ACTIVITY 9

Water Quality Design Challenge

LABORATORY

9: WATER QUALITY DESIGN CHALLENGE

GUIDING QUESTION

How can you utilize the processes of iteration and collaboration to construct a device to improve water quality?

INTRODUCTION

People are developing relatively low-cost and effective technologies for testing and treating local water sources, which can increase the amount of water available for people to use. In 2017, 12-year-old Gitanjali Rao (pictured on the following page) heard about the water issues in Flint, Michigan, and created a prototype device to detect lead in water. Her prototype included a 3-D-printed frame, a carbon nanotube sensor, and an internal processor. If lead was present, it would bind to the nanotube, create resistance, and send the data to a smartphone app. In 2022, a team of researchers from the Massachusetts Institute of Technology (MIT) in Boston, Massachusetts (pictured on the following page), developed a water desalination unit that removes salts from saltwater quickly and cheaply. In about half an hour, the device produces a cupful of clean drinking water. The unit requires less power to operate than a phone charger, weighs less than 10 kg (22 lbs), and costs around $50. MIT researcher Jongyoon Han said, "This is really the culmination of a 10-year journey that I and my group have been on. We worked for years on the physics behind individual desalination processes, but pushing all those advances into a box, building a system, and demonstrating it in the ocean, that was a really meaningful and rewarding experience for me." In this activity, you will work in teams to design and revise a simple water-filtration device.

CONCEPTUAL TOOLS

SCIENCE AS A HUMAN ENDEAVOUR

SCIENTIFIC ADVANCEMENT

SCIENTIFIC OPTIMISM

Gitanjali Rao working in the lab.

MIT desalination research team in 2022.

MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

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

FOR EACH STUDENT

- SAFETY GOGGLES
- LAB COAT
- STUDENT SHEET 9.1 "Filtration Design Challenge"

PROCEDURE

PART A: INITIAL DESIGN

1 Read the following scenario.

Now that you have experience testing for water quality, Skipton's city council has reached out to you to work with someone on the Water Resources Control Board to educate local elementary students on how water treatment works.

Your goal is to create an efficient, cheap water-filtration device that:

1. *reduces the turbidity of water.*
2. *adjusts the water to a safe pH level.*
3. *simulates the removal of harmful contaminants. The red dye in your contaminated water sample represents contaminants such as harmful metals or toxins that can affect living organisms.*

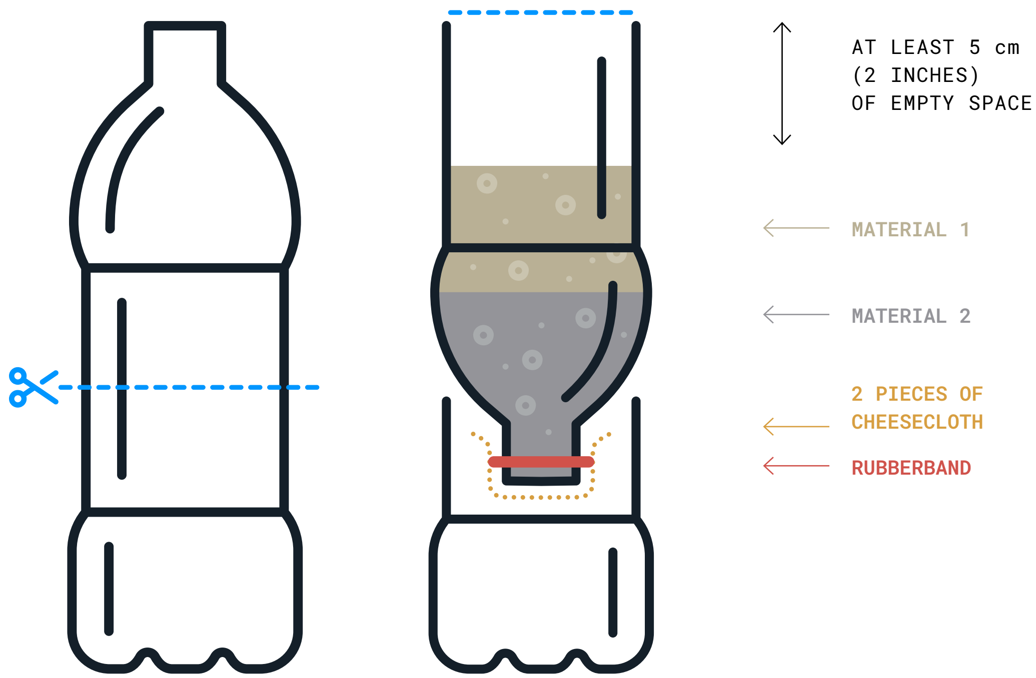
You will choose among various materials that can be used to filter the contaminated water sample that needs to be treated. Your design must use a plastic water bottle that is cut in half, cheesecloth, and a rubber band.

