Water, Water Everywhere but Not a Drop to Drink!

8th Grade

SCALE K-12

SCalable Asymmetric Lifecycle Engagement

PURDUE UNIVERSITY | INSPIRE Research Institute for Pre-College Engineering

INDIANA UNIVERSITY SCHOOL OF EDUCATION Bloomington

ROI REGIONAL OPPORTUNITY INITIATIVES

Cover Information

Unit Title: Water, Water Everywhere but Not a Drop to Drink!
Grade Level Range: 8th Grade

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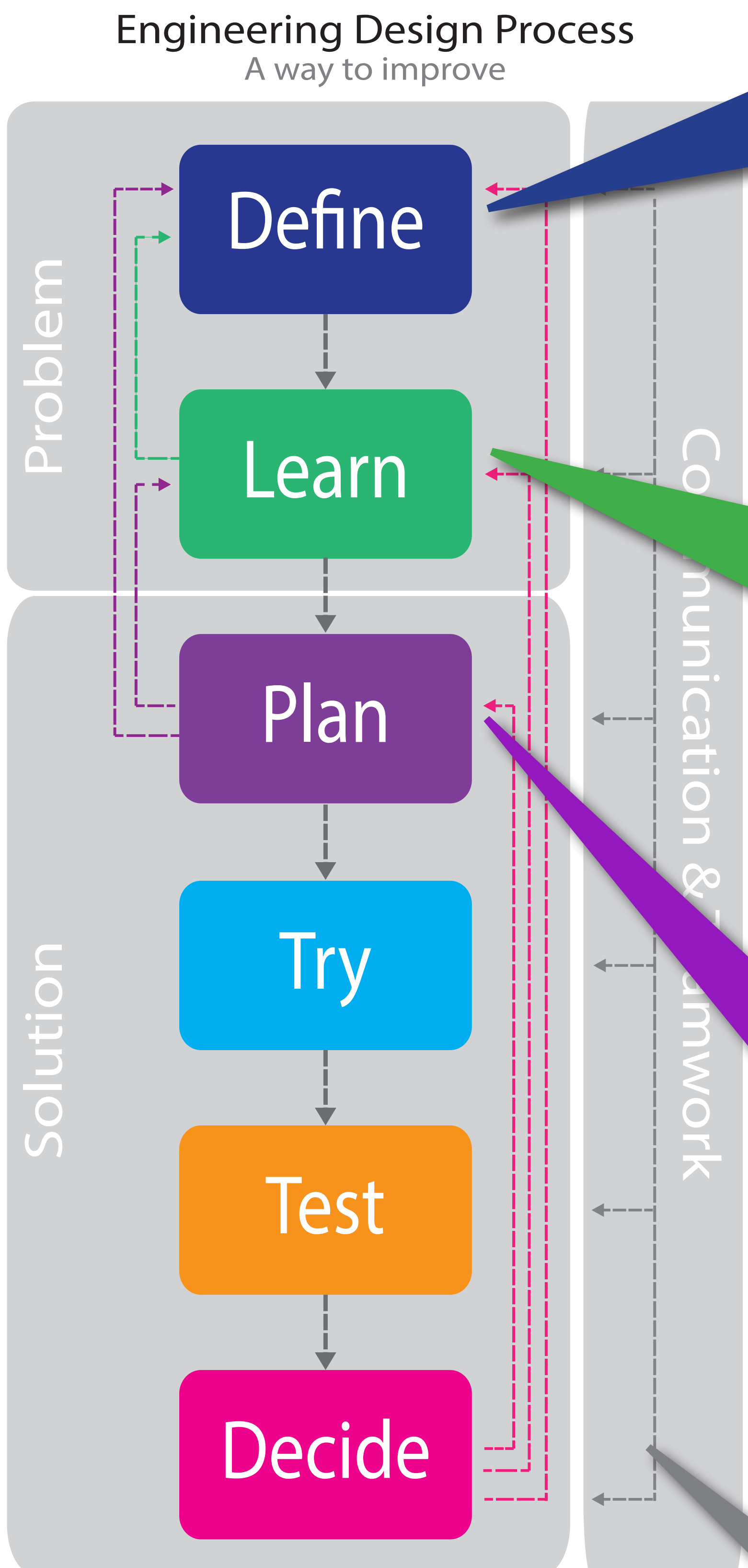


DEFINE THE PROBLEM

- Who is the **client**?
- What does the client need?
- Why does the client need it?
- Who is the **end user**?
- Why might the end user want it?
- What are the **criteria** (requirements)and **constraints** (limits) of the solution?

Problem Scoping:
WHO needs **WHAT** because **WHY**

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
  - What science/math knowledge will be needed?
  - What materials will be needed?
- What has already been done to solve the problem?
- What products fill a similar need?
- How should we measure success and improvement?

PLAN A SOLUTION

- Continue to specify the criteria/ constraints
- Generate ideas of possible solutions
- Develop multiple solution paths
- Consider **constraints, criteria**, and **trade-offs** (criteria that compete with one another)
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages, etc.)

COMMUNICATION

- Communicate the solution clearly and make sure it is easily understandable
- Use **evidence** to support why the client should use your solution

Overview: Engineering Design Process

TRY A SOLUTION

- Put the plan into action
- Consider risks and how to optimize work
- Use criteria/constraints and consider trade-offs from the problem/plan to build a **prototype** (a testable representation of a solution), **model**, or **product**

TEST A SOLUTION

- Consider testable questions or hypotheses
- Develop experiments or rubrics to determine if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

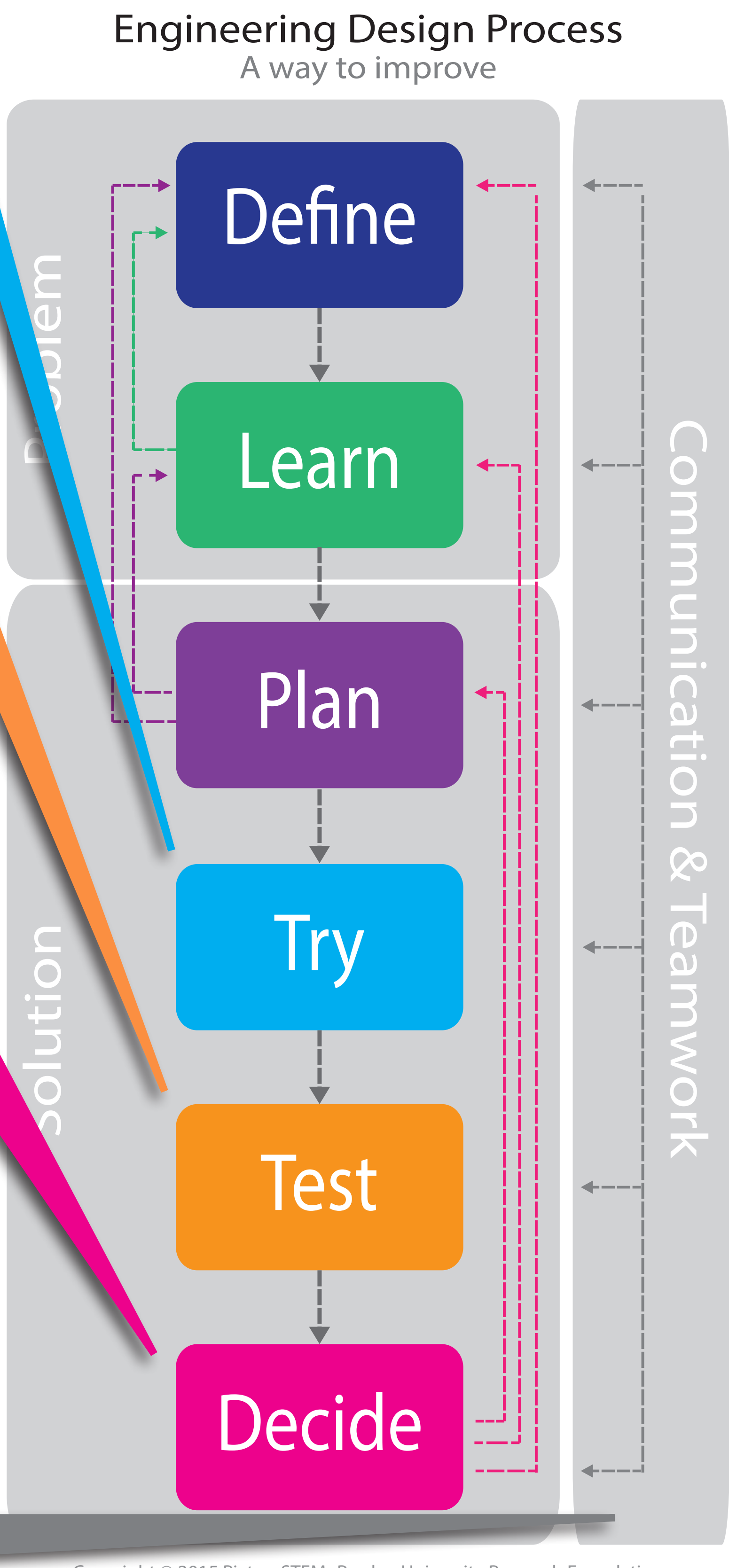
DECIDE IF THE SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does the design meet the criteria and constraints?
- How could the design be improved based on test results and feedback from the client/user?

Iterative nature of design: Always consider which step should be next!

