative. Options include:**

- Gather local water samples to bring to class and provide location photos and turbidity data that you have collected, using the app.
- Gather local water samples to bring to class and use an alternative test for turbidity in the classroom, such as a single turbidity test kit for the class to share. A turbidity test kit, while expensive, contains a bottle of standard turbidity reagent, two 50 mL graduated cylinders, distilled water, and a stirring rod that can be used for testing multiple samples.
- Gather local water samples to bring to class, test the samples for turbidity with the HydroColor app, and evaluate the validity of the resulting data (since the app is designed for use directly with bodies of water).
- Find turbidity and pH data for local reservoirs or water bodies through your local municipal water district and share the data with the class.
- Borrow a set of turbidity meters (or Secchi disks, which also require a pier or other method for taking measurements at depth) from a local college or university to test turbidity at a local lake or pond.
- Complete the activity without testing for turbidity and use tap water (from a different source than the one used in Activity 2) in lieu of water sampling of a local water body.

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Prepare the class for the field trip by reviewing safety rules and making sure that students have access to a smartphone app and other required materials.**

- Depending on the site of your school and your student body, you may have constraints with completing the activity as written. Make modifications as needed (see Advance Preparation), gather available materials, and prepare students to complete the activity safely.
- Review in advance the water quality observations and tests that students are expected to conduct and how they are expected to complete them.

## PROCEDURE (30-90 MIN)

2 **Students observe their surroundings.**

Remind students that science is grounded in observation, and an essential practice of naturalists is simply to observe their natural surroundings. Have them take a few minutes in silence, looking, listening, and smelling the area around the body of water to observe as much as they can. Have students share their observations with a partner.

3 **Students make an initial water quality assessment.**

Here, the comparison is of water in a local water body outdoors to distilled water, which is known to have no contaminants or turbidity.

## 4 Students test a local water body for turbidity and pH.

- Table 4.1 in the Student Book contains a turbidity value of <0.1 NTUs for distilled water, though measurements using classroom equipment may not be so precise, and the app is designed for use with deep water bodies (and not water samples). If you are using another method of determining turbidity, you may wish to take your own measurement of the turbidity of distilled water.
- Students should measure pH, using the method of pH paper as instructed in Activity 2.
- Procedure Step 6 describes how to use the HydroColor app to take a turbidity measurement at a local water body. Assist students as necessary in using an app.

## 5 Students compare their pH and turbidity measurements and make a final water quality assessment.

After completing their measurements, students should compare their data to the information found in the Scientific Review for Activity 2 and the information in Table 4.2 of the Student Book. Students should utilize these comparisons to make a final water quality assessment and explain their reasoning. A sample student response is shown here.

### TABLE 4.1: TESTING LOCAL WATER SAMPLE STUDENT RESPONSE

| WATER SAMPLE | OBSERVATIONS OF ODOR AND APPEARANCE | INITIAL WATER QUALITY ASSESSMENT AND REASONING | pH | TURBIDITY | FINAL WATER QUALITY ASSESSMENT AND REASONING |
|---|---|---|---|---|---|
| **distilled water (control)** | *no odor; appears clear (no color or suspended solids)* | *very good because it looks and smells fine; not sure if it has other chemicals in it* | *7* | *<0.1 NTUs* | *Very good because both the pH and turbidity data are the same as my observations and fall within ranges for good water quality for drinking water.* |
| **local water body** | *smells slightly musty; slightly cloudy brown* | *okay; probably has bacteria and other stuff we aren't testing* | *8* | *5 NTUs* | *Good; pH and turbidity were better than I thought they would be and fall within ranges for water recreation.* |

## SYNTHESIS OF IDEAS (10 MIN)

6 **The class discusses the use of new technologies to gather evidence.**

- Having completed water quality assessments based on odor, appearance, pH, and turbidity, students may have questions about other water quality indicators and their recommended (or legal) limits for safe drinking water. Use Visual Aid 4.1, "World Health Organization Drinking Sample Water Standards," to review some additional water quality indicators that are measured to determine safe drinking water. Discuss what impact these standards can have globally.

- Highlight the idea that water quality standards vary for different uses as well as for different organisms. The focus of this unit is primarily on drinking water. Standards exist for recreational use of water bodies as well as ecological standards for other living organisms.

- Have students discuss what was easy and what was challenging with using the app to collect turbidity data. Ask, How can technology enable nonscientists to contribute to data collection (that is, crowdsourcing)? The Internet and smartphones make it possible for anyone with an Internet connection to contribute observations to a central database and to look at the whole collection of information. Smartphones often have many tools for detecting and recording different types of data, including sounds, photos, videos, temperatures, geolocations, etc. As a result, there are increasing numbers of scientific projects that are utilizing crowdsourced data to create a bigger snapshot of what is happening in different parts of the world.

- Discuss how new technologies can improve the availability of evidence and enhance the contribution of nonscientists to data collection, resulting in larger data sets and increased scientific evidence. Ask, What are the advantages and disadvantages of crowdsourcing data collection? Crowdsourcing makes it possible to collect a much larger amount of data from a larger geographic area over more time than a team of professional scientists or even volunteers can do on their own. It also means that more people can be part of the process of science, contributing and learning from one another. One disadvantage is that the data may be of lower quality and reliability, since the people collecting it are not all trained in common methodologies. Such datasets might also be vulnerable to people trying to influence the conclusions made from the data (i.e., trolls). It is only possible to gather data from places where people are participating and making observations that they think are worth adding, so scientists have to be careful in interpreting the data; there might be missing data in places without much participation or when observations by untrained people are determined not to be relevant. Build Understanding items 4 and 5 provide an opportunity for students to apply their own thinking to the use of this technology.

- Ask, How can new technologies make new evidence available? New technologies make it possible to observe phenomena not visible to human senses or measured by previously existing technology. Then ask, How can new technologies help validate previously existing evidence? More precise or accurate technology can also help validate results from older technology.

## EXTENSION (10-30 MIN)

7 **Use the Extension as an opportunity for advanced learning.**

Students can conduct additional water quality tests on samples from your local water body. Highlight the use of human senses, as well as scientific tools and technology, in gathering data to evaluate the health of aquatic ecosystems and local water sources such as reservoirs.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

① **What was the difference between the information you were able to discover with your senses alone vs. the information you were able to discover with the pH and turbidity tests?**

*I could make observations about the general appearance of the water and odor. My senses could not provide pH information and could only provide a general observation of turbidity. The tests provide measurable values that I could compare to other groups to determine accuracy and reliability of the data.*

② ***Cryptosporidium* is a microscopic parasite that can cause gastrointestinal illness in humans and animals. At one stage of its life cycle, it can become part of the solids suspended in the water column. Which water quality test—pH or turbidity—would be a more valid test for the presence of this organism in drinking water? Explain.**

*Turbidity is a more valid test because turbidity measures suspended solids, and Cryptosporidium can be part of that material. pH would not provide any information about the parasite (unless, for example, there was information about a pH range in which it could survive).*

③ **Do you have enough evidence to determine if your local water body could meet drinking water quality standards, such as the ones listed in Table 4.3? Why or why not? Address strengths and/or limitations in the evidence in your response.**

*I do not have enough evidence to determine if the water body meets these drinking water standards. I had several pieces of evidence to support the idea that the water quality was good (odor, appearance, pH, turbidity). The quality of evidence from the measurements taken with scientific tools (pH and turbidity) was accurate. It was reliable because most groups had the same results. I don't have enough evidence to determine if the water body meets other drinking water standards, such as tests for lead or other contaminants.*

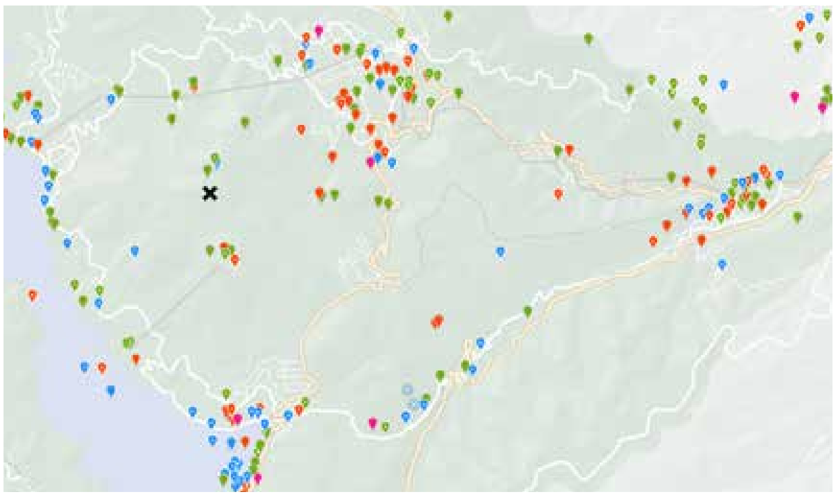
TABLE 4.3
SOME DRINKING WATER QUALITY STANDARDS

| WATER QUALITY TEST | MAXIMUM ALLOWABLE LIMIT |
|---|---|
| *Cryptosporidium* parasite | 0 |
| *E. coli* bacteria | 0 |
| Lead | 0 |
| Nitrates | 10 mg/L |
| pH | 6.5 – 9 |
| Turbidity | < 0.3 NTUs |

## CONNECTIONS TO EVERYDAY LIFE

④ **Technology is being used to collect scientific data in many ways. In the iNaturalist app, users contribute observations of plants and animals, which can then be identified through photos. The app generates maps that show where different species were observed. Biologists can use the app to track biodiversity and animal ranges.**

**The following map is an example of an iNaturalist map from Fuji Hakone Izu National Park in Japan. It is a mountainous area with many hiking trails. Look carefully at the map and notice the pattern of data. Would it be valid to use this data to determine the habitats of local plants and animals? Why or why not?**



INATURALIST MAP

- plants
- vertebrates
- invertebrates
- fungus and lichens

A sample student response is shown here. Look for accurate reasoning that demonstrates an understanding of validity when evaluating student responses.

*It would not be valid to use this data to determine the range of local organisms because the data is collected by people on hiking trails. This means that there are areas on the map where very little data is collected, and information about an organism's habitat would be missing.*

⑤ **Today there are an increasing number of apps that provide opportunities for citizens to contribute data or access information about the natural world. One such app is the U.S. Environmental Protection Agency's Bloomwatch app. It educates users about algal blooms—the rapid growth of algae that results in a layer of greenish scum on the surface of a body of water. Users can upload photos and provide additional information about observed blooms. Do you think information from such apps should be used to make government policy? Why or why not?**

Student responses will vary. A sample response is provided here:

*I think this data should be used to create policy because lots of people gathering information will increase the amount of evidence. The use of apps, especially with photos, means that the evidence can be evaluated by others, including scientific experts. Large amounts of reliable data can provide strong evidence for making decisions about policy.*

## REFERENCES

iNaturalist. Available from https://www.inaturalist.org. Accessed June 2022. Retrieved from https://www.inaturalist.org/observations?nelat=35.25733755&nelng=139.16704295&place_id=any&subview=map&swlat=35.16452535&swlng=138.94757515

The University of Maine, School of Marine Sciences In-situ Sound & Color Lab. Hydrocolor app. Available from Apple App Store, Google Play Store, Facebook Page. Retrieved from http://misclab.umeoce.maine.edu/research/HydroColor.php

| STANDARD | MAXIMUM ALLOWABLE LIMIT |
|---|---|
| Aluminum | 0.2 mg/L |
| Calcium | 75 mg/L |
| *Cryptosporidium* parasite | 0 |
| *E. coli* bacteria | 0 |
| Iron | 0.3 mg/L |
| Lead | 0 |
| Magnesium | 50 mg/L |
| Nitrates | 10 mg/L |
| pH | 6.8 – 8 |
| Total dissolved solids (TDS) | 1000 mg/L |

## VISUAL AID 4.2 | 18% GRAY-SCALE CARD

ACTIVITY 5

# Iteration of Ideas

READING

ACTIVITY 5

# Iteration of Ideas

## ACTIVITY SUMMARY

**Students read several case studies of modern scientists and others working to address global water issues. They examine how each case study illustrates particular unit concepts, including multiple lines of evidence, the validation of data through human senses and scientific technology, iteration, and scientific advancement. The case studies illustrate how scientific knowledge is a result of human endeavor.**

ACTIVITY TYPE
READING

NUMBER OF 40–50 MINUTE CLASS PERIODS
1-2

## KEY CONCEPTS & PROCESS SKILLS

1 New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.

2 Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.

3 The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.

4 Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS

MULTIPLE LINES OF EVIDENCE

SENSES & INSTRUMENTATION

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

## VOCABULARY DEVELOPMENT

**iteration**
`the revision of an idea or process`

## BACKGROUND INFORMATION

### Algae as an Indicator of Water Quality

The composition of algal species and their density in water bodies can be indicators of ecosystem health. For example, an increase in lake pH levels can affect the composition of organisms that are able to tolerate the changing conditions. Aquatic conditions include concentrations of nitrogen (N) and phosphorus (P), nutrients that are natural components of aquatic ecosystems. However, high levels of these nutrients contribute to eutrophication when excessive levels of nutrients cause a dense growth of aquatic plants, low oxygen levels, and the resulting death of aquatic organisms such as fish. The N:P ratio often determines which types of algae are present and/or dominant. Cyanobacteria (blue-green algae) blooms usually occur when the N:P ratio is low, with phosphorus as the limiting factor. When N:P ratios are high, green algae and diatoms are often the dominant genera. Common pollution-tolerant algae genera include *Euglena*, *Nitzschia*, and *Oscillatoria*.

### Environmental Racism in Flint, Michigan

Environmental racism is any policy or practice that differentially disadvantages communities based on race. It can lead to the siting of hazardous industries and other decisions that disproportionately negatively affect communities of color. These disparities are often due to power dynamics.

The Safe Drinking Water Act (SDWA), passed in 1974, requires the U.S. Environmental Protection Agency (EPA) to identify and regulate contaminants present in existing and future water systems to ensure water quality. States are expected to implement this law with EPA oversight. Until April 30, 2014, the city of Flint, Michigan, purchased water from Detroit Water and Sewerage; the water contained orthophosphate, a corrosion-inhibiting chemical used to control lead and copper levels. When Flint switched to the Flint River as an interim cost-saving measure, the orthophosphate treatment was not continued. By May, residents—40% who lived in poverty and 57% who were black—were complaining of smelly brown water coming from their faucets, but the majority of these complaints were ignored. Over the next few months, residents were twice told to boil tap water because of high levels of dangerous bacteria. In January 2015, residents were informed that elevated levels of carcinogenic trihalomethanes were detected but that the water was still safe to drink.

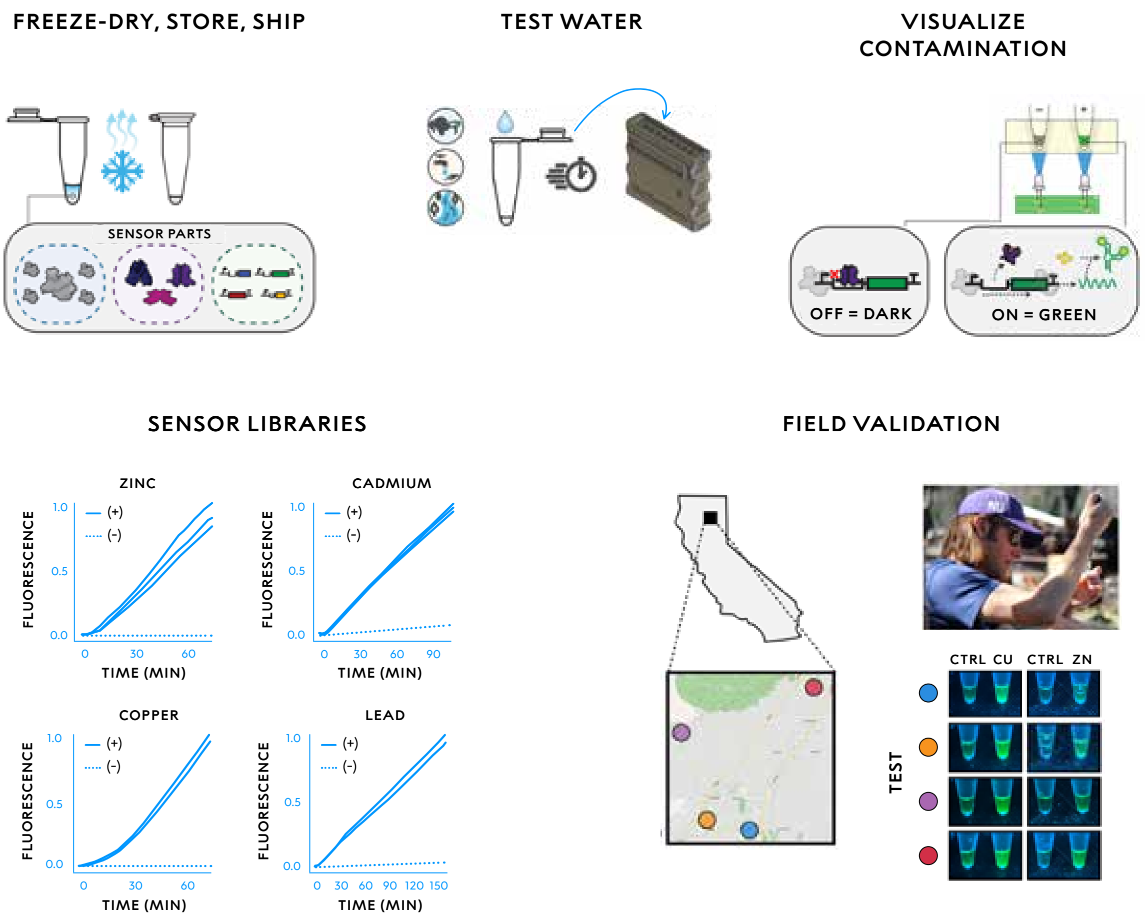
In February 2015, lead was first identified in the drinking water. EPA's Lead and Copper Rule requires that all water systems serving more than 50,000 people have corrosion treatment for lead and copper. At the time, the population of Flint was over 100,000. Officials violated these regulations for a year before the EPA cited them. In August and September 2015, researchers identified multiple homes with lead contamination. However, it was not until October 2015 that the city switched back to purchasing treated water from Detroit Water and Sewerage. In March 2016, the Michigan governor's nonpartisan Flint Water Advisory Task Force report stated that Flint's population "did not enjoy the same degree of protection from environmental hazards as that provided to other communities."

## Julius Lucks' Water quality Test Kits

Dr. Julius Lucks and his graduate students Khalid Alam and Kirsten Jung developed a water quality test using a biosensor, a device that uses a biological component to detect if a chemical is present. Lucks and his team combined bacterial proteins that could detect specific contaminants (the sensor), a viral enzyme (RNA polymerase) that can copy DNA into RNA (transcription), and DNA with a gene for making a green fluorescent RNA molecule. When contaminated water is added, the contaminant chemically binds to the sensor protein, changing the shape of the sensor. This allows the sensor to attach to the DNA and the enzyme to copy the gene into fluorescent green RNA. The system is named ROSALIND (RNA Output Sensors Activated by Ligand Induction). Ligand refers to a molecule (e.g., the contaminant) that can attach to the sensor and cause further chemical processes to occur (induction), such as production of the fluorescent green RNA molecule. Since these reactions can occur outside of a living cell, the required molecules can be added to a small tube and freeze-dried so they can be stored and shipped to any location and used as needed.

**FIGURE 5.01**

Synthetic Biology Solutions for Human Health: Global Water Monitoring



The first row of Figure 5.01 shows the process of preparing the sensor and testing it in the field. The mixture is freeze-dried in a clear microfuge tube that can be stored and shipped long distances until use. At the testing site, a drop of the water sample is added to the microfuge tube and placed inside a sensor box. The box contains LED lights that excite the fluorescent molecules if the contaminant is present. The second row shows what is happening inside the microfuge tube at the molecular level. Each tube has three sets of molecular parts: a "sensor" protein from a bacterium that will chemically bind to the contaminant if it is present, a "reporter" DNA template with a gene (code) for a fluorescent green molecule, and "machines"—enzymes from a virus (bacteriophage)—that read and copy the DNA template into green RNA if activated. If there is no contaminant in the water sample, then none of the parts interact and no fluorescent green RNA is made. If the contaminant (e.g., copper) is in the water sample, it will bind to the sensor. This allows the sensor to attach to the reporter molecule, activate the machines, and produce green fluorescent RNA (a process known as transcription). The lower-left box has four panels showing the time it takes (x-axis) for the fluorescent signal to peak (y-axis). Depending on which sensor proteins are added to the microfuge tube, you can detect different contaminants (e.g., zinc, cadmium), and the time can vary for how long you must wait to determine if the contaminant is in the water (from 1–3 hours). The lower-right box shows an example of field tests from four different areas (colored dots) in Paradise, California. Each smaller image shows the test results from pure water (1st tube: ctrl for control) and a water sample (2nd tube: Cu for copper or Zn for zinc) at one of the locations. Since the control tube does not contain the contaminant, comparing both tubes allows you to see how much of the green is actually due to the presence of the contaminant. A bright green in the sample tube (e.g., Cu) compared to the control tube indicates that the water is contaminated.

## MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 5.1 "Read, Think, and Take Note Guidelines"
- CLASS CONCEPT MAP FROM ACTIVITY 1 (OPTIONAL)

FOR EACH STUDENT

- STUDENT SHEET 5.1 "Anticipation Guide: The Process of Science"
- STUDENT SHEET 5.2 "Case Study Summaries"
- STUDENT SHEET 1.4 "Unit Concepts and Skills" (OPTIONAL)
- 3-5 STICKY NOTES

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10-15 MIN)

1 **Read the introduction in the Student Book, which introduces the concept of iteration.**

- The reading has a short introduction, whose main purpose is to introduce iteration. Iteration is the revision of an idea or process.
- Ask, Where have you used or learned about the use of iteration so far in this unit? Initially, students revised their thinking of the Skipton scenario as they gathered more evidence. In Activity 3, they observed the iteration of ideas when introduced to the concept of scientific advancement. They may have used iteration when making water quality assessments of their local water body.
- Help students identify the ways in which multiple lines of relevant, accurate, and reliable evidence have informed their thinking and resulted in the iteration of their ideas.

2 **Use an Anticipation Guide to elicit students' initial ideas about the reading.**

- Since the reading is complex, more than one literacy strategy is suggested to aid in students' sensemaking and reading comprehension.
- Student Sheet 5.1, "Anticipation Guide: The Process of Science," provides a preview of important concepts in this activity. An Anticipation Guide gives students an opportunity to explore their initial ideas and revisit and modify them at the end of the activity. Be sure students understand that they should complete only the "Before" column for the statements at this time; they will have a chance to revisit these statements after the reading to see whether their ideas have changed.

  While an Anticipation Guide supports sensemaking, it requires additional reading and interpretation and may need to be modified for some student populations, such as ELs. You may wish to complete Student Sheet 5.1 as a class, use it at the end of the activity to summarize key ideas, or use it as a formative assessment of students' learning.

## PROCEDURE (25 MIN)

**3 Review the Read, Think, and Take Note strategy to support students in completing the reading.**

The Read, Think, and Take Note strategy provides an opportunity for students to record their thoughts, reactions, and questions on sticky notes as they read. The notes serve to make concrete the thoughts arising in their minds and then serve as prompts to generate conversation or write explanations. You can use Visual Aid 5.1, "Read, Think, and Take Note Guidelines," to review this literacy strategy. If your students are unfamiliar with the strategy, it can be helpful to demonstrate with a short passage of simple text, such as the introduction to the activity.

**4 Assign individuals or pairs of students to one of the four case studies.**

- The four case studies provide an opportunity to "jigsaw"—students are responsible for reading and summarizing only one of the four case studies. Assign individuals or pairs of students to read one case study. Note that Case Study 3 has the most challenging reading level, while Case Study 2 is easier. Case Study 4 requires summarizing a more complex relationship of ideas.
- Support students, particularly ELs, in sensemaking and language acquisition as they read the text. Circulate around the room and check in, especially with ELs, to support them in using the strategy to decode scientific ideas and construct meaning as they read.
- Many of the essential ideas of the unit are stated in this reading. Point out the section headers to highlight key themes. Students are asked to describe the connections between these themes and the case study on a student sheet and in Build Understanding items.

