Smithsonian

SCIENCE
for the classroom

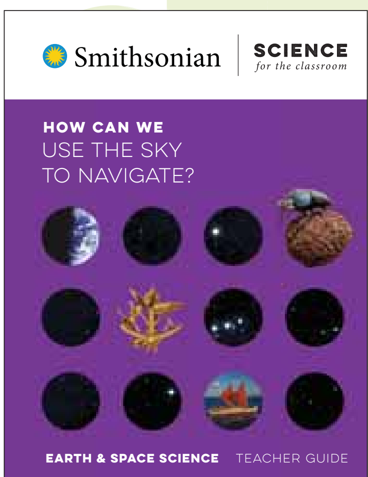
HOW CAN WE PROVIDE FRESHWATER TO THOSE IN NEED?

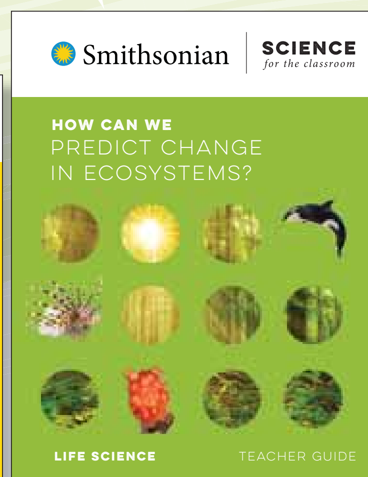
Overview and Lesson Sampler, Grade 5

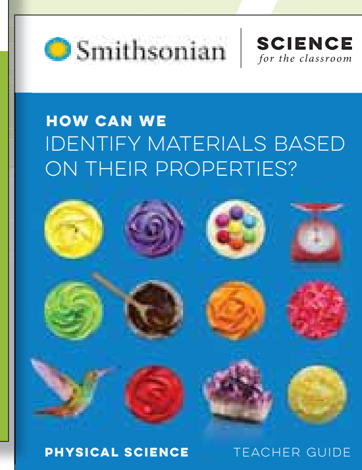
ENGINEERING

Smithsonian | SCIENCE for the classroom

INSIDE







Smithsonian Science for the Classroom, Grade 5

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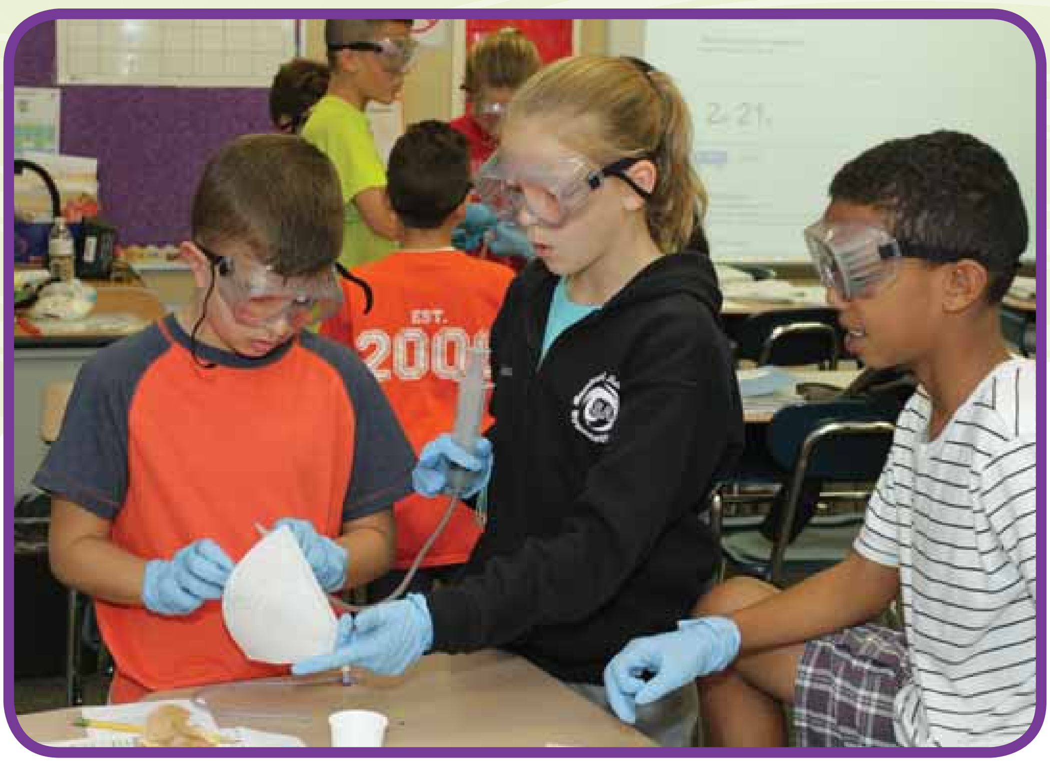
All New for NGSS—*Smithsonian Science for the Classroom*™ for Grades 1–5

For decades, the Smithsonian Science Education Center has been a leader in providing curriculum, professional development, and leadership development in support of inquiry-based science education. The release of the Next Generation Science Standards (NGSS) triggered key shifts in curriculum, instruction, and assessment.

The vision laid out by the NGSS explicitly requires performances that blend content, practices, and crosscutting concepts. The Smithsonian Science Education Center responded with a new generation of high-quality curriculum materials for Grades 1–5—*Smithsonian Science for the Classroom.*

Smithsonian Science for the Classroom **was developed to:**

- Meet the Next Generation Science Standards through intentional curriculum design
- Support for teachers as they learn to implement new standards
- Incorporate findings from education research on how students learn
- Center on coherent storylines that flow logically from lesson to lesson as students work toward explaining phenomena or designing solutions to problems
- Broaden access to world-class Smithsonian collections, experts, and resources
- Include instructional supports to ensure all students can meet the standards
- Seamlessly incorporate a comprehensive assessment system to monitor student progress



Smithsonian | SCIENCE for the classroom

Smithsonian Science for the Classroom Curriculum Framework—Designed for the Next Generation Science Standards

Module titles introduce phenomena or define problems

Life Science	Earth and Space Science	Physical Science	Engineering Design
Grade 1			
How Do Living Things Stay Safe and Grow? *1-LS1-1 • 1-LS1-2 • 1-LS3-1 • K-2-ETS1-1* **Supporting:** Engineering Design	**How Can We Predict When the Sky Will Be Dark?** *1-ESS1-1 • 1-ESS1-2 • 1-PS4-2* **Supporting:** Physical Science	**How Can We Light Our Way in the Dark?** *1-PS4-2 • 1-PS4-3 • 1-LS1-1 • K-2-ETS1-1* **Supporting:** Life Science and Engineering Design	**How Can We Send a Message Using Sound?** *K-2-ETS1-1 • K-2-ETS1-2 • K-2-ETS1-3 • 1-PS4-1 • 1-PS4-4* **Supporting:** Physical Science
Grade 2			
How Can We Find the Best Place for a Plant to Grow? *2-LS2-1 • 2-LS2-2 • 2-LS4-1 • K-2-ETS1-1* **Supporting:** Engineering Design	**What Can Maps Tell Us About Land and Water on Earth?** *2-ESS2-2 • 2-ESS2-3 • 2-PS1-1* **Supporting:** Physical Science	**How Can We Change Solids and Liquids?** *2-PS1-1 • 2-PS1-2 • 2-PS1-3 • 2-PS1-4 • K-2-ETS1-1* **Supporting:** Engineering Design	**How Can We Stop Soil From Washing Away?** *K-2-ETS1-1 • K-2-ETS1-2 • K-2-ETS1-3 • 2-ESS1-1 • 2-ESS2-1* **Supporting:** Earth and Space Science
Grade 3			
What Explains Similarities and Differences Between Organisms? *3-LS1-1 • 3-LS3-1 • 3-LS3-2 • 3-LS4-2 • 3-ESS2-2* **Supporting:** Earth and Space Science	**How Do Weather and Climate Affect Our Lives?** *3-ESS2-1 • 3-ESS2-2 • 3-ESS3-1 • 3-5-ETS1-1* **Supporting:** Engineering Design	**How Can We Predict Patterns of Motion?** *3-PS2-1 • 3-PS2-2 • 3-PS2-3 • 3-PS2-4 • 3-5-ETS1-1* **Supporting:** Engineering Design	**How Can We Protect Animals When Their Habitat Changes?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 3-LS2-1 • 3-LS4-1 • 3-LS4-3 • 3-LS4-4* **Supporting:** Life Science
Grade 4			
How Can Animals Use Their Senses to Communicate? *4-LS1-1 • 4-LS1-2 • 4-PS4-2 • 4-PS4-3 • 3-5-ETS1-1* **Supporting:** Physical Science and Engineering Design	**What Is Our Evidence That We Live on a Changing Earth?** *4-ESS1-1 • 4-ESS2-1 • 4-ESS2-2 • 4-ESS3-2 • 4-PS4-1 • 3-5-ETS1-1* **Supporting:** Engineering Design and Physical Science	**How Does Motion Energy Change in a Collision?** *4-PS3-1 • 4-PS3-2 • 4-PS3-3 • 4-LS1-1 • 3-5-ETS1-1* **Supporting:** Engineering Design and Life Science	**How Can We Provide Energy to People's Homes?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 4-PS3-2 • 4-PS3-4 • 4-ESS3-1* **Supporting:** Physical Science and Earth and Space Science
Grade 5			
How Can We Predict Change in Ecosystems? *5-LS1-1 • 5-LS2-1 • 5-PS1-1 • 5-PS3-1* **Supporting:** Physical Science	**How Can We Use the Sky to Navigate?** *5-ESS1-1 • 5-ESS1-2 • 5-PS2-1 • 3-5-ETS1-1* **Supporting:** Physical Science and Engineering Design	**How Can We Identify Materials Based on Their Properties?** *5-PS1-1 • 5-PS1-2 • 5-PS1-3 • 5-PS1-4 • 5-LS1-1* **Supporting:** Life Science	**How Can We Provide Freshwater to Those in Need?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 5-ESS2-1 • 5-ESS2-2 • 5-ESS3-1* **Supporting:** Earth and Space Science