SAFETY NOTE

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

2 Look at Figure 9.1, which shows the basic design of your filtration device. Brainstorm with your group about which two of the following materials—activated charcoal, baking soda, coarse sand, fine sand, gravel—you would like to use to treat the water and why. Record in your science notebook the material you think will best treat the water's pH, turbidity, and contaminants.

FIGURE 9.1
Water-bottle setup for testing filtration materials



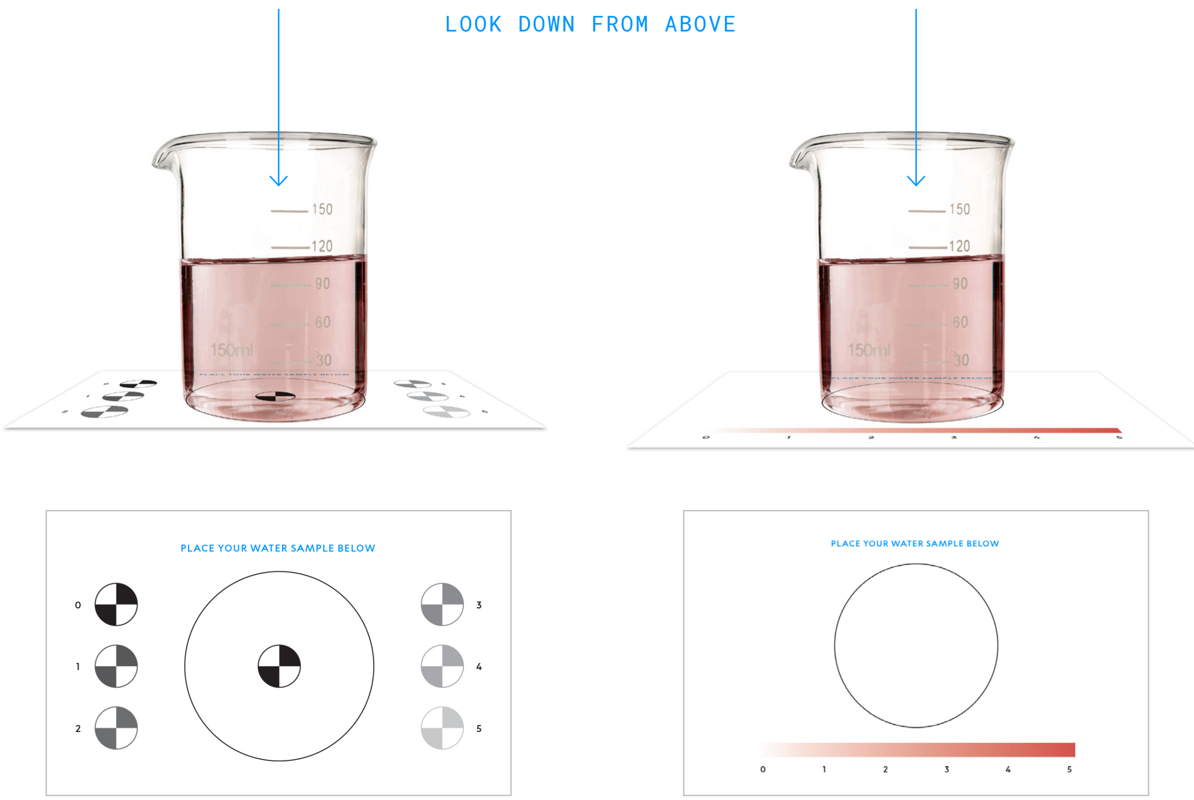
3 Before you build your device, test the turbidity, contaminant level, and pH of your water sample by pouring 100 mL into the empty beaker and completing the following steps.

a Measure turbidity by stirring the sample and placing the beaker in the middle of the Turbidity Rating Model card, as shown in Figure 9.2. The turbidity rating can be measured by looking straight down through your sample and choosing the Secchi disk (numbered 0–5) that most closely matches the one below your sample. Record your results on Student Sheet 9.1, "Filtration Design Challenge."

b Measure the contaminant level by placing the beaker with the sample in the white space above the colored scale of the Contaminant Level Rating card. The contaminant rating can be measured by looking straight down through your sample and choosing the color on the measurement card that most closely matches your sample (0–5). Record your results on Student Sheet 9.1.

c Test pH by dipping a piece of pH paper into your sample and comparing it to the pH scale for your pH paper. Record your results on Student Sheet 9.1.