TEAMWORK

- Discuss in teams how the solution meets the criteria and needs of the client
- Consider different viewpoints from each teammate



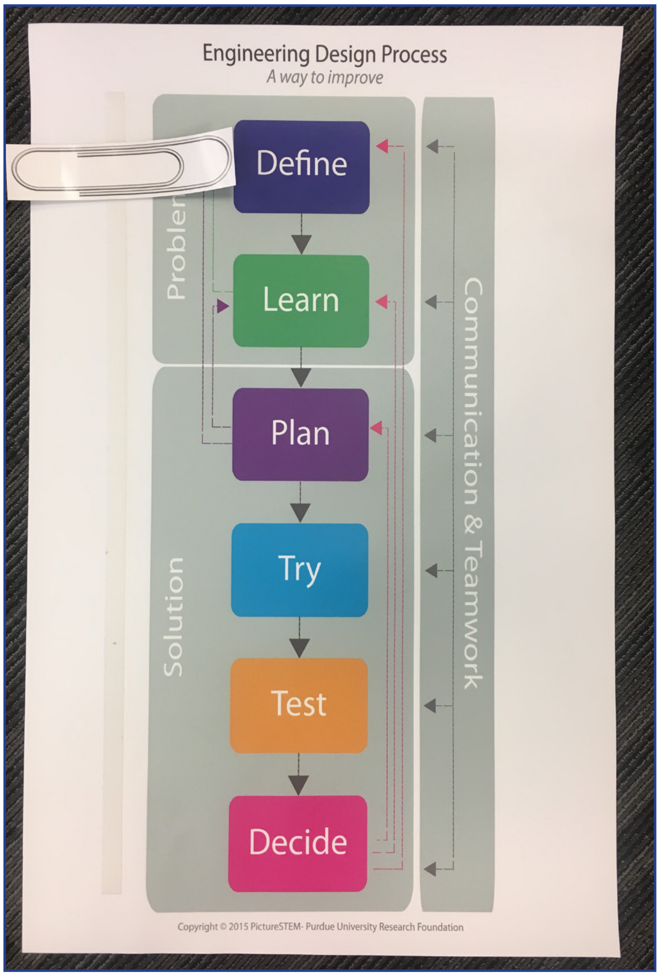
Overview: How to make EDP sliders

How to create the poster

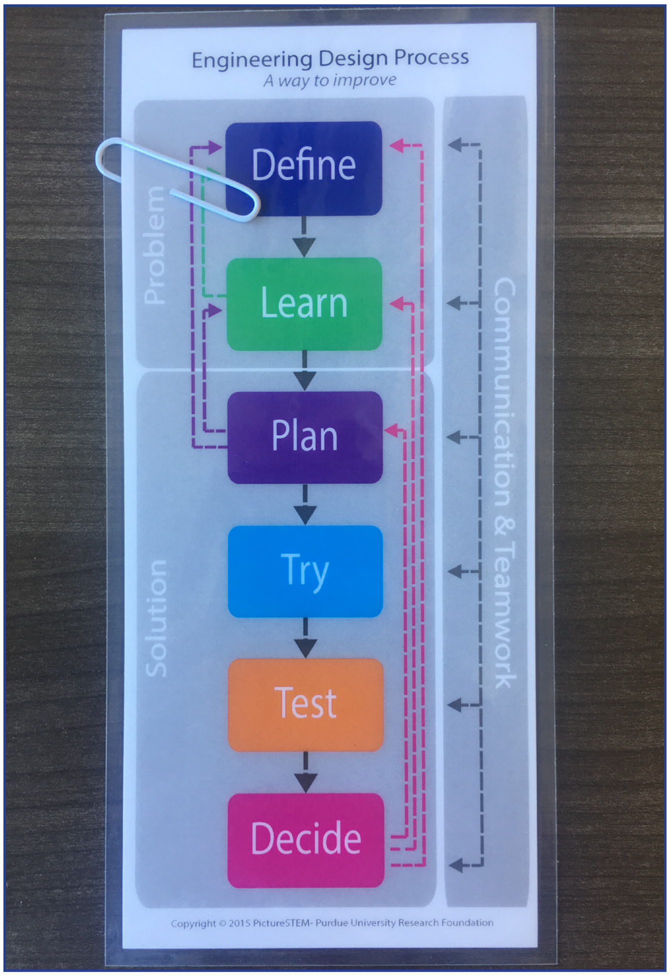
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the side of the poster so that the paper clip can be placed to point at all 6 sections of the slider.

How to create individual sliders

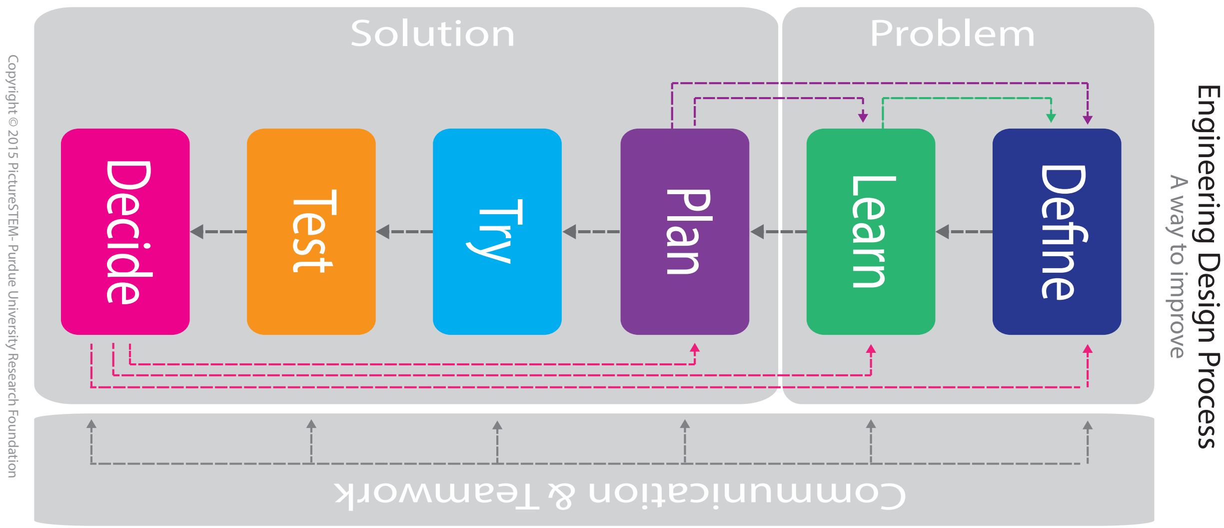
1. Print the sliders on the opposite page - enough for one slider per student in your class.
2. Cut the sliders apart.
3. Laminate the sliders individually.
4. Use a jumbo paper clip as the pointer for each slider.



Poster



Individual slider


Engineering Design Process
A way to improve
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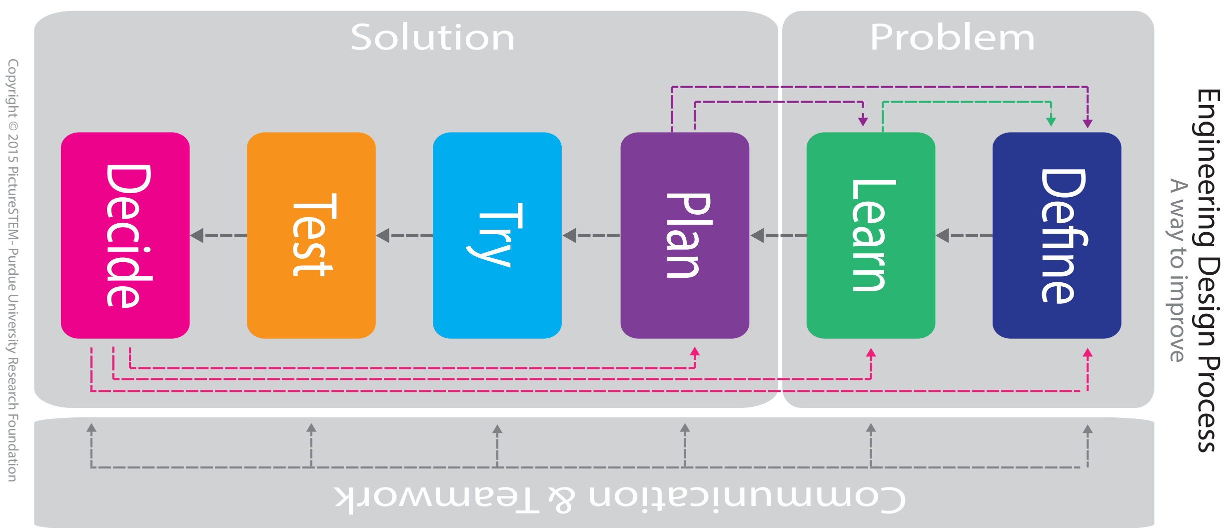
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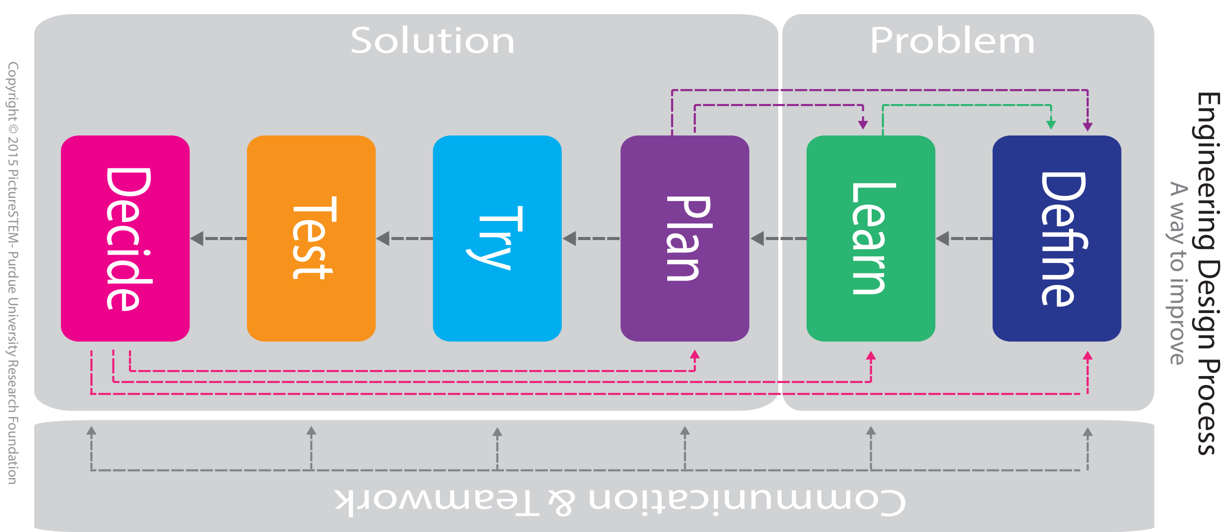
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Unit Overview

Grade Levels: 8th Grade

Approximate Time Needed to Complete Unit: 3 Weeks

Unit Summary:

QUENCH (QUality ENgineering for Community Health) is an organization that pursues environmental justice to improve public health through education and resource provision. QUENCH would like students to solve the problem of communities with poor water quality and minimal funding to treat water on their own. Students will learn about the water cycle, water scarcity, environmental justice, water treatment methods, microelectronic sensors, and water filtration. Through digital and analog measurement, students will learn about the importance of microelectronics when it comes to waterborne illness prevention. Based on the information learned and data acquired throughout the unit, students will make an evidence-based decision to design an efficient method of filtering water to potable quality.