Smithsonian Science for the Classroom Curriculum Overview

20 phenomena- and problem-based modules from the Smithsonian are setting the standard in 3D learning and 3D assessment

Coherent Storylines

- Coherent storylines build toward students answering a question or solving a problem
- Begin with the end in mind—students start with the big idea and then work progressively through tasks that build to a culminating science or design challenge

Teacher Support

- Investigations engage your students in 3D tasks and assessments
- Three-dimensional assessment system includes pre-assessment, formative assessment, student self-assessment, and a summative written assessment and performance assessment, accompanied by scoring rubrics
- From misconception support to ELL strategies, Teacher Guides provide everything you need to transition to NGSS and 3D instruction and assessment

Proven Results

- Research-based instruction proven to raise test scores in science, reading, and math
- Effective science and engineering instruction at every grade level
- Smithsonian Science Stories Literacy Series provides all students with access to the Smithsonian's research, scientists, and world-class collections while integrating science content and literacy

Provide Everything You Need to Meet the NGSS Standards

- Teacher support, step-by-step investigations, guiding questions, literacy, assessment, and hands-on materials

Bring the expertise of the Smithsonian's world-class collections, experts, and resources into your classroom.

Lesson design supports the NGSS teacher

Keep an Eye Out!

What to Look for in a *Smithsonian Science for the Classroom* Module:

Coherent Learning Progression

- Concepts and Practices Storyline shows how concepts build from one lesson to the next within the module using the 5-E model

NGSS Support at Point of Use

- Explanations at point of use explicitly define how students are engaging in the Science and Engineering Practices and Crosscutting Concepts

Literacy and Math

- ELA and Mathematics connections to Science overlap with student engagement in the science and Engineering Practices
- *Smithsonian Science Stories* On-Grade and Below-Grade Literacy Series
- STEM Notebooks

Misconception Identification

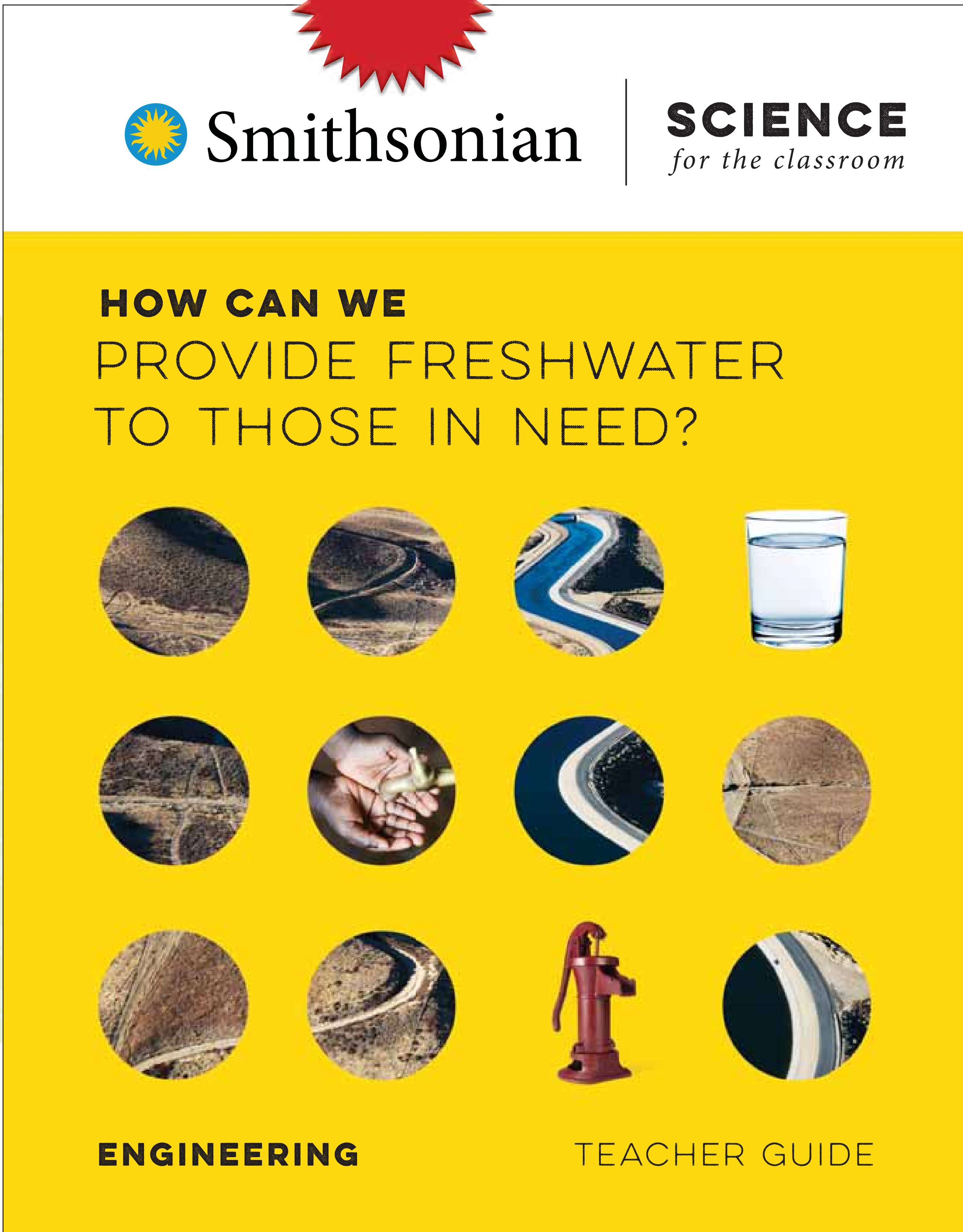
Good Thinking!

- Reveals common misconceptions students may have and offers ways to address them in the lessons

Technology Integration

- A balance between hands-on investigation and technology

Grade 5


Smithsonian
SCIENCE
for the classroom
HOW CAN WE
PROVIDE FRESHWATER
TO THOSE IN NEED?
ENGINEERING
TEACHER GUIDE

Summary

In this module, students will explore the topic of water scarcity and the various ways humans have attempted to get water to where it is needed. In the first focus question, students will collect evidence and experiences on their water footprints and on how little accessible freshwater actually exists. The culminating activity in the first focus question asks students to create a water scarcity–based public service announcement for a region in distress. The second focus question asks students to solve a water pumping challenge, develop models based on the interaction of Earth's four spheres, and then design a solution to a water pollution problem. In focus question three, students use a digital game and a newspaper activity to see how humans have tried to solve the global and regional problems of getting freshwater to where it's needed. The unintended consequences of our solutions are a point of emphasis in this focus question. In the final focus question, students engage in a two-part summative assessment. The written summative assessment complements the performance-based summative assessment and both focus on how key stakeholder groups must work together to design solutions to the water access, treatment, and allocation issues facing individuals and communities around the Earth.

Concepts and Practices Storyline

Focus Question 1: Where does the water you need come from?

1

Lesson 1: H_2GO

Accessing freshwater is a problem

Students define the problem of freshwater not being available where it is needed. Students design and test a system for moving water a short distance.

2

Lesson 2: Water Footprint

Human activities require freshwater

Students analyze and interpret data in order to construct explanations about how much water is required to produce different foods. Students learn how the food they eat, activities they participate in, and materials they use all affect their own water footprint.

3

Lesson 3: Our Water Picture

Freshwater is limited and not easily accessible

Students use a model to create a graph that shows how little freshwater is available compared to the large amount of water on Earth. Students define the problem of humans' need for freshwater and the limited amount of freshwater available.

