How Can We Provide Water for Developing Countries?

5E Unit Empowers Students to Solve the Global Water Crisis

BY AMY BOROS AND EMILIO DURAN

CONTENT AREA

Physical science/ interdisciplinary

GRADE LEVEL

5–8

BIG IDEA/UNIT

Possible solutions for clean drinking water in developing countries

ESSENTIAL PRE-EXISTING KNOWLEDGE

States of matter, phase changes, basic physics, basic microbiology (bacteria in water can make people sick)

TIME REQUIRED

Up to four weeks

COST

$10–$25

SAFETY

Safety around body of water, safe use of hot plate or burner

More than 4 billion people around the world face a severe water shortage for at least one month per year (Carrington 2016). What better way to engage students in a real-world problem than having them explore solutions to the global water crisis? In our integrated instructional unit called "Water for Developing Countries," students reach a decision about the best technology to use that could provide clean water for people in need in developing countries.

This interdisciplinary 5E unit is taught at the end of the school year as a four-week-long capstone project. To reach a decision about the best technology to use, students combine scientific concepts they have learned throughout the year (i.e., matter, microbiology, and physics) with engineering practices while considering human needs and environmental impact. Using essential questions, learning targets, and the *Next Generation Science Standards*, students explore possible solutions over multiple class periods (see Figure 1; *NGSS* box, p. 87). *Note:* All the resources, instructional materials, and lab instructions for this unit are available online (see Resources).

Engage

At the beginning of the unit, show a bottle of muddy water and ask, "Would you drink this? What if it was your only option?" After sharing how many parts of the world lack access to clean water, ask, "How can we, as compassionate people, get clean water to people in need?" Initially, my students came up with the obvious solution of mailing cases of water to those in need. We then discuss the implications of their choices, bringing about questions such as, "How much would that cost? How many would you need to send? What would they do with all of the empty water bottles? What if political or social conditions in the country made it difficult to get the water to those in need?"

Throughout the unit, I read aloud *A Long Walk to Water* (Park 2010) in its entirety and show a short documentary film inspired by the book's main character, titled *Just Add Water* (see Resources), to help students learn about global water shortage issues. This film follows Salva Dut of Sudan as he and his team attempt to bring potable water to a remote village in Africa. After the video, ask students: "What would be the best option for providing water to developing countries that do not have a clean water source readily available? Is a well, which is what Salva builds, the only option, or are there others?" To help them better understand the problem, we show a short video clip, "Why Care About Water?" (see Resources), and provide basic background information:

In some remote parts of Africa and other parts of the world, finding potable water is a six-hour journey. People in these regions spend 40 billion hours a year trying to find and collect water, according to the Water Project (*https://thewaterproject.org*). And even when they find it, the water is often not safe—collected from mud puddles or ponds and lakes contaminated with animal waste or other harmful substances. The water scarcity issue, which affects nearly one billion people in Africa alone needs a solution.

Next, students gather more information of worldwide water conditions using the "Global Concerns: Water" article (see Resources) and write about how they can increase the world's access to clean water in a table (see Online Supplemental Materials). In a teacher-led discussion, students reveal their findings about global water conditions such as:

- wars over water in Africa,
- unsanitary conditions limits clean water in parts of Bangladesh,
- unclean water is one of the leading causes of death in Haiti, and
- some people have to walk two to three hours to find a clean water source in Somalia.

Explore

In the Explore phase, students research six other possible solutions for providing clean water in developing countries such as Sudan. To help with the research, provide students with a list of websites (see Resources) containing information for the six possible solutions, which are:

1. *A machine that turns waste into water.* The Janicki OmniProcessor boils and treats feces into clean drinking water, electricity, and ash, with the goal of providing access to safe sanitation to those in developing countries.
2. *Water-extracting tower.* The 30-foot-tall Warka water tower captures water from the air via condensation overnight. The designer of the water tower says the structures could provide 25 gallons of water per day to those residing in remote villages.
3. *Filters that clean contaminated water.* Bio-Sand and Lifestraw water filters convert contami-