Subject Connections:

Technology Connections	Technology and Engineering Connections	Mathematics Connections
Water quality, water cycle, water filtration, water treatment, water scarcity, environmental justice	Microelectronics, sensors, evidence-based reasoning, engineering design process	Flow rate, water quality data, data analysis

Standards:

Next Generation Science Standards

MS-ESS2-4 Earth's Systems: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

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

MS-ESS3-4 Earth and Human Activity: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5 Earth and Human Activity: Ask questions to clarify evidence of the factors that have caused the rise in global temperature over the past century.

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 on impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Lesson Summaries

Lesson 1: What is our engineering design challenge?
Students are introduced to the environmental justice-focused Engineering Design Challenge by their client. This will serve as the context within which students can learn about the water cycle, water treatment, and filtration. Students will learn about the Engineering Design Process and then take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Lesson 2: What phase is the water?
Students will learn about the water cycle and how one molecule of H_2O moves through various phases and locations throughout its life. After introducing the water cycle and its terminology, students will complete a worksheet to solidify their understanding of important vocabulary. The class will then play a game with dice that helps students understand how water travels through the cycle.

Lesson 3: Where is all the water?
Students will use an online tool to see how much water it takes to make their favorite meal. They will then learn about water scarcity and how some countries are at risk of running out of water for their citizens. Students will work in their design teams to research one country at risk of experiencing water scarcity by 2040 and share their results with the class.

Lesson 4: Who gets to drink the water?
The client has sent students a new memo asking them to learn about water treatment methods and environmental justice. Students will then learn about various water treatment methods and the differences between them, as well as environmental justice. Students will finish the lesson by writing a paragraph about environmental justice and water treatment.

Lesson 5: How does the water taste?
Have you ever noticed that water tastes different depending on where it's from? Students will learn about this concept as they work through tasting and sensor stations. Each design team will taste several types of water and drinks to describe the difference between them. Design teams will use LabQuest sensors and their analog tools to compare the difference in the values collected.

Lesson 6: How do we test the water?
The last learn lesson will allow students to explore the microelectronics component of water quality sensors. Students will review a diagram of a turbidimeter and look at a microchip with a light sensor on it. Students will complete a turbidity calculation to understand the relationship between voltage and turbidity.

Lesson 7: How do we treat the water?
Students will learn about different types of water filters and how they work to remove contaminants from drinking water. Students will then work in their design teams to test different filter media and see what is most effective at improving water quality.

Lesson 8: What should our filter look like?
Now that students have learned about the water cycle, water scarcity, environmental justice, sensors, and water treatment methods, they are ready to develop their ideas and brainstorm a solution to the engineering design challenge. Students will work individually and then in teams to brainstorm different water filter systems. Using evidence-based reasoning, they will make a decision as a design team.

Lesson 9: How do we build our filter?
Now that students have designed their filtration systems, they will physically build it using the household materials available to them. During the building process, teams are required to fill out a Bill of Materials to keep track of the quantity used of each item. At the end, the team will have to calculate the total cost of their filtration system.

Lesson 10: Does the filter work?
Students will test their constructed filter systems by running “untreated” water through them. Design teams are required to test the water quality before and after treatment to determine if they were successful.

Lesson 11: Will this filter work better?
Now that students have tested their filters, they have seen how they perform and what could be improved. This lesson allows students to repeat the process of planning, building, and testing their filters. The iterative design process will allow students to use evidence-based reasoning and water quality data to design an improved filter.

Lesson 12: What is our recommendation to the client?
In this lesson, students will report out their group findings to provide a holistic, evidence-based recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client.

Unit Planner

Lesson	Time Needed	Objectives	Duplication Master
1. What is our engineering design challenge?	100 minutes	• Identify the problem from a client. • Explain the differences and similarities between the engineering design process and scientific inquiry. • Identify background knowledge needed to develop a solution. • Explain the criteria and constraints.	1.A Content Pre-Assessment 1.B Problem Scoping Prompts 1.C EDP and Scientific Inquiry Comparison 1.D Client Letter
2. What phase is the water?	100 minutes	• Explain each step of the water cycle • Define terminology associated with the water cycle	2.A Client Memo 1 2.B The Water Cycle 2.C Water Cycle Vocabulary Matching 2.D Water Cycle Vocabulary 2.E Water Journey Tracker 2.F My Water Journey
3. Where is all the water?	50 minutes	• Define water scarcity • Explain why a country is at risk of experiencing water scarcity	3.A Water Footprint of a Meal 3.B Water Water Everywhere? 3.C Water Scarcity Information
4. Who gets to drink the water?	50 minutes	• Explain the difference between chemical, biological, and physical water treatment methods • Define environmental justice • Discuss one method of water treatment that can alleviate injustice	4.A Client Memo 2 4.B Water Treatment Methods 4.C Water Treatment Pros and Cons 4.D Justice Paragraph
5. How does the water taste?	100 minutes	• Use sensors to measure water quality parameters • Discuss the importance of water quality standards • Discuss the qualitative differences in various types of water sources	5.A Tasting and Testing Experiments 5.B Water Quality Standards
6. How do we test the water?	50 minutes	• Explain how a turbidimeter works • Define the term microelectronics	6.A Client Memo 3 6.B Turbidimeter Diagram 6.C Turbidity Calculation Worksheet

Lesson	Time Needed	Objectives	Duplication Master
7. How do we treat the water?	100 minutes	• Discuss different water filter media • Explain the difference between different types of filter media	7.A Client Memo 4 7.B Filter Media Testing
8. What should our filter look like?	50 minutes	• Design solutions to an engineering design challenge • Use evidence-based reasoning while designing a solution to a problem	8.A Filter Media Information 8.B Evidence-Based Reasoning 8.C Materials List 8.D EBR Example
9. How do we build our filter?	50 minutes	• Work as a design team to construct a filter system • Calculate a product's total cost from a bill of materials	9.A Bill of Materials
10. Does the filter work?	50 minutes	• Filter untreated water through filtration systems • Analyze water quality data to determine if water has been properly treated	10.A Filter System Data
11. Will the filter work better?	50 minutes	• Redesign based on acquired data • Use evidence-based reasoning to improve filter design	11.A Evidence-Based Reasoning 11.B Bill of Materials 11.C Filter System Data
12. What is our recommendation to the client?	100 minutes	• Communicate science, technology, engineering, and mathematics ideas by giving presentations • Use evidence-based reasoning to support their engineering decisions	12.A Client Memo 4 12.B Client Communication Requirements 12.C Decision Matrix Directions 12.D Decision Matrix Activity 12.E Client Memo 5 12.F Content Post-Assessment

Master Material List

	Unit Materials	Lessons Where Material is Used
Per Classroom	EDP Poster	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Chart paper/Large (15” x 18”) Post-It Paper	1, 3
	Lab wash bottle	5, 7, 10, 11, 12
	Vernier LabQuest 3	5, 7, 10, 11
	Vernier pH Sensor	5, 7, 10, 11
	Vernier Salinity Sensor	5, 7, 10, 11
	Vernier Temperature Sensor	5, 7, 10, 11
	Vernier Turbidity Sensor	5, 7, 10, 11
	pH test strips	5
	Salinity test strips	5
	Thermometer (not digital)	5
	Turbidity tube with secchi disk	5
	Water from various sources (bottled, tap, etc.)	5
	Several drinks (lemonade, soda, milk, etc.)	5
	Four gallon-sized jugs	5
	Small plastic cups	5
	LifeStraw	7
	Brita filter replacement	7
	Soy sauce	7
	Cheesecloth	7, 9, 10, 11
	Cotton balls	7, 9, 11
	Gauze	7, 9, 11
	Gravel	7, 9, 11
	Paper towel	7, 9, 11
	Rice	7, 9, 11
	Sand	7, 9, 11
	Sponge	7, 9, 11
Per Group	Large Post-It page	4
	Light sensor	6
	100-mL breaker or graduated cylinder	7
	1-liter plastic water bottle	7, 8, 9, 11
	Ring stand	7, 9, 10, 11
	Coffee filter	7, 8, 11
	2 plastic cups (that can hold 8 oz or more)	7, 10
	Stopwatch	7, 19
	Constructed filter system	10

Master Material List

	Unit Materials	Lessons Where Material is Used
Per Student	EDP slider and paper clip	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Laptop/Chromebook/Tablet	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Engineering notebook	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Pencils and erasers	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	1 six-sided die	2
	Small disposable plastic cup	5

LESSON ONE:

Lesson Objectives

Students will be able to:

- Identify the problem from a client.
- Explain the differences and similarities between the engineering design process and scientific inquiry.
- Identify background knowledge needed to develop a solution.
- Explain the criteria and constraints.

Time Required

Two 50-minute lessons

Materials

Per classroom

- EDP Poster
- Chart paper/Large Post-Its

Per student

- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed

NGSS

- MS-ETS1-1

Key Terms

Client, engineering design process, criteria, constraints, microelectronics

Lesson Summary

Students are introduced to the environmental justice-focused Engineering Design Challenge by their client. This will serve as the context within which students can learn about the water cycle, water treatment, and filtration. Students will learn about the Engineering Design Process and then take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Background

Teacher Background

Teamwork: Students should be teamed strategically and may or may not be assigned jobs within their team. When forming student teams, consider academic, language, and social needs. In place of strategic teaming, a random teaming can be substituted. Students will work in these teams of 3 or 4 throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general. The teams will operate as consulting engineers with each team specializing in a specific measuring device eventually working together as a class to address the client's problem.

Career Connections: Students will be introduced to new STEM content potentially for the first time. There are many career opportunities that align with the content in this unit. Please plan to highlight these as you see fit and encourage students to think about how these topics align with their personal and future interests.

Engineering Design Process:
NOTE: If students are familiar with the engineering design process (EDP) before beginning the unit, the teacher can skip this (EDP) introduction.

The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is no one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas. Students will use an engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see the front matter section about it.