4

Lesson 4: Water Scarcity Explored

Water scarcity is a global problem

Students analyze and interpret data showing the scale of the global water scarcity issue and communicate their findings in a public service announcement.

Focus Question 2: How have humans impacted the water we need?

Featured lesson

5

Lesson 5: Water Pump

Identifying failure points informs how to improve a design

Students consider the structure and function of various tools in order to design a solution for pumping groundwater to the surface. Students communicate possible solutions to failure points encountered during system testing.

6

Lesson 6: The Global Water Connection

Humans impact Earth's four spheres

Students evaluate informational text in order to communicate information with peers about a particular sphere of the Earth. Students explain how one component of the Earth system is affected by or affects humans.

7

Lesson 7: Water Web

Earth's four spheres interact

Students develop a model by connecting the components of Earth's four spheres. Students use that model to make predictions about the effects of possible future events.

8

Lesson 8: Clean the Water—Design It

Human activities impact groundwater

Students develop a model to show how human activities interact with components of the Earth system to cause groundwater pollution. Students design a solution to a water pollution problem.

9

Lesson 9: Clean the Water—Test It

Design solutions should be compared based on how well they meet the criteria

After testing water treatment systems, students analyze and interpret quantitative data in order to compare different design solutions. Students use evidence to construct an explanation about which solution best meets different criteria.

Focus Question 3: How have humans tried to solve the problem of getting freshwater to where it's needed?

10

Lesson 10: Aquation

Human activities impact water availability and distribution

Groups of students use a model simulation to define the problem and design a solution to the water scarcity and water equity problem using existing technologies.

11

Lesson 11: Unintended Consequences—Read All About It!

Human activities can have unintended consequences

Students obtain and evaluate information from two different perspectives on the cause and effects of the Aral Sea environmental crisis.

12

Lesson 12: Unintended Consequences—Write All About It!

Human activities can have unintended consequences

Groups of students evaluate and communicate information on the cause and effects of the Aral Sea environmental crisis by writing a newspaper article.

Focus Question 4: How can we provide freshwater to agriculture, industry, the environment, and housing in your town?

13

Lesson 13: Water Ready?

Earth's four spheres interact

Students prepare for a design challenge by developing and using models to show the interactions of groundwater with other components of the Earth system. Students communicate a strategy to preserve water to a specific stakeholder.

Every module ends with a performance task

Design Challenge

14

Lesson 14: Get It, Treat It, Share It Part 1

Communication with peers is an important part of the design process

Groups of students evaluate information about a specific town in order to design a solution for accessing and treating water that meets specified criteria and constraints. Students analyze and interpret data to figure out effects of design choices in previous testing.

15

Lesson 15: Get It, Treat It, Share It Part 2

Identifying failure point informs how to improve a design

Groups of students carry out a live system test and analyze and interpret their findings. Groups communicate failure points that affected the overall system and a possible solution to that failure point.

Focus Question 2: How have humans impacted the water we need?

LESSON 5: **WATER PUMP**

Daily NGSS support

	Student Objectives	Misconceptions	Disciplinary Core Ideas
E **Engage** **Explore** **Class Periods: 2** **Preparation time:** 20 minutes **Vocabulary:** control failure point fair test	Consider the structure and function of various tools in order to design a system for pumping water vertically. Communicate possible solutions to failure points encountered during system testing in order to inform improvements to the original design. Evaluate whether all but one variable was controlled during two separate designs tests such that the two tests can be considered a fair test.	Impulse designing (grabbing materials and building/trial and error) is a good way for students to understand the pros and cons to their designs.	**ETS1.A:** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. **ETS1.B:** Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.

Good Thinking! videos for misconception support @ ScienceEducation.si.edu/goodthinking

50 How Can We Provide Freshwater to Those in Need?

5

Science and Engineering Practices*	Crosscutting Concepts*	ELA and Math Connections	Extension(s)
Obtaining, evaluating, and communicating information **Designing solutions**	**Cause and effect** **Structure and function** **Systems and system models**	**Speaking and listening** Comprehension and collaboration (SL.5.1) Presentation of knowledge and ideas (SL.5.4)	**Community and Home: Opportunity Knocks** Create an acrostic poem portraying failure points as opportunties for improvement.

Daily ELA and math support

* Science and Engineering Practices and Crosscutting Concepts that are assessed in the lesson are in bold.

Lesson Planner 51

Teacher notes:

Designing and evaluating solutions

5

Focus Question:
How have humans impacted the water we need?

Class periods: 2

LESSON 5: **WATER PUMP**

Objectives

- **Explore the structure and function of various tools in order to design a system for pumping water vertically.**
- **Communicate possible solutions to failure points encountered during system testing in order to inform improvements to the original design.**
- **Evaluate whether all but one variable was controlled during two separate designs tests such that the two tests can be considered a fair test.**

E Engage Explore

Vocabulary

control
failure point
fair test

5

Lesson Background Information

Engineers solve problems. How humans can access water that is stored underground is a problem. Engineers define the criteria and constraints of a problem before designing a solution. Then they test to see how well their solution meets the criteria and constraints. During testing, engineers identify potential failure points that may negatively impact the results of the test. Engineers use a fair test to test solutions to a failure point. A fair test isolates one variable to test the effect of changing it and controls (keep the same) all the other variables as best as possible. By conducting a fair test, engineers can determine that one aspect of their design is better because all the other variables have been controlled.

Figure 5.1 There are different tools people use to move water.

In this lesson, students simulate pumping groundwater to the surface by designing a water pump to move water from the floor to their desktop. After testing their design, students identify failure points in their system. Students discuss the failure point they encountered and possible solutions. Students re-design their water pump to fix the failure point(s) in the first test then test their updated water pump. Students compare their first and second test to determine whether the two tests can be considered a fair test.

Materials

For the teacher

- Timer or clock with a second hand*
- 1 Computer or tablet with Internet access*

For each student

- STEM notebook*
- 1 Lesson 5 Notebook Sheet A
- 1 Lesson 5 Notebook Sheet B

For each group of four students

- Student Activity Guide
- 2 Beakers, 1,000 mL
- 5 Lengths of airline tubing, 30 cm (12 in)
- 1 Plastic syringe, 60 mL
- 4 Connectors
- 1 Three-way valve
- 1 Graduated cylinder, 100 mL

For the class

- Scientists and Engineers in Our Classroom Poster
- Large rubber bands
- Small rubber bands
- Paper clips*
- Tape*
- Water*
- Paper towels*

*needed but not supplied

5

Preparation

1. Write the focus question and lesson title on the board.
2. Make sure the Scientists and Engineers in our Classroom poster is visible to the whole class, and write the following roles on the board: Manager, Organizer, Tester, Speaker.

3. Set up the following materials for each group:
   - 2 Beakers, 1,000 mL
   - 5 Lengths of airline tubing, 30 cm (12 in)
   - 1 Plastic syringe, 60 mL
   - 4 Connectors
   - 1 Three-way valve
   - 1 Graduated cylinder, 100 mL
   - Water

Figure 5.2 Materials for each group

4. Make a copy of Lesson 5 Notebook Sheet A and Lesson 5 Notebook Sheet B for each student.
5. Draw the following T-chart on the board.

Failure points	Solutions to failure points

Figure 5.3 Failure points and solutions T-chart

6. Navigate to **ScienceEducation.si.edu/water/**.

Procedure

Getting Started

1. Now that we know where our water comes from, let's take a look at how humans impact these water resources.
2. Remind students that groundwater represents the highest percentage of Earth's freshwater not locked up in our glaciers. Discuss with students how they think we get that groundwater to the surface of the Earth.
   - **How do you think humans can get groundwater to the surface of the Earth?**
     (I think people can dig holes.)
   - **If the water is really deep under the surface, how can we get it? Think about the activity we did during the first lesson.**
     (Build pipes and use a pump to pull or push the water through pipes.)

5

3. Explain to students that during this lesson they will design a solution to accessing groundwater by using the same materials we used in the Lesson 1 H_2GO activity. But this time, students will have to move water up.

Activity

1. Hand out the Student Activity Guide and ask students to turn to Lesson 5. Hand out the Lesson 5 Notebook Sheet A to each student.
2. Divide students into groups of four. Direct students to look at the Scientists and Engineers in Our Classroom Poster. Assign students to one of the following roles:
   - **Materials Manager**: collects materials from materials center, cleans up materials, and puts them away neatly
   - **Organizer**: makes sure members are participating and that the group is on schedule
   - **Tester**: takes the lead on testing solutions
   - **Speaker**: shares out ideas to the whole class when asked
3. Navigate to **ScienceEducation.si.edu/water/**. Open the Water Pump Criteria and Constraints file. Read criteria and constraints out loud and ask students if they have questions.