**5 Highlight essential ideas from the reading.**

- Hand out Student Sheet 5.2, "Case Study Summaries." Have students who read the same case study work together to summarize it for the class by completing the appropriate row of Student Sheet 5.2. A sample student response for Student Sheet 5.2 is provided.
- Have students who read the same case study work together to prepare and present a short summary for the class.
- Students can complete Student Sheet 5.2 by taking notes during other groups' presentations.

## SYNTHESIS OF IDEAS (10-15 MIN)

6 **Have students complete Student Sheet 5.1.**

- Build Understanding item 1 directs students to complete the Anticipation Guide on Student Sheet 5.1. Review student responses as a class to ensure that all students understood important ideas from the reading.

- You may wish to further review or summarize some of the key ideas from the reading as described in Key Concepts and Process Skills or ask students to find relevant passages in the reading.

- While each case study primarily focuses on one key concept from the unit (such as multiple lines of evidence), each case study relates to more than one key unit concept. Build Understanding item 5 provides an opportunity for students to connect their case study to other key unit concepts. As a class, discuss student responses to Build Understanding item 5 to deepen understanding of key concepts.

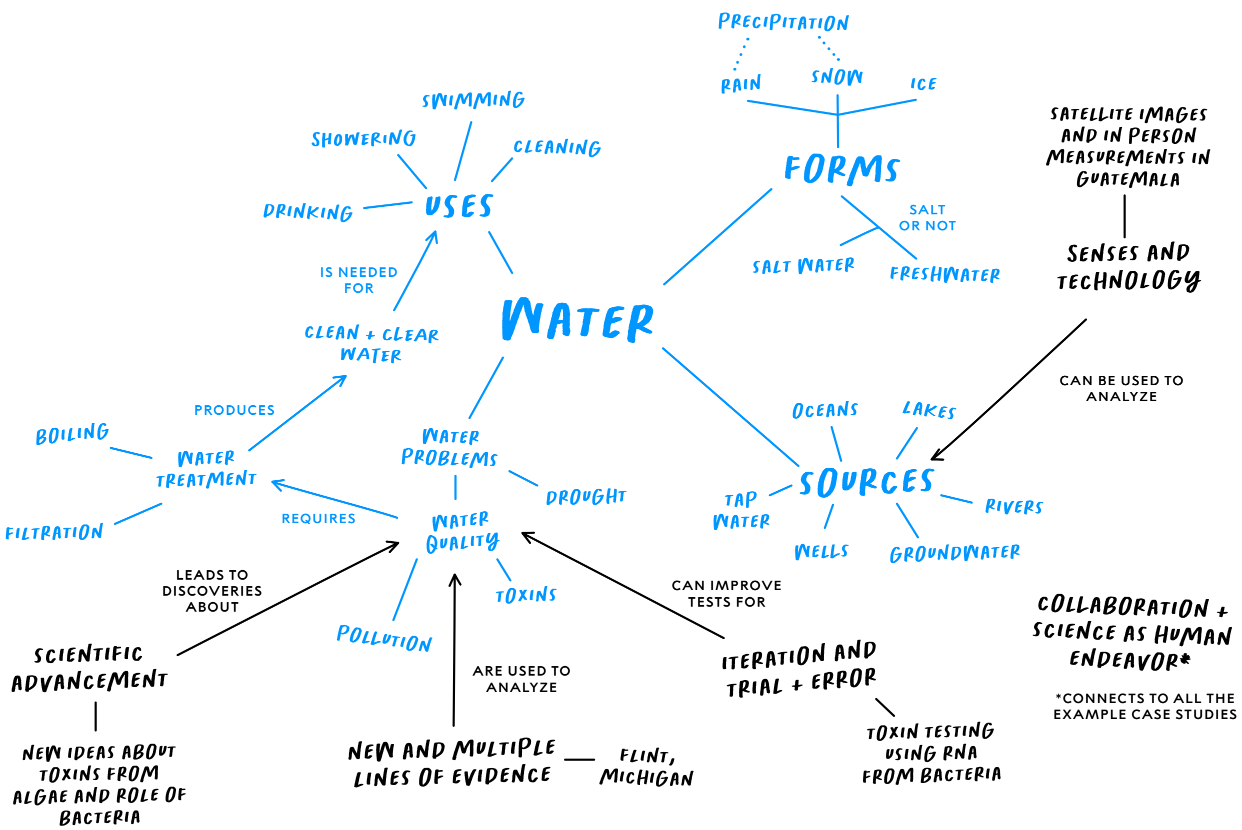
7 **Discuss how the ideas from the case studies relate to science as a human endeavor.**

- Make sure students can identify how the following key concept is highlighted in the reading.

Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

- Ask students to describe the relationship between people and the development of scientific knowledge. Students may begin to recognize that science is the result of the work and contributions of people. In some cases, human bias can limit understanding (such as in the case of Flint, Michigan); in other cases, people can be motivated to address local or global problems through science (as with Flores, Lucks, and shellfish poisoning). Students may also note that many different kinds of people and teams can contribute to the field of science.

- Consider building on the class concept map created in Activity 1. A sample concept map is provided here:




- You may wish to revisit Student Sheet 1.4, "Unit Concepts and Skills," to help students formally organize the ideas introduced in the unit so far. Students can place the headings of the case studies onto the organizer, as well as add the examples from the reading.
- Build Understanding item 3 can be used to either formatively or summatively assess students' understanding of the role of human senses and scientific tools and technology in the advancement of science.
- Build Understanding item 5 provides an opportunity for metacognitive thinking about the nature of science. Point out this opportunity for student reflection.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

① **Complete the Anticipation Guide on Student Sheet 5.1. Be sure to think about information from all four of the case studies, not just the one you read.**

A sample response is provided at the end of this activity.

② **The development of scientific knowledge occurs through continual re-evaluation and iteration of ideas that are informed by:**

- **new evidence**
- **improved methods of data collection and experimentation**
- **collaboration with others**
- **trial and error**

**Which of these were represented in the case study you read? Clearly describe how these elements were represented in your case study.**

Student responses will vary based on the assigned case study. Sample responses for each case study are provided.

- *The case study of Flint, Michigan, was informed by new evidence and collaboration with others. Evidence from residents' observations were supported by university research on the lead in buildings and homes as well as a medical study showing lead levels in children. Officials eventually tested residents after multiple complaints and cases of children having significant medical problems. The community groups worked together to make a case for addressing Flint's water supply.*

- *The case study of Africa Flores was informed by new evidence and improved methods of data collection and experimentation. She was able to gather new evidence from observations of her senses as well as satellite data. As satellite data improved, she could improve her conclusions.*

- *The case study of Lucks and his team was informed by collaboration with others and trial and error. He initially came up with his idea as a result of collaboration with his wife. He then collaborated with his team to create a water quality test. The team used trial and error to gather information on how well the test worked and used this information to revise the test.*

- *The case study of domoic acid poisoning was informed by new evidence and collaboration with others. Scientists did research to gather new evidence on what caused the outbreak and the production of toxic algal blooms. They collaborated by sharing their results in ways that were accessible to other scientists.*

③ **Think about your work over the course of this unit so far. What are the advantages and disadvantages of relying solely on scientific technology for data?**

*Advantages of relying solely on scientific technology for data include: the data can provide more precise measurements (as with pH meters); it can be easier to take multiple measurements to increase reliability; it can be more accurate than human observations; in some cases, it can be used to gather data remotely; and it can be validated by other scientific technology.*

*Disadvantages of relying solely on scientific technology for data include: it may not be accurate without validation, it may not work in all settings due to environmental conditions, it may be expensive or not accessible to a wide population of users, and the technology is only as accurate as its calibration.*

④ **In this activity, you read about the role of science in the accumulation of scientific knowledge about algal blooms. Explain how scientific research about algal blooms built on previous ideas and led to new questions.**

*Initially, it was known that toxic algal blooms can cause people to get sick. Evidence of large toxic blooms, such as the one in the Pacific Ocean in 2015, led to scientists figuring out that it was the cause of shellfish poisoning. Scientists used this information to study the conditions under which the toxin formed; the toxin is formed when there is a bacteria present. Other scientists figured out the enzymes that produce toxins in other algae. Scientists are now looking into whether the frequency of algal blooms is changing and why.*

⑤ **Each case study emphasized one of the key ideas listed here. Reflect on your case study and explain how it modeled another idea from the following list.**

- **multiple lines of evidence**
- **data from human senses and scientific tools and technology**
- **iteration**
- **scientific advancement**

*The Flint case study was focused on multiple lines of evidence. The multiple lines of evidence relied on data from human senses and scientific tools and technology. People observed that the water looked, smelled, and tasted different. This was supported by water quality tests.*

*The Africa Flores case study was focused on data from human senses and scientific tools and technology. She also relied on multiple lines of evidence (satellite data, ground observations) to make her conclusions about Lake Atitlan.*

*The Lucks case study of Lucks and his team focused on iteration. The team continued to revise their water-test kits based on evidence gathered from human senses and scientific technology. They used nanotechnology to develop their kit and then used field data to identify problems and improve the quality of their kits.*

*The domoic acid case study focused on scientific advancement. Scientists used data from scientific tools and technology to gather data about algal blooms. As they gathered new information and collaborated, they had iterations of their thinking about algal toxins.*

## CONNECTIONS TO EVERYDAY LIFE

6. **Think about how you use technology in your everyday life. Describe an instance when you used your senses to validate the information you received from your technology.**

   *One weekend, my alarm clock was supposed to go off at 8:00 a.m. When I woke up, it was still dark outside, so I guessed my alarm clock was wrong. When I checked on my phone, it was 5:00 a.m.*

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STUDENT SHEET 5.1 | ANTICIPATION GUIDE: THE PROCESS OF SCIENCE | NAME

In the "Before" column, mark whether you agree (+) or disagree (–) with each of the following statements. Then complete the reading. In the "After" column, mark whether you agree (+) or disagree (–) with the statements. Under each statement you agree with, explain how the activity gave evidence to support or change your ideas. Under each statement you disagree with, write and explain a corrected statement.

| BEFORE | AFTER | |
|---|---|---|
| | | 1 Scientists collaborate with others to develop scientific ideas. |
| | | 2 Data from human senses can be used to validate data from scientific technology. |
| | | 3 Without the creation of new scientific tools and technology, the development of scientific knowledge would stop. |
| | | 4 Scientific ideas are supported or refuted by multiple lines of evidence. |
| | | 5 Scientists spend a lot of time trying to develop investigations that are so unique that no one has considered them before. |
| | | 6 Science relies only on scientific technology to provide relevant, accurate, and reliable data. |
| | | 7 Iteration refers to the idea that scientific ideas depend on the amount of evidence. |
| | | 8 Individuals and teams from many nations and cultures have contributed to the field of science. |

**STUDENT SHEET 5.1** | **ANTICIPATION GUIDE: THE PROCESS OF SCIENCE** | **NAME** SAMPLE STUDENT RESPONSE

In the "Before" column, mark whether you agree (+) or disagree (–) with each of the following statements. Then complete the reading. In the "After" column, mark whether you agree (+) or disagree (–) with the statements. Under each statement you agree with, explain how the activity gave evidence to support or change your ideas. Under each statement you disagree with, write and explain a corrected statement.

| BEFORE | AFTER | |
|---|---|---|
| | + | 1 Scientists collaborate with others to develop scientific ideas.<br>*Scientists collaborate with others and build on ideas from previous scientific work, like the scientist teams in the reading.* |
| | + | 2 Data from human senses can be used to validate data from scientific technology.<br>*Observations made with other scientific tools and human senses are ways to validate a scientific tool, like Africa Flores did.* |
| | – | 3 Without the creation of new scientific tools and technology, the development of scientific knowledge would stop.<br>*The development of scientific knowledge occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.* |
| | + | 4 Scientific ideas are supported or refuted by multiple lines of evidence.<br>*Multiple lines of evidence contributed to identifying the source of water contamination in Flint, Michigan.* |
| | – | 5 Scientists spend a lot of time trying to develop investigations that are so unique that no one has considered them before.<br>*Scientists build on the research that has gone on before and collaborate with others on new investigations, like the scientist teams in the reading.* |
| | – | 6 Science relies only on scientific technology to provide relevant, accurate, and reliable data.<br>*Human senses, as well as scientists working together, can provide data, as demonstrated by Africa Flores; Marilou Sison-Mangus and her team; Julius Lucks and his team; and the residents of Flint, Michigan.* |
| | – | 7 Iteration refers to the idea that scientific ideas depend on the amount of evidence.<br>*Iteration refers to the idea that science is always open to changing if new evidence requires a revision of earlier ideas, as modeled by Julius Lucks and his team.* |
| | + | 8 Individuals and teams from many nations and cultures have contributed to the field of science.<br>*Africa Flores; Marilou Sison-Mangus and her team; Julius Lucks and his team; the residents of Flint, Michigan, and researchers are all examples of people who have contributed to science.* |

STUDENT SHEET 5.2 | CASE STUDY SUMMARY | NAME

| | WHO AND WHERE | WHAT HAPPENED | KEY CONCEPT AND HOW |
|---|---|---|---|
| CASE STUDY 1 | | | |
| CASE STUDY 2 | | | |
| CASE STUDY 3 | | | |
| CASE STUDY 4 | | | |

| STUDENT SHEET 5.2 | CASE STUDY SUMMARY | NAME *SAMPLE STUDENT RESPONSE* |
|---|---|---|

| | WHO AND WHERE | WHAT HAPPENED | KEY CONCEPT AND HOW |
|---|---|---|---|
| CASE STUDY 1 | *residents of Flint, Michigan, such as LeeAnne Walters; city officials; University of Michigan researchers; Virginia Tech research team; Hurley Medical Center* | *City switched from lake water to Flint River water to save money. Changes in water quality lead to illness and death among residents. After 1.5 years and multiple lines of evidence, city officials accepted that river water was leaching lead from city pipes and was now in the drinking water.* | ***Multiple lines of evidence:***<br>• *residents' observations of water*<br>• *high rates of lead in buildings and homes*<br>• *Walters' son with lead poisoning*<br>• *increase in children with elevated lead in blood* |
| CASE STUDY 2 | *Africa Flores, Guatemala and the United States* | *Flores researched local environment conditions by collecting data in person and from satellites. She was able to make better conclusions and revise her model of algal blooms. Now works for NASA to track environmental change.* | ***Human observations and scientific technology:***<br>• *Flores collected satellite data, which had limits*<br>• *she went to Lake Atitlán to ensure data was correct*<br>• *USGS and NASA now have free satellite data for others to use* |
| CASE STUDY 3 | *Julius Lucks (bioengineer) with his team (Khalid Alam and Kirsten Jung) and Sera Young (anthropologist); Northwestern University, Chicago, Illinois; Kenya* | *Lucks learned about safe drinking water issues in East Africa from wife Young. Used research in microbe fluorescence to create ROSALIND water quality test.* | ***Iteration:***<br>• *initial design of water quality test to identify toxins, using others' research into RNA*<br>• *Paradise, CA, tests had desiccant leak: packaging fixed*<br>• *Kenya tests all positive; transport through UAE exposed them to high temperatures: keep cooler*<br>• *revised to show how much toxin is in water*<br>• *working to address people wanting to use tests* |
| CASE STUDY 4 | *Prince Edward Island, Canada; Marilou Sison-Mangus; scientists from Scripps Institution of Oceanography at University of California, San Diego; University of São Paulo, Brazil; University of California, Santa Cruz; state of Ohio* | *1987 outbreak of shellfish poisoning in Canada caused illness and death. Scientists identified cause of outbreak and conditions for algal bloom, when tiny aquatic plant-like organisms grow in large quantities in a body of water. 2013–2015: Pacific Ocean heatwave caused record-setting algal bloom. More research is providing information about how toxins are produced and what triggers their production.* | ***Scientific advancement:***<br>• *research identified cause of shellfish poisoning as domoic acid produced by marine algae Pseudo-nitzschia*<br>• *additional research identified environmental conditions for algal growth*<br>• *Sison-Mangus research identified role of bacteria in production of toxin by Pseudo-nitzschia*<br>• *university researchers identified enzyme causing production of another freshwater algal toxin: guanitoxin* |

# Read, Think, and Take Note Guidelines

**Stop at least three times during each section of the reading to mark on a sticky note your thoughts or questions about the reading.**

**As you read, use a sticky note from time to time to:**

- explain a thought or reaction to something you read.
- note something in the reading that is confusing or unfamiliar.
- list a word from the reading that you do not know.
- describe a connection to something you've learned or read previously.
- make a statement about the reading.
- pose a question about the reading.
- draw a diagram or picture of an idea or connection.

After writing a thought or question on a sticky note, place it next to the word, phrase, sentence, diagram, drawing, or paragraph in the reading that prompted your note.

After reading, discuss with your partner the thoughts and questions you had while reading.

ACTIVITY 6

# Claims and Evidence

COMPUTER SIMULATION

## ACTIVITY 6

# Claims and Evidence

## ACTIVITY SUMMARY

**Students use a computer simulation to gather evidence and evaluate claims about the water quality of Skipton's Lake Timtim. They use multiple lines of evidence to support or refute their claims. The class discusses how new evidence can lead to a re-evaluation and revision of ideas. Based on the evidence, students make a recommendation to Skipton's city council about whether to use Lake Timtim as a water source for Skipton.**

ACTIVITY TYPE
COMPUTER SIMULATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
2–3

## KEY CONCEPTS & PROCESS SKILLS

1. Scientific knowledge and explanations are based on evidence and strengthened by multiple lines of relevant, accurate, and reliable evidence.
2. New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.
3. Various observations of a single phenomenon from human senses and scientific tools can be used to verify the accuracy of evidence.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS


## VOCABULARY DEVELOPMENT

**claim**

(assumed prior knowledge)

a statement that asserts something is true

## MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 6.1 "Map of Skipton Area"
- VISUAL AID 6.2 "Invention Timeline"
- VISUAL AID 6.3 "Interpreting Graphs" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 6 Build Understanding item 1

FOR THE CLASS

- COMPUTERS WITH INTERNET ACCESS
- ADDITIONAL MATERIALS (poster paper, markers, etc.) FOR CLASS PRESENTATIONS (OPTIONAL)

FOR EACH STUDENT

- STUDENT SHEET 6.1 "Assessing My Evidence"
- STUDENT SHEET 6.2 "Writing Frame: Claims, Evidence, and Reasoning"
- STUDENT SHEET 6.3 "Sharing Claims and Evidence"
- STUDENT SHEET 6.4 "Writing Frame: Evidence and Trade-Offs Letter" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)

Arrange for classroom computer use and familiarize yourself with the simulation found at https://sepup.lawrencehallofscience.org/lake-timtim-evidence-simulation/.

If you do not have computer accessibility, you can create a printed version of this activity by printing the Evidence cards from the simulation found at the end of this Teacher Edition activity. Refer students to the screenshots of the simulation found in the Student Book. Read through the student and teacher instructions to further determine how to modify the activity for use offline with your students.

At the end of this activity, student groups present their claims and evidence. Decide how you would like your students to present their ideas to the class. You may ask students to make a poster, a digital slide presentation, or an oral presentation. There are also opportunities for extended writing identified in teaching notes. Decide if you would like students to do the writing activities, whether you would like them to use the writing frames provided, and how you will scaffold the writing process for students.

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Review the evidence about Skipton's water quality in the previous activities.**

- Remind students that in Activity 1, they made a decision about using water from the Mizu River vs. Lake Timtim. In this activity, they will further investigate Lake Timtim.
- Ask, "What evidence do you have so far about Skipton's water quality?" Students may recall the turbidity data based on the observations of some residents, which did not align with the treatment plant data and which found that the water met quality standards for turbidity. Students may point out that there was limited data about different water quality indicators as well as the test results of these indicators.

2 **Review the idea of a claim.**

- Use the introduction to review the idea of a claim, which was first introduced in Activity 1. In general, a **claim** is a statement that asserts something is true. In science, scientists make claims based on experimental results or other evidence.
- Discuss the relationship between a claim and evidence. You may wish to clarify the following points:
  - When data is used to support or refute a claim, it is called evidence.
  - When evaluating a claim, scientists consider how evidence is related to a claim and whether the evidence supports or refutes the claim.
  - When evidence is consistent with the claim or makes the claim stronger, the evidence is said to support the claim.
  - When evidence is contrary to or makes the claim weaker, the evidence is said to refute the claim.

## PROCEDURE SUPPORT (90 MIN)

3 **Present the scenario of Skipton's city council from Procedure Part A, Step 1.**

- In this scenario, Skipton's city council is gathering more evidence with which to make a decision about the city's water source. The scenario can be shared with the class in multiple ways: You can read it aloud to the class (using a storytelling approach), have individual students read the paragraph aloud to the class while others follow along with the text, or have students read it individually or cooperatively in their groups of four.

- Depending on your student population, use oral storytelling to support diverse learners in decoding scientific ideas and constructing meaning and ask questions about the main points of the scenario to ensure comprehension. Students can refer to the text in the Student Book as needed.

- Review the four claims that students will evaluate. You might find it helpful to review the geography of the Skipton area by projecting Visual Aid 6.1, "Map of the Skipton Area."

4 **Assign students a claim and background information to read and review.**

- Be aware when assigning groups that Claims 3 and 4 have evidence that is easier to interpret and understand, while Claims 1 and 2 have evidence that requires evaluating long-term trends and making more inferences.

- Support students, particularly English learners (ELs), in sensemaking and language acquisition as they read their claims and background information. Circulate around the room and check in, especially with ELs, to support them in using the strategy to decode scientific ideas and construct meaning as they read.

- Some of the evidence in the simulation is presented as graphs. If you have students who struggle with interpreting graphs, use Visual Aid 6.3, "Interpreting Graphs," to review these skills.

5 **Students explore the computer simulation.**

- Inform students that they will use a computer simulation to gather more evidence related to these claims. Go to the simulation of Lake TimTim at https://sepup.lawrencehallofscience.org/lake-timtim-evidence-simulation/

- First, give students time to explore the simulation freely. After they've had a few minutes to familiarize themselves with the simulation, ask them to share what they observe, such as the types of features the simulation has and the types of information that it provides.

- Help orient students to the simulation by pointing out that the evidence at Location 7 is from Wazi Lake, a lake 200 miles away from Lake Timtim. The rest of the data is from various locations around Lake Timtim.

- Have students save a piece of evidence and enter Evidence mode. Point out that they will use this mode to sort the evidence related to their claim. Remind them that when they first look at data or observations at each location, they should first decide whether that information can be used as evidence related to their claim. Switch back to Map mode and show them the clear saved Evidence button to reset the evidence.

  TEACHER'S NOTE: The simulation has a few intentional features to be aware of. First, evidence for each claim is addressed at only two locations on the interactive map. Students are not aware of this as they begin to examine the evidence because their first goal is to practice identifying evidence that is relevant to their assigned claim. Second, when saving evidence, the simulation has a preset limit of eight Evidence cards that can be saved from the Map mode. This function is meant to help remind students that they should be saving only evidence that is relevant to their claim. Students will get an alert if they try to save more than eight Evidence cards. If they want to change their saved evidence, they will need to reexamine their saved evidence and unsave prior evidence before they can save more.

6 **Students gather evidence about their claim in the Map mode of the simulation.**

- If needed, demonstrate how to find and save relevant evidence in the simulation.
- After seeing the first piece of evidence at a particular location, students can select Gather More Evidence for more evidence related to the first evidence card at that location.
- Students can look at the locations in any order, and they should continue exploring, saving Evidence cards, and gathering more evidence until they have gone through all eight locations. The simulation tracks which locations they have looked at and where they have saved evidence by using colored circles under each location number. (White: unviewed data; gray: viewed data; green: saved evidence).
- Remind students that their focus as they look through the map locations is to find evidence that is relevant to their claim. You might use the following questions to model for students how to determine if the evidence is relevant to their claim:
  - Is the evidence telling me information that is on the same topic as my claim?
  - Does this evidence tell me anything new about my claim?
  - Does this evidence make me think of any questions related to my claim?
- Circulate and assist students as needed. Remind them that they should be working in Map mode and looking for and saving evidence that is relevant to their claim.