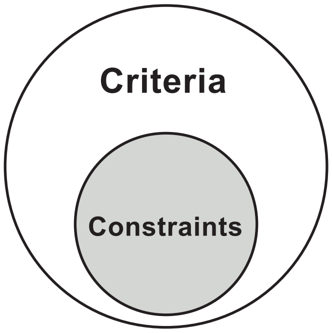
Some common misconceptions about engineering:

- Engineers do not have to learn anything new when they are working on a project. **In reality:** Engineers need to continually learn throughout their lives.
- Engineers come up with solutions that are just "good enough" and do not take risks. **In reality:** Engineers strive to create the best solution possible through optimization. It is normal to experience failure when solving engineering problems.
- Engineers work alone to solve a design problem. **In reality:** Engineers collaborate with people in different disciplines and fields to best solve a problem. Engineering problems often require a wide range of content knowledge.

Some common misconceptions about the EDP:

- The engineering design process is linear, and you never need to go back to previous phases. **In reality:** The EDP is a cyclical process that requires many iterations.
- Once the project is done, it is considered complete and not revisited. **In reality:** The engineering design process is never really "done" and it is revisited so engineers can improve projects and make changes.

Criteria and Constraints: One difficulty that students might experience is distinguishing between criteria and constraints. Criteria are the things required for a successful design, or goals of the designed solutions. They help engineers decide whether the solution has solved the problem. Another way of thinking about criteria are that they are anything that the client and the engineers will use to judge the quality of a solution. Constraints are a specific type of criteria; they are those criteria that limit design possibilities, or the ways that that problem can be solved. If constraints are not met, the design solution is by default not a viable solution to the problem. The relationship between criteria and constraints is represented in the figure. It may be helpful to post the definitions with the figure somewhere in the classroom for future reference.



Assessment

Pre-Activity Assessment

Assess students' prior knowledge by listening to their responses to 1.B Problem Scoping Prompts. Use students' answers to 1.A Content Pre-Assessment as baseline data about the students' current level of understanding and background knowledge.

Activity Embedded Assessment

Observe students' discussions and written responses to 1.B Problem Scoping Prompts. Check students' brainstorming lists to see if they can identify the content they will be expected to master by the end of the unit.

Post-Activity Assessment

Use the 1.E Problem Scoping Section 3 Key to evaluate students' answers to the notebook prompts.

Duplication Masters

- 1.A Content Pre-Assessment
- 1.B Problem Scoping Prompts
- 1.C EDP and Scientific Inquiry Comparison
- 1.D Client Letter

Educator Resources

- 1.E Content Pre-Assessment Key
- 1.F Problem Scoping Section 3 Key

Problem Scoping: In this lesson, students will be in the Problem Scoping section of the engineering design process, specifically on the define the problem step. Define the problem and learn about the problem combine to make Problem Scoping. In this stage, students will be first introduced to the engineering problem through a client letter and then be given a chance to ask questions to the client to receive more information about the problem. The problem statements given in the client memos purposefully do not provide all the information necessary to solve the problem. Students are tasked with generating questions about the problem to try to fill in this missing information. Based on all information from the client, students will then define the problem in terms of: what the problem is and why it is important, who are the client and end users, what are the criteria and constraints, and what other information they may need to learn about in order to solve the problem. This process of generating ideas and questions for the client is an important skill on its own both in engineering and in other fields, but it also helps to ensure that the students fully understand the problem and their task in the engineering design challenge.

Solution Generation: The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration as a means to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints, and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering Notebook: Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook immediately in Lesson 1. The engineering notebook is digital set of documents which includes writing prompts, black space to take notes or upload pictures of work, and digital copies of the duplication masters that are listed in each lesson. The engineering notebook is offered as a google doc but can be adapted to your classroom needs. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit.

Vocabulary: Students will be introduced to many new science and engineering vocabulary terms throughout the unit. It may be helpful to create a vocabulary section in their notebook with term definition and memory clue. Additionally, the class could maintain a word wall.

Before the Activity

- Assemble the Engineering Design Process Sliders and post the EDP poster in the classroom (see the front matter for how to assemble them). If your students do not want to use the sliders, simply hanging the poster achieves the same result. Make sure you and your students can refer to the EDP sliders and/or poster throughout the unit.
- Determine student teams of three or four. These teams should be their teams throughout the rest of the unit.
- Print and make copies of the following worksheets in the labeled amounts:
  - (1 per student) 1.A Content Pre-Assessment, 1.D Client Letter
  - (1 per group) 1.C EDP and Scientific Inquiry

Classroom Instruction

Introduction

1. **Complete the pre-assessment activity.** The students will participate in a more formal pre-assessment to assess their current level of knowledge and understanding regarding the topics the water cycle, filtration, environmental justice, microelectronics, and the engineering design process. Using the questions on the 1.A Content Pre-Assessment, distribute hard copies or have students respond to a digital version of the survey. Make sure to tell students that this is just to assess any prior knowledge, so it is okay to not know the answers.
2. **Review prior knowledge.** Lead a discussion with the class in which students are able to share their prior knowledge on the topics of engineering, the water cycle, filtration, and electronics. Prompts may include the following: *What do engineers do? What kinds of industries do engineers work in? Other than hydrogen and oxygen, what is in your drinking water? How do we know if water is ok to drink?*
3. **Set up engineering notebooks. Say:** *Engineers use notebooks to document their design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the engineering notebooks to take notes and record what you are learning. In addition, there*

are questions that you'll be asked to answer.

NOTE: You can have your students write in their notebooks in two different colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This will help both you assess, and the students recognize, where ideas came from. You also may want to have students start a Table of Contents page.

4. **Complete problem scoping section 1.** Direct students to the 1.B Problem Scoping Prompts in their engineering notebooks. Have students individually answer the prompts from section 1. Make sure to let them know that it is okay if they do not know very much about engineers or engineering – just have them answer these questions to the best of their ability.
5. **Form teams.** After students have finished the prompts, explain that for the rest of the unit they will start the day with a review of the engineering design process, and then look at a specific problem that will require the use of that process. Explain that students will be working in small teams to solve a problem being brought to them by the client. Divide students into teams of 3 or 4.

Activity

6. **Discuss engineers and engineering.** Allow students to share their answers from 1.B Problem Scoping Prompts section 1. Define engineers and engineering and take some notes for students to type in their notebooks. As a class create a list of the different types of engineering and have students brainstorm careers that may fall within each type of engineering in their notebooks. Explain that the problem they will be solving falls under the category of environmental engineering and draws on biology and electronics to understand the context and generate a solution.
7. **Introduce the Engineering Design Process.** Display the Engineering Design Process poster and pass out individual EDP Sliders and a paper clip to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. Since we are working as engineers during this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.* Go through the EDP Slider and ask the students what they think each stage involves. Be sure to clarify any misconceptions and elaborate where needed. There is a detailed description of the

EDP Slider in the front matter of the unit. **Ask:** *Based on what we have discussed so far, where do you think we are in the engineering design process?* **(Define).**

8. **Compare the Engineering Design Process and Scientific Inquiry.** Have students individually examine 1.C EDP and Scientific Inquiry Comparison then, in their groups, discuss the differences and similarities between the two methods. Remind them to keep track of the discussion in their engineering notebooks to share back with the class later. Have a class discussion allowing groups share what they noticed about the two methods.

   NOTE: If you don't have time, you can skip comparing the two processes.
9. **Introduce the problem.** Allow students time to read copies of the 1.D Client Letter. Encourage them to write in their notebooks as they read to keep track of important information. Give students time to discuss in small teams what information they read in the letter. **Ask:** *What is the challenge? What are some possible constraints and criteria?*
10. **Identify the problem from the client.** Have the students reread the letter, if necessary, to identify the problem and type it in their notebooks.
11. **Identify required information.** Have students work together to brainstorm a list of "required information" in order to help the client with their request. Encourage them to highlight/underline the things on their list they already know. Then as a class create an anchor chart that will be revisited throughout the unit. As students learn information you can check content off of the anchor chart or add to it if they think of some other information that they will need to help the client.
12. **Complete problem scoping section 2.** After reading the letter, direct students to respond to section 2 of the 1.B Problem Scoping Prompts in their notebooks. They can do this individually or in teams.
13. **Complete problem scoping section 3.** After students have completed the section 2 prompt, direct students to section 3 of 1.B Problem Scoping Prompts. They can do this individually or in teams.

Closure

14. **Revisit the problem.** Give the students a chance to revise their list of questions or required information they composed for the engineering challenge.
15. **Discuss the engineering design process. Ask:** *Which phase of the engineering design process did we focus on related to our challenge today? Why is this important?* Ex: Students need to understand the root problem from the perspective of the client and other stakeholders before attempting a solution.

What is our engineering design challenge?

Name______________________________________ Date_______________ Period __________

1.A Content Pre-Assessment

1. Name two filter media that may be used in water filtration.

2. Why is environmental justice important?

3. What are some methods of resolving environmental injustice?

4. Why are countries such as Pakistan and Spain are predicted to experience water scarcity in the year 2040?

5. Name at least one component of drinking water other than the chemical components of hydrogen and oxygen.

Name____ Date_______________ Period __________

1.A Content Pre-Assessment

6. Why is it important to use microelectronic-based water sensors as opposed to their analogs?

7. What does the term, “microelectronics” mean?

8. How are microelectronics used in the field of science?

9. What jobs would you be interested in that use microelectronics?

10. Provide one example of how microelectronics is used in that job.

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

Section 1:

Directions: Please answer the following questions.

1. What do engineers do?

2. How do engineers solve problems?

Section 2:

Directions: Please answer the question after hearing about the engineering design challenge.