Diverse learner support

ELL strategy
It may be helpful to ask English Language Learners to discuss the goals of the activity with a peer and rewrite the goals in their own words (10).

4. Show students where materials are located at the materials center. Have students proceed with steps 1–4 in their Student Activity Guide (collect materials, discuss materials, build a design, test the design with air, sketch the design on the notebook sheet). Circulate around the room to make sure that students understand how the three-way valve works.

Figure 5.4 Three-way valve screwed into the syringe

Teacher tip

Tell students to look carefully at the three-way valve to figure out how it works. Point out that the white switch has a word on it.

Teacher tip

If students don't notice that the syringe screws into the three-way valve, point out the spiral pattern on the end of each piece.

Misconception support

Good Thinking!

Misconception

Many students consider conducting spontaneous trial-and-error testing as a good way to identify the strengths and weaknesses of a design (6). Help students see the value of observing materials carefully instead, in order to plan a successful design.

Comprehension and collaboration

Structure and function

Students carefully observe the structure of the three-way valve in order to determine how it will function in the water pump system.

5

5. Once students have sketched their design, ask students to complete step 5 in their Student Activity Guide (fill bottom beaker with 400 mL of water).
6. Use a stop watch or second hand of a clock to time students as the Tester takes the lead on pumping water for 2 minutes.
7. Ask students to complete steps 6–7 in the Student Activity Guide (record amount of water moved and identify difficulties).
8. Ask the Speaker from each group to share how much water they were able to move and one difficulty that they had. Point out that these difficulties can also be described as failure points. Failure points are elements of a design that surface during testing that can be addressed to optimize (or improve) the design. Write the failure points on the T-chart on the board. The first column of the T-chart in Figure 5.5 shows possible failure points.

Tech tip

Project an online timer in the front of the room.

Teacher tip

Remind students that if they pump more than 100 mL of water, they will need to fill the graduated cylinder more than once.

Scale, proportion, and quantity

Students measure the amount of water moved using a graduated cylinder.

Obtaining, evaluating, and communicating information

5

Students share their test results as well as their failure points.

Suggested class period break

Comprehension and collaboration

9. Tell students they will have a chance to modify their design and try it again. Students can use rubber bands, paper clips, and/or tape to help with their design. Place these materials at the materials center. Ask students to complete step 8-9 in the Student Activity Guide. (Discuss how to modify design, get additional materials, build revised design, and test it with air).

Point-of-use teacher support

126 How Can We Provide Freshwater to Those in Need?

10. After students have had a chance to discuss some solutions and test some solutions with air, bring the class together for a discussion about solutions to common failure points. Ask them to provide evidence supporting their solutions and how they think the change will impact their overall system. Document shared solutions to the failure points on the T-chart. The left column of Figure 5.5 shows possible solutions to failure points. Figures 5.6, 5.7, 5.8, 5.9, and 5.10 illustrate possible solutions.

- **Does anyone have any solutions to these failure points?**
  (We are going to put our 3-way valve directly in the beaker of water on the floor and only connect a length of airline tubing leading out of the three-way valve.)
- **What evidence do you have that this might work?**
  (It looks like water can go straight into the part of the three-way valve that was previously connected to the connector.)
- **How do you think that change will affect your design on your next test?**
  (The connection between the three-way valve and the connector did not stay together well. If we remove that connection, we should have a better system.)

Failure Points	Possible Solutions
Syringe does not fill with water	Syringe is not screwed into three-way valve (see Figure 5.4)
Leaking between three-way valve and connector	Use a paper clip and two small rubber bands to secure it (see Figures 5.6 and 5.7)
Connector and three-way valve came apart	Remove connector from three-way valve and place the three-way valve directly into the beaker of water on the floor (see Figures 5.8 and 5.9)
Airline tubing in the bottom beaker does not stay underwater	Use a large rubber band to secure it (see Figure 5.10)
Airline tubing in the top beaker falls out	Use a large rubber band to secure it (see Figure 5.10)

Figure 5.5 The T-chart shows possible failure points and possible solutions.

Presentation of knowledge and ideas

Cause and effect

Students should interpret a direct cause-and-effect relationship between their solution to a failure point and the overall output of the system.

Systems and system models

Students talk about how correcting for a single failure point, such as a bad connection between lengths of airline tubing or a better way of using the three-way valve, can have an impact on the productivity of their entire design.

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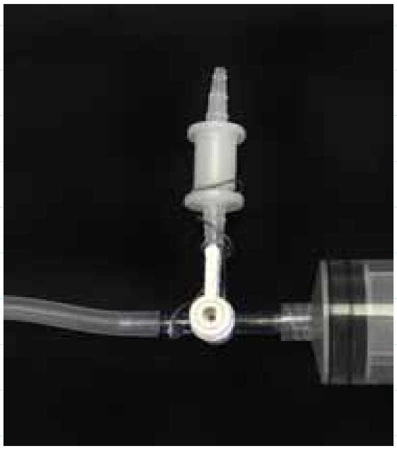


Figure 5.6 A paper clip can hold the connector to the syringe.

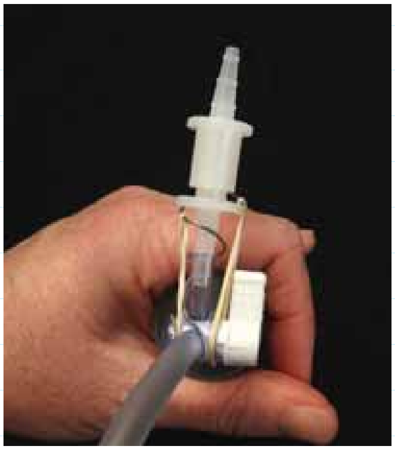


Figure 5.7 Small rubber bands and paper clip hold the connector to the syringe.

5

Figure 5.8 Water can go directly into the three-way valve without connecting it to a length of airline tubing.

Figure 5.9 The three-way valve can be placed directly into the beaker of water.

Figure 5.10 A large rubber band secures the airline tubing to a beaker.

11. Hand out Lesson 5 Notebook Sheet B. Have students finish step 9 in the Student Activity Guide (continue to modify design) and then complete step 10. (Write changes on notebook sheet.)

12. Once students have recorded how they have modified their design, ask students to complete step 11 in their Student Activity Guide (fill bottom beaker with 400 mL of water).

Designing solutions

Students use evidence from their own group's first test as well as their classmates' first tests to inform design changes.

5

13. Use a stop watch or second hand of a clock to time students as the Tester takes the lead on pumping water for 2 minutes.

14. Direct students to complete steps 12 and 13 in their Student Activity Guide (record results and identify one difficulty).

Bringing It All Together

Engineering, technology, and applications of science

Students learn that one of the ways engineers can improve a design is by working together to identify and decrease known risks, also known as failure points, during testing and redesign.

5

1. Ask the class how they would define the term "failure point" and why it is important to identify failure points before and during testing.

   - **How would you define failure point?**
     (Failure points are parts of something that you think might not work well or that need to be fixed to make the whole thing work better.)

   - **Why do you think they are important to identify during testing?**
     (They are useful to identify because it helps to break up big problems into smaller problems that are easier to fix.)

2. Ask students to articulate the importance of sharing ideas or suggestions on designs or failure points before and during testing.

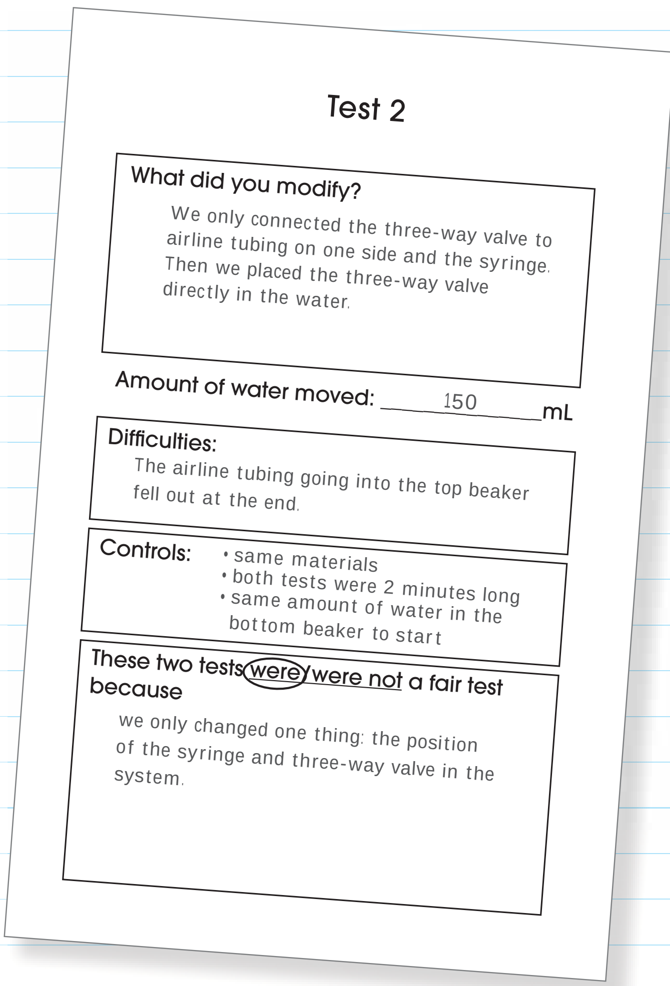
   - **Can you see a benefit to sharing ideas or suggestions before and during testing?**
     (Yes, the ideas from someone else can be helpful because sometimes they see a problem we didn't see when we came up with our design.)

