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.

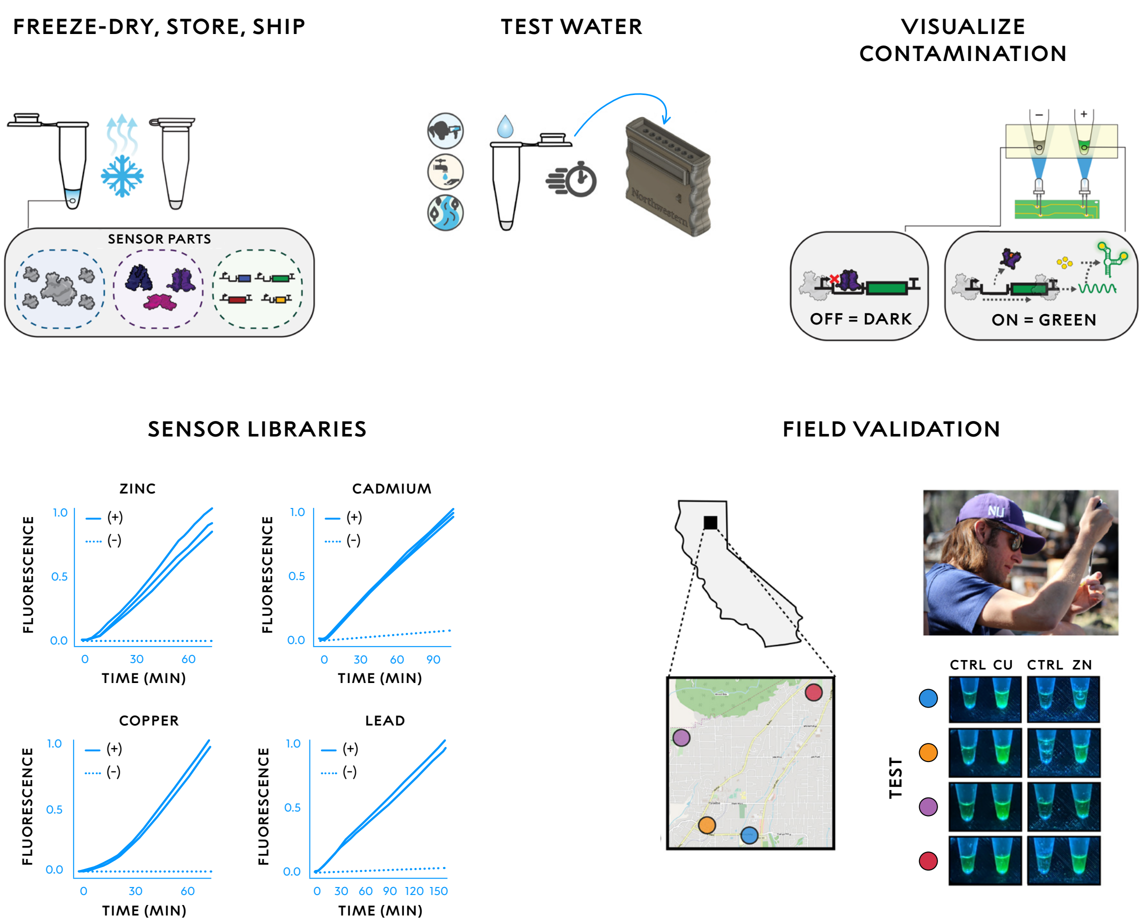
The Safe Drinking Water Act (SDWA), passed in 1974, requires the U.S. Environmental Protection Agency (EPA) to identify and regulate contaminants present in existing and future water systems to ensure water quality. States are expected to implement this law with EPA oversight. Until April 30, 2014, the 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.