7 **Students evaluate the evidence in the Evidence mode of the simulation.**

- When students have finished working in Map mode, hand out Student Sheet 6.1, "Assessing My Evidence." Students should use it to record if their saved evidence is relevant and whether it supports or refutes their claim, as well as any explanations they may have about their sorting. As students complete Student Sheet 6.1, they can begin to determine whether the evidence they have supports or refutes their assigned claim. At the bottom of Student Sheet 6.1, they are asked to determine if the evidence as a whole supports or refutes their claim.
- If needed, review how students can use Evidence mode of the simulation, which shows all the evidence that students saved from the map. Students will now think more deeply about how each piece of evidence is related to the claim they are investigating.
- Remind students that they will have to make inferences about the observations or data in the Evidence cards—they will need to form ideas about what each piece of data means and how it applies to the claim.
- If you would like students to screenshot the final sort of their evidence, give them instructions (e.g., using computer commands, using a phone) and let them know how to provide the image to you.

8 **Have pairs who have investigated the same claim share their findings.**

- Assign students to work with another pair who investigated the same claim. Students should compare their evidence and conclusions about their claim. If students need more support, you might suggest that they discuss the following questions with their group:
  - Did the other pair find the same evidence as you?
  - Did the other pair have similar or different ideas about how the evidence related to the claim?
  - Did the other pair have any evidence or ideas that made you change your thinking about the claim and evidence?
- Distribute Student Sheet 6.2, "Writing Frame: Claims, Evidence, and Reasoning," which can help students summarize their claim and evidence related to their claim.

9 **Students present their claim and relevant evidence to the class.**

- Students should share with the class their claim, the relevant evidence, and whether the claim was supported or refuted. Instruct students on how you would like them to present their information to the class. Possible formats include:
  - a short oral presentation
  - 1–2 slides in a digital presentation

  If appropriate, review expectations for presentations.

- Hand out Student Sheet 6.3, “Sharing Claims and Evidence,” before students begin their presentations. Students should record notes on the other claims and evidence. Inform students that they will make a recommendation to Skipton’s city council regarding whether Lake Timtim should be used as a water source based on multiple lines of evidence, which the other claims will provide.

- Foreshadow Build Understanding item 5, which asks students to consider how much evidence might be considered enough to make a *decision*. Note that while the question asks about the application of evidence, it relates to a decision, while in the activity, students are evaluating a claim. Since a *claim*, even one based on evidence, still comes with some uncertainty, making a decision based on that claim often requires trade-offs of cost and/or risk. Ask student groups to address the quality and quantity of evidence related to their claim by asking questions such as:

  How confident are you about whether your claim was supported or refuted based on the evidence that you found? What would make you feel more sure? Responses will vary depending on the claim and how students interpreted different evidence. Claim 1 (The algae in Lake Timtim is harmless.) has evidence that refutes it. Students may feel very confident that the algae in the lake is harmful due to the graphs and water-sample readings that identified the presence of potentially harmful algae species and algal toxins. Since it is not clear whether there is enough harmful algae in the lake to be a threat to humans, additional data about whether there was algal toxin found in the tissue of the dead organisms would increase students’ confidence levels.

  Did you have evidence from multiple sources to support or refute your claim? Did this make you feel more confident or less confident about your claim? Students should have found at least 4–6 different types of evidence to support or refute each claim. Having multiple lines of evidence is likely to increase confidence levels. For example, students investigating Claim 3 might state that the combination of Secchi disk measurements and turbidity meter readings from around the lake comparing past data to current data made them very confident that their claim was supported.

**10 Student groups discuss their recommendation to Skipton’s city council.**

- In Procedure Step 11, student groups revisit their recommendation(s) from Procedure Step 7, which was based solely on evidence related to their individual claim (and prior evidence from the unit). They now have evidence for all four of the claims and can re-evaluate their decisions based on these multiple lines of evidence.

## SYNTHESIS OF IDEAS (10-15 MIN)

**11 Discuss the role of human senses and scientific technology in evidence.**

- Use Visual Aid 6.2, "Invention Timeline," to share how the scientific tools and technology described in this activity have developed over time.
- Highlight how evidence was provided by both human senses and scientific technology by asking:

What can human senses provide that scientific tools and techniques cannot? What can scientific tools and techniques provide that human senses cannot? Some possible responses are that human senses can help people notice things and direct attention to a problem. However, there is only so much information that senses can provide. Human senses cannot make precise measurements or see things that are very small or very big. That is why scientific tools, techniques, and technology are helpful.

How do evidence from human senses and scientific tools and technology build on one another? Is it important to have both sense observations and data from scientific tools and techniques? Why? Students might mention that human senses can often provide the first step in motivating more investigation—people notice something is wrong, such as cloudy water or dead organisms, and then want to learn more. Sometimes the results of data from technology need to be validated by human senses. A satellite image might seem to indicate one thing, but people may need to visit the place to make direct observations to confirm it.

You encountered the idea of validation of data in an earlier activity. What are some examples from the simulation where evidence from human senses or a scientific tool/technique was validated by another data source? Prompt students to think back to the claim they investigated in the simulation and then share their ideas. In Claim 1, human senses were able to observe algae in the water, which were validated by the microscope images of algae in the water. In Claim 2, decreasing water levels in the satellite images over time were validated by the observation of "bathtub rings." In Claim 3, the results of the Secchi disk measurements and turbidity meter data validated each other. In Claim 4, laboratory tests of water samples and soil samples provided similar data, validating the results.

**12 Discuss how new evidence about Lake Timtim affected decisions about the source of water.**

- Have students share their recommendations to Skipton's city council about the city's source of water. You may want students to:
  - answer the question as a warm-up at the start of the next class period.
  - do a quick-write in their science notebooks.
  - do a show of hands to see who would use Lake Timtim and who would not.
  - do a kinesthetic activity by having students who would use Lake Timtim move to one side of the room and those who would not use Lake Timtim move to the opposite side of the room.

- Discuss student recommendations as a class by asking questions such as:

  What evidence from other groups made you rethink your recommendation about Lake Timtim? Student responses will vary. They might indicate that hearing evidence from groups investigating other claims changed how they thought about the safety or availability of Lake Timtim's water. Hearing evidence from other groups may or may not have changed their recommendation.

  Do you think it is important to revise your thinking about a phenomenon when you get new evidence about it? Explain your reasoning. Students may agree that it is important to consider new evidence. It can make an explanation stronger or weaker or raise new questions to investigate.

  Why do you think it is important for decision-makers to think about a problem in different ways and with lots of different evidence before they make a decision? Decision-makers should consider as much evidence as possible because their decision affects others.

- For students who are visual learners, you can construct a table for them to list the various pieces of evidence they have seen thus far in the unit.

- While reviewing questions about claims and evidence, discuss the implications of having a claim refuted. Ask, Do you think it is a bad thing when a claim is refuted by evidence? Why or why not? Have students share ideas. When new evidence refutes a claim, it requires revisiting conclusions and explanations. New evidence that refutes an idea may require reconsidering problems in a new way. It may lead to a different question to investigate or the exploration of a new claim that could explain the evidence.

- Build Understanding item 1 can be assessed using Scoring Guide: Evidence and Trade-Offs (E&T). You may wish to provide students with Student Sheet 6.4, "Writing Frame: Evidence and Trade-Offs Letter."

- Use Build Understanding item 4 to revisit the application of multiple lines of evidence as a tool that can be used in everyday life. Ask students to share their everyday examples and how they utilize evidence to make those decisions. Discuss the amount and types of evidence that affect their decision-making, as well as other factors that may influence their choices.

## EXTENSION (10 MIN)

13 **Use the Extension as an opportunity for advanced learning.**

Students select a water quality indicator and describe what information it can provide about water quality, why it's important, and its limitations. For example:

*pH is an indicator of whether the water is acidic or basic. This type of information is important because many organisms can only survive within a certain pH range. The limitation of pH is that it is only one piece of evidence. Determining water quality requires information from lots of different water quality tests.*

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

① **E&T Scoring Guide**

**What is your recommendation to the Skipton City Council about the use of Lake Timtim as a drinking water source? Write a letter supporting your answer with multiple lines of evidence and identifying the trade-offs of your decision.**

A sample student response can be found here and on Student Sheet 6.4, Sample Student Response.

### Level 4 response

*Dear Skipton City Council,*

*My recommendation is that Lake Timtim not be used as a water source for Skipton. Tests of the water show that there is a small amount of toxic algae present. While it is not high enough to be a threat to humans, it could in the future. Second, data shows that Lake Timtim's water levels have been decreasing since 2000. Lake Timtim appears to follow the same water-level patterns as Wazi Lake, where water levels have also been declining. Third, Skipton and Lake Timtim are in an area that occasionally experiences drought, and it is likely that the lake would not be able to meet Skipton's water needs in these years. The trade-offs of not using this water source are that we will need to find a different water source to meet Skipton's needs and do tests on that water to see if it is safe enough and has enough supply for Skipton.*

*Sincerely,*
*Stu Dent*

### Level 3 response

*Dear Skipton City Council,*

*I recommend Lake Timtim not be used as a drinking water source for Skipton. There is toxic algae present in the water. Water levels of the lake are decreasing. Lake Timtim is also in an area where there might be a drought. The trade-off is that we will need to find a different solution.*

*Sincerely,*
*Stu Denta*

**Level 2 response**

*Dear Skipton City Council,*

*I recommend that Skipton not use Lake Timtim as a source for drinking water. There might not be enough water because Lake Timtim's water levels are becoming lower. The trade-off is we still need water.*

*Sincerely,*
*Stu Dentbee*

**Level 1 response**

*Dear Skipton City Council,*

*Skipton should not use Lake Timtim for drinking water because there might be bad water quality.*

*Sincerely,*
*Stu Dentsy*

② **In the simulation, each location provided different evidence, such as observations from human senses, results of lab tests, or data from scientific technology.**

a **Select one site and describe all the evidence found at that location.**

*At Location 6, there was a visual observation of ducks swimming in algae-filled water, followed by a visual observation of a dead fish on shore, and then a microscope image of algae in a water sample that turned out to be a toxic algae species.*

b **How could you improve the reliability of this data?**

*I could improve the reliability by gathering data from many locations around the lake. If there are other places where ducks are swimming in algae and appear healthy, then that would make the conclusion that algae is probably not harmful and that the data are more reliable. I could examine the dead fish to determine how it died or visit other shoreline areas to see if there are other dead fish. For the microscope analysis, I could collect multiple water samples from the same area and from around different parts of the lake to see if there is harmful algae present. All these steps would increase the reliability of the data.*

## CONNECTIONS TO EVERYDAY LIFE

③ **Your teacher just told the class that soccer is the most popular sport in the world. What evidence could you collect (without using an Internet search) to evaluate this claim? Explain how this evidence would support or refute this claim.**

*I could ask a bunch of people who are from different parts of the world what their favorite sport is. That would give me data that I can use as evidence to support or refute the claim. If most people say that soccer is their favorite sport, the claim would be supported.*

④ **In your everyday life, how do you decide if you have enough evidence to support a decision? Explain your thinking by describing an everyday example, such as when you go to sleep or how you spend money.**

*I don't think there is a set amount of evidence that is enough because there can always be more or new evidence. It's important to have some evidence, but sometimes one piece of evidence is more important than the rest. For example, I decide a lot of nights to stay up late. If I went to bed earlier, I would be less tired in the morning, I wouldn't be tardy, and I wouldn't fall asleep in class. One piece of evidence supporting my decision is homework: I have a lot of it. That is more important than any other evidence that says I should go to sleep early.*

### REFERENCES

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Environmental Protection Agency (EPA) Office of Water. (2002, December). EPA fact sheet: Notice of ambient water quality criteria: Document for tributyltin (TBT). EPA-822-F-02-003. Retrieved from https://www.epa.gov/sites/default/files/2019-02/documents/ambient-wqc-tributyltin-draft-factsheet.pdf

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Minnesota Pollution Control Agency. (2002, March 12). Plumbing the depths. NASA Earth Observatory. Retrieved from https://earthobservatory.nasa.gov/features/WaterQuality/water_quality2.php

STUDENT SHEET 6.1 | ASSESSING MY EVIDENCE | NAME

## Which claim are you investigating?

- ○ **CLAIM 1:** The algae in Lake Timtim is harmless.
- ○ **CLAIM 2:** Lake Timtim will likely have water for another 100 years.
- ○ **CLAIM 3:** The amount of suspended solids in Lake Timtim is decreasing.
- ○ **CLAIM 4:** Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.

| EVIDENCE CARD NUMBER AND BRIEF DESCRIPTION | IS THIS EVIDENCE RELEVANT TO YOUR CLAIM? | | DOES THIS EVIDENCE SUPPORT YOUR CLAIM, REFUTE YOUR CLAIM, OR NEITHER? | | | EXPLAIN YOUR EVIDENCE (questions or thoughts you have, connections to other evidence, connections to the claim) |
|---|---|---|---|---|---|---|
| | YES | NO | SUPPORT | REFUTE | NEITHER | |
| | | | | | | |
| | | | | | | |
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**Based on the evidence, my claim is** ○ SUPPORTED ○ REFUTED

**STUDENT SHEET 6.1** | **ASSESSING MY EVIDENCE** | **NAME** SAMPLE STUDENT RESPONSE CLAIM 1

### Which claim are you investigating?

● **CLAIM 1:** The algae in Lake Timtim is harmless.
○ **CLAIM 2:** Lake Timtim will likely have water for another 100 years.
○ **CLAIM 3:** The amount of suspended solids in Lake Timtim is decreasing.
○ **CLAIM 4:** Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.

| EVIDENCE CARD NUMBER AND BRIEF DESCRIPTION | IS THIS EVIDENCE RELEVANT TO YOUR CLAIM? | | DOES THIS EVIDENCE SUPPORT YOUR CLAIM, REFUTE YOUR CLAIM, OR NEITHER? | | | EXPLAIN YOUR EVIDENCE (questions or thoughts you have, connections to other evidence, connections to the claim) |
|---|---|---|---|---|---|---|
| | YES | NO | SUPPORT | REFUTE | NEITHER | |
| **1A:** photo of green film on a rock in the lake | *x* | | | *x* | | *The green film on the rock and the smell can indicate that blue-green algae is in the water. Blue-green algae can be harmful. We need more info about what type of algae it is.* |
| **1B:** pie graph of algae populations | *x* | | | *x* | | *Most of the algae in Lake Timtim is not toxic, but there is a small population of potentially toxic algae. Is it enough to be harmful to humans?* |
| **1C:** line graph algae toxin measure measurement | *x* | | | *x* | | *Currently there is Microcystis toxin present in the lake, indicating that there are harmful algae present. In the past, the levels of algal toxin in the lake water have been unsafe to drink.* |
| **3A:** ducks swimming in algae water | *x* | | | | *x* | *The ducks are swimming in the water. They seem okay, but we don't actually know what happens to them.* |
| **3B:** dead fish | *?* | | | *x* | | *Could the algae be the cause of the dead fish? Maybe. I need to know if there's algae toxin in/on the dead fish.* |
| **3C:** microscope analysis of Microcystis algae | *x* | | | *x* | | *Microscope image of the water sample is Microcystis, a toxic algae.* |

**Based on the evidence, my claim is** ○ SUPPORTED ● REFUTED

 SAMPLE STUDENT RESPONSE CLAIM 2

### Which claim are you investigating?

- ○ **CLAIM 1:** The algae in Lake Timtim is harmless.
- ● **CLAIM 2:** Lake Timtim will likely have water for another 100 years.
- ○ **CLAIM 3:** The amount of suspended solids in Lake Timtim is decreasing.
- ○ **CLAIM 4:** Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.

| EVIDENCE CARD NUMBER AND BRIEF DESCRIPTION | IS THIS EVIDENCE RELEVANT TO YOUR CLAIM? | | DOES THIS EVIDENCE SUPPORT YOUR CLAIM, REFUTE YOUR CLAIM, OR NEITHER? | | | EXPLAIN YOUR EVIDENCE (questions or thoughts you have, connections to other evidence, connections to the claim) |
|---|---|---|---|---|---|---|
| | YES | NO | SUPPORT | REFUTE | NEITHER | |
| 7A: Wazi Lake has low water levels | X | | | X | | *This evidence is for Wazi Lake, a nearby lake which also has low water levels. The data is only for one year, so I wonder what the trend is?* |
| 7B: satellite images of Wazi Lake over time | X | | | X | | *Wazi Lake water levels have had big reductions in water level since 2000. Lake Timtim is nearby with similar geography and climate and likely to follow the same pattern.* |
| 7C: line graph of Wazi Lake surface levels | X | | | X | | *Wazi Lake's water surface levels have decreased since 2000. Lake Timtim is nearby and likely to follow the same pattern.* |
| 8A: observation of part of Timtim shoreline that is lower than usual | X | | | X | | *Lake Timtim levels are lower than the previous year.* |
| 8B: line graph of water levels of Timtim | X | | | X | | *Lake Timtim's water levels are trending down over time.* |
| 8C: climate data for Skipton area | X | | | X | | *The climate data indicate that the area sometimes experiences drought, which could make the lake levels go down.* |

**Based on the evidence, my claim is** ○ SUPPORTED ● REFUTED

STUDENT SHEET 6.1 | ASSESSING MY EVIDENCE | NAME SAMPLE STUDENT RESPONSE CLAIM 3

**Which claim are you investigating?**

- ○ **CLAIM 1:** The algae in Lake Timtim is harmless.
- ○ **CLAIM 2:** Lake Timtim will likely have water for another 100 years.
- ● **CLAIM 3:** The amount of suspended solids in Lake Timtim is decreasing.
- ○ **CLAIM 4:** Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.

| EVIDENCE CARD NUMBER AND BRIEF DESCRIPTION | IS THIS EVIDENCE RELEVANT TO YOUR CLAIM? | | DOES THIS EVIDENCE SUPPORT YOUR CLAIM, REFUTE YOUR CLAIM, OR NEITHER? | | | EXPLAIN YOUR EVIDENCE (questions or thoughts you have, connections to other evidence, connections to the claim) |
|---|---|---|---|---|---|---|
| | YES | NO | SUPPORT | REFUTE | NEITHER | |
| 2A: cloudy and clear water samples | X | | X | | | *Lake Timtim's water sample from this year is clearer than last year.* |
| 2B: Secchi disk measurements | X | | X | | | *The current measurement is much deeper, indicating that there is less turbidity than before.* |
| 2C: additional Secchi disk readings | X | | X | | | *The measurements from around the lake confirm that the turbidity has decreased since 1988.* |
| 5A: cloudy water after a storm | X | | | | X | *It is cloudy, but we don't have data from the past to compare.* |
| 5B: satellite images of sediment levels after storm | X | | | | X | *The lake has more sediment right after the storm, and it decreases a couple weeks after the storm. But this is not really related to whether the turbidity is decreasing over the long term.* |
| 5C: graph showing amount of suspended solids | X | | X | | | *The average turbidity meter readings show that turbidity has decreased since 2012, and the current levels are within safety guidelines.* |

**Based on the evidence, my claim is** ● SUPPORTED ○ REFUTED

| STUDENT SHEET 6.1 | ASSESSING MY EVIDENCE | NAME | SAMPLE STUDENT RESPONSE CLAIM 4 |
|---|---|---|---|

**Which claim are you investigating?**

- ○ **CLAIM 1:** The algae in Lake Timtim is harmless.
- ○ **CLAIM 2:** Lake Timtim will likely have water for another 100 years.
- ○ **CLAIM 3:** The amount of suspended solids in Lake Timtim is decreasing.
- ● **CLAIM 4:** Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.

| EVIDENCE CARD NUMBER AND BRIEF DESCRIPTION | IS THIS EVIDENCE RELEVANT TO YOUR CLAIM? | | DOES THIS EVIDENCE SUPPORT YOUR CLAIM, REFUTE YOUR CLAIM, OR NEITHER? | | | EXPLAIN YOUR EVIDENCE (questions or thoughts you have, connections to other evidence, connections to the claim) |
|---|---|---|---|---|---|---|
| | YES | NO | SUPPORT | REFUTE | NEITHER | |
| 4A: dead fish on the shore | ? | | | | X | *TBT can be toxic to animals. Did the fish die because of TBT exposure?* |
| 4B: TBT measurements in the lake bed and soil at shore | X | | X | | | *Both of the levels reported are less than the TBT maximum.* |
| 4C: tissue samples found little TBT | X | | X | | | *The TBT found in the tissues of the dead organisms are less than the TBT maximum. So it seems like the TBT is not the cause of the dead fish.* |
| 6A: the water is clear and odorless at this location | | X | | | X | *You can't tell by looking at the water whether or not there is TBT in it.* |
| 6B: Timtim TBT measurements from 2005–2015 | X | | X | | | *TBT has been decreasing over time and was below safety maximum levels from 2014–2015. But what about current levels?* |
| 6C: current water sample TBT measurements | X | | X | | | *Current TBT measurements are far below the maximum safety values.* |

**Based on the evidence, my claim is** ● SUPPORTED ○ REFUTED

STUDENT SHEET 6.2

## WRITING FRAME: CLAIMS, EVIDENCE, AND REASONING

NAME

THE CLAIM I INVESTIGATED WAS

BASED ON MY INVESTIGATION, I THINK THE CLAIM WAS ○ SUPPORTED ○ REFUTED

THE FIRST LINE OF EVIDENCE THAT ○ SUPPORTS ○ REFUTES MY CLAIM IS

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ○ REFUTES MY CLAIM IS THAT

THE SECOND LINE OF EVIDENCE THAT ○ SUPPORTS ○ REFUTES MY CLAIM IS

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ○ REFUTES MY CLAIM IS THAT

THE THIRD LINE OF EVIDENCE THAT ○ SUPPORTS ○ REFUTES MY CLAIM IS

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ○ REFUTES MY CLAIM IS THAT

STUDENT SHEET 6.2 | WRITING FRAME: CLAIMS, EVIDENCE, AND REASONING | NAME: SAMPLE STUDENT RESPONSE

THE CLAIM I INVESTIGATED WAS

*Claim 2: Lake Timtim will likely have water for another 100 years.*

BASED ON MY INVESTIGATION, I THINK THE CLAIM WAS ○ SUPPORTED ● REFUTED

THE FIRST LINE OF EVIDENCE THAT ○ SUPPORTS ● REFUTES MY CLAIM IS

*The line graph shows that Lake Timtim's water levels have been trending down since 2000.*

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ● REFUTES MY CLAIM IS THAT

*If Lake Timtim's water levels continue following the same trend, the lake will run out of water in a few decades.*

THE SECOND LINE OF EVIDENCE THAT ○ SUPPORTS ● REFUTES MY CLAIM IS

*The climate data shows that sometimes the Skipton/Lake Timtim area experiences low rainfall years and varying degrees of drought.*

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ● REFUTES MY CLAIM IS THAT

*In drought years, it is possible that water levels in Lake Timtim could fall below what is needed to support Skipton, since rainfall is one of the main factors that affect lake water levels.*

THE THIRD LINE OF EVIDENCE THAT ○ SUPPORTS ● REFUTES MY CLAIM IS

*The satellite and water-level data about Wazi Lake showed that water levels there have been decreasing since 2000.*

MY REASONING FOR HOW/WHY THIS EVIDENCE ○ SUPPORTS ● REFUTES MY CLAIM IS THAT

*Wazi Lake is only 200 miles away from Lake Timtim. Because weather patterns and droughts tend to affect large areas in a similar way, Lake Timtim water levels are likely to follow the same patterns as Wazi Lake. This means Timtim water levels will likely continue to decrease over time.*