3. Write the words "fair test" on the board. Engineers use a fair test to solve problems to failure points. During a fair test, engineers try something two different ways, but keep everything else the same. If the problem is solved, you know it was the one thing that changed that solved the problem.

   - **What problems might arise if you change many things during an experiment?**
     (I think the main problem would be if it works you won't know what change actually helped the most.)

4. During a fair test, everything that is the same is called a control. Ask students to list what was controlled between test 1 and test 2 on their Notebook Sheet.

5. Ask students to determine if the two tests they completed can be considered a fair test and write an explanation on their notebook sheet. To help students determine if their two tests were a fair test, ask them if they changed one thing between the two tests (fair test) or more than one thing (not a fair test). It's okay if their two tests were not a fair test.



Test 2

What did you modify?

We only connected the three-way valve to airline tubing on one side and the syringe. Then we placed the three-way valve directly in the water.

Amount of water moved: 150 mL

Difficulties:

The airline tubing going into the top beaker fell out at the end.

Controls:

- same materials
- both tests were 2 minutes long
- same amount of water in the bottom beaker to start

These two tests were/were not a fair test because

we only changed one thing: the position of the syringe and three-way valve in the system.

Figure 5.11 Possible answers to Lesson 5 Notebook Sheet B

5

Assessment tools aligned to the three dimensions of NGSS

Assessment

Formative Assessment

Use this table to provide timely, actionable feedback for individual students on their successes and areas for improvement, as well as plan any necessary whole-class remediation. Revisit the Common Misconceptions table in the module overview to familiarize yourself with other possible difficulties.

5

Assessed Task Activity: Steps 3–12 (Discussion and STEM notebook)		
Concepts and Practices	***Indicators of Success***	***Indicators of Difficulty***
Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.	¨ Students observe and discuss how the three-way valve works before figuring out how to incorporate it into the solution. Students use data from the first test in order to inform design changes.	¨ Students make design decisions without considering evidence from the first test.
At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.	¨ Students share proposed solutions to failure points. Students apply ideas heard during class discussion to inform design changes.	¨ Students do not share proposed solutions to failure points and do not apply ideas heard in class to inform design changes.
Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.	¨ Students identify and share failure points with the class.	¨ Students do not identify or share failure points in their design with the class.

Designing solutions	¨ Students use evidence from the first test to redesign a solution to the problem of moving water from the floor to the desk.	¨ Students do not use evidence from the first test while redesigning their solution to the problem of moving water from the floor to the desk.
Structure and function	¨ Students observe the structure of the three-way valve in order to determine its function.	¨ Students do not figure out the function of the three-way valve.
System and system models	¨ Students discuss how changing one failure point will impact the entire system.	¨ Students suggest the only way to change the entire system is to change every aspect of the system.
Cause and effect	¨ Students identify a direct cause-and-effect relationship between their improvement and overall output of the system.	¨ Students do not identify a direct cause-and-effect relationship between their improvement and overall output of the system.

5

Differentiated learning

Remediation

Give students the Lesson 1 challenge of moving water horizontally, except this time only allow students to move the syringe and the three-way valve. The challenge will be easier than moving water vertically, but will require students to figure out how the three-way valve works. To help students understand the function of the three-way valve, ask students why they think the white switch is labeled “Off.” Ask students why they think the switch can move.

Enrichment

Give students the challenge of pumping water from the ground to the top of a 2-meter (7-foot) bookshelf or from the bottom to the top of a 3-meter (10-foot) stairwell. Have students complete a fair test to see if they can pump more water with the pump near the source of the water or near the destination.

Extension

Community and Home: Opportunity Knocks

Materials

For each student

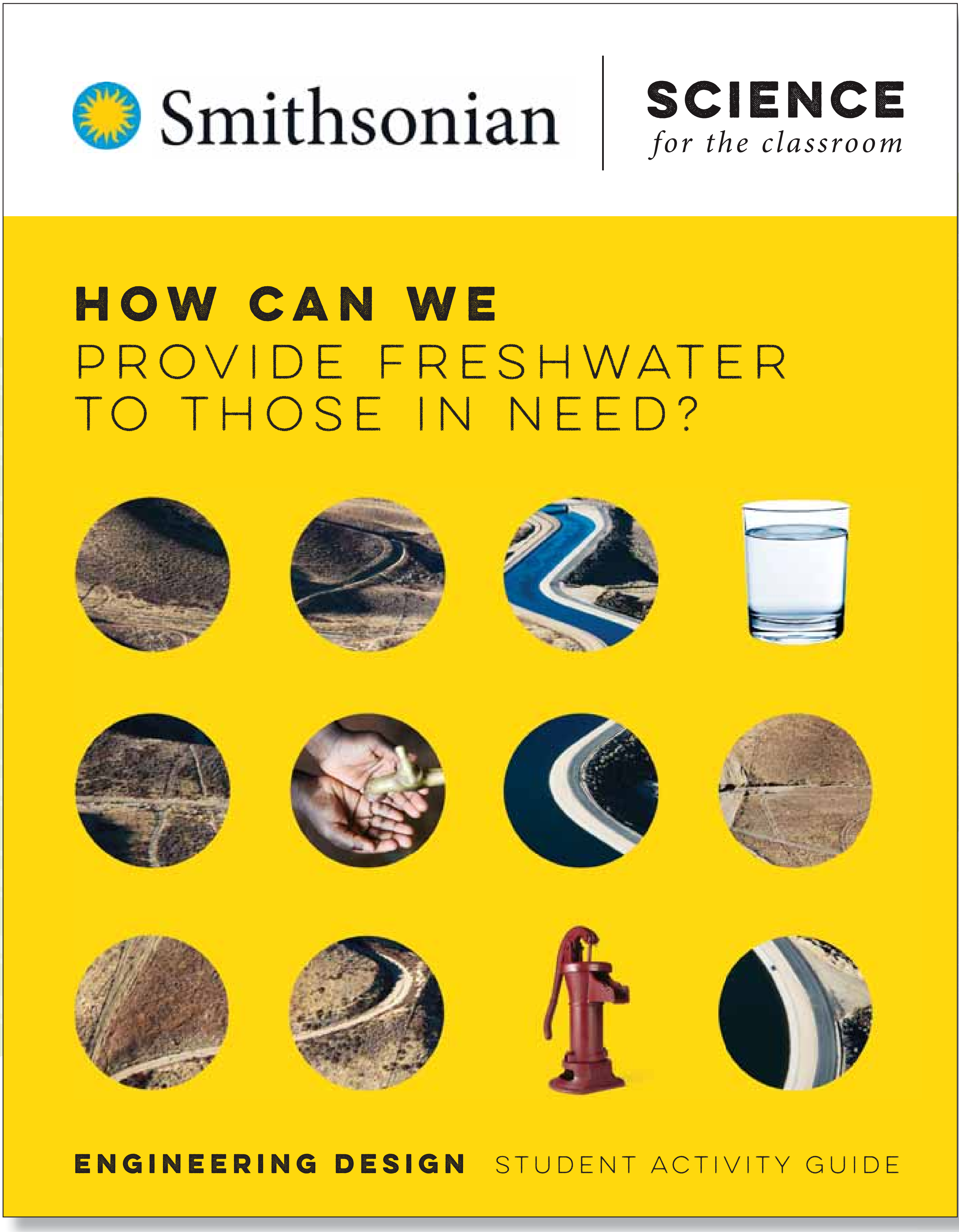
- Colored pencils*
- Printer paper*

*needed but not supplied

Procedure

5

Ask students to create an acrostic poem showcasing the term “failure point.” The goal is to convey the benefits of identifying and correcting for failure points during engineering challenges, activities in other classes, at home, and even in their own learning. Emphasize that failure points are opportunities for improvement. Remind students that an acrostic poem begins by writing the word(s) down vertically, brainstorming ideas that relate to your subject, and then filling in the rest of the lines using letters of the term “failure point” to complete their poem.


Smithsonian
SCIENCE
for the classroom
HOW CAN WE
PROVIDE FRESHWATER
TO THOSE IN NEED?
ENGINEERING DESIGN STUDENT ACTIVITY GUIDE

Lesson 5: **Water Pump**

We are investigating:
How have humans impacted the water we need?