FIGURE 9.2
Estimating turbidity and contaminant level using the measurement cards.



4 Plan the design of your filtration device by deciding on the order of placement of the two materials in your device and the thickness of each layer (in centimeters). Record your choices in Table 9.1 on Student Sheet 9.1. Then rinse out your testing beaker and follow your teacher's instructions for gathering your materials.

5 Attach 2 pieces of the cheesecloth across the neck of the bottle with a rubber band, as shown in the diagram of the water-bottle setup in Step 2. Add your 2 filtration materials to the inside of the bottle while keeping it over the second piece of the cut bottle. Note: You must leave at least 4 cm of empty space between the uppermost layer of filtration material and the very top of the bottle for the water sample.

6 Pour 150 mL of the water sample into the top of your filtration device. You may wish to note the time in order to record the amount of time it takes for the water to filter through your device. You can also measure the total amount of water recovered.

7 After the water has been filtered through, pour it into an empty beaker similar to the one used for your control. Compare the filtered water sample to that of clear tap water.

8 Test your filtered solution for turbidity, contaminant level, and pH as described in Step 3. Record your results in the second row of Table 9.2 on Student Sheet 9.1 and compare your test results to your initial ideas.

PART B: COLLABORATION WITH OTHER GROUPS

9 As a group, visit at least two other teams to:
   a share the results of your filtration device.
   b learn about their use of materials and their results.

10 Based on these findings, record in your science notebook at least two ideas for improving your filtration device.

PART C: ITERATION OF YOUR DESIGN

11 As a group, work together to decide how you will improve the design of your filtration device. For your second iteration, you may choose up to 3 filtration materials but must still leave at least 4 cm of empty space at the top. Record in your science notebook how you think these materials will affect turbidity, contaminant level, and pH. Note: You may use different materials or some of the same materials used in your first iteration. Rinse out your testing beaker and follow your teacher's instructions for gathering your materials.

12 Build your second filtration device with your three chosen materials, once again recording the order and thickness of your layers in Table 9.1 of Student Sheet 9.1.

13 Pour 150 mL of the water sample into the top of your filtration device. You may wish to note the time in order to record the amount of time it takes for the water to filter through your device. You can also measure the total amount of water recovered. If you saved a sample of filtered water from your first iteration, you can also compare the water samples.

14 Test the filtered solution for turbidity, contaminant level, and pH as described in Step 3. Record your results in the third row of Table 9.2 on Student Sheet 9.1.

15 Re-evaluate the ideas for your second design based on your new results.

   a As a group, compare your findings to at least two other teams and record in your science notebook two or more new or revised ideas.

   b Based on your findings and those from other teams, evaluate which parts of your design were a success and which still need to be improved upon. Record your ideas in your science notebook.

   c Work together to propose a design for a third iteration of your filtration device. As before, you may choose up to 3 filtration materials but must still leave at least 4 cm of empty space at the top. Record your ideas in the last column of Table 9.1 on Student Sheet 9.1.

Filtration device

BUILD UNDERSTANDING

1. During this design challenge, you collaborated with other teams to share your findings. Imagine your group had been working alone and was not able to receive feedback or share results with other groups. Explain how this would have affected:
   - the iteration process.
   - your success at finding materials that improved water quality.

2. Water treatment involves the use of chemical additives as well as filtration. Which process(es) do you think would have been more useful in addressing Skipton's water quality issues in Activity 1? Explain your reasoning.

3. What are the advantages and disadvantages of using iteration to develop scientific knowledge?

CONNECTIONS TO EVERYDAY LIFE

4. You follow a cookie recipe and end up with bland, burnt cookies. Describe how you could use iteration to perfect the recipe.

5. A friend of yours is developing a new video game. Describe ways in which she could use iteration and collaboration to improve the graphic design, user experience, and storyline of the video game.

EXTENSION

Revision of scientific ideas can sometimes occur quickly. The Internet started as a way for government researchers to share information quickly and easily. Find out how the invention of the Internet was a result of iteration, collaboration, and scientific advancement by doing research online.

KEY SCIENTIFIC TERMS

desalination