STUDENT SHEET 6.3 | SHARING CLAIMS AND EVIDENCE | NAME

As you listen to your classmates present about their claims and evidence, record notes in the following table. This information will help you with your recommendation to Skipton's City Council.

| CLAIM | SUPPORTED OR REFUTED | MAIN EVIDENCE PRESENTED | OTHER NOTES |
|---|---|---|---|
| CLAIM 1<br>**The algae in Lake Timtim is harmless.** | | | |
| CLAIM 2<br>**Lake Timtim will likely have water for another 100 years.** | | | |
| CLAIM 3<br>**The amount of suspended solids in Lake Timtim is decreasing.** | | | |
| CLAIM 4<br>**Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.** | | | |

STUDENT SHEET 6.3 | SHARING CLAIMS AND EVIDENCE | NAME *SAMPLE STUDENT RESPONSE*

As you listen to your classmates present about their claims and evidence, record notes in the following table. This information will help you with your recommendation to Skipton's City Council.

| CLAIM | SUPPORTED OR REFUTED | MAIN EVIDENCE PRESENTED | OTHER NOTES |
|---|---|---|---|
| CLAIM 1<br><br>**The algae in Lake Timtim is harmless.** | *Refuted*<br><br>*(by evidence at locations 1 and 3)* | *There is a small population of algae in the lake that could potentially include harmful algae species.*<br><br>*The toxin-producing algae species Microcystis has been identified in at least one location of the lake.*<br><br>*Although the levels of algae toxin are currently within safe levels, there have been unsafe levels of algae toxin in the past.* | *Although toxic algae is present in the lake, the current population is not very high, and the toxin levels are within safety limits.*<br><br>*Timtim might still be a good water source as long as the water is moni-tored closely.* |
| CLAIM 2<br><br>**Lake Timtim will likely have water for another 100 years.** | *Refuted*<br><br>*(by evidence at locations 7 and 8)* | *Lake Timtim's water levels have been trending down since 2000.*<br><br>*The region is prone to drought, even though it is not currently experienc-ing a drought.*<br><br>*Comparing data from nearby Wazi Lake shows that the water levels at that lake have also decreased in the past 20 years. Timtim could follow similar patterns.* | *Lake Timtim could still be a good choice for Skipton's water in the short term because it currently has enough water (and has for the last 10 years), and the water currently meets safety guidelines.* |
| CLAIM 3<br><br>**The amount of suspended solids in Lake Timtim is decreasing.** | *Supported*<br><br>*(by evidence at locations 2 and 5)* | *Current Secchi disk measurements from around the lake have shown increased Secchi depths compared to past readings.*<br><br>*Turbidity meter readings comparing past data to current data have shown that the present turbidity levels mea-sured around the lake are lower than in past years.* | *The data did show that turbidity levels can change after events like severe storms, but those changes are temporary.*<br><br>*The lower turbidity is a sign that the water quality has improved.* |
| CLAIM 4<br><br>**Lake Timtim does not contain levels of the chemical tributyltin (TBT) high enough to pose a health concern.** | *Supported*<br><br>*(by evidence at locations 4 and 6)* | *The evidence shows that although TBT is still present in the water and soil samples, it is not a high enough level to pose a risk to humans and wildlife.*<br><br>*TBT levels in the water have de-creased over time.*<br><br>*Tests on dead organisms found at the lake showed levels of TBT within safety guidelines.* | *Although the soil samples from Lake Timtim z that significant amounts of TBT were still present in the lake bed, all the soil and water samples contained TBT levels well under the maximum levels. TBT doesn't seem like it is a concern for this lake.* |

Dear Skipton City Council,

There has been a lot of discussion about the issue of which drinking water source is the best for Skipton. My recommendation is that

My recommendation is based on the following evidence:

First,

Second,

Third,

The trade-off(s) of using this water source are

People who disagree with my recommendation might say that

Even with these counter-arguments and trade-offs, I stand by my recommendation because

Sincerely, ______________________

Dear Skipton City Council,

There has been a lot of discussion about the issue of which drinking water source is the best for Skipton. My recommendation is that

*Lake Timtim should be used as a water source for Skipton.*

My recommendation is based on the following evidence:

First,

*Tests of the water show low levels of toxic chemicals such as TBT.*

Second,

*Tests of the water show that there is not enough algal toxin to be a concern for humans.*

Third,

*Lake Timtim water levels have been higher than the needs of Skipton residents when you look at water levels over the last 20 years.*

The trade-off(s) of using this water source are

*That we may need to do regular testing of the water to make sure that algae levels don't reach toxic levels. We might also need to conserve water or find additional water sources in years when there is extreme drought.*

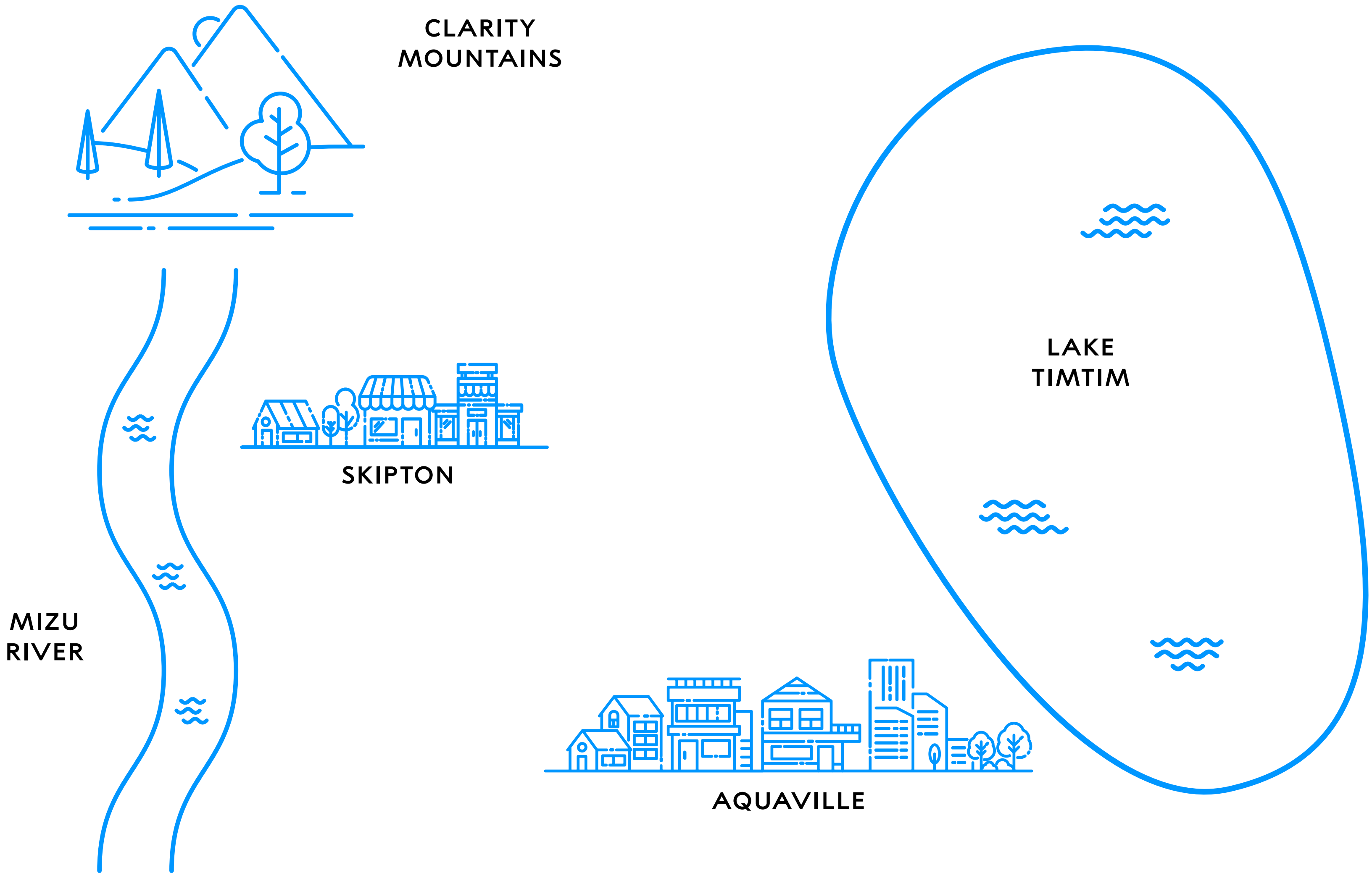
People who disagree with my recommendation might say that

*Lake Timtim might be dangerous to humans at some point due to the presence of a small amount of toxic algae. They might also say that Lake Timtim won't last 100 years.*

Even with these counter-arguments and trade-offs, I stand by my recommendation because

*I believe that Lake Timtim is a safe solution to Skipton's water problem.*

Sincerely, ______________________

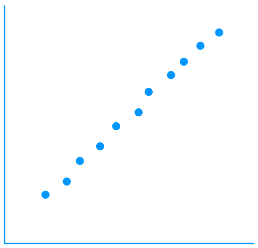

CLARITY
MOUNTAINS
LAKE
TIMTIM
SKIPTON
MIZU
RIVER
AQUAVILLE

| | INVENTION | INVENTOR |
|---|---|---|
| **1865** | Secchi disk | Italian priest Angelo Secchi |
| **1912** | mass spectrometer | British physicist J. J. Thomson (best known for his discovery of the electron) |
| **1931** | scanning electron microscope (prototype) | German physicist Ernst Ruska and electrical engineer Max Knoll |
| **1952** | gas chromatography | British scientists Anthony T. James and Archer J. P. Martin* |
| **1955** | gas chromatography-mass spectrometry (GC-MS) | Dow Chemical scientists Fred McLafferty and Roland Gohlke |
| **1959** | first satellite image of Earth | U.S. National Aeronautics and Space Administration (NASA) [image taken by *Explorer 6* satellite] |

*German scientist Erika Cremer's unpublished 1944 paper on gas chromatography and the laboratory where she worked were both destroyed during World War I. In 1951, she published several papers on gas chromatography in lesser-known German journals, and her work remained relatively unknown until after James and Martin's work was popularized.

**Determine the path that describes the data.**

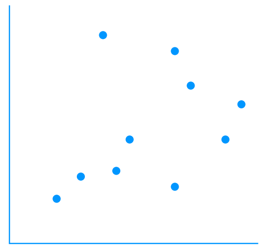
## IS THERE A RELATIONSHIP?



THERE IS A PATTERN.

↓

RELATIONSHIP



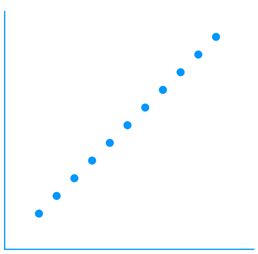
THERE IS NO PATTERN.

↓

NO RELATIONSHIP

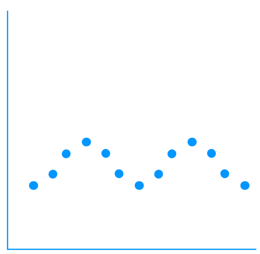
↓

## WHAT IS THE GENERAL TREND OF DATA?



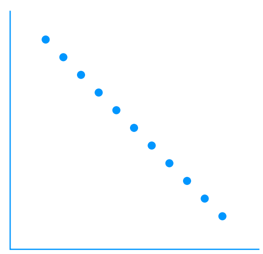
**POSITIVE**

as x increases, y increases



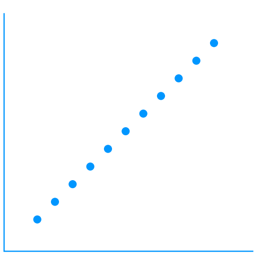
**CYCLICAL**

as x increases, y repetitively increases and decreases



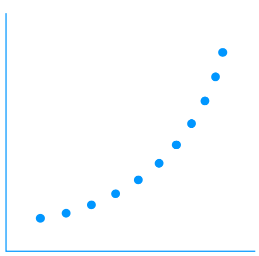
**NEGATIVE**

as x increases, y decreases



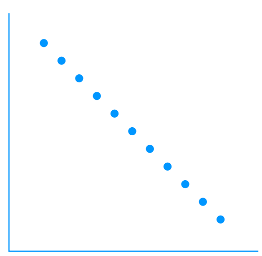
**LINEAR**

as x increases, y consistently increases *(sometimes called "direct")*



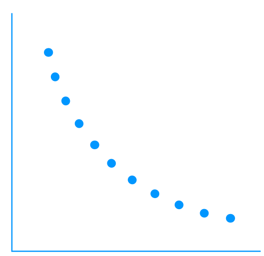
**NONLINEAR**

as x increases, y increases at a changing rate



**LINEAR**

as x increases, y consistently decreases



**NONLINEAR**

as x increases, y decreases at a changing rate *(sometimes called "inverse")*

### WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue when arguments may include judgments based on nonscientific factors.

### WHAT TO LOOK FOR:

- Response uses relevant evidence, concepts, and process skills to compare multiple options in order to make a choice.
- Response takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 4**<br>**Complete and correct** | The student provides a clear and relevant choice with appropriate and sufficient evidence, including BOTH of the following:<br>• a thorough description of the trade-offs of the decision<br>• reasons why an alternative choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their recommendation about using the lake as a water source.<br>• a clear, thorough description of at least three lines of evidence that are relevant to and support their position.<br>• a clear, thorough description of at least one appropriate trade-off. |
| **Level 3**<br>**Almost there** | The student provides a clear and relevant choice with appropriate and sufficient evidence, BUT one or both of the following are insufficient:<br>• the description of the trade-offs<br>• reasons why an alternate choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their recommendation about using the lake as a water source.<br>• at least two lines of evidence that are relevant to and support their position.<br>• at least one appropriate trade-off.<br>• descriptions of evidence and trade-offs may be unclear or insufficient |

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 2**<br>**On the way** | The student provides a clear and relevant choice, BUT the evidence is incomplete. | **The student's response includes:**<br>• a clear description of their recommendation about using the lake as a water source.<br>• at least one line of evidence that is relevant to their decision.<br>**And may include:**<br>• at least one trade-off<br>**However, evidence is less than three pieces and/or trade-off is missing or unclear.** |
| **Level 1**<br>**Getting started** | The student provides a clear and relevant choice BUT provides evidence that is subjective, inaccurate, or irrelevant. | **The student's response includes:**<br>• a clear description of their recommendation about using the lake as a water source.<br>**However, evidence is subjective, inaccurate, or irrelevant and/or trade-off is missing or unclear.** |
| **Level 0** | The student's response is missing, illegible, or irrelevant. | |
| **X** | The student had no opportunity to respond. | |

## EVIDENCE 1A

Swimmers noticed that some of the rocks at the edge of the water had a green film and a gasoline-like, fishy smell. These observations can indicate blue-green algae in the water.

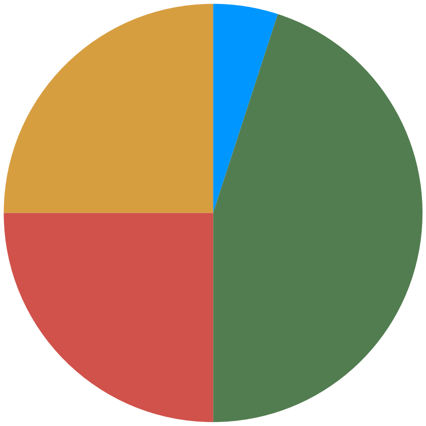
SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 6

## EVIDENCE 1B

Types of Algae Found in Lake Timtim

- blue-green algae* 5%
- green algae 45%
- red algae 25%
- brown algae 25%

*indicates a potentially toxic algae*



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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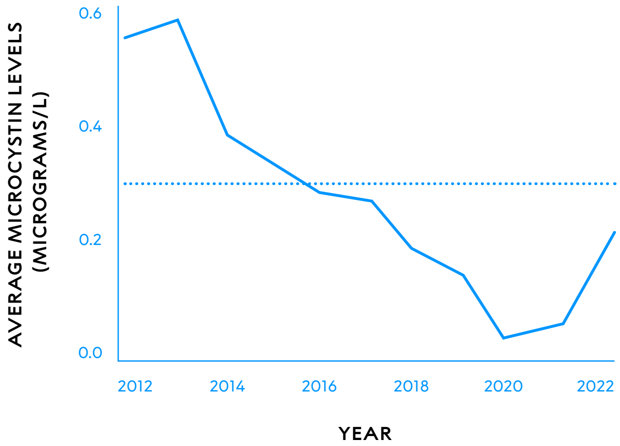
## EVIDENCE 1C

Lake Timtim:
Average Algae Toxin Measurement

2012-2022

average algae toxin

potentially unsafe for drinking water sources




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 2A

Water samples at this location were collected to compare to samples from the previous year.

PREVIOUS YEAR THIS YEAR

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 2B

Secchi disk measurements were conducted at the same location of the lake.

1988
1.7 m VISIBILITY

2023
8.0 m VISIBILITY

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 2C

Secchi disk measurements were conducted at the same locations of the lake.

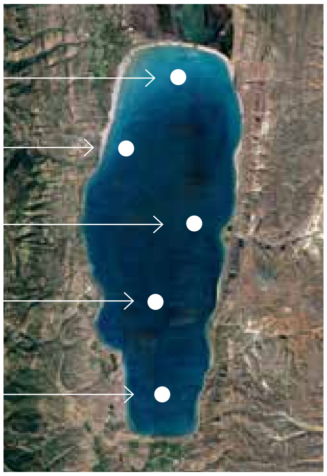
1988 : 2.0 m
PRESENT : 8.5 m

1988 : 2.2 m
PRESENT : 7.5 m

1988 : 5.3 m
PRESENT : 10.0 m

1988 : 1.7 m
PRESENT : 8.0 m

1988 : 2.5 m
PRESENT : 7.1 m



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 3A

Boaters noticed ducks swimming in this part of the lake, which has a lot of algae.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 3B

A person fishing at this location noticed that there are several dead fish floating near the shore.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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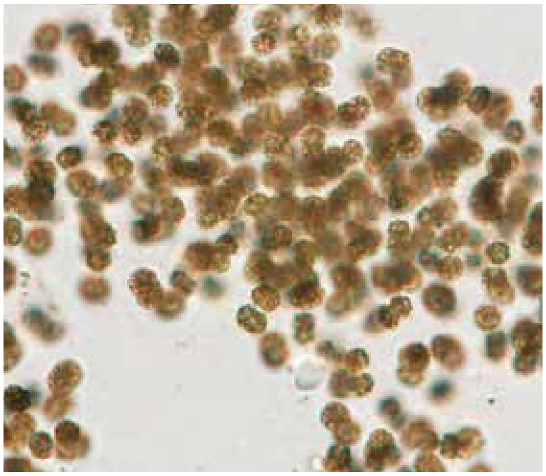
## EVIDENCE 3C

A water sample taken to the lab for microscope identification shows *Microcystis* blue-green algae present.



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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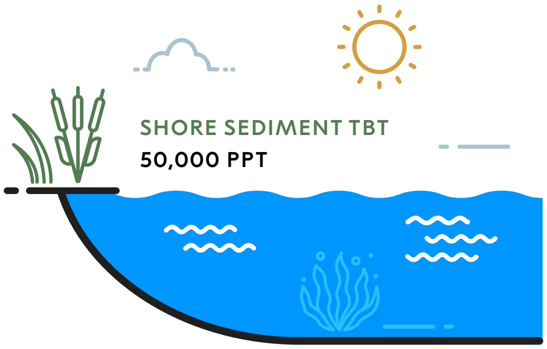
## EVIDENCE 4A

A person fishing at this location noticed that there are several dead fish and a handful of shells on the shore.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 6

## EVIDENCE 4B

Sediment samples from the shore and the lake bottom showed there was TBT in the soil sediments in 2023.




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 4C

Tissue samples from the dead organisms found along the shore showed levels of TBT at 1,500 ppt.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 6

## EVIDENCE 5A

After a severe winter storm, the water looks more brown than usual.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 5B

Satellite images of Lake Timtim 1 day after a severe storm compared to 3 weeks after the storm show changes in sediment levels in the lake.

1 DAY AFTER SEVERE STORM

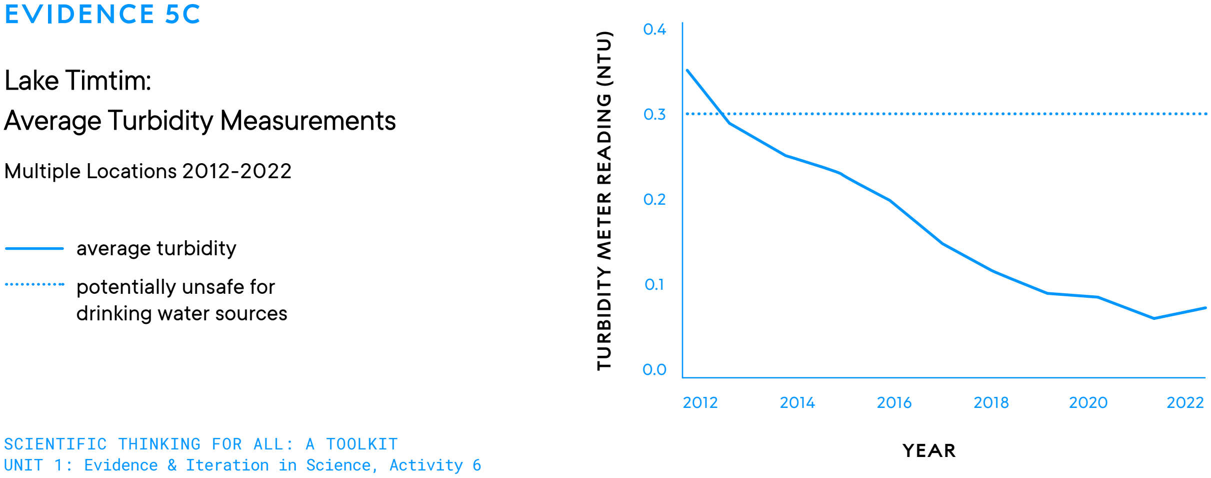
3 WEEKS AFTER SEVERE STORM

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 6

## EVIDENCE 5C

Lake Timtim:
Average Turbidity Measurements

Multiple Locations 2012-2022




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 6A

The lake water at this location is clear and odorless.

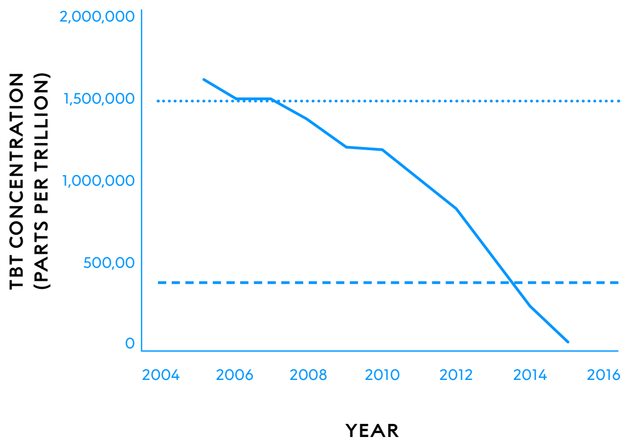


## EVIDENCE 6B

Measurements of TBT in Lake Timtim

2005-2015

- tbt concentration (solid line)
- potentially harmful to wildlife (dotted line)
- maximum level for drinking water (dashed line)






## EVIDENCE 6C

Skipton University researchers tested water samples from Lake Timtim in 2023. The tests showed TBT at this location to be around 1,200 ppt.

## EVIDENCE 7A

In 2023, visitors to nearby Wazi Lake could see a pale section of the canyon walls where the water level was below normal. These are sometimes called "bathtub rings."