3. What questions do you want to ask the client?

Section 3:

Directions: Please answer these questions after you have been able to ask questions about the challenge. First, complete each prompt on your own. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

4. The client is:

5. The client's problem is:

Name_______________________________________ Date_______________ Period __________

1.B Problem Scoping Prompts

6. The problem is important to solve because:

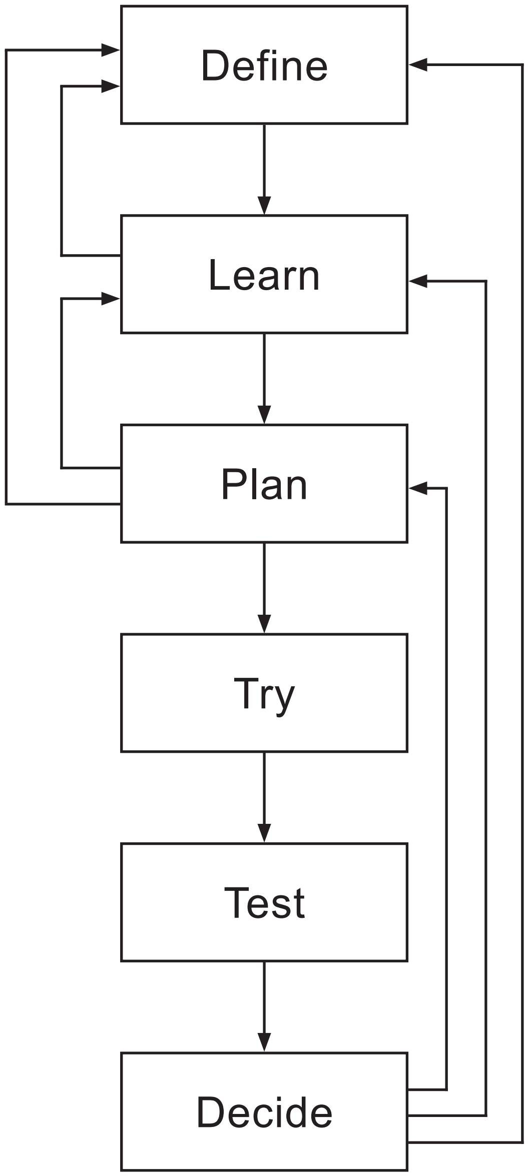
7. The end-users are:

8. An effective solution for the client will meet the following criteria:

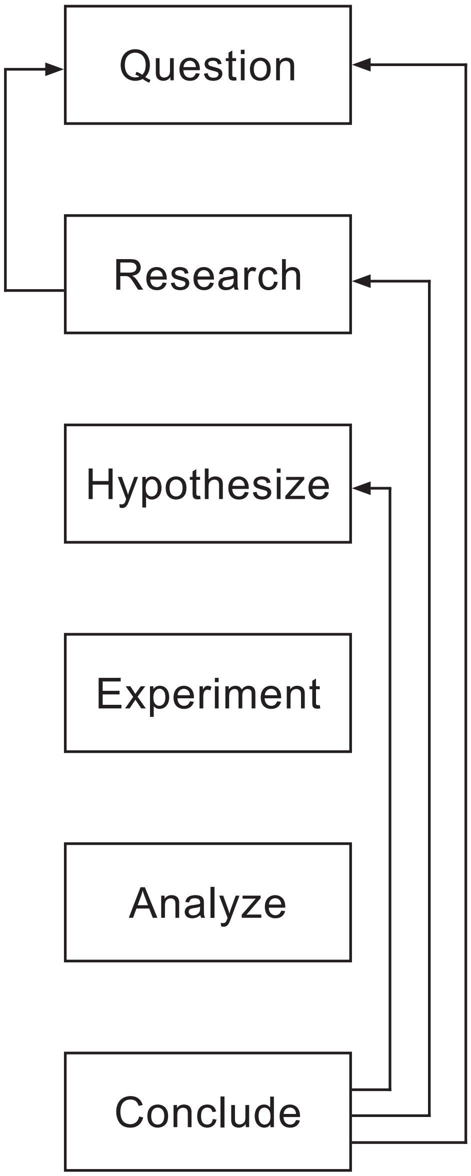
9. The constraints (or the limits) of the solution are:

10. Think about the problem of providing safe water access. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

1.C EDP and Scientific Inquiry Comparison



Engineering Design Process



Scientific Inquiry

1.D Client Letter

Dear Engineers,

People across the globe face challenges including poverty, hunger, inequality, and climate change. Some challenges are a result of contamination in the environment. For example, if a factory releases a toxic chemical into the environment, it may get into drinking water sources and then make people in that local community sick.

There is evidence that shows that households with a lower income are more likely to experience negative impact from environmental contamination. This is considered unfair, as every person, regardless of their economic status, should have the right to a safe and healthy environment. This idea is called environmental justice.

My company works within communities to pursue environmental justice through education and resource provision. This is important for helping all people have access to a safe and healthy environment. Specifically, we provide water treatment for communities that do not have access to safe, potable water. However, many of these communities are still building their economy and cannot afford to install and maintain complex, expensive treatment systems. I want to enlist your help to provide us with a design of how we can help these communities improve their drinking water quality.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to make an evidence-based recommendation for us. Please include this recommendation in your final report so we know why you have come to your conclusion. Note that this recommendation must be reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning. We look forward to reading your report and implementing your result.

Sincerely,

Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

1.E Content Pre-Assessment Key

1. Name two filter media that may be used in water filtration.

   Answers will vary, but correct answers include sand, gravel, or activated carbon.

2. Why is environmental justice important?

   Answers should vary based on students' personal convictions and opinions. Satisfactory responses should state why it is unfair to receive different treatment from another person based on demographics.

3. What are some methods of resolving environmental injustice?

   There are many answers, but potential ideas include changing policies to be fair and inclusive, stricter limits on factory emissions, or providing public health information to the general public.

4. Why are countries such as Pakistan and Spain are predicted to experience water scarcity in the year 2040?

   Answers will vary, but correct answers include increased consumption by farms and industry, rapidly increasing populations, migration toward cities, and climate change.

5. Name at least one component of drinking water other than the chemical components of hydrogen and oxygen.

   Correct answers include minerals, metals, small particles, and organic material.

6. Why is it important to use microelectronic-based water sensors as opposed to their analogs?

   Microelectronic sensors provide very accurate measurements which ensure water quality standards are met.

7. What does the term, "microelectronics" mean?

   Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

1.E Content Pre-Assessment Key

8. How are microelectronics used in the field of science?

    There are many answers to this question, but examples include sensors, controllers, measurement tools, instruments, computers, etc.

9. What jobs would you be interested in that use microelectronics?

    Students' answers will vary based on interest. Credit may be given as long as at least one job example is provided.

10. Provide one example of how microelectronics is used in that job.

    Students' answers will vary based on interest. Credit may be given as long as at least one example is provided of how microelectronics is used in the job they provided in question nine.

1.F Problem Scoping Section 3 Key

Section 3:

4. The client is:

   Brooks Eaton at QUENCH.

5. The client's problem is:

   Providing safe water access for people that do not have potable water.

6. The problem is important to solve because:

   All people should have access to a safe and healthy environment.

7. The end-users are:

   Community members that do have access to safe, potable water.

8. An effective solution for the client will meet the following criteria:

   The recommendation should be reliable, cost effective, ethical, and demonstrate the use of scientific reasoning.

9. The constraints (or the limits) of the solution are:

   These communities cannot afford to install and maintain complex, expensive systems.

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

    Answers will vary. Potential ideas include how to treat water, what in the water needs to be treated/removed, how many people need potable water per community, where the communities are, how to determine if water is potable, etc.

LESSON TWO:

Lesson Objectives
Students will be able to:
- Explain each step of the water cycle
- Define terminology associated with the water cycle

Time Required
Two 50-minute lessons

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers
- 1 six-sided die

Standards Addressed
NGSS
- MS-ESS2-4

Key Terms
Water cycle, evaporation, condensation, precipitation

Lesson Summary

Students will learn about the water cycle and how one molecule of H_2O moves through various phases and locations throughout its life. After introducing the water cycle and its terminology, students will complete a worksheet to solidify their understanding of important vocabulary. The class will then play a game with dice that helps students understand how water travels through the cycle.

Before the Activity

- Prior to class, the teacher should print out one copy per student of Duplication Master 2.C Water Cycle Vocabulary Matching. Cut out each of the rectangles so students can match the words to the definitions during the activity.
- Prior to class, the teacher should print out one copy of Duplication Masters 2.G through 2.V for the water cycle game. There will be 8 stations around the room for the dice game.
  - The first eight duplication masters (2.G through 2.N) can be hung above the stations to help students know where each one is located.
  - The second set of eight duplication masters (2.O through 2.V) can be set out at each station. These are the instructions for students.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.
3. **Read the client memo.** Hand out Duplication Master 2.A Client Memo 1. Allow students a few minutes to read the memo.

Activity

4. **Introduce the water cycle.** Hand out Duplication Master 2.B The Water Cycle. Explain the concept that water cycles through different phases by experiences various processes as shown in the image. Briefly walk through some of the processes in the image to explain this process.
5. **Provide scaffolding for students about the water cycle.** Hand out the cut-out pieces of Duplication Master 2.C Water Cycle Vocabulary Matching. **Say:** *Each piece has a picture and either a word or its definition. Match the pictures together to match a word to its definition. Each word here is a process in the water cycle.*
6. **Allow students to work through the worksheet.** Hand out Duplication Master 2.D Water Cycle Vocabulary. **Say:** *Use the definitions you just found to guide you as you work through this activity.* Allow students 5 – 10 minutes to work through the activity individually or in their groups.
7. **Play the water cycle dice game. Say:** *Each of you represents one molecule of water. You are going to take a journey through the water cycle as a water molecule.* Hand out Duplication Master 2.E Water Journey Tracker. **Say:** *As you travel from station to station, or remain at a station, write down the process you experience and your location.*
8. **Prepare for the game.** Split the class into eight groups and have each group start at a different station. **Say:** *When I say you can begin, you can pick up a die at your station and take your first turn by rolling the die. After your roll, write down what happened on your Journey Tracker. Then, either stay at your station or move to the next one, bringing your die with you. Your first turn is now over and you can begin your second turn. You will repeat this process until you have rolled the die ten times.* When the teacher is ready, they will let the students begin and take their ten turns.
9. **Have students draw their water cycle journey.** Hand out Duplication Master 2.F My Water Journey. **Say:** *Now that you have completed your water cycle journey, draw the path you took. Start at your first station and draw an arrow each time you moved to a new station.*
10. **Compare water cycle journeys. Say:** *Compare your journey to the students sitting next to you. How similar or different are they?* Allow students a moment to compare journeys. **Say:** *Just like your journeys were different, each water molecule experiences different paths through phases and locations.*

Assessment

Activity Embedded Assessment

Observe students as they work through Duplication Master 2.B The Water Cycle. Take note on their knowledge of the water cycle processes or if they are having trouble identifying each term. Note if they understand what is happening during the water cycle game and thinking about each process, or just rolling the die for fun.

