MACGILLIVRAY FREEMAN'S
DREAM BIG
ENGINEERING OUR WORLD

GRADE 8:
WATER PURIFICATION DEVICE

Grade level: 8

Lesson length: 3 hours (can be broken into multiple class periods; this time doesn't include collecting water to test)

> Students design a portable water purification device that creates clean, drinkable water for people who live in places where clean water is not always available.

In the Film

In the film *Dream Big*, we see ways that engineers help build the world of tomorrow. As seen in the film, the population of Earth continues to grow exponentially and to concentrate in major cities. It is estimated that by the end of the century, 90% of Earth's population will live in a city. With the dense concentration of human inhabitants, we face new challenges to use our limited resources in the most effective ways. Engineers are solving the problem of limited space by creating vertical homes like the tower in Shanghai. Engineers are also working on maintaining the health of the water systems in major cities. With more people, we have more waste. How can we keep our fresh water clean?

NGSS Disciplinary Core Ideas

MS-ESS3.B Natural Hazards

Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.

MS-ESS3.A Natural Resources

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

NGSS Engineering Practices

MS-ETS1.A Defining and Delimiting an Engineering Problem

The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will work. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

MS-ETS1.B Developing Possible Solutions

A solution needs to be tested and then modified on the basis of the test results.

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

Key Words/Vocabulary

Agricultural runoff: Pollution that enters a system from fertilizer and pesticides dissolving in water during a period of rain.

Disinfection: The removal of dangerous bacteria and pathogens in a water sample.

Fecal coliform: Harmful bacteria found in the digestive system of mammals, including humans, that can contaminate water through runoff.

Filtration: The removal of dirt and particulate in a water sample.

Industrial runoff: Water pollution that enters a system as a result of industrial waste or spills, such as oil spills.

Municipal runoff: Pollution that enters a water system from human waste in the municipal water system.

pH: The amount of H or OH ions in a water sample; how acidic or basic a solution is.

Potable: Safe to drink.

Turbidity: The amount of suspended dirt in a water sample.

Materials

Per class:

- ☐ Standard water quality kit capable of testing for pH, fecal coliform, and turbidity
- ☐ Receptacle for dirty water that needs filtering
- ☐ Receptacles to pour filtered water into to be tested

Per group:

- ☐ 1 L water bottle (other sizes work as well; adjust the amount and size of filtration materials below to fit)
- ☐ 5 coffee filters
- ☐ Empty 20 oz. bottles for collecting water to test and filter
- ☐ 100 mL each of coarse sand, fine sand, gravel, pebbles, and stones
- ☐ 20 g of activated charcoal
- ☐ 10 cotton balls
- ☐ Several sponges
- ☐ Other materials that might be useful in creating a filtration device

Per student:

- ☐ Protective equipment (goggles, gloves)
- ☐ Water Filtration Engineering Sheet

Teacher Prep Notes

Cut off the bottom of the 1 liter bottles with scissors or a razor. Students will be inverting them and pouring dirty water into the top; filtered water will come out of the mouth of the bottle.

Prepare to review or teach students about the water cycle, natural ways that storms contaminate clean water supplies, and the role that the runoff phase plays in transporting pollutants into larger bodies of water. An example could be Brazil, where up to 50% of the surface water is contaminated with raw sewage, which caused concerns about the water conditions at the 2016 Olympic Games.

Prepare to teach about the natural processes of filtration and how aquifers can remove impurities and preserve clean drinking water underground. Prepare to explain how water in rivers is naturally purified from UV light exposure.

Students will also need to learn about ways that municipalities mimic and build on such natural processes to purify drinking water. Real-life examples of this are available from Civil Engineering Magazine online articles (see asce.org/ce-magazine/web-exclusives/, in the environmental and water resources area).

Be ready to review the two major functions of water purification systems:

- Filtration: The removal of dirt and particulate in a water sample.
- Disinfection: The removal of dangerous bacteria and pathogens in a water sample.

Students will also need to learn about the qualities that municipalities test before releasing drinking water (turbidity, salinity, fecal coliform, and pH).

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - As the population of humans continues to increase exponentially and concentrate in cities, what are some ways that engineers are working to make life comfortable and feasible?
   - Can you predict any other challenges that humans will face as we continue to concentrate in cities? What will engineers have to "dream big" to create to solve these problems?
2. Debrief as a whole class after viewing the film. Allow students to verbally reflect on the guiding questions you gave them.
3. Introduce the design challenge. Students will create a water filter to help people living in major cities, or other places where clean water is not readily available, gain potable water from the closest water sources.

Research and Gather Information: 60 minutes

1. Assign students to small groups. As students learn and gather research, tell them to fill in the relevant section of their Water Filtration Engineering Sheet.
2. Review the water cycle, natural ways that storms contaminate clean water supplies, and the role that the runoff phase plays in transporting pollutants into larger bodies of water. Brazil is an example: Up to 50% of their surface water is contaminated with raw sewage, caused concern about the water conditions at the 2016 Olympic Games.
3. Have students watch associated *Dream Big* webisode content: "Drinking Water."
4. Teach students about the natural processes of filtration: how aquifers can remove impurities and preserve clean drinking water underground, and how water in rivers is naturally purified from UV light exposure.
5. Teach students, and have them research, how municipalities mimic and build on such natural processes to purify drinking water. Real-life examples of this are available from Civil Engineering Magazine online articles (asce.org/ce-magazine/web-exclusives/), in the environmental and water resources area.
6. Review the two major functions of water purifications systems:
   - Filtration: The removal of dirt and particulate in a water sample.
   - Disinfection: The removal of dangerous bacteria and pathogens in a water sample.
7. Teach students about the qualities that municipalities test before releasing drinking water (turbidity, salinity, fecal coliform, and pH).
8. Have students brainstorm materials that are capable of filtering dirt out of water and materials that are capable of disinfecting water.