Materials

For each student

- STEM notebook
- 1 Lesson 5 Notebook Sheet A
- 1 Lesson 5 Notebook Sheet B

For each group of four students

- 2 Beakers
- 5 Lengths of airline tubing
- 1 Plastic syringe
- 4 Connectors
- 1 Three-way valve
- 1 Graduated cylinder
- Water

For the class

- Large rubber bands
- Small rubber bands
- Paper clips
- Tape

4

Info

Criteria and Constraints

Criteria (goals)

- Pump at least 50 mL of water from the floor to the desktop.
- The water must travel from one beaker on the floor, through 5 lengths of airline tubing, to the other beaker on the desktop.

Constraints (limits)

- Move only the syringe and three-way valve during testing.

Procedure

1. The Materials Manager collects the materials.
2. Discuss the materials and how they may help your group with this activity.
3. Build a design and test it by pumping air through the system. Modify your design if necessary.
4. Draw a diagram of your design.
5. Fill the bottom beaker with 400 mL of water. Wait for your teacher to tell you to start pumping water.

Group Work Check in with your group to make sure everyone understands their roles.

Stop & Check How does the three-way valve work?

Group Work The Organizer should make sure everyone is contributing during the design.

5

6. Measure how many milliliters of water your group was able to move using the graduated cylinder. Record the amount of water in your notebook.
7. As a group, identify and write down at least one difficulty you experienced during this test.
8. Discuss how you could modify your design to better meet the criteria. The Materials Manager gets additional materials from the materials center if needed.
9. Build your revised design and test it by pumping air throught the system. Modify your design if necessary.
10. Write what you changed about your design.
11. Fill the bottom beaker with 400 mL of water. Wait for your teacher to tell you to start pumping water.
12. Record how many milliliters of water, measured using the graduated cylinder, your group was able to move.
13. As a group, identify and write down at least one difficulty you experienced during this test.

Stop & Check

Which step in your process do you think was most important in meeting the criteria (designing, building, testing, sharing results and failure points, sharing solutions to failure points, redesigning, or retesting)? Why?

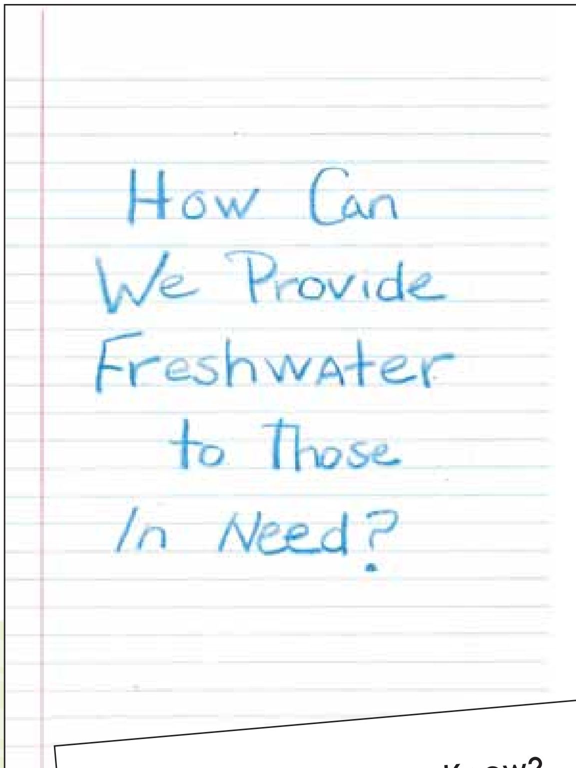
6

Provide Opportunities for Students to Think, Act, Reflect, and Communicate Like Scientists and Engineers

Anyone with a question can be a scientist! *Smithsonian Science for the Classroom* gets students thinking, acting, reflecting, and communicating like scientists and engineers.

Scientists and engineers explore and investigate, read to gather information, record their data, and reflect on their ideas. *Smithsonian Science for the Classroom* provides students with:

- Hands-on investigations that integrate literacy through the *Smithsonian Science Stories* Literacy Series, available in both on-grade and below-grade reading levels.
- Multiple lessons dedicated to reading, writing, speaking, and listening to gather information to support claims
- STEM Notebooks built by students to keep records of their questions, predictions, claims linked to evidence, and conclusions. Lesson notebook sheets scaffold student thinking and provide opportunities for students to explain phenomena, communicate their design for solutions, and self-assess.
- Math integrations that offer opportunities for students to represent and interpret data and quantitatively describe and measure objects, events, and processes.


How Can We Provide Freshwater to Those In Need?

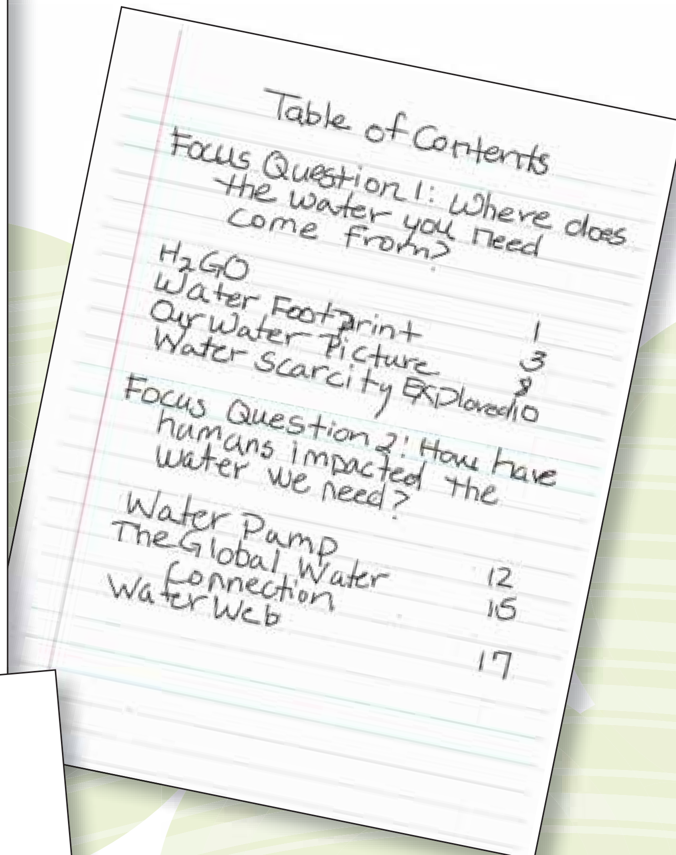


Table of Contents

What Do I Already Know?

Write or draw your answers on a blank page in your STEM notebook.

1. Humans need freshwater. Where is freshwater found on Earth? What percent of water on Earth is freshwater?

These two images show California's snowpack over a 3-year period.

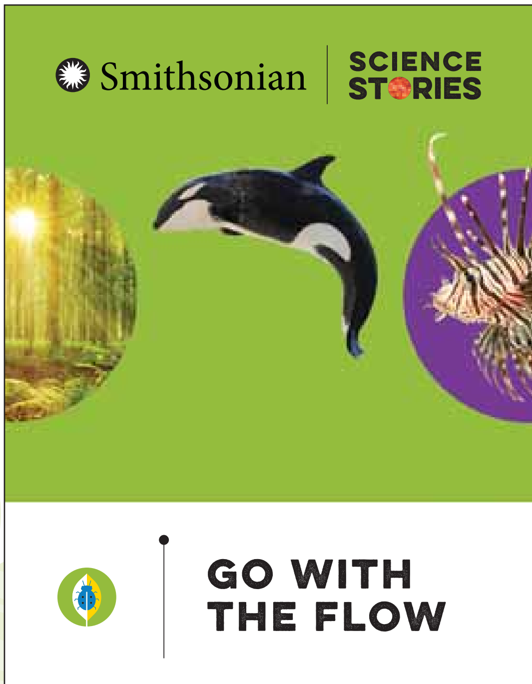
2. Describe the change that occurred between 2011 and 2014.
3. Describe one way this change could impact the surrounding land, water, plants, animals, or people.
4. What problems are associated with moving water to where it is needed?
5. What should you do before designing a solution to a problem? How can you test to see if your solution was successful?

Identifying problems

Identifying problems and testing solutions

Test 1	Test 2
Draw a diagram of your design	What did you modify?
Amount of water moved: ________________mL	Amount of water moved: ______________mL
Difficulties:	Difficulties:
	Controls:
	These two tests were/were not a fair test because

Module-Specific On-Grade, Below-Grade, and Spanish Nonfiction Literacy Supports Every Module of the *Smithsonian Science for the Classroom* Program.