FIGURE 1: Essential questions, learning targets, and *NGSS* connections

Essential questions	Learning targets	*NGSS* standards (Grades 6–8)	*NGSS* Crosscutting Concepts and Practices
1. How can we help provide clean water to people in developing countries? 2. How does water change states in each of the different possible solutions? 3. What microorganisms are found in water that make humans sick?	1. Using the various methods for collecting clean water, I can identify changes in the states of matter. 2. Through research and investigation, I can identify microorganisms found in water that may make humans sick. 3. After building the model of a water well, I can describe how water travels in soil. 4. I can analyze research, data, and opinions on six different methods for providing clean water. 5. I can synthesize research, data, experiences, and opinions to form my own opinion on the best method to provide water for people in developing countries. 6. I can present my opinion using Claim, Evidence, and Reasoning in an appropriate format.	**MS-PS1-4 Matter and its Interactions** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **MS-ESS3-2 Earth and Human Activity** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. **MS-ETS1-1 Engineering Design.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	**Crosscutting Concepts** • Energy and Matter • Structure and Function • Stability and Change • Influence of Science, Engineering, and Technology on Society and the Natural World **Science and Engineering Practices** • Asking Questions and Defining Problems • Developing and Using Models • Analyzing and Interpreting Data • Engaging in Argument From Evidence • Obtaining, Evaluating, and Communicating Information

nated water into clean drinking water. The BioSand filter, for instance, purifies water for up to 10 people for 25–30 years.

4. *Desalination.* The process of desalination involves turning saltwater into clean drinking water by removing salt from the water.

5. *Self-filling water bottle.* The Fontus water bottle uses water vapor from the air to fill the bottle with water.

6. *Fan that pulls water from the air.* The WaterSeer uses wind turbines to pull air into an underground chamber, where it turns into water.

Safety

During the lesson, students are reminded to follow the basic science rules and regulations that I covered at the beginning of the year as part of a Safety Contract signed by the student and parent/guardian. These include but are not limited to: safe use of equipment during experiments, not eating or drinking in the lab, and cleaning up and alerting the teacher of spills and accidents.

When working with hot materials, use gloves, heat- or cold-resistant mitts, or other hand protection; tie back long hair and secure loose clothing and dangling jewelry. Remind students to keep science materials away from their mouths, noses, or eyes when conducting or cleaning after an activity or experiment.

Use only laboratory-type hot plates that are sealed against minor spills. Place the hot plate in a location where a student cannot pull it off the worktop or trip over the power cord. Never leave the room while the hot plate is plugged in. Keep students away from hot plates that are in use or still hot, unless you are right beside the students and have given them specific instructions. Before handling a hot plate, make sure that it is unplugged and cool. To see if a hot plate is too hot, place a few drops of water on the surface. If the water does not evaporate, it should be cool enough to touch, according to the American Chemical Society. (from ACS Chemistry For Life Safety in the Elementary Classroom)

Students then fill in information about the solutions in a table (see Online Supplemental Materials) as they form opinions on the best solution to the global water crisis. Students have the opportunity over the next two to three class periods to design, build, and test models of the Warka water tower, LifeStraw filters, desalination plants, and wells (see Online Supplemental Materials for complete directions on conducting these four investigations). The investigations can be completed as whole-class activities or in centers around the room. All of the activities use inexpensive household items (*Note:* Materials for each investigation are listed in the Online Supplemental File). Students may also choose the activity that their research indicates will be the best solution for the water crisis. Students can learn about the technology involved in each solution by conducting further research online.

Carrying out the investigations

In the first investigation, students design and build a working model of a Warka water tower using a variety of materials, such as plastic netting, plastic cups, rubber bands, twist ties, and straws. They are also encouraged to ask for other materials, if needed. Students then test their model overnight. They draw their model and reflect on design process, completion, and results (see Online Supplemental Materials for an example).

In the second investigation, students use materials such as filter paper, gravel, and cotton balls to design and build a working water filter that filters muddy water. Students record design drawings and results in a lab report. (*Safety note:* Remind students to not drink the water.)

In the third investigation, students build and test a model of a well made from a large coffee can, gravel, and a cardboard tube. Students record the results of the investigation and discuss the feasibility of installing wells in developing countries. Students find that the model well does work and that the water that seeps into the well is relatively clean (the cardboard traps the particles of sand). Reflective questions include:

- Where is the water in the well coming from?
- How does the water get inside the well?
- How is this miniature well related to real-life wells?
- Why is it important to be aware of what we put in our soil?