Plan a Solution: 30 minutes

Place the following on a table for groups to consider for use: coffee filters, cotton balls, rocks, pebbles, sand, sponges, activated charcoal, and any other material you think would be useful in a water filter. Show students the inverted 1 liter bottle that they will use to make their water filter and where dirty water will be poured in and clean water will be poured out.

Allow students time to brainstorm with each other what each material might do, how much of each material they could use, and what order they should be placed in the 1 liter bottle. Tell students to write down their plans in the Plan section of their worksheet.

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a class brainstorming the criteria and constraints of this particular engineering challenge.

When they are ready, students should write down on their worksheet a step-by-step process for how their device will be built and what materials they will use. Based upon student knowledge of water purification systems and quality indicators, they should explain how each step of their water filtration device works to provide clean water.

Make It: 30 minutes

Once students have drawn their plan, instruct them to begin building their device. As students are building, visit each group, reviewing what they learned about water quality and purification processes and how their device works to create clean water. Allow students to make mistakes along the way and struggle. When they do, ask questions about what the students observed and what they could change to fix the problem. Avoid offering solutions and instead encourage students to test ideas as they build.

Test: 20 minutes

To test their device, students will bring in a 20 oz. water bottle of locally sourced water (from streams, rivers, ponds, or lakes). Students will then complete pre-assessment of the water source by testing pH levels and testing for turbidity and fecal coliform. After filtering their water source through their filtration device, students will then test again, with the goal of removing as many contaminants as possible. Students should record their test results on the chart provided in the Water Filtration Engineering Sheet.

Evaluate: 15 minutes

Have students assess their device using the Evaluate section of the Water Filtration Engineering Sheet.

As time allows, discuss students' thoughts about the success of their devices and what they would do to improve them.

Taking It Further

Learn about this engineering in the real world: Fresh water availability is one of the greatest issues our planet faces. The United Nations estimates that over 1.8 billion people do not have access to clean water systems. Water in developing countries is often contaminated with human and agricultural waste. Recently, one group of engineers created a life-saving device that allows people to drink from contaminated systems by purifying the water in a "straw." This device is called the LifeStraw. Learn more about this device at lifestraw.com

Research and investigate how the revolutionary LifeStraw works to disinfect and filter water for individuals living in water-threatened areas. How is it similar and different from the devices that students made? What scientific principles are at play in the LifeStraw?

Document your students' work through our social media outlet: #dreambigfilm

Dream Big: Engineering Our World is a film and educational project produced by MacGillivray Freeman Films in partnership with the American Society of Civil Engineers and presented by Bechtel Corporation. The centerpiece of the project is a film for IMAX and other giant screen theaters that takes viewers on a journey of discovery from the world's tallest building to a bridge higher than the clouds and a solar car race across Australia. For a complete suite of *Dream Big* hands-on activities, educational videos, and other materials to support engineering education, visit discovere.org/dreambig. The *Dream Big* Educator Guide was developed by Discovery Place for the American Society of Civil Engineers.

WATER FILTRATION ENGINEERING SHEET

Name: ____

Problem to Be Solved

Create a water filter to help the people of Haiti rid their water of both human-caused pollutants and contamination from storms and floods.

Research and Gather Information

1. What are ways that storms can contaminate fresh water systems?

2. What are ways that cities and industries can contaminate fresh water systems?

3. How do municipal water filtration systems work? How does this relate to what we must create in our water filter?

Plan

- ☐ The criteria of the engineering and design challenge are:
- ☐ The constraints of the engineering and design challenge are:
- ☐ Draw a picture of what you plan to make.
- ☐ Write a step-by-step process of how to create your design.
- ☐ Describe how each step of your water filtration device works to provide clean water.

Make It!

Evaluate

Test	Before Filtration	After Filtration
Turbidity		
Fecal Coliform		
pH		

1. Did your device meet the constraints of the engineering challenge?
2. Did you test the device using water that is similar to water you would find in environments threatened by natural disasters and human runoff?
3. How did the water sample you tested live up to (or not live up to) this constraint?
4. Did your device meet the criteria of the engineering challenge?
5. Did your device filter the water sample effectively? Why or why not?
6. Did your device disinfect the water sample effectively? Why or why not?

DREAM BIG VIDEO SERIES

WATCH *WATER WISHES: ENGINEERING FOR THOSE IN NEED*

What can an engineering student in New Jersey do to help mountain villagers in Peru who lack clean water to drink? Building a safe water system for people halfway across the globe is an example of how Engineers Without Borders and other organizations are helping people build healthier communities. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.

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NCEES advancing licensure for engineers and surveyors

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