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 7B

This series of satellite images of Wazi Lake was taken in July of 2000, 2010, and 2020.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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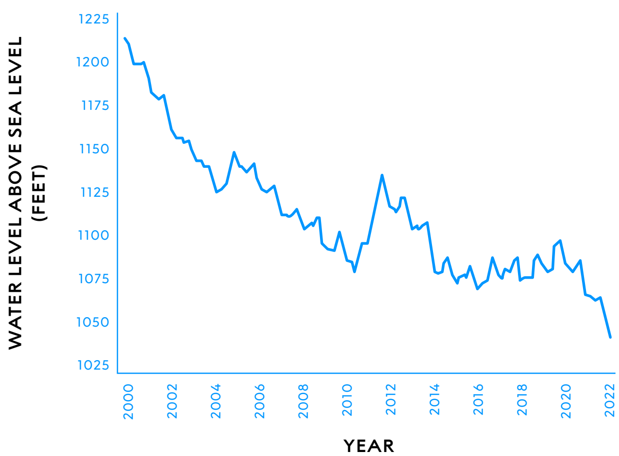
2000 2010 2020

## EVIDENCE 7C

Wazi Lake Monthly Elevation

2000-2022




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 8A

In 2023, visitors to Lake Timtim noticed that the water level of this section of shoreline was lower than the previous year.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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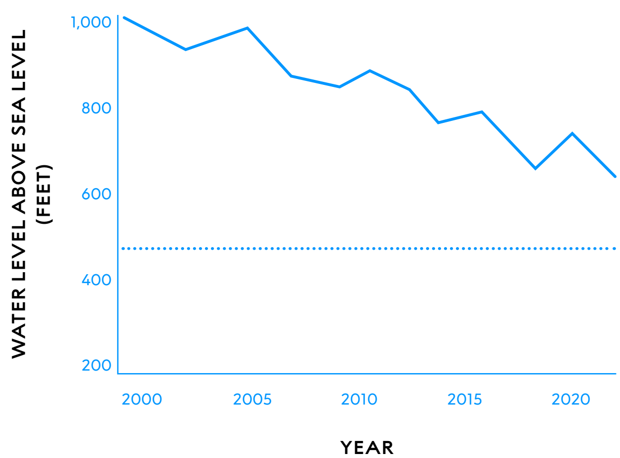
## EVIDENCE 8B

Lake Timtim: Average Water Level

2000-2022




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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## EVIDENCE 8C

Climate data and drought status for the Lake Timtim area were provided by Skipton University Dept. of Meteorology.

| YEAR | AVERAGE TEMPERATURE (°C) | TOTAL PRECIPITATION (cm) | DROUGHT STATUS |
|---|---|---|---|
| 2017 | 15.8 | 41.1 | severe drought |
| 2018 | 14.7 | 60.5 | normal |
| 2019 | 18.6 | 52.1 | normal |
| 2020 | 16.8 | 48.0 | mild drought |
| 2021 | 18.9 | 64.1 | slightly wet |
| 2022 | 15.9 | 51.3 | mild drought |

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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ACTIVITY 7

# Evidence and Explanations

CARD-BASED INVESTIGATION

ACTIVITY 7

# Evidence and Explanations

## ACTIVITY SUMMARY

**Students further investigate the use of multiple lines of evidence to support or refute a scientific explanation, using the context of cholera outbreaks in 19th-century London. They compare their thinking about cholera transmission to three widely held explanations of the time. Students receive Evidence cards and evaluate which explanation is most substantiated by the evidence. They brainstorm investigations that could provide additional evidence.**

ACTIVITY TYPE
CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
1–2

## KEY CONCEPTS & PROCESS SKILLS

1. The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.
2. Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

CONCEPTUAL TOOLS

MULTIPLE LINES OF EVIDENCE

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

# BACKGROUND INFORMATION

### History of Water Treatment and Waterborne Disease

The recognition of the importance of clean water began in prehistoric times. Recorded knowledge of water treatment is found in Sanskrit medical texts and in Egyptian inscriptions dating back to the 15th century B.C. Boiling of water, the use of wick siphons, filtration through porous vessels, and even filtration with sand and gravel as a means to purify water are methods that have been prescribed for thousands of years. The first widely referenced evidence of waterborne disease were the studies of cholera done by Dr. John Snow in 1854. During the 17th to the early 19th centuries, a number of improvements in water supply were made, primarily new filtration techniques that improved water turbidity. During this same period, the germ theory of disease became established as a result of research by Louis Pasteur, Robert Koch, and others. In 1884, Koch isolated the cause of cholera—the bacteria *Vibrio cholera*.

### John Snow and Evidence for Cholera Transmission

This activity is based on a historical case study. Initially, most scientists believed cholera was transmitted via miasma, or bad air that rose from contaminated rotting material in the ground. But in the 1850s, John Snow collected evidence that made him believe that contrary to the miasma theory, cholera was transmitted through contaminated water. At first he had difficulty convincing people, so he collected more evidence. Still, most people were not convinced. Snow believed cholera was spreading because the neighborhood well, the Broad Street pump, was contaminated with feces from the open sewers. He tried removing the handle from the Broad Street pump, making it impossible for people in the neighborhood to get water from that well. The spread of cholera stopped. This evidence convinced most people of the contaminated water explanation. Because of this work, John Snow is often called the father of modern epidemiology.

For more resources on John Snow and cholera, see:

- Primary documents and contemporary discussions: https://www.ph.ucla.edu/epi/snow.html#YOUTH
- 8-minute video from HarvardX: https://www.youtube.com/watch?v=lNjrAXGRda4

### Cholera in Modern Times

Cholera is an acute illness caused by infection of the intestine by the bacterium *Vibrio cholerae*. It is primarily spread through drinking water or food contaminated with the bacteria and is most prevalent in places with untreated drinking water or poor sanitation. Events that interfere with safe drinking water systems, including weather disasters, human conflict, and poverty, can contribute to outbreaks. An estimated 1.3–4 million people around the world get cholera each year, and 21,000–143,000 people die as a result. The majority of people who get cholera have mild symptoms or no symptoms. Approximately 10% of infected people develop severe symptoms such as diarrhea, vomiting, and cramps. In these cases, the rapid loss of body fluids can lead to dehydration and sometimes death; rehydration and antibiotics are used to treat the disease. A cholera vaccine is available, though it is effective for relatively short periods (6 months for children aged 2–5 and 2 years for adults), becoming less effective over that time.

# MATERIALS & ADVANCE PREPARATION

FOR EACH GROUP
OF FOUR STUDENTS

- 15 EVIDENCE CARDS
- 3 EXPLANATION CARDS

FOR EACH STUDENT

- STUDENT SHEET 7.1 "Evaluating Evidence"

You  may find it helpful to reproduce the Evidence cards in a different color than the Explanation cards for easy reference and sorting.

TEACHER'S NOTE: Other curriculum produced by SEPUP utilizes the story of John Snow to teach scientific concepts. This activity, while utilizing the same historical event, is a different activity than those found in other SEPUP materials.

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Elicit students' experience of being ill.**

- Invite students to describe a time they felt sick, but they did not know why, and what evidence they used to guess at the cause of their sickness.
- Ask, Why did you want to know what made you sick? Students are likely to respond that if they knew the cause, they could better treat their illness and avoid that source of illness in the future (and, thus, avoid getting sick again).
- Some questions in this activity may require sensitivity, depending on students' individual experiences. Questions about serious illness can require particular care. Some students or their family members may have been seriously ill (or died) due to the COVID-19 pandemic, an example raised in Build Understanding item 3. Modify the introduction and questions in this activity as needed.

2 **Read the introduction in the Student Book to set the context for the activity.**

- Point out that cholera is an illness that has been identified and diagnosed since the 1800s. Do not focus on the cause or transmission of the disease at this point in the activity—that is the focus of the activity itself.
- Let students know that in this activity, they will use what they have learned thus far—namely that science knowledge is based on multiple lines of relevant, accurate, and reliable evidence—to identify how cholera is transmitted.

## PROCEDURE SUPPORT (25–30 MIN)

**3 Present the scenario of the cholera outbreak during 1850s London found in Procedure Step 1.**

- The procedure takes students through the experience of the scientists in England in 1850 who initially had incomplete evidence, which made the incorrect explanations seem more likely than the correct explanation.
- The scenario presented in Step 1 can be shared with the class in multiple ways: You can read it aloud to the class (using a storytelling approach), have individual students read a paragraph aloud to the class while others follow along with the text, or have students read it individually or cooperatively in their groups of four.
- Depending on your student population, use oral storytelling to support diverse learners in decoding scientific ideas and constructing meaning and ask questions about the main points of the scenario to ensure comprehension. Students can refer to the text in the Student Book as needed.

**4 Students brainstorm possible modes of cholera transmission and compare their ideas to three Explanation cards.**

- Based on their prior knowledge and the information in the scenario, students are likely to conclude that the disease is infectious (vs. genetic or some other type of disorder). Students may hypothesize that the disease is spread through direct contact, such as touching; is airborne; or is transmitted through contaminated food or water.
- The three Explanation cards represent ideas popular at the time, including miasma (bad air), effluvia (airborne), and foul water (contaminated water).
- Students may consider that evidence of a contaminated food source could provide evidence for contaminated food. Respiratory symptoms such as coughing might provide evidence for an airborne illness, while finding evidence of a parasite could provide evidence for spreading through direct contact.
- Most students will not propose evidence for miasma (bad air) since that explanation appears unbelievable through modern eyes; it was, however, the most popular theory at the time. You may want to ask students what aspects of the miasma explanation are similar to or different from modern scientific knowledge about disease transmission.

**5 Student groups examine Evidence cards 1–4.**

- Student groups work together to determine whether each Evidence card supports one or more of the three explanations or is not relevant evidence.

- Students should record their responses on Student Sheet 7.1, "Evaluating Evidence." A sample response to Student Sheet 7.1 is found at the end of this activity.

- Facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support. Consider how to best adapt the activity to the needs of your particular student population. Students who need more time processing language (such as students with dyslexia) can be provided with a set of the cards in advance of the day's activity.

- While groups work, walk around and ask students to share their thinking about the Evidence cards and the cards' relationship to one or more of the explanations. For example, students may note that people got sick in the same family within a few days of each other, supporting the airborne explanation because families breathe the same air. This explanation could also be supported by the fact that people were regularly interacting with one another (and breathing the same air).

- Encourage students to reflect on their own thinking processes in terms of evaluating the evidence and considering how it might support one or more of the three explanations. If students disagree about the relevance of a piece of evidence to a particular explanation, encourage them to explain their thinking to the group and to consider what might convince their group members to change their minds about their conclusion.

**6 Hand out Evidence cards 5–15 to each group.**

- The remaining Evidence cards provide more support for the three explanations. Encourage students to discuss the additional evidence with their groups and evaluate how it supports each of the explanations.

- Procedure Steps 6 and 8 provide opportunities for metacognitive thinking. Reflecting on one's confidence level can help reduce overconfidence by reminding students to consider potential sources of uncertainty or error. Point out this opportunity for student self-reflection and have students share their confidence levels, as well as what factors contributed to these levels, at these two different points of the activity.

**7 Students evaluate the evidence supporting the three explanations.**

- Students are likely to conclude that foul water (contaminated water) is the source of cholera transmission. Much of the evidence, such as the proximity of smelly (potentially leaking) sewers to the well, support this explanation.

- Suggestions for stopping the spread of cholera through contaminated water may include getting drinking water from another well, treating the contaminated water by filtration or boiling, repairing or moving potentially leaking sewers to stop the likely source of contamination, or digging a drinking water well at another location.

- Discuss students ideas from Procedure Step 9 by asking, What other evidence would help you be more confident in your conclusion? Students may want to know whether cholera could be detected in the water, whether the water could be analyzed in some other way, or if boiling drinking water helped people avoid getting sick. Finding out that there was no evidence of cholera in the water or that treating the water did not reduce disease transmission might change students' minds about the source of the spread.

- Possible investigations include preventing the use of the Broad Street pump for drinking water and determining if this action stops the spread (as was done by John Snow) or by testing the water by having a few animals drink the water and observing if they also get sick. Students may also suggest investigations using modern scientific tools and techniques that were not available or well established at the time.

## SYNTHESIS OF IDEAS (10 MIN)

**8 Discuss the quantity and quality of evidence supporting the explanations.**

- Highlight the roles of both quality and quantity of evidence in constructing a scientific explanation. Ask, What was more important in making your decision about cholera transmission: the quantity or quality of evidence? There was some evidence supporting each explanation, but the evidence supporting foul water was more accurate and reliable, and there was the most evidence for it. Discuss the importance of evaluating the quality of evidence as well as the quantity. For example, having large quantities of biased, inaccurate, or unreliable evidence would lead to suspect explanations.

- Ask, Did you revise your initial explanation based on evidence? Explain your reasoning. Some students may have initially hypothesized that the spread of the disease would be airborne, like COVID-19. Have them identify what evidence was most convincing in changing their thinking.

**9 Highlight common misconceptions about science that can influence decision-making.**

- Highlight how this activity addresses two opposing common misconceptions of science by asking students to describe how making decisions about cholera transmission might reinforce one of the following misconceptions. Have students consider how they might address these misconceptions, either with their own thinking or with the thinking of others. The two common misconceptions are summarized here:
    - Sometimes people believe that science is always right or always progresses linearly toward greater accuracy with no false directions. This is untrue; science is a human enterprise, and people make mistakes. In addition, limitations of human senses and scientific tools mean that data may not be available or may not have been gathered to make accurate and reliable conclusions.
    - Sometimes when people learn that scientists make mistakes and their resulting claims may be uncertain, they conclude that people can believe anything and that there is no method for

making conclusions reliably. However, the practices of science are designed deliberately to iteratively approach increasingly accurate descriptions of the world. They do this by (1) grounding claims in observations—evidence, and (2) continuing to be open to new observations that may reveal errors or limitations of earlier ideas based on more limited observations. By considering both previously collected evidence and new evidence, the full amount of information available to scientists to make sense of the world can keep on growing. More complete evidence makes it easier to form better explanations and theories.

- Highlight the connection between better scientific understanding and better solutions. For example, the germ theory of disease is not just more accurate, but it has led to interventions and treatments that are more likely to produce desirable outcomes.
- Build Understanding item 4 can be used to formatively or summatively assess students' ability to support or refute a claim.
- Build Understanding item 5 provides an opportunity for metacognitive thinking about the nature of science. Point out this opportunity for student reflection.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

① **Cholera outbreaks in the 19th century occurred before many modern scientific tools were developed. What is one modern scientific tool that might have helped doctors of the time figure out the transmission of cholera more quickly? How could this tool have been used to investigate cholera?**

*Microscopes could have been useful to figure out the transmission sources more quickly. Scientists could have collected water samples and looked for evidence of microbial transmission.*

② **The development of scientific knowledge is iterative and occurs through continual re-evaluation and iteration of ideas that are informed by:**

- **new evidence**
- **improved methods of data collection and experimentation**
- **collaboration with others**
- **trial and error**

**Which of these were relevant to Dr. Snow's investigation of cholera? Provide examples that describe how these elements were represented in his work.**

*Dr. Snow gathered new evidence by collecting, analyzing, and interpreting the cases of cholera. He improved the method of data collection by asking questions and mapping cases to observe patterns.*

③ **How was the cholera outbreak in 1800s London similar to the Skipton scenario? How was it different?**

*It was similar to the Skipton scenario because people became sick from a microbe in their drinking water. In both cases, it took time to gather evidence to prove that the contamination was in the water and not another source. It was different from Skipton because John Snow analyzed the data more methodically, looking for patterns between illness and the source of water. Also, people had a common water source vs. today when people have water piped directly into their homes. This means that there are more potential points of contamination in the water, and it can be difficult to make conclusions without lots of data.*

## CONNECTIONS TO EVERYDAY LIFE

4. **Evidence can be useful in making everyday decisions. Imagine that your family decides they want to eat more fruit and less cereal at breakfast. Your dad says he heard that having smaller package sizes of foods in the house reduces the amount people eat. He buys more fruit and smaller boxes of cereal and then claims that the family has met their goal.**

   a **Did he support his claim?**

   b **Identify the relevant evidence and explain your reasoning.**

   c **Explain what additional evidence could support his claim.**

   *He was wrong—he did not support his claim. The only evidence he had was something he heard and what he shopped for. He did not explain who provided the information that he quoted, so it is difficult to determine if it is accurate. Also, he did not provide information about whether the family was eating less cereal, or if he was buying smaller boxes of cereal more often. To support his claim, he could provide evidence about how much cereal the family was eating before and how much they are eating now.*

5. **How do you think scientists know when they have enough information to construct a scientific explanation?**

   *I think scientists know if they have enough information to construct a scientific explanation if they have multiple lines of reliable, accurate, and precise data that is validated through the scientific community. Scientists work with others in person and in the literature, and these people provide feedback on the scientific ideas that are presented.*

## REFERENCES


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Summers, Judith. (1989). *Soho: A history of London's most colourful neighborhood*. London: Bloomsbury. pp. 113–117.

| STUDENT SHEET 7.1 | EVALUATING EVIDENCE | NAME |
|---|---|---|

| EVIDENCE | SUPPORTS EFFLUVIA (AIRBORNE) EXPLANATION | SUPPORTS FOUL WATER EXPLANATION | SUPPORTS MIASMA (BAD AIR) EXPLANATION | NOT RELEVANT TO ANY EXPLANATION |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |

| STUDENT SHEET 7.1 | EVALUATING EVIDENCE | NAME SAMPLE STUDENT RESPONSE |
|---|---|---|

| EVIDENCE | SUPPORTS EFFLUVIA (AIRBORNE) EXPLANATION | SUPPORTS FOUL WATER EXPLANATION | SUPPORTS MIASMA (BAD AIR) EXPLANATION | NOT RELEVANT TO ANY EXPLANATION |
|---|---|---|---|---|
| 1 | X | | X | |
| 2 | X | | | |
| 3 | X | | X | |
| 4 | | | X | |
| 5 | | X | X | |
| 6 | | X | X | |
| 7 | | X | | |
| 8 | | | | X |
| 9 | | X | X | |
| 10 | | X | | |
| 11 | | | | X |
| 12 | X | X | X | |
| 13 | | X | | |
| 14 | | X | | |
| 15 | | X | | |

### EXPLANATION A
### MIASMA (BAD AIR)

Cholera is caused by the transmission of poisonous vapors from foul smells due to poor sanitation.

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### EXPLANATION B
### EFFLUVIUM (AIRBORNE)

People who are ill with cholera give off effluvia in their breath, releasing contagious particles into the air, which can be inhaled into the lungs by others nearby.

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### EXPLANATION C
### FOUL WATER
### (CONTAMINATED WATER)

Cholera comes from water that people drink that is contaminated by particles from the feces of other people who are infected with cholera.

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## EVIDENCE 1

Hot weather caused the smell of untreated human waste in the River Thames to be so strong it was known as "The Great Stink." It occurred one summer in central London during a period of cholera transmission.

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## EVIDENCE 2

Residents of the area interacted with one another, though mostly outside. People who lived closer together interacted more often, especially those who lived in nearby houses. They often went in and out of one another's homes.

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## EVIDENCE 3

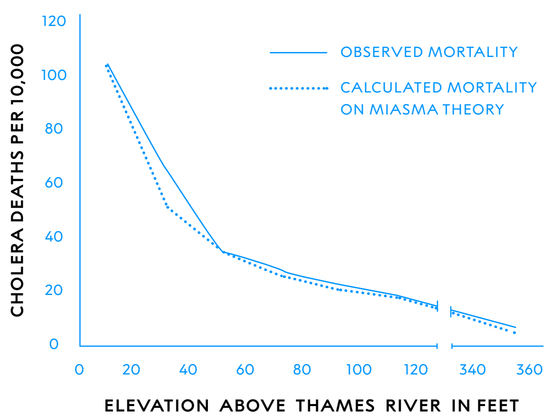
A number of people got sick with cholera a day or two after someone else in the same family became sick.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 4

Dr. William Farr reasoned that soil at low elevations, especially near the banks of the River Thames, contained a lot of organic matter, which contributes to miasma (bad air). The concentration would be greater at lower elevations than in communities in the surrounding hills. He supported his reasoning with the following data.

Cholera Mortality, London 1849




SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 5

Some of the patients who caught cholera had no contact with any previous victims.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 6

There was a well below the Broad Street water pump that was 28 feet deep. At 22 feet down, near the well, there was a sewer. A few people reported that the water had smelled offensive or that it was a bit "off" near the time of the cholera outbreak.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 7

Dr. John Snow mapped the cases of cholera during the 1849 outbreak and observed a pattern showing that the majority of cases surrounded the Broad Street water pump.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 8

Patients with severe cholera were injected with a weak saline solution, causing them to look and feel much healthier for a short time.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 9

A widow who had not lived near the Broad Street water pump died of cholera on September 2nd. Dr. Snow interviewed the widow's son and discovered that the widow had once lived on Broad Street. She had liked the taste of the well water there so much that she had sent her servant to bring back a large bottle of it every day.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 10

The men who worked in a brewery on Broad Street did not get cholera. The men drank the beer they made or water from the brewery's own well and not the water from the Broad Street pump.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 11

There were four major cholera outbreaks in London between 1832 and 1866.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

# EVIDENCE CARDS | 12-15

CONTINUED

## EVIDENCE 12

In houses much nearer another water pump (not the Broad Street pump), there had only been 10 deaths.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 13

A factory at 37 Broad Street kept two tubs of water from the Broad Street water pump on hand for employees to drink; 16 of the workers died from cholera.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 14

Two water companies provided water pumps and supplied most of the water to London residents. Dr. Snow noted that the S&V Water Company supplied water directly from the River Thames in London, while the Lambeth Water Company had moved its water intake on the Thames upstream, outside of London.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

## EVIDENCE 15

A prison nearby had 535 inmates but almost no cases of cholera. Dr. Snow discovered that the prison had its own well and bought water from a different water company, the Grand Junction Water Work.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 1: Evidence & Iteration in Science, Activity 7

ACTIVITY 8

# Science Is a Human Endeavor

VIDEO

ACTIVITY 8

# Science Is a Human Endeavor

*Activity 8 is still under development and will be available in future downloads*

ACTIVITY TYPE
VIDEO

NUMBER OF 40–50 MINUTE CLASS PERIODS
1

CONCEPTUAL TOOLS

SENSES & INSTRUMENTATION

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

SCIENTIFIC OPTIMISM

ACTIVITY 9

# Water Quality Design Challenge

LABORATORY

ACTIVITY 9

# Water Quality Design Challenge

## ACTIVITY SUMMARY

**Students work together to design and build a simple water-filtration device. They test their filtered water for turbidity, pH, and simulated contaminants (red food dye). They collaborate with other groups to share results and improve their designs. The process illustrates unit concepts such as iteration, collaboration, and science as a human endeavor.**

ACTIVITY TYPE
LABORATORY

NUMBER OF 40–50 MINUTE CLASS PERIODS
3

## KEY CONCEPTS & PROCESS SKILLS

1. The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.
2. Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.
3. Scientific optimism enables scientists to solve difficult problems over long periods of time.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

SCIENTIFIC OPTIMISM

## VOCABULARY DEVELOPMENT

**desalination**
removal of salt from saltwater

## MATERIALS & ADVANCE PREPARATION

FOR THE CLASS

- 1 GALLON (3.8 L) CONTAMINATED WATER SAMPLE, COMPOSED OF:
  - 2 cups (470 mL) distilled vinegar
  - ½ cup (110 mL) top soil
  - 6–8 drops red food coloring
  - approximately 3.22 L tap water (fill to achieve final volume of 3.8 L)
- 8 CUPS (2 L) ACTIVATED CHARCOAL (or carbon)
- 2 CUPS (470 mL) BAKING SODA
- 4 CUPS (1 L) COARSE SAND
- 8 CUPS (2 L) FINE SAND
- 4 CUPS (1 L) GRAVEL
- CUPS (OR LARGE SPOONS) TO SCOOP MATERIAL
- SCISSORS
- PAPER TOWELS

FOR EACH GROUP OF FOUR STUDENTS

- 1–2 500 mL PLASTIC WATER BOTTLES, CUT IN HALF
- 4 PIECES OF CHEESE CLOTH, 3 inches x 3 inches
- 1–2 RUBBER BANDS
- 400 mL CONTAMINATED WATER SAMPLE
- BEAKER OF 100 mL CLEAR TAP WATER (control)
- EMPTY 200 mL BEAKER*
- TURBIDITY RATING MODEL CARD
- CONTAMINANT LEVEL RATING CARD
- pH PAPER
- RULER (cm)

FOR EACH STUDENT

- SAFETY GOGGLES
- LAB COAT
- STUDENT SHEET 9.1 “Filtration Design Challenge”

*The size and type of container can vary as long as each group has the same size container with a clear bottom (e.g., a clear plastic cup).