Duplication Masters

- 2.A Client Memo 1
- 2.B The Water Cycle
- 2.C Water Cycle Vocabulary Matching
- 2.D Water Cycle Vocabulary
- 2.E Water Journey Tracker
- 2.F My Water Journey

Educator Resources

- 2.G Water Cycle Game – Atmosphere Station Label
- 2.H Water Cycle Game – Clouds Station Label
- 2.I Water Cycle Game – Groundwater Station Label
- 2.J Water Cycle Game – Lake Station Label
- 2.K Water Cycle Game – Land Station Label
- 2.L Water Cycle Game – Mountains Station Label
- 2.M Water Cycle Game – Ocean Station Label
- 2.N Water Cycle Game – Plants Station Label
- 2.O Water Cycle Game – Atmosphere
- 2.P Water Cycle Game – Clouds
- 2.Q Water Cycle Game – Groundwater
- 2.R Water Cycle Game – Lake
- 2.S Water Cycle Game – Land
- 2.T Water Cycle Game – Mountains
- 2.U Water Cycle Game – Ocean
- 2.V Water Cycle Game – Plants
- 2.W Water Cycle Vocabulary KEY

Closure

11. Connect the activity to the engineering design challenge.
Ask: *What did we learn today that will help us provide a recommendation to the client? What part of the water cycle are we working within for our challenge?* **Say:** *We will continue in the Learn stage during our next class.*

What phase is the water?

2.A Client Memo 1

Dear Engineers,

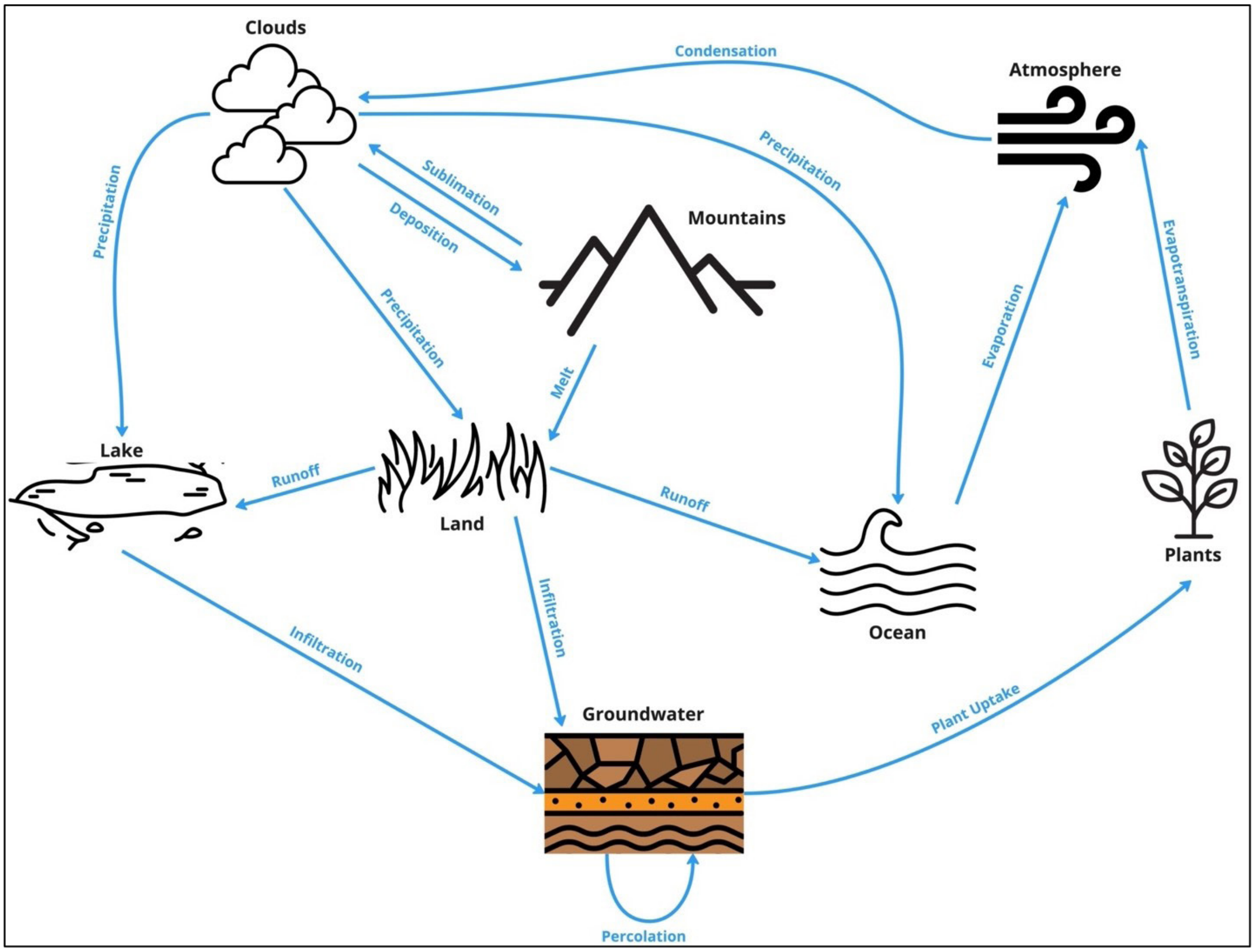
Thank you for agreeing to work with us on our engineering design challenge. Before you can begin solving the problem, it is important to learn relevant information to ensure you fully understand the context. I have prepared a few lessons for you about the water cycle, water scarcity, environmental justice, and different types of filters. I hope you find these activities helpful as we continue working toward pursuing environmental justice.

Sincerely,

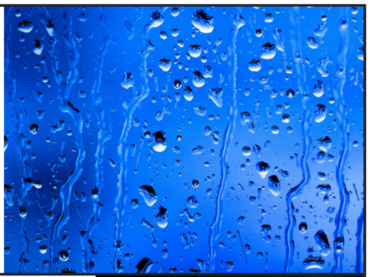
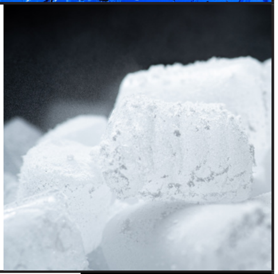
Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

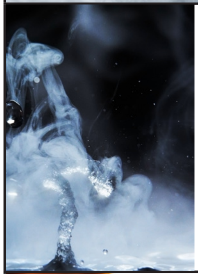
2.B The Water Cycle



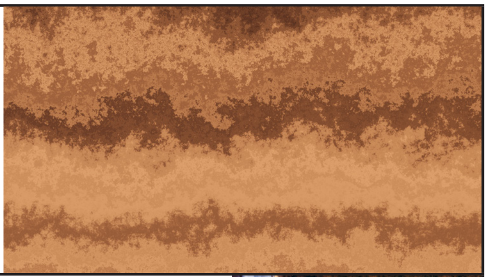
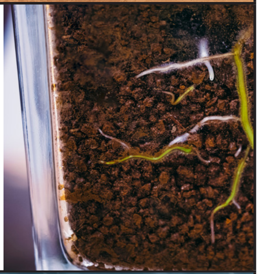
2.C Water Cycle Vocabulary Matching

Condensation	
Deposition	
Evaporation	
Evapotranspiration	
Infiltration	
Melt	

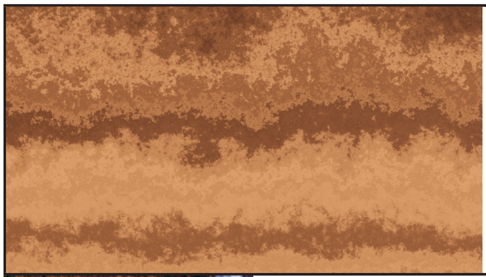
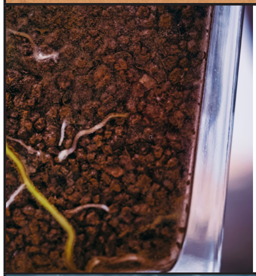
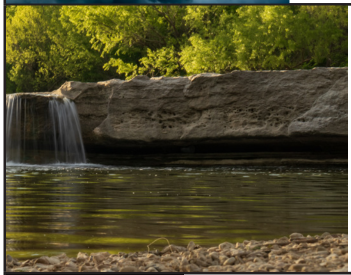
2.C Water Cycle Vocabulary Matching

	Water vapor converts to liquid water.
	Water vapor directly converts to solid water.
	Liquid water converts to water vapor.
	A combination of evaporation and transpiration: water in the soil and on plants is transferred into the atmosphere.
	Water on the surface of the ground enters into the soil.
	Fallen snow melts into liquid water.

2.C Water Cycle Vocabulary Matching

Percolation	
Plant Uptake	
Precipitation	
Runoff	
Sublimation	

2.C Water Cycle Vocabulary Matching

	The movement of water through soil.
	Water in the soil is absorbed by a plant’s roots.
	Water vapor in the atmosphere becomes liquid water and falls toward the earth.
	The flow of liquid water over a land surface, typically downhill.
	Solid water directly converts to water vapor.

Name________________________________ Date______________ Period __________

2.D Water Cycle Vocabulary

How does water move around the planet and convert from one water source to another? For each row, choose the word from the word bank that describes the process. Some words in the word bank may not be used, or some may be used more than once. Circle Yes or No to answer the question if the water changed phases during this process.