In the fourth investigation, students design, build, and test a small-scale desalination plant that is capable of removing salt from a saltwater solution. Students use a saltwater circuit to test their model. In this investigation, students learn the role that the water cycle plays in the desalination process. Students must wear eye protec-

FIGURE 2: Digital presentation planning template

My choice for access to clean water (my opinion)	Claim (why I think it is the best)	Evidence (facts and benefits of my choice)	Reasoning (negatives of other options)

tion during the activity and are taught how to handle hot plates (see Safety sidebar).

Reaching a decision

Next, students make an informed opinion about the best solution based on their building experience, from researching to testing models and discussing their ideas with peers. We provide a planning template (Figure 2) that uses the Claim, Evidence, and Reasoning (CER) framework to help them justify their choice. Finally, students create a digital presentation using tools such as Google Slides and PowerPoint (see Resources for examples) that explains the need for clean water, cites their *claim*, supports their choice with *evidence* (pros and cons), and justifies their claim with *reasoning*. Students may use pictures, data (e.g., costs and output of clean water), and evidence from credible sources to support their opinion. Before students present their findings, I share the guidelines and project rubric with them (Figure 3). The final presentations are shared with the entire class, and students are asked to reflect on each other's ideas in a constructive manner.

Differentiation

The unit lends itself to multiple levels of cognition, including content, process, learning style, and product. Students of various academic abilities should receive more guidance, minimum content for mastery, and modified versions of the tables (see Online Supplemental Materials) that are completed throughout the research and planning phase.

Strategies are incorporated to address the learning needs of students with disabilities in terms of student readiness, interest, and ability. For example, students are asked to choose four of the six possible solutions. The teacher also pulls the facts from the websites for them and into a more easily understood format. During the model development and testing phase, students can be partnered with another student or paraprofessional to ensure the activities are conducted safely and accurately.

Explain

During this phase, students first discuss the possible solution, how it works, and the pros and cons of each. Students also discuss their thoughts

Take-home task

Materials:

- one or two five-gallon buckets
- a source of water (e.g., a river, creek, or lake)
- a measured distance to walk and time yourself

Instructions:

Carry the one or two five-gallon buckets from your starting point to the water source. Fill the buckets to the top with water from the source, then walk back to your starting point.

How do you feel?

- Was it easier or harder than you thought it would be?
- Were you able to carry the water all the way?
- Would you want to do that for your family every day, sometimes twice a day?

FIGURE 3: Guidelines and rubric for presentations with Google Slides

Google Slide presentation slide requirements

Slide 1: Title, name, period.

Slide 2: Explain the need for increasing the world's access to clean water.

Slide 3: Make your claim for the best solution.

Slide 4: Explain how your option works and why it is the best option.

Slide 5: Pros of the option you chose (evidence).

Slide 6: Cons of the option you chose (evidence).

Slide 7: Reasons why you didn't choose the other options (to justify your choice).

Slide 8: Evaluate environmental impact (How will your option affect the land? Water? Air?).

Slide 9: Conclusion as to why your choice is the best overall.

Project rubric

Choice for clean water ____________________   Main reason why _______________________

Self-assessment of project	*Teacher's assessment of project:*
Did you include:	1. Opinion/choice clearly stated _____/5
1. Opinion/choice clearly stated _____/1	2. Evidence and reasons for choice _____/10
2. Evidence and reasons for choice_____/1	3. Pros of choice are listed _____/10
3. Pros of choice are listed _____/1	4. Cons of choice or another system _____/10
4. Cons of choice or another system _____/1	5. Creatively presented to the class _____/5
5. Creatively presented to the class _____/1	Total _____/40 points
6. Used a presentation program or app _____/1	
Comments on your project:	
Total _____/6 points	

Reflections on four projects other than your own:

While watching or listening to presentations from other students, write down things that strike you or that you find interesting.

1.

2.

3.

4.

Total _____/4 points   Project Total _____/50 points

and present their ideas with three other students for validation and critical questioning. This allows students to refine their thinking and to gather further data and information.