Life Science: *How Can We Predict Change in Ecosystems?*

Earth/Space Science: *How Can We Use the Sky to Navigate?*

Physical Science: *How Can We Identify Materials Based on Their Properties?*

Engineering Design: *How Can We Provide Freshwater to Those in Need?*

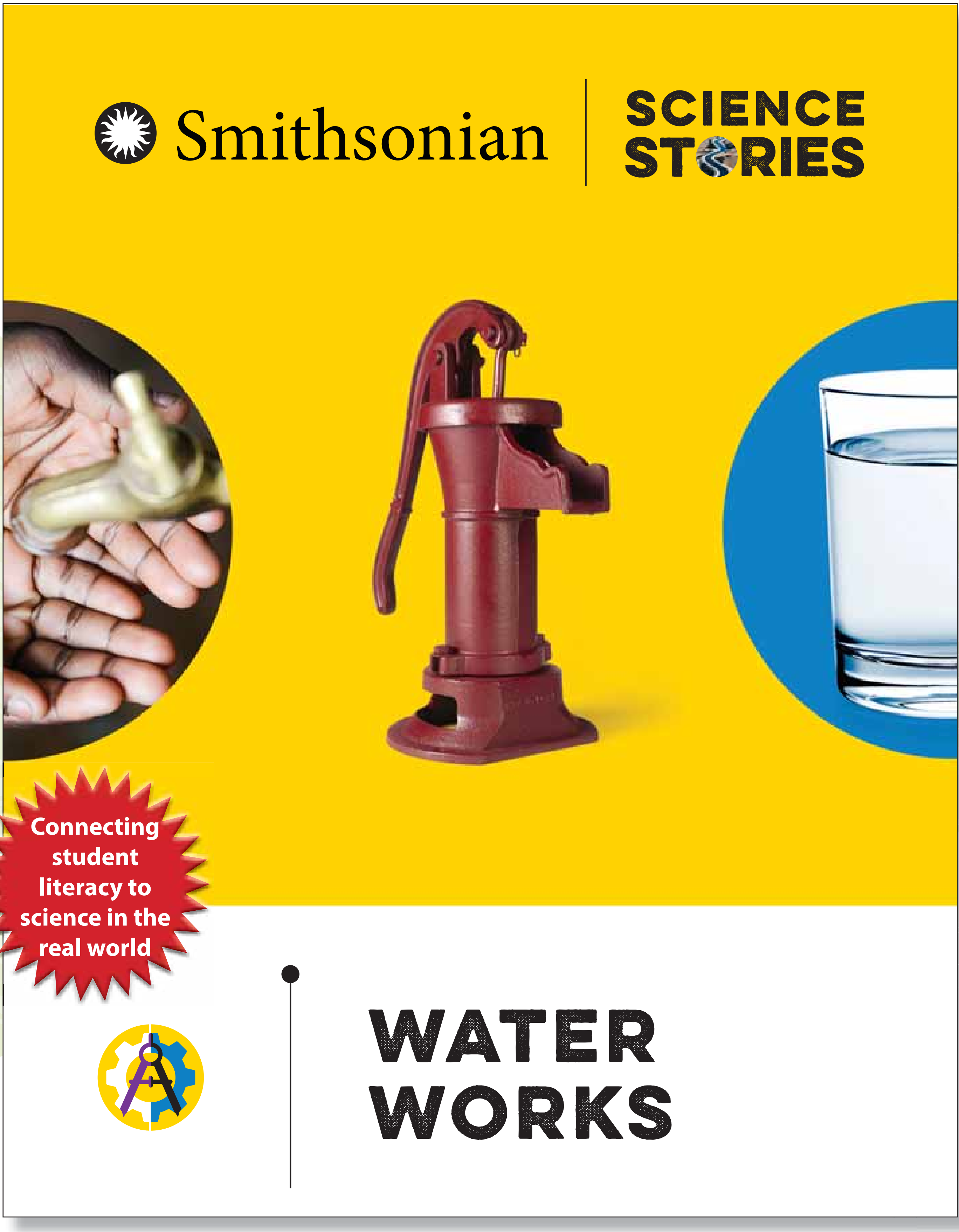

Smithsonian
SCIENCE STORIES
Connecting student literacy to science in the real world
WATER WORKS

TABLE OF CONTENTS

Bring the expertise of the Smithsonian into your classroom

READING

5

PIPES, PUMPS, AND PACES

People run into problems related to all aspects of life. When faced with a problem, you must try to solve it. There appears to be a lot of water in the world. But there are problems. How much of the water can we actually use? And where is the water we can use located? How do people solve these problems? It turns out people have been engineering solutions for ages.

Back in the first century, the people of the Roman Empire needed to move clean water into their cities from far away. The river water was not as clean as the water from natural springs.

Rivers have freshwater, but you might not live close to one.

25

The Romans built this bridge to move water.

The Romans built systems for moving spring water called **aqueducts**. Most of the water went through underground tunnels. There were some obstacles over the distance of 50 or more kilometers (30 or more miles) that the water needed to travel. Water moves down a slope by gravity. How do people move it across low valleys and deep canyons? Today we can still see some of the high bridges people built to move water. You may not see the downward slope of a bridge like the one shown here. The bridge slopes by just 2.5 centimeters (1 inch). The whole aqueduct drops by 17 meters (56 feet) from one end to the other.

26

Romans connected pieces of lead to make pipes.

You may see pipes like these around your home.

The Romans built the bridges out of rock and built the pipes out of lead. The materials were natural, not advanced. Most water went to the public fountains and baths. Few homes had water going straight into them through pipes.

Today developed countries have much larger networks of pipes that get water into individual homes. Using pipes is nothing new. But the materials used to make them have changed over time. The lead that the Romans used dominated for a long time. Minerals in the water coated the pipes, so flowing water did not touch the lead. Today, there are health risks caused by lead pipes because minerals are removed and water sits in the pipes longer. The Romans didn't turn off the water as much as we do. Now metal pipes such as steel, iron, and copper are part of our water systems. Plastic has become a suitable material, too.

FUN FACT

Buildings have pipes in many shapes and sizes. Look around your home with an adult and see what kind of pipe you can find!

27

Water towers store clean water before it goes to homes, schools, or offices.

Pipes bring surface water into homes in big cities and towns. First, water goes through a treatment plant to make it ready to drink. Treated water has chemicals added to it. The chemicals separate out dirt and kill bacteria. The water leaves the plant through pipes that go to homes in the city water network.

A home outside the city in a more rural spot still has pipes but gets the water that flows through the pipes from a different source. The water gets pumped up from the ground through a well. Some pumps are outside of the well and pull water up like drinking from a straw. Other pumps are down inside the well and push the water up. The pumped water goes into a storage tank so that the pump doesn't have to run all the time. Remember, groundwater is protected from surface pollution, so it doesn't need extra chemicals to treat it. The drawback to private wells is that they can go dry from too much pumping and not enough rain or snowmelt to replace the pumped water.

28

LECTURA 5

TUBERÍAS, BOMBAS Y PASOS

Literacy available in Spanish

La gente se encuentra con problemas relacionados a todos los aspectos de la vida. Cuando te enfrentas a un problema, debes intentar resolverlo. Parece que hay mucha agua en el mundo. Pero hay problemas. ¿Cuánta de esa agua podemos usar en realidad? ¿Dónde se ubica el agua que podemos usar? ¿Cómo la gente resuelve estos problemas? Resulta que la gente ha ideado soluciones durante mucho tiempo.

En el siglo primero, la gente del Imperio Romano necesitaba transportar agua limpia a sus ciudades desde muy lejos. El agua de los ríos no estaba tan limpia como el agua de los manantiales naturales.

Los ríos tienen agua dulce, pero es posible que no vivas cerca de uno.

25

Los romanos construyeron este puente para transportar el agua.

Los romanos construyeron sistemas para transportar el agua de los manantiales llamados **acueductos**. La mayor parte del agua iba por túneles subterráneos. Había algunos obstáculos en una distancia de 50 kilómetros o más (30 millas o más) que el agua necesitaba recorrer. El agua se transporta hacia abajo en una pendiente por la gravedad. ¿Cómo la gente transporta el agua a través de valles bajos y cañones profundos? Hoy en día todavía podemos ver algunos de los puentes altos que la gente construyó para transportar agua. Es posible que no notes la pendiente hacia abajo de un puente como el que se muestra aquí. El puente tiene una pendiente de apenas 2.5 centímetros (1 pulgada). Todo el acueducto tiene una caída de 17 metros (56 pies) de un extremo al otro.

Los romanos conectaban trozos de plomo para hacer tubos.

Puedes ver tubos como estos en tu casa.

Los romanos construyeron puentes de roca y tuberías de plomo. Los materiales eran naturales, pero no avanzados. La mayor parte del agua iba a los bebederos y baños públicos Pocas casas tenían agua que le llegaba a través de tuberías.