The contaminated water sample should be made ahead of class by combining vinegar, food coloring, top soil, and enough tap water to fill up to the final volume. The plastic bottles for each group can also be prepared in advance by using the scissors to cut each 500 mL bottle in half. The lower part of the bottle should be able to hold approximately 150 mL of liquid. If you have a limited supply of plastic bottles, students can use 1 bottle per group and rinse bottle pieces between iterations.

An estimated amount of the materials needed for one class containing eight groups of four students is listed in the Materials list. They are based on the materials students are likely to use the most. Each student group can be given ⅛ of these amounts in small containers in advance, or each group can independently get materials from a common bin, using scoops.

TEACHER'S NOTE: After materials have been used to filter the water sample, they mix together and cannot be separated for reuse.

Results can vary for this lab, based on materials. For best results or if you have limited access to materials, be sure to test with your materials beforehand and see the following Teacher's Note for general guidelines.

Instructions for rating the turbidity and contaminant level (amount of dye) using the measurement cards are located in Step 3 of the Student Book, but should be reviewed in advance. The measurement cards can be used multiple times if laminated or placed in sheet protectors.

### Teacher's Note: About Laboratory Materials

Due to variation in materials, the following guidelines are intended to support the success of the activity.

- The smaller the particle size of the material (sand, charcoal, or baking soda), the slower the filtration will take place, and the better it will be at decreasing the turbidity (reducing cloudiness).
- The smaller the particle size of the activated charcoal/carbon (more surface area), the better it works for removing the contaminant (colored dye). However, extremely fine particles of charcoal in a very thick layer may slow down the speed of filtration significantly. In contrast, larger chunks of charcoal only work if there is a thicker layer and the filtration speed is slower, so the sample does not flow through too quickly to react with the charcoal. A balance between charcoal particle size, layer thickness, and speed of filtration is needed.
- Many of the filter materials can be purchased at an aquarium store, including the activated charcoal. Alternatively, finer charcoal can be purchased online from many science education retailers, or you can grind larger chunks of charcoal into smaller-size particles by using a mortar and pestle.
- Rinse the charcoal with water before giving it to students to reduce black impurities from getting into the filtered water. Likewise, it is important to use clean aquarium gravel and play sand (instead of yard gravel or beach sand because these may add pollutants into the water).
- Baking soda affects the pH, but very little is needed. Too much baking soda will slow down the speed of filtration and cause the pH to become too basic.

- Generally, a few centimeters of fine sand, a little baking soda (less than 0.5 cm), and a couple of centimeters of charcoal with particles that are a similar size to the sand works well. If the charcoal is finer, use less of it and more sand.

## SAFETY NOTE

**This activity models some aspects of the process of purifying drinking water. The water-filtration devices will remove some impurities but will NOT make the water safe to drink.**

# TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Use the Student Book introduction to highlight the role of trial and error in science.**

- Read the introduction to Activity 9 in the Student Book, either as a class or individually. Connect to students' prior knowledge and ideas about global water accessibility. Remind them of how the Skipton scenario raised the issue of clean water quality accessibility and how cheaper solutions to improve water quality are still needed in many parts of the world.
- After the reading, discuss the following question. Ask, Why do you think it took 10 years to fully develop this desalination unit? Student responses may include ideas such as finding materials that could work successfully but were not expensive could have been a challenge.
- Introduce the concept of trial and error and emphasize to students that trial and error relies on small, step-by step changes, which can be random if no better information is available.

## PROCEDURE SUPPORT (40 MIN)

2 **Review classroom safety expectations**

- Remind students to wear lab coats and goggles and to follow all classroom safety rules.
- Point out that while they will be filtering a water sample, the final product will still NOT be safe to drink.

3 **Present the scenario of Skipton found in Procedure Part A.**

- Explain to students that they will be designing a filter device in an attempt to improve three factors of water quality: turbidity, pH, and contaminant level. Red food-coloring dye will be used to simulate contaminants in the water that must be removed.

- In their designs, students must leave 5 cm (2 inches) of empty space at the top of their devices when building them.

  NOTE: This limit is so there is enough room in the upper part of the bottle so the water sample will not overflow.

- If needed:
  - Review the basic setup for the water-bottle device and how to apply the rubber band and cheesecloth around the mouth (as shown in the Student Book).
  - Review the terms turbidity and pH. Remind students that water has an approximate pH of 7 and safe drinking water levels are between 6.5–9.
  - Demonstrate how to rate the turbidity and contaminant level by using the provided Turbidity Rating Model card and the Contaminant Level Rating card, as described in Step 3 in the Student Book.
  - Remind students how to measure the pH by using the pH paper.

- To reduce the use of materials, consider having students work in groups of four. Since this is an inquiry-based lab, you may want to use heterogeneous groups to help support the needs of all learners and encourage all students to participate. Group roles can be divided based on the three different water quality factors, with a different student responsible for testing and improving pH/turbidity/contaminant level, and a fourth student having the role of project manager (including being responsible for getting materials and helping the group to share results and reach consensus).

- Hand out Student Sheet 9.1, "Filtration Design Challenge."

**4 Have students do initial tests of the three measures of water quality.**

- Students test the initial pH, turbidity, and contaminant level of the sample water by pouring 100 mL of the water sample into the empty beaker.

- To measure turbidity and contaminant level, students need good lighting and to be able to look straight down through the sample.

- If needed, remind students:
  - to stir the sample in the testing beaker right before they measure turbidity.
  - to compare their results to that of the clear tap water.
  - that they can only use, at most, two materials for this first iteration.

**5 Have students build their first design iteration and test for the three measures of water quality.**

- Student groups work together to select, gather, and construct their water-filtration devices. Support students as needed and provide directions for how you would like them to gather the materials for their groups.

- You may wish to ensure that groups are not all using the same materials for their first designs. This can be accomplished by assigning or encouraging groups to use different materials during their first iterations.

- Remind students to fully rinse out their testing beakers before using them to test their filtered water sample.

- Students should compare their turbidity and contaminant level results to the clear tap water (control). Responses will vary depending on the materials chosen. For instance, if fine sand is chosen, the results will be less turbid (cloudy) and closer to the clear tap water in appearance.

- Students can save the filtered sample from each iteration by using plastic cups. This allows students to compare the saved samples at the end of their experimentations.

- Direct students about how you would like them to dispose of their filtration materials prior to the next iteration.

6 **In Procedure Part B, student groups collaborate with one another.**

- Students can first visit other groups who used the same materials to compare their results.
- Students can then visit groups who used different materials, so they can gather new information.

7 **In Procedure Part C, have students build their second iterations, retest water quality, and compare results before proposing a third iteration.**

- Inform students that they can now use up to three materials for this second design.

- Remind them to fully rinse out their testing beakers before using them to test their filtered water samples.

- Direct students on how you would like them to dispose of their filtration materials.

- Students should compare their turbidity and contaminant level results to the clear tap water (control). If students saved a sample of filtered water from the first iteration, they can also compare their samples.

- Student groups should collaborate with other groups and share results.

## SYNTHESIS OF IDEAS (10 MIN)

8 **Facilitate a class discussion about which design materials worked best and how collaboration between groups affected the outcome.**

- Ask, What is an advantage of using iteration to solve problems or search for answers to scientific questions? How do you think iteration is different from trial and error? Ideas to emphasize include:
  - Iteration can speed up the design and discovery process.
  - A simple trial-and-error process is random, while an iterative process relies on analyzing your results based on the finding of each cycle.
- Ask individuals to summarize which materials worked best. Ask, What is the optimal design of the water-bottle filter, based on the combined results of all the groups? (Materials, layers, thicknesses, order of the layers, etc.) Generally, the best design will include a very small amount of baking soda to adjust the pH, just enough activated charcoal to remove the red dye without greatly slowing down the filtration process, and fine sand on the bottom to prevent very small particles of other materials from going through the cheesecloth.
- You may want to ask students to come up with ideas for improvements or what iterations they would like to test next to make an even better filter.
- Ask, How did collaboration affect your ability to iterate? How would the design process been affected if you had all been working in separate rooms and could not have shared results? Ideas to emphasize include that:
  - Collaboration can speed up the design and discovery process.
  - It can be more difficult to catch mistakes and confirm that your results are relevant, reliable, and accurate.
- You can use Build Understanding item 3 to formatively assess a student's thinking about the strengths and limits of gathering data from scientific technology alone.

## EXTENSION (10-30 MIN)

9 **Use the Extension as an opportunity for advanced learning.**

Students can discover the roles of iteration, collaboration, and scientific advancement in the development of the Internet by doing online research. Student research can be facilitated by providing specific website links, such as:

https://www.scienceandmediamuseum.org.uk/objects-and-stories/short-history-internet

https://www.internetsociety.org/internet/history-internet/brief-history-internet/

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

1. **During this design challenge, you collaborated with other teams to share your findings. Imagine your group had been working alone and was not able to receive feedback or share results with other groups. Explain how this would have affected:**

   - **the iteration process.**
   - **your success at finding materials that improved water quality.**

   *Without collaboration, the process of iteration would have been a lot slower. It would have taken us a lot longer to find out which materials worked better for the different measures of water quality because we would have needed to test all of them ourselves. Collaboration also allowed us to compare and confirm our results with other groups so we could be more sure of our conclusions/design ideas.*

2. **Water treatment involves the use of chemical additives as well as filtration. Which process(es) do you think would have been more useful in addressing Skipton's water quality issues in Activity 1? Explain your reasoning.**

   *Residents observed a change in turbidity, which could have been addressed by improved filtration to remove particles from the water. Evidence also suggested that the cause of illness might have been Cryptosporidium in the tap water, which probably would be killed by chemicals such as chlorine.*

3. **What are the advantages and disadvantages of using iteration to develop scientific knowledge?**

   *Advantages of iteration are that an idea can be tested multiple times. This increases both accuracy and reliability. Iteration can build on prior scientific findings and support collaboration with others. Disadvantages of iteration are that it takes more time to continually retest ideas and more resources.*

## CONNECTIONS TO EVERYDAY LIFE

4. **You follow a cookie recipe and end up with bland, burnt cookies. Describe how you could use iteration to perfect the recipe.**

   *I would increase the amount of sugar to make the cookies less bland. I would also lower the baking temperature to try to prevent them from getting burnt. After seeing what happened, I could continue to make adjustments such as further lowering the baking temperature or adding chocolate chips if the cookies were still too bland.*

5. **A friend of yours is developing a new video game. Describe ways in which she could use iteration and collaboration to improve the graphic design, user experience, and storyline of the video game.**

   *She can try the game or recruit her friends to try her first version to evaluate how good the graphics, story, and experience are for players. Based on feedback, she could try to update those features and ask her friends to review it again. She could continue this process until the game has no more suggested improvements.*

### REFERENCES


Myers, L. (2022, April 29). MIT researchers build portable desalination unit that generates clean water at the push of a button. Designboom. Milan, Italy. Retrieved from https://www.designboom.com/technology/mit-researchers-portable-desalination-unit-generates-clean-water-04-29-2022/

National Aeronautics and Space Administration (NASA) Education, Jet Propulsion Laboratory, California Institute of Technology. Water filtration challenge. Retrieved from https://www.jpl.nasa.gov/edu/teach/activity/water-filtration-challenge/

## TABLE 9.1
## DESIGN FOR WATER-FILTRATION DEVICE

| MATERIAL AND THICKNESS (IN cm) | FIRST ITERATION (INITIAL) | SECOND ITERATION (REVISED) | THIRD ITERATION (PROPOSED) |
|---|---|---|---|
| Material 1 (top layer) | | | |
| Material 2 (bottom/middle layer) | | | |
| Material 3 (bottom layer) | *none* | | |

## TABLE 9.2
## RESULTS FROM WATER QUALITY TESTING

| | TURBIDITY RATING (0–5) | CONTAMINANT LEVEL RATING (0–5) | pH (1–14) | ADDITIONAL NOTES OR OBSERVATIONS |
|---|---|---|---|---|
| Water sample *before* filtration | | | | |
| Water sample *after* Iteration 1 (2 layers) | | | | |
| Water sample *after* Iteration 2 (3 layers) | | | | |

TABLE 9.1
DESIGN FOR WATER-FILTRATION DEVICE

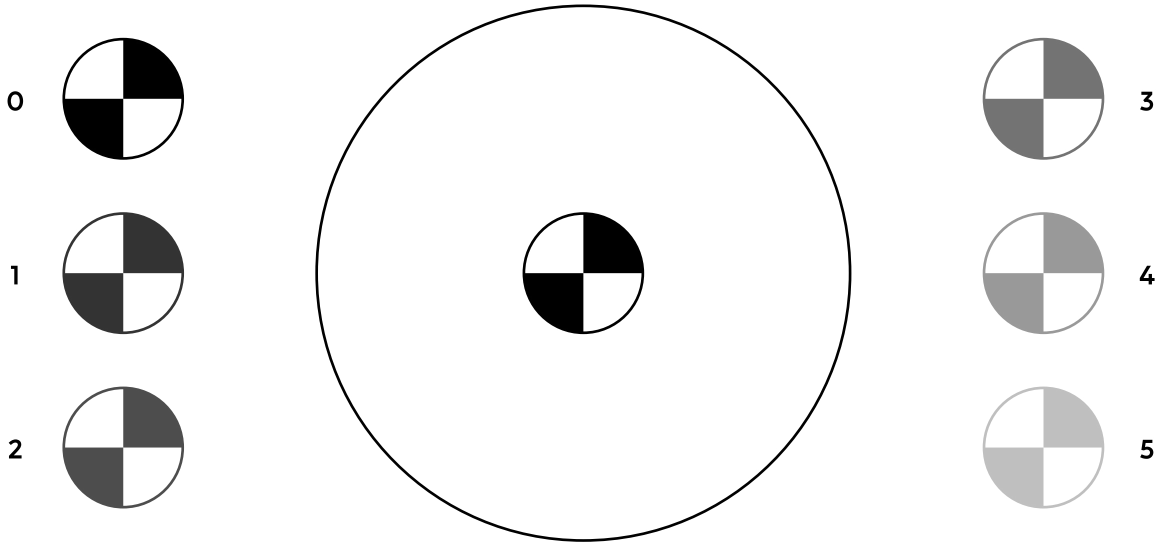
| MATERIAL AND THICKNESS (IN cm) | FIRST ITERATION (INITIAL) | SECOND ITERATION (REVISED) | THIRD ITERATION (PROPOSED) |
|---|---|---|---|
| Material 1 (top layer) | *fine sand, 3 cm* | *charcoal, 2 cm* | *charcoal, 1 cm* |
| Material 2 (bottom/middle layer) | *baking soda, 1 cm* | *baking soda, 0.5 cm* | *baking soda, 0.2 cm* |
| Material 3 (bottom layer) | *none* | *fine sand, 3 cm* | *fine sand, 4 cm* |

TABLE 9.2
RESULTS FROM WATER QUALITY TESTING

| | TURBIDITY RATING (0–5) | CONTAMINANT LEVEL RATING (0–5) | pH (1–14) | ADDITIONAL NOTES OR OBSERVATIONS |
|---|---|---|---|---|
| Water sample *before* filtration | *4* | *3* | *3* | *The color measurement was hard to make because of the high turbidity of the sample.* |
| Water sample *after* Iteration 1 (2 layers) | *0* | *2.5* | *9* | *The cloudiness was gone. It took a long time. The pH is way too high now.* |
| Water sample *after* Iteration 2 (3 layers) | *0* | *0.5* | *8* | *The red color disappeared, but a tiny amount of black charcoal went through. The pH was closer to neutral.* |

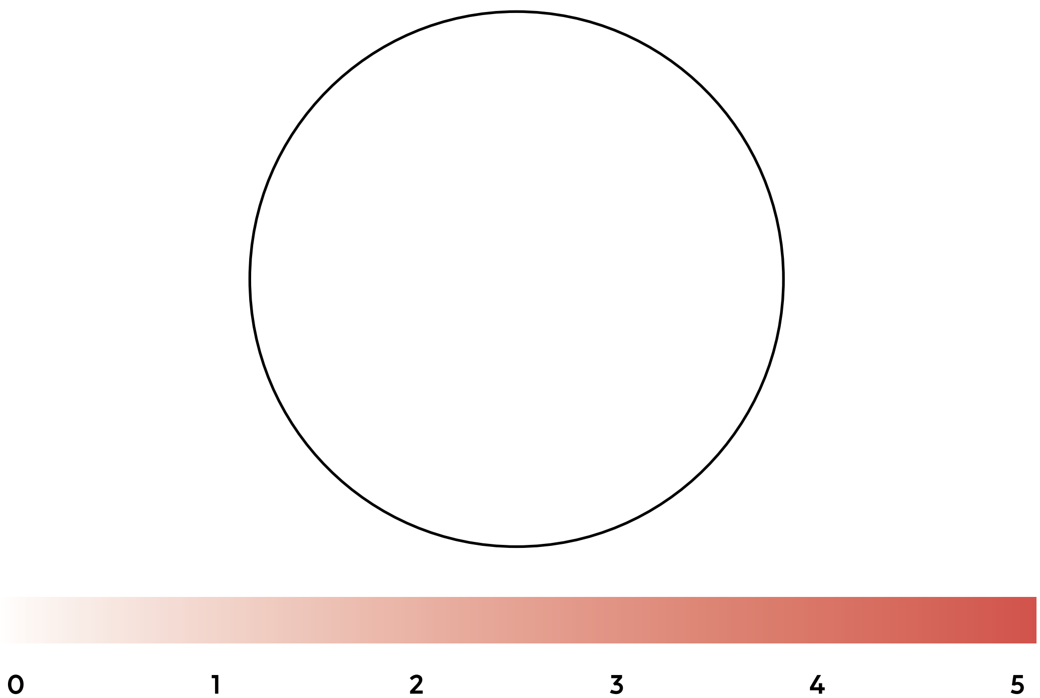
Turbidity Rating Model Card

PLACE YOUR WATER SAMPLE BELOW




Contaminant Level Rating Card

PLACE YOUR WATER SAMPLE BELOW



ACTIVITY 10

# Solutions Through Scientific Optimism

PRESENTATION

ACTIVITY 10

# Solutions Through Scientific Optimism

## ACTIVITY SUMMARY

**Students brainstorm solutions for addressing global needs for clean and accessible water. They then read about some of the most common proposed solutions to global water needs and identify connections to some key ideas of the unit. Students select a community to represent and research specific aspects of its water needs. They propose a plan for addressing these water needs and communicate an aspect of their proposal by creating a public service announcement (PSA). They re-visit decisions made in Activity 1 and elsewhere in the unit.**

ACTIVITY TYPE
PRESENTATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
3+

## KEY CONCEPTS & PROCESS SKILLS

1. New scientific tools and techniques contribute to the advancement of science by providing new methods to gather and interpret data and can lead to new insights and questions. Technology can enhance the collection and analysis of data.
2. The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error.
3. Scientific optimism enables scientists to solve difficult problems over long periods of time.
4. Through science, humans seek to improve their understanding and explanations of the natural world. Individuals and teams from many nations and cultures have contributed to the field of science.

**NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:**
Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). *(Science and Engineering Practice: Engaging in Argument from Evidence)*

CONCEPTUAL TOOLS

## VOCABULARY DEVELOPMENT

**public service announcement**
(assumed prior knowledge)
an educational message created to raise awareness and change people's attitudes or behavior

## BACKGROUND INFORMATION

### *Cryptosporidium* Outbreak

The case of Skipton was based on a real outbreak caused by a microscopic parasite known as *Cryptosporidium* that occurred in Milwaukee, Wisconsin, in 1993. Between March and April 1993, approximately 403,000 people experienced symptoms of gastroenteritis including diarrhea, vomiting, and stomach pain. About 4,400 people were admitted to hospitals, and at least 69 people, most of whom were immunocompromised (had impaired immune systems), died. The cause of the outbreak was linked to the inefficiency of one of the two drinking water treatment plants drawing water from nearby Lake Michigan. Immediately before the outbreak, strong spring thunderstorms had increased the lake turbidity, causing an increase in the passage of particulates—including *Cryptosporidium*—through the water-treatment plant. As a result of such outbreaks, treatment plants now test for this and other microscopic parasites.

## MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- LIST OF GLOBAL WATER SOLUTIONS from Activity 8, Procedure Step 4
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- CLASS CONCEPT MAP FROM ACTIVITIES 1 AND 5 (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 10, Build Understanding item 3

FOR THE CLASS

- COMPUTERS WITH INTERNET ACCESS

FOR EACH STUDENT

- STUDENT SHEET 10.1 "Water Solutions and Key Concepts"
- STUDENT SHEET 10.2 "Research Notes for a PSA"
- STUDENT SHEET 10.3 "Evaluating Websites" (OPTIONAL)
- VISUAL AID 1.2 "Scoring Guide: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- MATERIALS REQUIRED FOR PSA

# TEACHING NOTES

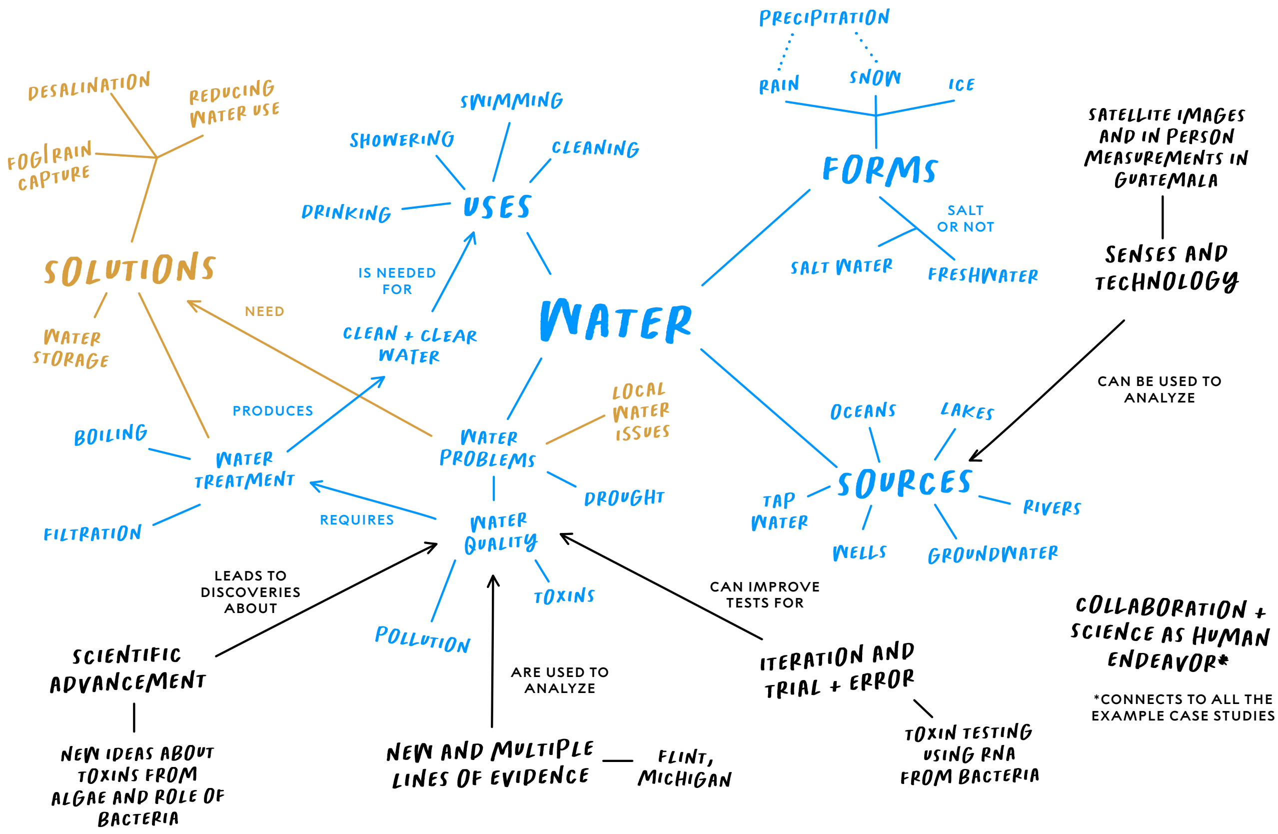
Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion** are highlighted in blue.