Now is also the time for the teacher to discuss the science behind each solution. For example, explain how the Jackni OmniProccessor turns human feces into drinkable water by burning the feces, extracting the water out via steam, and purifying and condensing the steam into clean drinking water. It's also important to make sure students understand the changes of matter during this process—a connection to science concepts learned earlier in the school year. Similarly, discuss how the desalination methods transfer heat and change matter to separate salt from ocean water, and how the Warka water tower can extract water droplets from the air due to the temperature

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standards

MS-ESS3 Earth and Human Activity
www.nextgenscience.org/dci-arrangement/ms-ess3-earth-and-human-activity

MS-ETS1 Engineering Design
www.nextgenscience.org/dci-arrangement/ms-ets1-engineering-design

Performance Expectations

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	Students investigate possible solutions for obtaining clean water in developing countries and present and defend their choices.
Developing and Using Models	Students design, build, and test Warka water towers, water filters, wells, and small-scale desalination plants.
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	Students analyze the Global Concerns: Water article about increasing the world's access to clean water to understand the condition of water around the world.
ETS1.A: Defining and Delimiting Engineering Problems • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	Students research and discuss the advantages and disadvantages of possible solutions to clean water for developing countries and assess their feasibility.
Crosscutting Concept	
Structure and Function	Students build water purification models and evaluate their effectiveness as possible solutions for purifying water in developing countries.

differences between night and day. You can also make an additional connection to microbiology by bringing to light the number of bacteria found in unclean drinking water. During this phase, provide additional resources, including books (e.g., Strauss 2007) about the water crisis and additional websites to help students look beyond the scope of the project.

Elaborate

To begin this phase, ask students: "What is it like to carry water back and forth from a river every day like the characters in *A Long Walk to Water* and for many people around the world?" To answer this question, students complete a take-home task (see sidebar). The activity could also be completed at any school by having students carry five-gallon buckets of water at a distance such as 100 yards or once around a school track.

Evaluate

In the evaluation phase, students use the CER model to design and share digital presentations expressing their opinions for the best solution to the water crisis. Their presentations are evaluated with the rubric shown in Figure 3. Based on three years of implementing this project, students tended to choose the Warka Water Tower and LifeStraw Filters, providing varying and suitable reasons and evidence for their opinions.

Conclusion

The goal of this unit is not to point students to one option or another, but to teach them to be thinkers who analyze ideas and products to solve problems with science. This capstone project helps students improve mastery of science content and develop scientific reasoning while increasing their general interest in science and social causes. More importantly, this instructional approach appeared to be effective in helping diverse groups of learners meet the learning targets. ●

REFERENCES

Carrington, D. *The Guardian*. 2016. Four billion people face severe water scarcity. February 12.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

Park, L.S. 2010. *A long walk to water*. New York: Clarion Books.

Strauss, R. 2007. *One well: The story of water on Earth*. Toronto, ON: Kids Can Press, Limited.

RESOURCES

Instructional materials, lab instructions, and resources for the unit—*https://goo.gl/G9qlRK*

Just Add Water—*https://vimeo.com/32861550*

Global Concerns: Water—*https://schools.concernusa.org/content/uploads/2014/07/GIG-Water.pdf*

Student examples—*https://sites.google.com/a/perrysburgschools.net/water-for-developing-countries/teacher-page/student-project-examples*

Why Care About Water?—*https://video.nationalgeographic.com/video/env-freshwater-whycare?source=relatedvideo*

Solutions for providing clean water

Solution #1 (feces to water)—*www.gatesnotes.com/Development/Omniprocessor-From-Poop-to-Potable*

Solution #2 (water-extracting towers)—*www.smithsonianmag.com/innovation/this-tower-pulls-drinking-water-out-of-thin-air-180950399/?no-ist*

Solution #3 (filters)—*www.vestergaard.com/our-products/lifestraw, https://grosche.ca/grosche-safe-water-project*

Solution #4 (desalination)—*http://water.usgs.gov/edu/drinkseawater.html, http://idadesal.org/desalination-101/desalination-by-the-numbers*

Solution #5 (self-filling water bottle)—*http://fontus.at*

Solution #6 (fan that pulls water from the air)—*www.waterseer.org*

ONLINE SUPPLEMENTAL MATERIALS

Investigation instructions and tables for background and research, options for clean water, reflections on lab activity, and modified tables—*www.nsta.org/scope0218*

Amy Boros is a science teacher at Perrysburg Junior High School in Perrysburg, Ohio. **Emilio Duran** (*eduran@bgsu.edu*) is an associate professor at Bowling Green State University in Bowling Green, Ohio.