Hoy en día los países desarrollados tienen redes mucho más grandes de tuberías que llevan agua a hogares individuales. Usar tuberías no es algo nuevo. Pero los materiales usados para fabricarlas han cambiado con el tiempo. El plomo que los romanos usaban dominó durante mucho tiempo. Los minerales en el agua recubrían las tuberías, así que el agua que fluía no tocaba el plomo. Hoy en día hay riesgos a la salud causados por las tuberías de plomo debido a que los minerales desaparecieron y el agua se queda más tiempo en las tuberías. Los romanos no cerraban los grifos tanto como nosotros. Ahora, las tuberías de metales tales como acero, hierro y cobre son parte de nuestros sistemas de agua. También el plástico se ha vuelto un material apropiado.

DATO CURIOSO

Los edificios tienen tuberías de muchas formas y tamaños. Busca en tu casa con un adulto y ve qué tipo de tubería puedes encontrar.

27

Las torres de agua almacenan agua limpia antes de que vaya a los hogares, escuelas u oficinas.

Las tuberías llevan el agua superficial a los hogares en grandes ciudades y pueblos. Primero, el agua pasa por una planta de tratamiento para prepararla para beber. Se agregan productos químicos al agua tratada. Los productos químicos separan la tierra y matan bacterias. El agua deja la planta a través de tuberías que van a las casas en la red hidráulica de la ciudad.

Un hogar fuera de la ciudad en un punto rural todavía tiene tubería, pero obtiene el agua que fluye a través de la tubería de una fuente diferente. El agua es bombeada desde el suelo a través de un pozo. Algunas bombas están fuera del pozo y jalan el agua como si la bebieran de una pajilla. Otras bombas están dentro del pozo y empujan el agua hacia arriba. El agua bombeada va a un tanque de almacenamiento para que la bomba no tenga que trabajar todo el tiempo. Recuerda, el agua subterránea está protegida de la contaminación de la superficie, así que no necesita productos químicos extra para tratarla. La desventaja de los pozos privados es que se pueden secar debido al bombeo excesivo sin suficiente lluvia o nieve derretida para reemplazar el agua bombeada.

GLOSSARY

algae: Aquatic organisms colored like plants but lacking features such as stems and roots

aqueduct: A man-made water supply system that moves water from one place to another

area: Measure of the size of a 2-D (two-dimensional) surface

arid: Having little or no rain; a dry climate

atmosphere: The portion of the Earth system made up of the surrounding gases

biosphere: The portion of the Earth system that includes all life

climate: The average weather in a region over many years

desalination: The process by which salt and minerals are removed from sea water

desertification: The process by which an area becomes a desert

divert: To change direction

ecosystem: A system formed by the interaction of all living and nonliving things in an environment

engineer: Someone who uses science to solve a problem

evaporate: The process by which water changes from a liquid to a gas

fossil: The remains of a plant or animal that was once living

freshwater: Water that has no salt and is a natural resource

geosphere: The portion of the Earth system that includes rocks, minerals, landforms, and the interior

glacier: A large, slow-moving mass of ice

groundwater: Water found underground in cracks and spaces in soil, sand, and rock

hydrologist: A scientist who studies water and water-related problems in society

GLOSARIO

acueducto: Un sistema de suministro de agua construido por el hombre para transportar agua de un lugar a otro.

agua dulce: Agua que no tiene sal y que es un recurso natural.

agua subterránea: El agua que se encuentra bajo el suelo en grietas y espacios en la tierra, arena y rocas.

agua superficial: Agua que se encuentra en la superficie de un planeta.

algas: Organismos acuáticos con colores como las plantas pero que no tienen características tales como tallo y raíz.

árido: Que tiene poca o nada de lluvia; un clima seco.

atmósfera: La porción del sistema de la Tierra compuesta de los gases circundantes.

área: Medición del tamaño de una superficie 2-D (de dos dimensiones).

biósfera: La porción del sistema de la Tierra que incluye toda la vida.

clima: El tiempo promedio en una región durante muchos años.

cuenca: Un área de tierra en la que el agua drena y se va al mismo lugar, usualmente un río o un lago.

cuenca de lago: Un área de tierra en la que el agua drena en un lago.

desalinización: El proceso por el cual se quitan las sales y los minerales del agua de mar.

desertificación: El proceso por el cual un área se convierte en desierto.

desviar: Cambiar dirección.

ecosistema: Un sistema formado por la interacción de todos los seres vivos y no vivos en un ambiente.

evaporar: El proceso por el cual el agua cambia de estado líquido a estado gaseoso.

ingeniero: Alguien que usa la ciencia para resolver un problema.

fósil: Los restos de una planta o animal que vivió alguna vez.

geósfera: La porción del sistema de la Tierra que incluye rocas, minerales, formas terrestres y el interior.

glaciar: Una masa grande de hielo que se mueve lentamente.

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	Life Science	Earth and Space Science	Physical Science	Engineering Design
Grade 1				
	How Do Living Things Stay Safe and Grow? *1-LS1-1 • 1-LS1-2 • 1-LS3-1 • K-2-ETS1-1* **Supporting:** Engineering Design	**How Can We Predict When the Sky Will Be Dark?** *1-ESS1-1 • 1-ESS1-2 • 1-PS4-2* **Supporting:** Physical Science	**How Can We Light Our Way in the Dark?** *1-PS4-2 • 1-PS4-3 • 1-LS1-1 • K-2-ETS1-1* **Supporting:** Life Science and Engineering Design	**How Can We Send a Message Using Sound?** *K-2-ETS1-1 • K-2-ETS1-2 • K-2-ETS1-3 • 1-PS4-1 • 1-PS4-4* **Supporting:** Physical Science
Grade 2				
	How Can We Find the Best Place for a Plant to Grow? *2-LS2-1 • 2-LS2-2 • 2-LS4-1 • K-2-ETS1-1* **Supporting:** Engineering Design	**What Can Maps Tell Us About Land and Water on Earth?** *2-ESS2-2 • 2-ESS2-3 • 2-PS1-1* **Supporting:** Physical Science	**How Can We Change Solids and Liquids?** *2-PS1-1 • 2-PS1-2 • 2-PS1-3 • 2-PS1-4 • K-2-ETS1-1* **Supporting:** Engineering Design	**How Can We Stop Soil From Washing Away?** *K-2-ETS1-1 • K-2-ETS1-2 • K-2-ETS1-3 • 2-ESS1-1 • 2-ESS2-1* **Supporting:** Earth and Space Science
Grade 3				
	What Explains Similarities and Differences Between Organisms? *3-LS1-1 • 3-LS3-1 • 3-LS3-2 • 3-LS4-2 • 3-ESS2-2* **Supporting:** Earth and Space Science	**How Do Weather and Climate Affect Our Lives?** *3-ESS2-1 • 3-ESS2-2 • 3-ESS3-1 • 3-5-ETS1-1* **Supporting:** Engineering Design	**How Can We Predict Patterns of Motion?** *3-PS2-1 • 3-PS2-2 • 3-PS2-3 • 3-PS2-4 • 3-5-ETS1-1* **Supporting:** Engineering Design	**How Can We Protect Animals When Their Habitat Changes?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 3-LS2-1 • 3-LS4-1 • 3-LS4-3 • 3-LS4-4* **Supporting:** Life Science
Grade 4				
	How Can Animals Use Their Senses to Communicate? *4-LS1-1 • 4-LS1-2 • 4-PS4-2 • 4-PS4-3 • 3-5-ETS1-1* **Supporting:** Physical Science and Engineering Design	**What Is Our Evidence That We Live on a Changing Earth?** *4-ESS1-1 • 4-ESS2-1 • 4-ESS2-2 • 4-ESS3-2 • 4-PS4-1 • 3-5-ETS1-1* **Supporting:** Engineering Design and Physical Science	**How Does Motion Energy Change in a Collision?** *4-PS3-1 • 4-PS3-2 • 4-PS3-3 • 4-LS1-1 • 3-5-ETS1-1* **Supporting:** Engineering Design and Life Science	**How Can We Provide Energy to People's Homes?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 4-PS3-2 • 4-PS3-4 • 4-ESS3-1* **Supporting:** Physical Science and Earth and Space Science
Grade 5				
	How Can We Predict Change in Ecosystems? *5-LS1-1 • 5-LS2-1 • 5-PS1-1 • 5-PS3-1* **Supporting:** Physical Science	**How Can We Use the Sky to Navigate?** *5-ESS1-1 • 5-ESS1-2 • 5-PS2-1 • 3-5-ETS1-1* **Supporting:** Physical Science and Engineering Design	**How Can We Identify Materials Based on Their Properties?** *5-PS1-1 • 5-PS1-2 • 5-PS1-3 • 5-PS1-4 • 5-LS1-1* **Supporting:** Life Science	**How Can We Provide Freshwater to Those in Need?** *3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 5-ESS2-1 • 5-ESS2-2 • 5-ESS3-1* **Supporting:** Earth and Space Science

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