Word Bank

Condensation	Dilution	Infection	Plant Uptake	Reflection
Deletion	Evaporation	Infiltration	Precipitation	Runoff
Deposition	Evapotranspiration	Melt	Reaction	Sublimation
Digestion	Ignition	Percolation	Reduction	Vibration

Description of Event	Name of Process	Did the water change phases?
Water vapor becomes solid.		Yes No
What happens to ice and snow when the weather gets warmer.		Yes No
Rain or snow fall from the sky.		Yes No
Thanks to this process, we can drink groundwater from our wells.		Yes No
Liquid water becomes a gas.		Yes No
The soil cannot absorb any additional water, so this occurs.		Yes No
It is snowing and you get a snow day!		Yes No
There is so much water on the ground that some of it moves down into the soil.		Yes No
Ice is converted directly to vapor without melting.		Yes No
Your snowman turns into a puddle.		Yes No
Water vapor forms liquid droplets.		Yes No
Plants retrieve water from the soil.		Yes No
Water droplets form on the outside of your glass of cold water.		Yes No
You pour too much water into your flowerpot.		Yes No
Water droplets on land become water vapor in the atmosphere.		Yes No
Water moves through the soil.		Yes No

Name____ Date_______________ Period __________

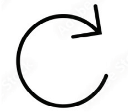
2.E Water Journey Tracker

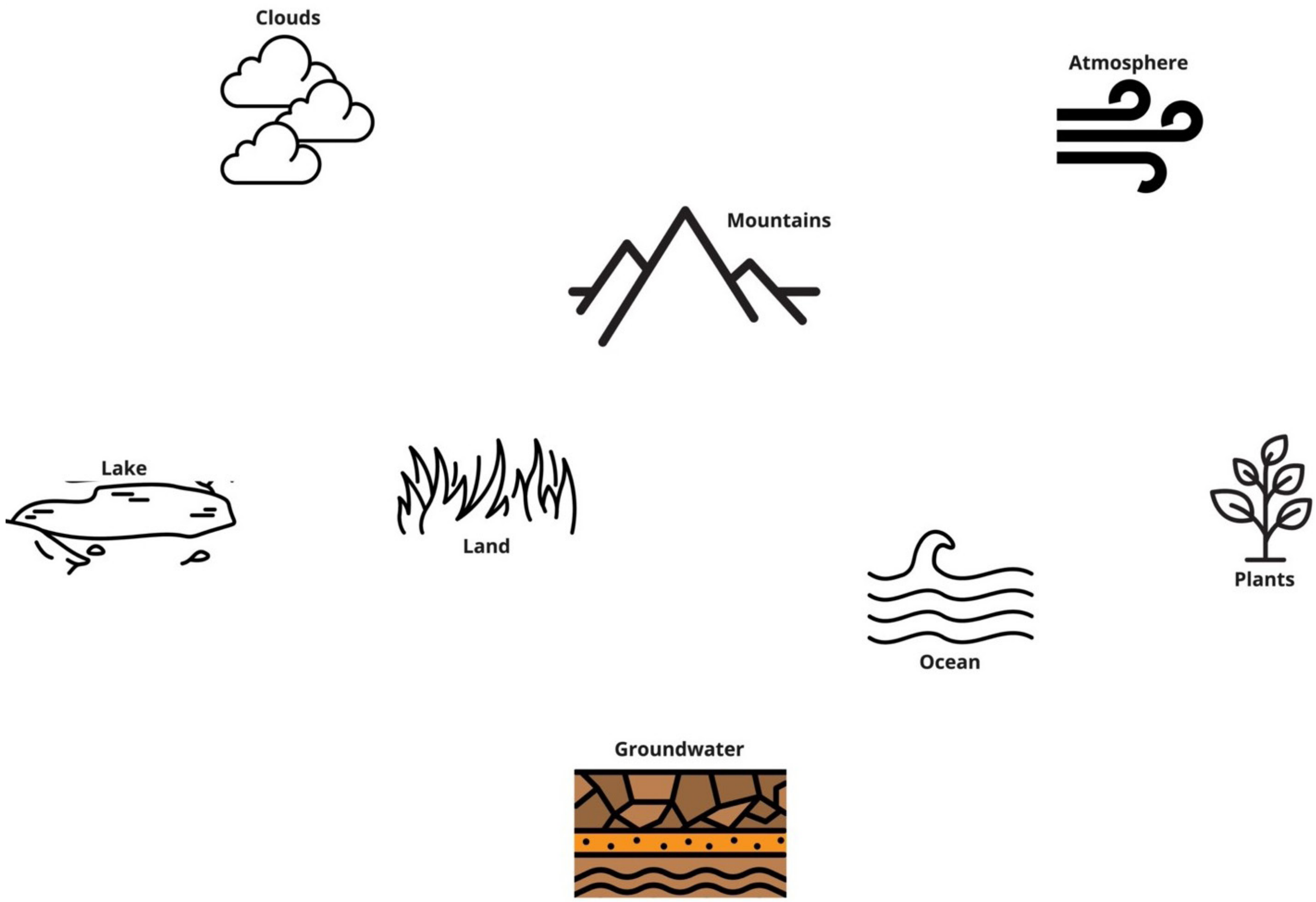
At the start of each turn, write down your location. Then write down the process that you experienced (e.g., evaporation, precipitation, condensation, etc.). If you stay at the same station, you can leave the "Process You Experienced" box blank for that turn. Finally, write down where you ended your turn.

Turn	Location at Start of Turn	Process You Experienced	Final Destination
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

2.F My Water Journey

Using your water journey tracker, draw the path you took from turn 1 all the way through turn 10. Use arrows to show where you traveled, or use a circular arrow (shown below) if you stayed in the same location. Compare with other students to see how your paths may have differed.

Circular arrow: 



2.G Water Cycle Game – Atmosphere Station Label

ATMOSPHERE

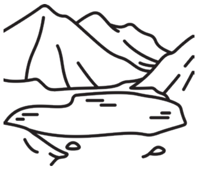
CLOUDS

2.I Water Cycle Game – Groundwater Station Label

GROUNDWATER

2.J Water Cycle Game – Lake Station Label

LAKE



2.K Water Cycle Game – Land Station Label

LAND

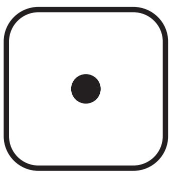
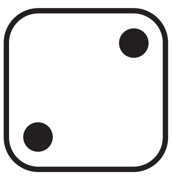
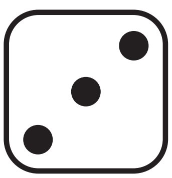
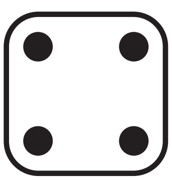
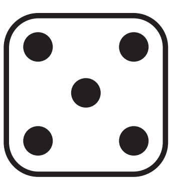
MOUNTAINS

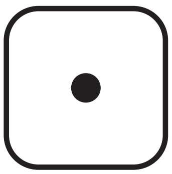
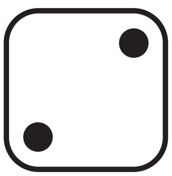
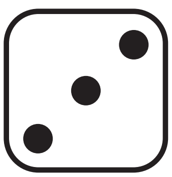
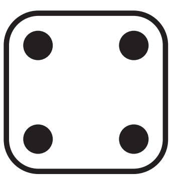
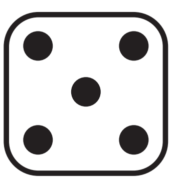
2.M Water Cycle Game – Ocean Station Label

OCEAN

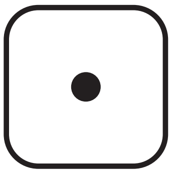
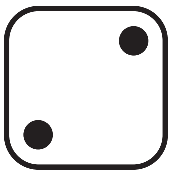
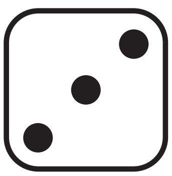
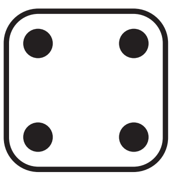
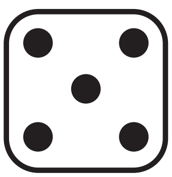
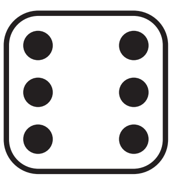
PLANTS

2.0 Water Cycle Game – Atmosphere

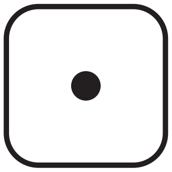
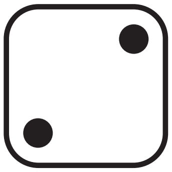
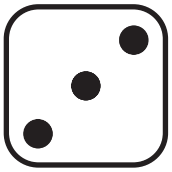
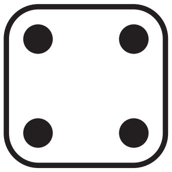
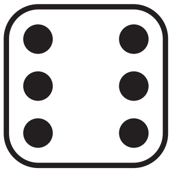
Atmosphere		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You love being water vapor and remain in the atmosphere!	STAY IN: **Atmosphere**
	You love being water vapor and remain in the atmosphere!	STAY IN: **Atmosphere**
	You love being water vapor and remain in the atmosphere!	STAY IN: **Atmosphere**
	You condense into an ice crystal!	MOVE TO: **Clouds**
	You condense into an ice crystal!	MOVE TO: **Clouds**
	You condense into an ice crystal!	MOVE TO: **Clouds**

Clouds		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You remain an ice crystal in the sky.	STAY IN: **Clouds**
	You remain an ice crystal in the sky.	STAY IN: **Clouds**
	Incoming! You precipitate into a body of other water molecules.	MOVE TO: **Lake**
	Time to precipitate with many of your water molecule friends!	MOVE TO: **Land**
	Incoming! You precipitate into a body of other water molecules.	MOVE TO: **Ocean**
	It's snowing! You experience deposition and head to the mountains.	MOVE TO: **Mountains**

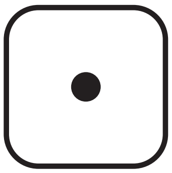
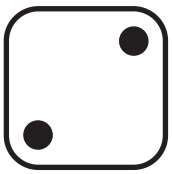
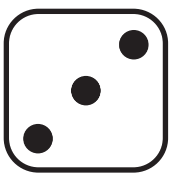
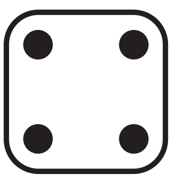
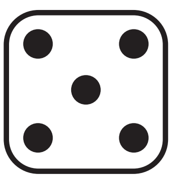
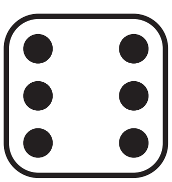
Groundwater

If you rolled a…	…you experience this…	…and move/stay here!
	You continue to percolate through the ground.	STAY IN: **Groundwater**
	You continue to percolate through the ground.	STAY IN: **Groundwater**
	You continue to percolate through the ground.	STAY IN: **Groundwater**
	You continue to percolate through the ground.	STAY IN: **Groundwater**
	Those plants are thirsty! You experience plant uptake.	MOVE TO: **Plants**
	Those plants are thirsty! You experience plant uptake.	MOVE TO: **Plants**