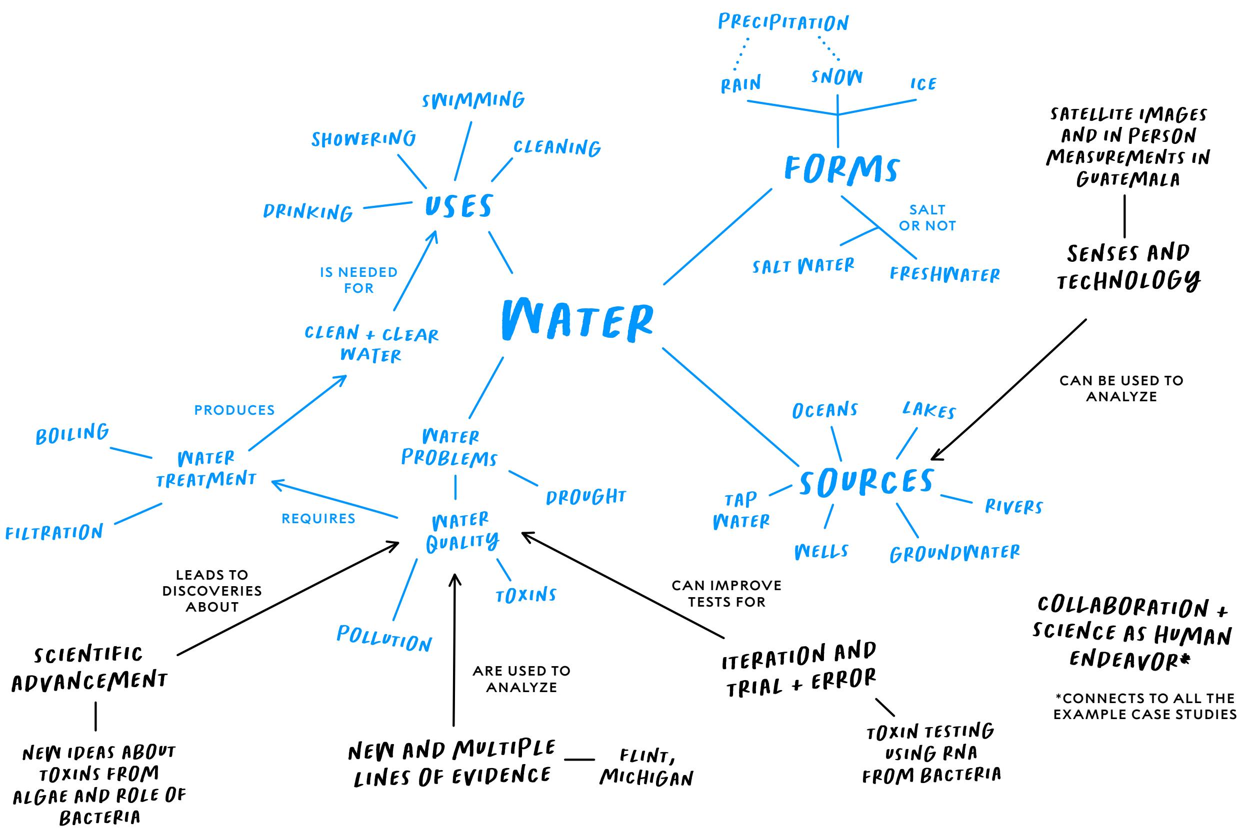
7 **Discuss how the ideas from the case studies relate to science as a human endeavor.**

- 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. *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. *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. *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. *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. *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. *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. *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. *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:*** *• residents' observations of water* *• high rates of lead in buildings and homes* *• Walters' son with lead poisoning* *• 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:*** *• Flores collected satellite data, which had limits* *• she went to Lake Atitlán to ensure data was correct* *• 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:*** *• initial design of water quality test to identify toxins, using others' research into RNA* *• Paradise, CA, tests had desiccant leak: packaging fixed* *• Kenya tests all positive; transport through UAE exposed them to high temperatures: keep cooler* *• revised to show how much toxin is in water* *• 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:*** *•research identified cause of shellfish poisoning as domoic acid produced by marine algae Pseudo-nitzschia* *•additional research identified environmental conditions for algal growth* *•Sison-Mangus research identified role of bacteria in production of toxin by Pseudo-nitzschia* *•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.