## GETTING STARTED (10 MIN)

1 **Revisit students' list of global water solutions from Activity 8.**

- Review the list of global water solutions students suggested in Activity 8, Procedure Step 4. Ask, Have you thought of any new ideas since you last brainstormed these ideas? Would you revise your ideas in any way? Inform students that they will have the opportunity to add to or revise their thinking in this activity.
- Either verbally summarize or read the introduction in the Student Book to highlight other recent innovations in the field of water quality and accessibility. You may wish to build on the class concept map created in Activities 1 and 5, either here or at the end of the activity. A sample concept map is provided here:



## PROCEDURE SUPPORT (90-120 MIN)

**2 The class brainstorms a list of the water issues raised in the unit.**

- Since this activity both provides an opportunity for students to express their own open-ended ideas and describes current work in the field, consider conducting the first part of the Procedure without the use of the Student Book.
- Work together to summarize a list of the water issues raised in the unit, such as :
  - water contamination by chemicals and organisms that live in water and can make people sick (*Cryptosporidium*, cholera, algae blooms)
  - increasing global water scarcity
  - uneven distribution of freshwater resources
  - any locally relevant water issues that have been raised over the course of the unit such as issues related to water contamination, disrupted water lines, drought, pollution of local lakes and rivers, and wastewater treatment
- Compare this list to the concept map created in Activity 1. Add new ideas from this list to the concept map.
- Discuss how student ideas have changed over the course of the unit and any new ideas and questions they may have about global water needs.
- Read the introduction in the Student Book. Students may be interested in knowing that some elements of the Skipton scenario are based on an actual outbreak of *Cryptosporidium* that occurred in the drinking water of Milwaukee, Wisconsin, in 1993. Prior to that outbreak, drinking water was not routinely tested for the presence of the *Cryptosporidium* parasite. As students have learned, drinking water is now tested for *Cryptosporidium*, and water quality standards have set a limit of 0.

**3 Student groups work together to brainstorm solutions to a specific water issue.**

- Student groups should select one of the water issues that were identified by the class and brainstorm solutions to addressing that specific issue. Encourage students to be as innovative as possible and not to be constrained by issues of cost, etc. Students can record their ideas in their science notebooks.
- Student groups should discuss the role of scientific tools and scientific optimism in their proposed solutions.

- You may wish to have students share their ideas with the class and to compare their ideas with their previously brainstormed list. For example, in Activity 8, one sample student idea was:

  *I would like to make something that could turn shower water into drinking water or water for plants. It is a waste for shower water to just go down the drain. It would need to be filtered to get all the soap and dirt out first.*

- Have students describe in what ways they revised their initial ideas. Ask, What solutions were particularly strong and were proposed both times? Have students share their thinking. Students may propose the same ideas and have suggestions for improvement, such as using a filter for cleaning the water.

**4 Students learn about eight current approaches to addressing global water needs.**

- The Student Book describes eight current approaches to addressing global water needs: water conservation, water storage, water transportation, water recycling, desalination, nature-based solutions, rainwater capture, and geological "paleo valleys."
- Assign each paragraph to one student group, give them 5–10 minutes to work, and have them create a quick summary of the information for the class, in their own words.
- Hand out Student Sheet 10.1, "Water Solutions and Key Concepts," which lists four of the key concepts from the unit. While listening to group summaries, have students mark which of these ideas are represented in each approach. While a sample student response is provided, there is not one correct response. Engage students in explaining their ideas.
- Students may note the obvious benefit of these solutions. They may also have questions or concerns about potential disadvantages or other impacts. Ask, What do you think are the disadvantages of any of these solutions? How do you think they could be overcome? For example, one disadvantage of water conservation is that it relies on individuals to change their behavior, which is not easy to do. Many local governments provide financial incentives and disincentives to push people to make changes more quickly.

**5 Students research global water issues for a particular region.**

- Students are asked to research water issues for a particular region. Hand out Student Sheet 10.2, "Research Notes for a PSA," as a place for students to record their research. A sample student response can be found at the end of this activity. Point out that students are expected to record their source of information as well as their notes. You may want to provide Student Sheet 10.3, "Evaluating Websites," as a guide to determining the reliability of websites, which is related to the conceptual tool of determining credible sources.
- Depending on your student population and available resources, this research task can be as open-ended or as constrained as you wish to make it. It is relatively easy to find out general information about drinking water sources and water issues for various countries and regions around

the world by simply performing an Internet search. If your students are having trouble choosing a location or you would like to make sure to have a variety of water issues and solutions represented in the research, consider making a list of locations, along with a couple suggested websites to start with, for students to choose from. The regions of the Middle East and North Africa are currently the worst off globally in terms of water stress, and solutions are not limited to increasing water quality or access. For example, the United Arab Emirates (UAE) imports nearly all its food as a way to bypass the need to use large amounts of water for local agriculture. Another suggestion is to have students focus on different water issues and solutions in your own region or country. For example, in the United States, different regions of the country experience different water challenges: The Southwestern United States is experiencing an extreme drought; parts of the Midwestern and Southern United States often experience flooding; and other regions, such as Newark, New Jersey, have aging drinking water infrastructure that affects clean water access.

- Students can begin by typing the country/region they are investigating, along with the phrases "primary source of drinking water" or "water issues" to find out where most people get their water and what the most pressing concerns are in that region.
- Students are likely to have the greatest challenge in identifying currently utilized solutions in each area. Students may want to use the phrase "water problems and solutions in . . ." to begin their research.
- Guide students to gather more detailed research on one currently utilized solution rather than creating a comprehensive list. This will be more useful in developing a PSA. Point out that students should focus on a solution they are interested in since they will be using their research to develop a PSA.
- If your students need more guidance, consider limiting the regions that they can research or selecting a local city or state to focus on. For countries with lots of available online data or geographically varied concerns, such as the United States or Brazil, it can be easier to focus on a particular region than the country as a whole.

6 **Students create a PSA for their country or region.**

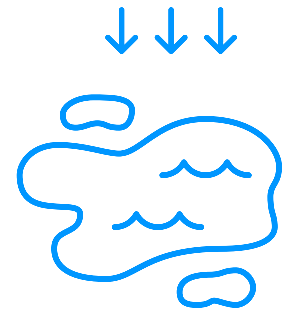
- Review the concept of a PSA. Students may have observed billboards that warn young people about the risks of smoking, seen magazine ads that recommend drinking milk, or watched short TV segments encouraging reading.
- Ask, What PSAs have you seen? What made that particular PSA memorable? Did it influence your behavior? Why or why not? Encourage students to reflect on the best elements of the PSAs they are familiar with in order to incorporate those elements into their own work.
- PSAs can take different forms, such as a print ad, an infographic, a TikTok video, a Twitter feed, an Instagram post, a YouTube video, a billboard, etc. Have students brainstorm different forms of a PSA. Decide which ones you would consider acceptable for the purposes of this assignment. If you do not want students to use a particular social media platform, consider having them design their PSA as a storyboard proposal for possible consideration by one of the platforms.

# DROUGHT AFFECTS US ALL

## WHAT'S THE PROBLEM?

**Water levels in Lake Arid have decreased by over 50% over the last 30 years.**

- 60% of our region's water supply comes from Lake Arid and the remainder relies on private ground wells.
- 10 of the last 16 years have had record levels of low rainfall.
- Over half of our local economy depends on water for agriculture and livestock capacity.
- Our region is in a state of "severe drought" (level D2) according to government agencies.



**If drought conditions continue...**
*current usage levels will raise water rates and we may need a new source for water.*

## WHAT CAN WE DO?

**Our city is currently investigating alternative water sources and water-saving initiatives:**

- *Damming the nearby Rolling River*
- *A water reclamation project to use recycled water for crop irrigation*
- *Water restrictions for lawns and other non-essential usage*

## GET INVOLVED!

Join city board meetings

Contract and join the local water council

Volunteer with others:
www.sourcewatercollaborative.org

## HOW CAN I HELP?

**Conservation of water**

- Check for leaks in toilets, faucets, and pipes
- Plant drought resistant plants
- Water lawns only when they need it
- Take short showers
- Don't leave water running
- Install low-flow high-efficiency toilets, Energy Star rated appliances for saving water

The average washing machine uses...
*41 gallons of water*

**TIPS**

- Always run a full load
- Use newer water-saving front-loaded machines

## SYNTHESIS OF IDEAS (30-40 MIN)

7 **Students present their PSAs to the class.**

- Review students' PSAs for accuracy and appropriateness before having them present to the class.
- Provide each student with a sticky note for each PSA being presented. Have them write one positive feedback comment to the presenting person or group. Distribute the notes to each presenter after first reviewing the notes.

8 **The class discusses decisions made in Activity 1 and elsewhere in the unit.**

- Ask, What questions do you still have about global water use? Students may be curious about specific technologies such as how saltwater can be treated to become freshwater, how changes in global climate patterns will affect water quality and availability in other parts of the world, and so on.
- Use Build Understanding items 2 and 3 to review some of the work done in the unit.
- Build Understanding item 5 provides an opportunity for metacognitive thinking. Point out this opportunity for student self-reflection.
- Ask, Has your understanding of science changed over the course of this unit? If so, how? If not, explain. Create a list of student responses. Students may identify the interaction of human senses and scientific tools and technology to gather evidence, the importance of evidence in informative scientific explanations, and the role that people play in the development of scientific ideas. Encourage students to identify new understandings that have been developed over the course of the unit.
- Discuss the Unit Guiding Question found at the beginning of the unit: How do people use evidence and iteration of ideas to construct scientific explanations that are relevant to everyday issues, such as water quality? Have students share their thinking about the relationship between scientific ideas—such as evidence, iteration, and explanation—to everyday life. Over the course of the unit, students have encountered many examples of the use of evidence and iteration in the development of explanations of water quality, such as with the fictional town of Skipton and the real-world case of Flint, Michigan.

## EXTENSION (10 MIN)

9 **Use the Extension as an opportunity for advanced learning.**

The development of new scientific ideas and innovations is ongoing. Students can do online research to find out the latest discoveries and inventions that address global water use. Alternatively, you may choose to do some additional research and present recent news to the class. Or print/link to a single recent news article or video that you would like students to read or watch.

# SAMPLE STUDENT RESPONSES

## BUILD UNDERSTANDING

1. **Consider which characteristics of your region informed your choice of water solutions.**

   a **What is one characteristic in this region that may change in the future due to climate or economic changes?**

   *Rainfall in this area may change over time.*

   b **If this change occurs, how would it affect your proposed solution?**

   *There would be less water conservation from water storage because less water could be collected from rainfall.*

   c **How could you modify your proposal to be prepared for this change?**

   *I could suggest increasing other water-conservation methods, such as reduced home water use, to balance the loss of water from rainfall.*

2. **You began this unit by making decisions about Skipton's water supply.**

   a **Based on what you know now, would you change your decision? Why or why not?**

   *Originally, I recommended that Skipton use water from Lake Timtim. I would change my decision to first try to reduce water use in the town. This reduction in water use could make it easier to meet the town's water needs.*

   b **Are there other decisions you made during this unit that you would change? Explain.**

   *I would keep my other decisions the same because they were informed by evidence, and I haven't found out anything else that would change my thinking.*

### ③ E&T Scoring Guide

**How do you think global water issues, such as water quality and water availability, should be addressed? Support your answer with multiple lines of evidence from this unit and identify the trade-offs of your decision.**

**Level 4 response**

*I think global water issues should be addressed in multiple ways. Water conservation, water storage, and water recycling, combined with thorough water quality testing, could help address water quality and water availability. Water quality tests such as pH and turbidity can help ensure that water is safe to drink. Reducing water use, storing rainwater, and recycling wastewater can increase the water available to a community. The trade-offs are that people will have to be more aware of their water use and change their water habits. This will take time, so change may be slow. People who disagree with my decision might say that this approach is too slow and other methods should be used.*

**Level 3 response**

*I think the global water issue of water availability should be addressed by using several methods. I think some of the best ways to do this are to reduce water use and to recycle wastewater. There are many easy ways to reduce water use, such as turning off the water when you brush your teeth and making sure leaks get fixed. Communities could also help with programs to teach people how to recycle wastewater in easy ways, like keeping a bucket in the shower to catch the water when you're waiting for it to warm up and using that water in the garden. The trade-off is that it is hard for people to change their habits so it might not be an easy or quick way to address water availability.*

**Level 2 response**

*I think the global water issue of water quality should be addressed by more water testing. Communities should test for things like pH and turbidity to make sure water is safe to drink. The trade-off is that these tests cost money.*

**Level 1 response**

*I think the global water issue of water quality should be addressed by more water testing because sometimes the water might not be good to drink.*

## CONNECTIONS TO EVERYDAY LIFE

④ **Many people think that advances in science and technology will eventually result in solutions to most global problems. Do you agree or disagree? Explain your ideas.**

*I agree that advances in science and technology will be able to help address many global problems, but not all. For example, science and technology may help find new solutions but cannot prevent the problem itself. Some parts of the world will have less water and may not be able to gather enough clean water for its entire population.*

⑤ **How can the concepts you learned in this unit be applied to your own life?**

*I am more aware of possible water quality issues in my own drinking water and my own water-use habits. I will probably waste less water and pay more attention to water availability and water quality in my community.*

### REFERENCES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STUDENT SHEET 10.1 | WATER SOLUTIONS AND KEY CONCEPTS | NAME

| SOME KEY CONCEPTS FROM UNIT 1 | A<br>water conservation | B<br>water storage | C<br>water transportation | D<br>water recycling | E<br>desalination | F<br>nature based | G<br>rainwater capture | H<br>paleo valleys |
|---|---|---|---|---|---|---|---|---|
| 1 New scientific tools and techniques contribute to the advancement of science. | | | | | | | | |
| 2 Individuals and teams from many nations and cultures have contributed to the field of science. | | | | | | | | |
| 3 Scientific optimism enables scientists and others to solve difficult problems over time. | | | | | | | | |
| 4 The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error. | | | | | | | | |

| SOME KEY CONCEPTS FROM UNIT 1 | A water conservation | B water storage | C water transportation | D water recycling | E desalination | F nature based | G rainwater capture | H paleo valleys |
|---|---|---|---|---|---|---|---|---|
| 1 New scientific tools and techniques contribute to the advancement of science. | X | X | | X | X | X | X | X |
| 2 Individuals and teams from many nations and cultures have contributed to the field of science. | | X | X | X | X | X | X | X |
| 3 Scientific optimism enables scientists and others to solve difficult problems over time. | | | | X | X | X | X | X |
| 4 The development of scientific knowledge is iterative; it occurs through the continual re-evaluation and revision of ideas that are informed by new evidence, improved methods of data collection and experimentation, collaboration with others, and trial and error. | | X | X | | X | | | X |

STUDENT SHEET 10.2 | RESEARCH NOTES FOR A PSA | NAME

| | RESEARCH NOTES | DATA SOURCE |
|---|---|---|
| Country (or geographic location) | | |
| Primary source of drinking water | | |
| Most pressing water issues facing this area | | |
| Currently utilized solutions to water issues facing this area | | |

**STUDENT SHEET 10.2** | **RESEARCH NOTES FOR A PSA** | **NAME** SAMPLE STUDENT RESPONSE

| | RESEARCH NOTES | DATA SOURCE |
|---|---|---|
| **Country (or geographic location)** | *United States* | |
| **Primary source of drinking water** | *85% of the population uses a municipal water supplier that sources surface water from rivers, lakes, reservoirs, or groundwater. Other 15% relies on private groundwater wells.* | *USGS* |
| **Most pressing water issues facing this area** | • *tap water is not reliably clean due to contamination, aging infrastructure, and less government oversight*<br>• *water scarcity particularly in Southwestern U.S.* | *Pulitzer Center*<br>*The Water Project* |
| **Currently utilized solutions to water issues facing this area** | • *water conservation*<br>• *financial incentives for agricultural uses to decrease contamination from runoff*<br>• *consolidation of small water systems*<br>• *educating the public and elected officials*<br>• *water reuse and reclamation for agricultural and industrial use*<br>• *collecting data about water contamination of public water supplies* | *Consumer Reports*<br>*USDA* |

**Website URL** ______

**Name of site/title** ______

**Who is the author?** ______

**What type of website is it (.gov, .edu, .com, .org)?** ______

**What date was the page published/last updated?** ______

**Who is the intended audience?** ______

**Purpose of the site (to inform, entertain, persuade)** ______

**Does the site provide facts, opinions, or both?** ______

**Evaluate the site for evidence of credibility**

(Is there a conflict of interest? Is it free of ideological bias? Is it politically neutral? Are sources acknowledged? Are the sources credible? This often requires looking for other sources that describe the site or its institutional context.)

**Evaluate the site for evidence of expertise**

(Does the author have appropriate credentials or relevant expertise? A track record of integrity? A strong reputation among peers? A reliable institutional context? Evaluating this may require looking at other sites.)

**Evaluate the site for the accuracy and reliability of its information**

(Check if you can find other credible sites that agree. Is there consensus among relevant scientific experts about this information? If not, what is agreed upon vs. what is the nature of the disagreement? What range of findings are scientifically plausible?)

**Is there any indication of bias? If so, what is the bias?**

 SAMPLE STUDENT RESPONSE

**Website URL** *https://thewaterproject.org/community/2021/07/16/facing-the-future-without-fear*

**Name of site/title** *The Water Project: Facing the future without fear*

**Who is the author?** *Tom Murphy*

**What type of website is it (.gov, .edu, .com, .org)?** *.org*

**What date was the page published/last updated?** *July 16th, 2021*

**Who is the intended audience?** *People who might donate to their nonprofit organization*

**Purpose of the site (to inform, entertain, persuade)** *To inform and persuade*

**Does the site provide facts, opinions, or both?** *Facts*

### Evaluate the site for evidence of credibility

(Is there a conflict of interest? Is it free of ideological bias? Is it politically neutral? Are sources acknowledged? Are the sources credible? This often requires looking for other sources that describe the site or its institutional context.)

*There is a small conflict of interest because the site describes a successful project they completed to encourage more people to donate to their charity. The source seems credible because it is a non-profit organization and other sources describe it as having a good charity rating. The site also includes photos documenting the project and links to more information about the project.*

### Evaluate the site for evidence of expertise

(Does the author have appropriate credentials or relevant expertise? A track record of integrity? A strong reputation among peers? A reliable institutional context? Evaluating this may require looking at other sites.)

*According to other websites, the author works for this organization, and designs and manages other similar projects in Kenya, Uganda, and Sierra Leone. He has first-hand experience. The site is an established non-profit, so it should be reliable.*

### Evaluate the site for the accuracy and reliability of its information

(Check if you can find other credible sites that agree. Is there consensus among relevant scientific experts about this information? If not, what is agreed upon vs. what is the nature of the disagreement? What range of findings are scientifically plausible?)

*Other sites support information in the story: typhoid can be common in Kenya, water capture tanks can be more reliable than shallow wells, and they can save time and resources for people who need water. But captured rainwater is not always safe to drink.*

### Is there any indication of bias? If so, what is the bias?

*Yes, because though they are a nonprofit, they want you to donate to their charity. They might be showing only the most successful projects to demonstrate how well they are addressing global water issues.*

**WHEN TO USE THIS SCORING GUIDE:**

This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue when arguments may include judgments based on nonscientific factors.

**WHAT TO LOOK FOR:**

- Response uses relevant evidence, concepts, and process skills to compare multiple options in order to make a choice.
- Response takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 4**<br>**Complete and correct** | The student provides a clear and relevant choice with appropriate and sufficient evidence, including BOTH of the following:<br>• a thorough description of the trade-offs of the decision<br>• reasons why an alternative choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their recommendation for addressing global water issues, including water quality and availability.<br>• a clear, thorough description of at least three distinct lines of evidence that are relevant to and support their position.<br>• a clear, thorough description of at least one appropriate trade-off. |
| **Level 3**<br>**Almost there** | The student provides a clear and relevant choice with appropriate and sufficient evidence, BUT one or both of the following are insufficient:<br>• the description of the trade-offs<br>• reasons why an alternate choice was rejected (if applicable) | **The student's response includes:**<br>• a clear description of their recommendation for addressing global water issues, including water quality and/or availability.<br>• a clear, thorough description of at least two distinct lines of evidence that are relevant to and support their position.<br>• at least one appropriate trade-off.<br>• descriptions of evidence and trade-offs may be unclear or insufficient. |

| LEVEL | GENERAL DESCRIPTION | ITEM-SPECIFIC DESCRIPTION |
|---|---|---|
| **Level 2**<br>**On the way** | The student provides a clear and relevant choice, BUT the evidence is incomplete. | **The student's response includes:**<br>• a clear description of their recommendation for addressing global water issues, including water quality and/or availability.<br>• a clear, thorough description of at least one line of evidence that is relevant to and supports their position<br>**And may include:**<br>• at least one trade-off<br>**However, evidence is less than three pieces and/or trade-off is missing or unclear.** |
| **Level 1**<br>**Getting started** | The student provides a clear and relevant choice BUT provides evidence that is subjective, inaccurate, or irrelevant. | **The student's response includes:**<br>• a clear description of their recommendation for addressing global water issues, including water quality and/or availability.<br>**However, evidence is subjective, inaccurate, or irrelevant and/or trade-off is missing or unclear.** |
| **Level 0** | The student's response is missing, illegible, or irrelevant. | |
| **X** | The student had no opportunity to respond. | |

## APPENDIX 1

# LITERACY STRATEGIES

Teaching **Scientific Thinking for All: A Toolkit** provides constant opportunities for students to improve their English language skills. For example, students are expected to read informational text and procedures, write clearly to respond to assessment items, and use oral language skills during discussions. Research-based support strategies are embedded throughout the activities to help students process new content, develop analytical skills, connect concepts, become more proficient readers, and express their knowledge.

The literacy strategies offered in the curriculum depend on the instructional needs of the activity in which they are embedded. Because a full explanation of each research-based strategy is not practical to provide in the Teaching Steps of the Teacher Edition, a more detailed description for each goal is described below.

### Eliciting Prior Knowledge

**Concept Map**
**Anticipation Guide**

### Processing Information

**Frayer Model**
**Venn Diagram**
**Word Sort**

### Reading Comprehension

**Annotation/Read, Think, and Take Note**
**DART (Directed Activity Related to Text)**

### Oral Discussion and Debate

**Walking Debate**
**Developing Communication Skills**

### Writing Support

**Writing Frame**
**Science Notebook**

## CONCEPT MAP

### What It Is

A concept map is a visual representation of the relationship between ideas and concepts. Concept maps ask students to make and describe relationships between main ideas and subtopics and among the subtopics themselves.

### Why Use It?

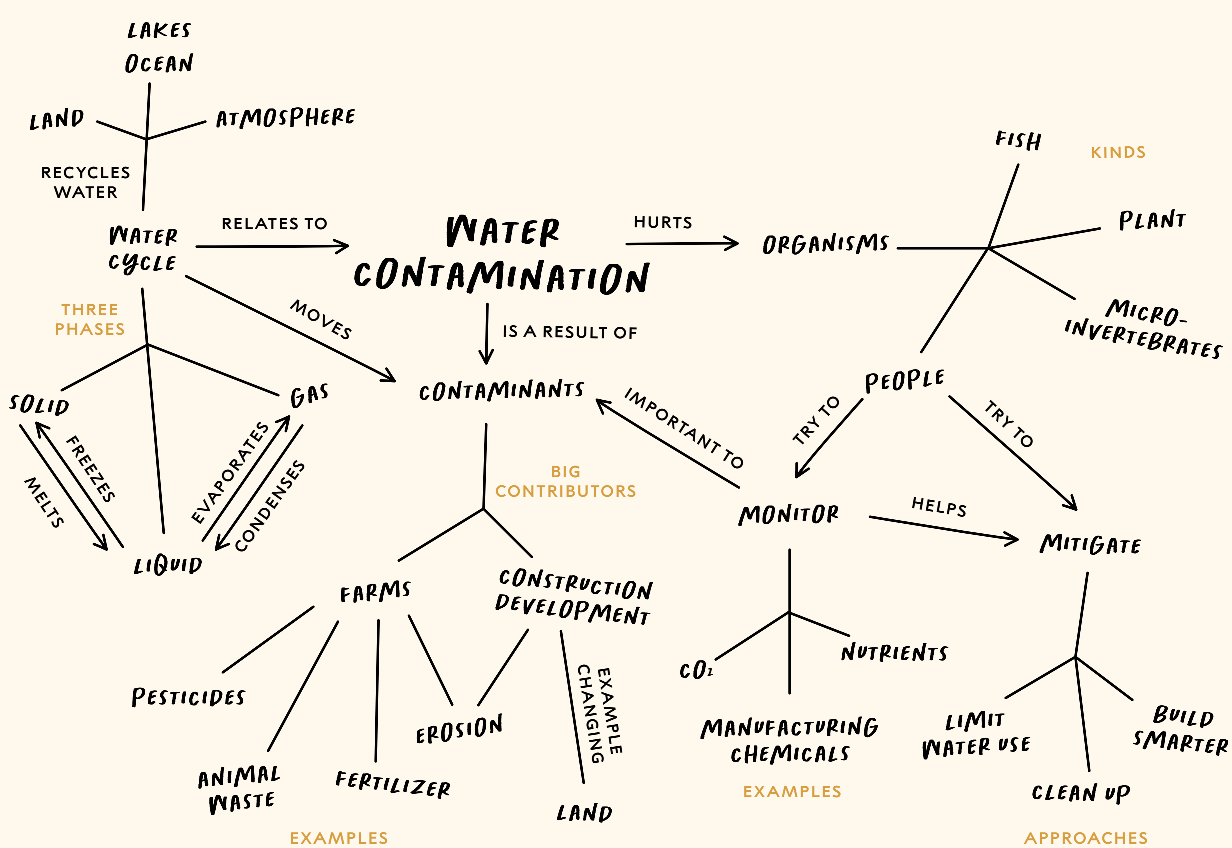
Concept maps demonstrate students' understanding of the connections between topics in a spatial manner. They also allow students to expand their knowledge related to a topic.

### How to Use It

The main concept is written in the center of a page (or on the board), and students place subtopics around it, connecting lines between each subtopic and the main concept. On or near each line they've drawn, students add a brief description of the relationship between the two words.

The following example is from a prompt in an Earth science unit where students are asked to draw a concept map for the earth processes of weathering, erosion, and deposition they are investigating in the unit.

Initially, students may find it helpful to have a list of words that must be included in the map or an incomplete concept map to fill in. Later, students might brainstorm words that should be included and make a list before beginning their concept maps. It may also be helpful to write each subtopic on an index card or sticky note so students can physically manipulate them and lay out the map.



If your students are unfamiliar with concept maps, model the process by using a familiar central idea, such as school. Write "school" on the board and with the class, brainstorm subtopics to place around it (i.e., What are words and ideas associated with school?). Off to the side, organize these subtopics in a hierarchy, listing the more general ideas first and the more specific ones toward the bottom. Arrange the ideas spatially on the map, with the more general ideas closer to the central topic and the more specific ideas radiating out from the general ideas. Link the general ideas to the central concept with ideas, words, or short sentences defining the connection between the concepts. Then add links explaining the connection between the general and more specific ideas.

### Where It Is

Concept maps are most often part of the Teaching Notes in the Teacher t; they may also be Build Understanding items in the Student Book. Instructions for constructing a concept map can be found in the Teacher Edition.

## ANTICIPATION GUIDE

### What It Is

An Anticipation Guide is a pre-reading exercise to help students activate their background knowledge about a topic and generate curiosity about the material they will learn. Students answer a set of prompts before reading; after reading, students discuss how their predictions compare with the information in the reading.

### Why Use It?

The value of an Anticipation Guide is in the discussion that occurs before and after the reading. Before reading, students discuss their predictions and the reasons for them. During this discussion, the teacher gleans information about the depth of students' existing knowledge and their misconceptions about a topic. The post-reading discussion on how students' answers have changed allows teachers to formatively assess what students gained from the reading.

### How to Use It

Students begin by individually responding to a series of statements related to the text they will read. They state whether they agree or disagree with a statement by marking it with a + (agree) or a – (disagree). The statements give students a sense of the key ideas in the reading and elicit their current ideas about and knowledge of the material. Students then discuss their predictions as a class. After completing the reading and participating in another discussion, students revisit the statements and record whether they now agree or disagree with each one. Their final task is to cite information from the reading to explain how the text either supported or changed their initial ideas.

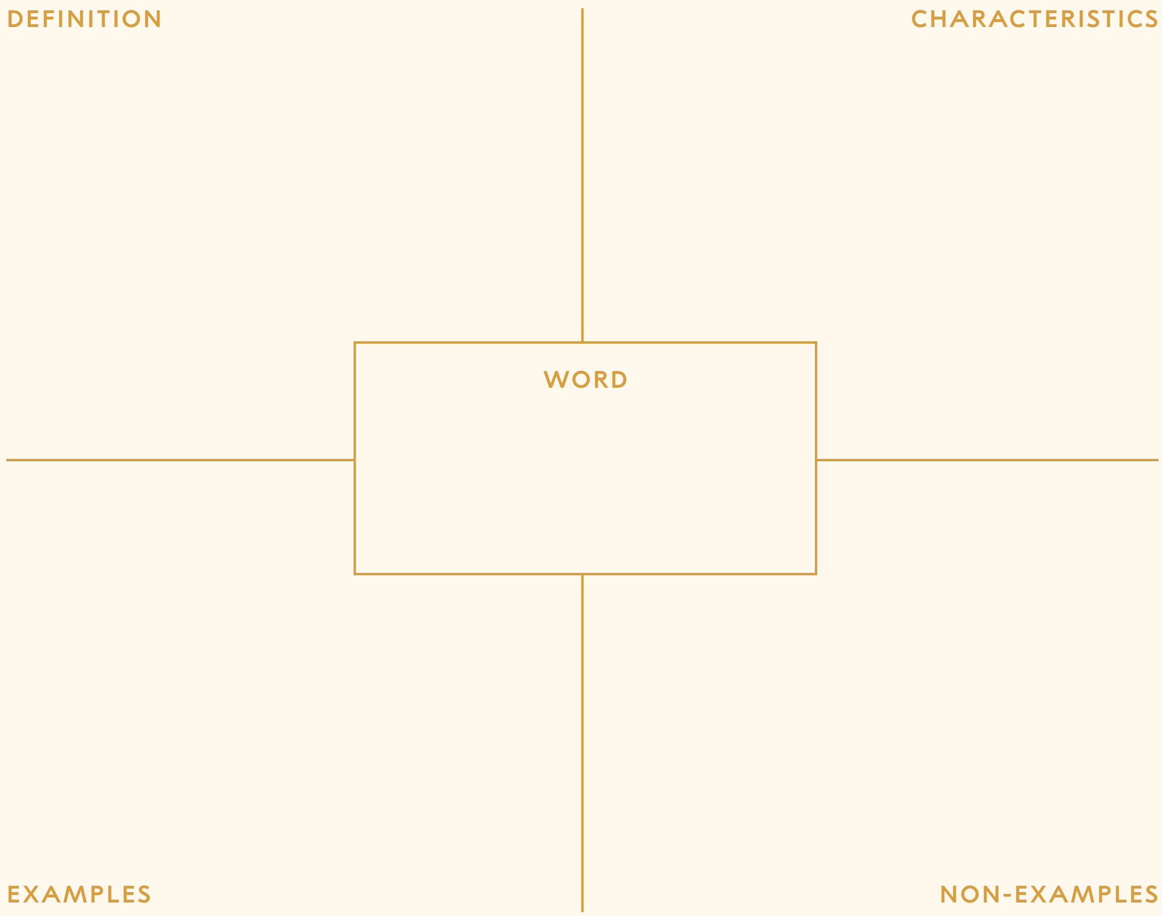
### Where It Is

The Anticipation Guide Student Sheet can be found in the Teacher Edition for the activities in which it is used. Sample student responses are also located in the Teacher Edition.

## FRAYER MODEL

### What It Is

The Frayer Model is a graphic organizer used in direct instruction of discipline-specific vocabulary. In a Frayer Model, students define a word and examine its characteristics and then offer examples and non-examples to build a deep conceptual understanding of the word.




### Why Use It?

The Frayer Model offers support as students examine the conceptual meaning of discipline-specific vocabulary. The Frayer Model supports the conceptual development of terms and concepts as they are introduced. Students can return to the Frayer Model as they continue to use the word throughout a course of learning to revise the model, based on their deepening understanding of the word.

### Where It Is

Frayer Models can be found as Build Understanding items in the Student Book and in the Teaching Notes in the Teacher Edition.

## VENN DIAGRAMS

### What It Is

A Venn diagram is a strategy for comparing the relationship between two ideas or concepts in a simple visual format. Students visually map the characteristics that are unique to a set of ideas or concepts and the characteristics that are shared.

### Why Use It?

By placing words on a page in relation to each other and then explaining their placement, students show that they understand the meaning of each word and the relationship between them. A Venn diagram can be used as a focus for a discussion or for a writing assignment that asks students to compare and contrast ideas. It can also be used as a formative assessment that probes students' understanding of a set of concepts.The simplicity and flexibility of setting up a Venn diagram makes it easily adaptable to many classroom situations.

### How to Use It

A Venn diagram involves drawing two to four overlapping circles, each labeled according to the subject being compared. In the outer part of each circle, students write the information that is unique to the subject of the circle. In the overlapping space, they write the elements common to both subjects. Students may complete Venn diagrams as a class, in groups, or individually.

### Where It Is

Venn diagrams can be found as Build Understanding items in the Student Book and in the Teaching Notes in the Teacher Edition.

## WORD SORT

### What It Is

A word sort is a categorization activity that helps students synthesize science concepts and vocabulary. Students classify words and phrases into categories based on the relationship between them.

### Why Use It?

Word sorts encourage students to accurately draw on what they've learned and to use logic to determine how different words and phrases are related. Teachers can use students' explanations as a formative assessment of how well they understand the overall concepts.

### How to Use It

Students are first asked to look for a relationship among a list of four or five words or phrases related to a topic and to cross out the one word or phrase that does not belong. Next, they are asked to circle any word or phrase that includes all the other words. (There may be more than one correct answer to a single word sort.) Finally, students must explain how the circled word or phrase is related to all the other words or phrases in the list.

### Where It Is

Word sorts can appear as Build Understanding items in the Student Book and in the Teaching Notes in the Teacher Edition.

## READ, THINK, AND TAKE NOTE

### What It Is

Read, Think, and Take Note is a strategy that helps students externalize their thinking by recording their thoughts, reactions, or questions on sticky notes as they read. The notes serve to make concrete the thoughts arising in students' minds and then serve as prompts to generate conversation or write explanations.

### Why Use It?

Asking students to record thoughts on sticky notes as they read helps with literacy development by providing a structure for students to record the thinking process. Students may later return to that record to clarify misconceptions or to add depth to their thoughts. The notes also provide a way for the teacher to see how students think as they read, enabling the teacher to select appropriate supports. For example, a student who is unsure of the meaning of a word benefits from the teacher's suggestion to look up the definition. Or, if a student has noted how a reading reminds them of an event from their own life, the teacher can note how making those connections helps with comprehension.

### How to Use It

Teachers can explain to students that as they follow this strategy, they are learning some ways that proficient readers think while reading. After reviewing the "Read, Think, and Take Note Reading Strategy" in the Student Book, teachers can then model the strategy, using a section of text from the Student Book. There are many ways to respond to text, and each student will create a unique set of comments. Teachers should emphasize that everyone is learning and has questions and that they should all be respectful of one another's ideas. One option is to conduct small-group discussions or a class discussion during which students can clarify any points of confusion, and the teacher can see how students are interpreting the reading.

### Where It Is

The Read, Think, and Take Note directions can be found in the Student Book.

## DIRECTED ACTIVITY RELATED TO TEXT

### What Is It?

A Directed Activity Related to Text (DART) supports reading comprehension and critical thinking by having students interact with and manipulate the information they are reading. Examples of DARTs are matching and labeling exercises, sequencing, grouping, predicting, and completing a diagram or table. DARTs that require higher-order processing include extracting information and placing it in tables and flowcharts.

### How to Use It

A DART must be prepared before students begin so that it can be tailored to a particular text. Students usually complete the DART after they finish the reading. To help students further engage with the content, they may discuss the DART in groups before completing it or complete it as a group.

### Where It Is

DARTs are usually found as Build Understanding items or as Student Sheets in the Teacher Edition for the activity in which they are used.

## WALKING DEBATE

### What It Is

A Walking Debate allows students to practice oral argumentation. The teacher designates specific locations around the classroom that represent differing perspectives on an issue. Students stand in the location that best represents their opinion regarding the issue. In turns, students argue for the merits of their perspective and support their arguments with evidence. As they hear others' arguments and evidence, students can opt to change their opinions and physically move to the area of the room that best represents what they now believe.

### Why Use It?

Walking Debates require students to physically engage in oral discourse in the classroom. By committing to a position, both literally and figuratively, Walking Debates support oral discourse that uses claims, evidence, and reasoning. Students' engagement in scientific argumentation is motivated by seeing the distribution of perspectives among their classmates. Research also suggests that the inclusion of movement in the activity provides sensory input to the brain that enhances learning.

### How to Use It

Begin by identifying the question or issue to be debated and designate different parts of the classroom as representing certain points of view. For example, for the question *Which vehicle do you think is safer, Vehicle 1 or Vehicle 2?*, one corner of the room could be designated as Vehicle 1 and a different corner designated as Vehicle 2.

Students walk to the corner that best represents their point of view and then talk within that group to come up with a convincing argument to bring people from the other area(s) to their own area. It is helpful to have students keep a record of the evidence they will consider for the Walking Debate, especially when they are new to the strategy. Teachers might also have students work in pairs to generate the evidence.

Each group makes its presentation, and students from the other group(s) may ask questions. When all groups have presented, students who change their minds move to the area that represents their final position.

### Where It Is

Walking Debates are usually identified in the Procedure steps in the Student Book. The corresponding Teacher Edition provides instructions on how to run the specific debate.

| COMMUNICATION | SENTENCE STARTERS |
|---|---|
| **to better understand** | One point that was not clear to me was . . .<br>Are you saying that . . . ?<br>Can you please clarify . . . ? |
| **to share an idea** | Another idea is to . . .<br>What if we tried . . . ?<br>I have an idea—we could try . . . |
| **to disagree** | I see your point, but what about . . . ?<br>Another way of looking at it is . . .<br>I'm still not convinced that . . . |
| **to challenge** | How did you reach the conclusion that . . . ?<br>Why do you think that . . . ?<br>How does it explain . . . ? |
| **to look for feedback** | What would help me improve . . .<br>Does it make sense, what I said about . . . ? |
| **to provide positive feedback** | One strength of your idea is . . .<br>Your idea is good because . . . |
| **to provide constructive feedback** | The argument would be stronger if . . .<br>Another way to do it would be . . .<br>What if you said it like this . . . ? |
| **to discuss information presented in text and graphics** | I'm not sure I completely understand this, but I think it may mean . . .<br>I know something about this from . . .<br>A question I have about this is . . .<br>If we look at the graphic, it shows . . . |

## DEVELOPING COMMUNICATION SKILLS

### What It Is

The Developing Communication Skills Visual Aid is a tool to help students effectively participate in class discussions. It promotes positive classroom discourse by suggesting how students might appropriately express disagreement, seek clarification, or build on one another's ideas.

### How to Use It

Suggestions are presented in the form of sentence starters that students can use to initiate a conversation and express their ideas. Teachers can gradually incorporate this strategy into group work by introducing one sentence starter at a time to elicit students' ideas.

### Where It Is

The Developing Communication Skills Visual Aid can be found in the Teacher Edition for the activities in which it is used, in Appendix E: Group Interactions in the Student Book, and under the Embedded Student Support Sheets tab of these Teacher Resources.

## WRITING FRAME

### What It Is

A Writing Frame creates an outline to guide student composition. It can be geared to a particular type of explanatory writing, such as arguments that depend on evidence. Through prompts that students briefly respond to in writing, the Writing Frame leads students to develop headings, sentences, and main content points.

### Why Use It?

Writing Frames are an excellent strategy to help students develop and organize their ideas prior to writing extended Analysis-item responses or completing a writing assignment. Writing Frames also support assessment of student work.

### How to Use It

Teachers first provide direct instruction on the appropriate type of Writing Frame and the components it includes. When introducing the Writing Frame, teachers instruct students on the components essential to the structure of the essay, including an opening sentence that states the decision or conclusion each student has come to, evidence that supports the decision or conclusion, and a discussion of the trade-offs associated with their conclusion.

### Where It Is

The Writing Frame Student Sheet can be found in the Teacher Edition for the activities in which it is used. Sample student responses are also located in the Teacher Edition.

## SCIENCE NOTEBOOK

### What It Is

The science notebook is an informal place for students to record their ideas and develop new constructs that aid in their sensemaking. In their notebooks, students bring together their ideas as they make sense of the unit issue and key concepts.

### Why Use It?

A science notebook allows students to authentically engage in the practices of science. It supports students' efforts to process ideas, ask questions, keep track of data during investigations, and build their scientific observation and writing skills. Students can also use the science notebook to keep complete records of their data and investigations.

### How to Use It

When introducing science notebooks, model how students should record information. The Keeping a Science Notebook Visual Aid has guidelines for how to keep good records, including the purpose, background, hypothesis, experimental design, data, and conclusion for an investigation.

### Where It Is

The Student Book regularly prompts students to use their science notebooks, particularly during Procedures. The Keeping a Science Notebook Visual Aid is included in the Teacher Edition to support the use of a notebook in class.

APPENDIX 2

# ASSESSMENT RESOURCE

The assessments provided in **Scientific Thinking for All: A Toolkit** are designed to be used as formative and summative assessment of students' progress. Assessments support classroom instruction while ensuring that students are provided with adequate opportunities to demonstrate their developing understanding of the content and receive feedback to further this learning process. Teachers can use this research-based approach to interpreting students' work to monitor and facilitate students' progress. The assessment approach for the course shifts the assessment of knowledge from **what students know to how they are able to apply what they know**. As such, students engage in the key concepts and process skills of the course as they analyze evidence and make decisions related to everyday issues.

Assessment tasks are embedded in **Scientific Thinking for All: A Toolkit** and are an integral part of the learning activities. Teachers can use these assessments to inform future instruction, with the aim of helping to enhance students' learning. This is done through the use of purposefully designed assessment variables, assessment items, and Scoring Guides, as shown in the following diagram and description of each component.

| ASSESSMENT VARIABLES<br>concepts and practices | ASSESSMENT ITEMS | SCORING GUIDES<br>general and item-specific rubrics |
| --- | --- | --- |
| Evidence and Trade-Offs E&T<br>Developing and Using Models MOD<br>Analyzing and Interpreting Data AID<br>Decision-Making DMK | → embedded in activities for each variable | → describe competency levels for each variable |

## ASSESSMENT VARIABLES

The assessment variables listed in the first box in the diagram are the key areas across which students are expected to progress throughout a unit or sequence of units. Each unit focuses on one of these variables as shown in the following table:

| UNIT | ASSESSMENT VARIABLE | DESCRIPTION |
|---|---|---|
| 1 **Scientific Tools and Evidence** | Evidence & Trade-offs | This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue where arguments may include judgments based on nonscientific factors. |
| 2 **Scientific Modeling** | Developing & Using Models | This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about scientific phenomena. |
| 3 **Systematic Scientific Investigations** | Analyzing Data | This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them. |
| 4 **Evaluating Data** | Analyzing Data | This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them. |
| 5 **Human Bias in Science** | Argumentation | This Scoring Guide is used when students are developing arguments about alternative explanations of scientific phenomena. |
| 6 **Making Group Decisions** | Decision-Making or Argumentation | This Scoring Guide is used when students are making a decision by integrating evidence, facts, and values. |

Within each unit, the focus should be on progress, and each student's goal should be to improve with each subsequent assessment in a unit. Across the units, the variables build upon each other as the course progresses. Over time, the progression of variables supports students' increasing sophistication in using the conceptual thinking tools of the course for decision-making in their everyday lives. For example, in Unit 1, students are assessed on their ability to use evidence to make a decision and identify simple trade-offs based on that decision. By unit 5, students' understanding of how evidence is used in claims has increased and they are expected to articulate their decision using more complex claims, evidence, and reasoning.

## ASSESSMENT ITEMS

Assessment items are questions, tasks, or prompts related to the assessment variables, which are designed to gather evidence about students' progress. They may take the form of a procedural step, a Build Understanding or Everyday Connection prompt that asks students to reflect on and then communicate about a new idea, analyze data from an experiment, model concepts and relationships, transfer their understanding to a novel context, or make predictions. For example, in Unit 6, students make a recommendation for a fictional community's energy generation system. After their group collectively comes up with a recommendation, each student is assessed on their individual response to a Build Understanding item that prompts students to describe in detail how they used facts and values to make a decision.

## SCORING GUIDES

*Scientific Thinking for All: A Toolkit* Scoring Guides directly correspond with each assessment variable and are used to interpret students' responses. Scoring Guides allow teachers and students to monitor students' growth and encourage their progression from novice to expert on each variable. The general Scoring Guides are formatted as holistic scoring guides. Additionally, all items designated as assessments within the curriculum also have a detailed Item-Specific Scoring Guides with criteria specific to that assessment item. A detailed Item-Specific Scoring Guides is provided for all items in the curriculum. These Item-Specific Scoring Guides can be found in the Teacher Edition for the activity in which a summative assessment appears.

**Students' responses are categorized into five competency levels:**

| | |
|---|---|
| **Level 4** | **Complete and correct** |
| **Level 3** | **Almost there** |
| **Level 2** | **On the way** |
| **Level 1** | **Getting started** |
| **Level 0** | **Missing or off task** |

To achieve a particular score level, a student's response must fulfill all the requirements of that level. A score of Level 4 indicates that the student has mastered the practice or concept. The Teacher Edition includes Level 1–4 student exemplar responses in the Teaching Steps or Sample Responses for each designated assessment item.

Note that while the Scoring Guides involve assigning numerical values from 0 to 4 to student work, these scores are not equivalent to a grading system. Rather, scores on assessment items are indicative of the level of performance demonstrated by the student on a specific task, evaluated through a clearly defined lens.They are meant to reflect levels of performance on individual tasks, whereas a grading system inevitably reflects the goals and desired outcomes of a district, school, and/or teacher.

## USING A SCORING GUIDE

Initially, it is not reasonable to expect students to perform at Levels 3 and 4. The targets for a score may vary over the course of a unit and a school year. Likewise, it is not always useful to use students' work to set the standards for each scoring level. For example, the best student response should not automatically be given a score of 4. The important thing is that both teacher and student understand what each various score represents, and that it can identify growth over multiple uses of the scoring guide. For most students, achieving consistent improvement of one level or more in an assessment variable over the course of a unit is an indicator of academic progress.

Before using a Scoring Guide, teachers must make sure that the criteria for each scoring level are clear to themselves and their students and that everyone understands the distinctions between levels. While the Item-Specific Scoring Guide is provided only for teacher use, as it can "give away" an appropriate response, students should be provided the general Scoring Guide in advance of an assessment item. They should be encouraged to refer to the Scoring Guide as they develop their response. This helps them develop the ability to evaluate their own work and take on more ownership of their learning.

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