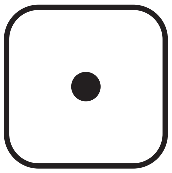
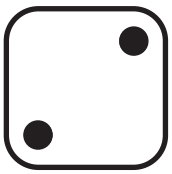
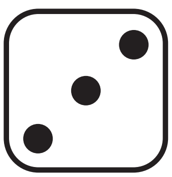
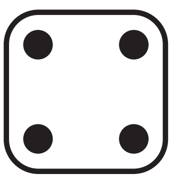
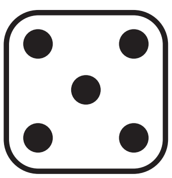
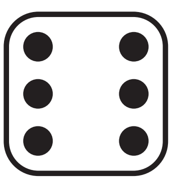
2.R Water Cycle Game – Lake

Lake		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are having a great time hanging out in the lake.	STAY IN: **Lake**
	You are having a great time hanging out in the lake.	STAY IN: **Lake**
	You are having a great time hanging out in the lake.	STAY IN: **Lake**
	You are having a great time hanging out in the lake.	STAY IN: **Lake**
	You travel through the soil by infiltration.	MOVE TO: **Groundwater**
	You travel through the soil by infiltration.	MOVE TO: **Groundwater**

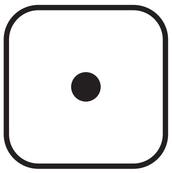
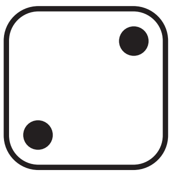
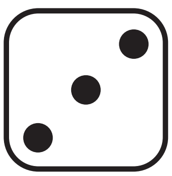
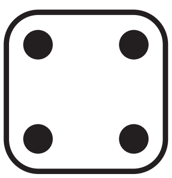
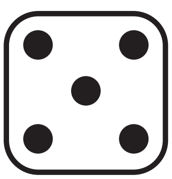
2.S Water Cycle Game – Land

Land		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are happy where you are.	STAY IN: **Land**
	You are happy where you are.	STAY IN: **Land**
	You travel through the soil by infiltration.	MOVE TO: **Groundwater**
	You travel through the soil by infiltration.	MOVE TO: **Groundwater**
	You slide on the land and runoff into water!	MOVE TO: **Ocean**
	You slide on the land and runoff into water!	MOVE TO: **Ocean**

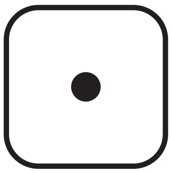
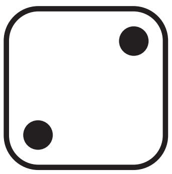
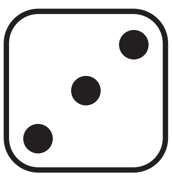
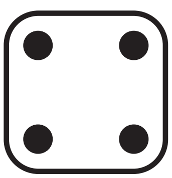
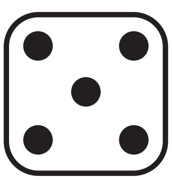
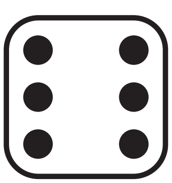
2.T Water Cycle Game – Mountains

Mountains		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You're having a great time on the slopes.	STAY IN: **Mountains**
	You're having a great time on the slopes.	STAY IN: **Mountains**
	You experience sublimation and transition back into water vapor.	MOVE TO: **Clouds**
	You experience sublimation and transition back into water vapor.	MOVE TO: **Clouds**
	You take the long path down the mountain as runoff.	MOVE TO: **Land**
	You take the long path down the mountain as runoff.	MOVE TO: **Land**

2.U Water Cycle Game – Ocean

Ocean		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	There is so much to explore in the ocean!	STAY IN: **Ocean**
	There is so much to explore in the ocean!	STAY IN: **Ocean**
	There is so much to explore in the ocean!	STAY IN: **Ocean**
	There is so much to explore in the ocean!	STAY IN: **Ocean**
	You evaporate and become water vapor!	MOVE TO: **Atmosphere**
	You evaporate and become water vapor!	MOVE TO: **Atmosphere**

2.V Water Cycle Game – Plants

Plants		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are helping this plant stay alive and thrive!	STAY IN: **Plants**
	You are helping this plant stay alive and thrive!	STAY IN: **Plants**
	You are helping this plant stay alive and thrive!	STAY IN: **Plants**
	You experience evapotranspiration and become water vapor!	MOVE TO: **Atmosphere**
	You experience evapotranspiration and become water vapor!	MOVE TO: **Atmosphere**
	You experience evapotranspiration and become water vapor!	MOVE TO: **Atmosphere**

2.W Water Cycle Vocabulary KEY

Description of Event	Name of Process	Did the water change phases?	
Water vapor becomes solid.	**Deposition**	**Yes**	No
What happens to ice and snow when the weather gets warmer.	**Melt**	**Yes**	No
Rain or snow fall from the sky.	**Precipitation**	**Yes**	No
Thanks to this process, we can drink groundwater from our wells.	**Percolation**	Yes	**No**
Liquid water becomes a gas.	**Evaporation**	**Yes**	No
The soil cannot absorb any additional water, so this occurs.	**Runoff**	Yes	**No**
It is snowing and you get a snow day!	**Precipitation**	**Yes**	No
There is so much water on the ground that some of it moves down into the soil.	**Infiltration**	Yes	**No**
Ice is converted directly to vapor without melting.	**Sublimation**	**Yes**	No
Your snowman turns into a puddle.	**Melt**	**Yes**	No
Water vapor forms liquid droplets.	**Condensation**	**Yes**	No
Plants retrieve water from the soil.	**Plant Uptake**	Yes	**No**
Water droplets form on the outside of your glass of cold water.	**Condensation**	**Yes**	No
You pour too much water into your flowerpot.	**Infiltration**	Yes	**No**
Water droplets on land become water vapor in the atmosphere.	**Evapotranspiration**	**Yes**	No
Water moves through the soil.	**Percolation**	Yes	**No**

LESSON THREE:

Lesson Objectives
Students will be able to:
- Define water scarcity
- Explain why a country is at risk of experiencing water scarcity

Time Required
One 50-minute class

Materials
Per classroom
- EDP poster
- Chart Paper/Large (15" x 18") Post-It Pad

Per student
- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS
- MS-ESS3-3, MS-ESS3-4, MS-ESS3-5

Key Terms
Water scarcity, socioeconomic status

Lesson Summary

Students will use an online tool to see how much water it takes to make their favorite meal. They will then learn about water scarcity and how some countries are at risk of running out of water for their citizens. Students will work in their design teams to research one country at risk of experiencing water scarcity by 2040 and share their results with the class.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem and learned about the water cycle.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

Activity

3. **Look at the water footprint for a common meal. Ask:** *Think of your favorite meal – what would you love to have for dinner tonight? How much water do you think it takes to make that meal?* Send out the link for the food water footprint website (which can be found in the margin under Educator Resources). Hand out Duplication Master 3.A Water Footprint of a Meal. **Say:** *Make that meal and look at how many gallons of water are needed to make just that one serving of your favorite meal. Write down your results on the worksheet.*
4. **Share out results for water footprints. Ask:** *How much water does it take to make your meal?* Try to figure out who used the most and least water. **Ask:** *Did you realize how much water it takes to make food? Why do you think it takes so much water?* Facilitate a discussion about why so much water is used to make food. Every step – from growing the food and watering it, to transporting it across states or countries, to storing it in grocery stores…it takes a lot of water!
5. **Produce a list of what water is used for. Ask:** *Other than for drinking or to produce your food, what is water used for?* Hand out Duplication Master 3.B Water Water Everywhere? **Say:** *You have two minutes to write down as many things as possible that water is used for other than drinking water and food!*

6. **Share out list of what water is used for. Ask:** *What items did you list?* Facilitate a discussion about all of the ways water is used in your daily life.
    - **A few ideas include:** brushing your teeth, in other drinks (soda, tea, coffee, juice, Gatorade, etc.), cooking, cleaning, cooling, to manufacture microchips, etc.
7. **Introduce the idea of water scarcity. Say:** *Water scarcity is the concept that there is not enough water in a community to meet the needs of its people. For example, there may be a town that pulls water from a nearby river, but the river is running dry because people are using more water than is available to them.* **Ask:** *What would happen if you didn't have enough water?* Facilitate a discussion about how water is used for food, laundry, showering, soap, etc.
8. **Introduce the activity. Say:** *Research a country that is in danger of experiencing water scarcity.* Hand out Duplication Master 3.C Water Scarcity Information. **Say:** *Fill out the information on this page about your country.* Allow 15 – 20 minutes to fill out the information. Note – the teacher may have students research countries individually instead of in their design teams.
9. **Present information on the countries.** Once all teams have filled out the sheet, they can begin putting their information on a big post-it page. These pages will then be hung around the room. Each team can take 2-3 minutes to talk about their country.

Closure

10. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? Why is water scarcity an issue? How will our problem help with water scarcity?* **Say:** *We will continue in the Learn stage during our next class.*

Assessment

Activity Embedded Assessment

Listen to students' observations about the water footprint of a common meal. Review the students' answers to Duplication Master 3.A Water Scarcity Information. Do they understand the true reasons why water scarcity is a serious issue? Do students know what the reasons are for countries being in danger of experiencing water scarcity?

Duplication Masters

- 3.A Water Footprint of a Meal
- 3.B Water Water Everywhere?
- 3.C Water Scarcity Information

Educator Resources

- 3.D Water Scarcity Key
- Link for food water footprint: https://graphics.latimes.com/food-water-footprint/

Name____ Date_______________ Period __________

3.A Water Footprint of a Meal

Write down the food item you pick for each category, how many ounces you would typically eat, and the gallons of water it takes to get each of those food items to your table. Once you have chosen all four items, add up the total gallons of water it takes to make that meal.

	Food Item	Ounces	Gallons of Water
Protein:			
Starch:			
Fruit/Vegetable:			
Drink:			
		TOTAL WATER:	

Name____ Date_______________ Period __________

3.B Water Water Everywhere?

Other than drinking and making your food, what is water used for? Write down as many ideas as possible in the next two minutes!

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________
14. ______________________________
15. ______________________________
16. ______________________________
17. ______________________________
18. ______________________________
19. ______________________________
20. ______________________________

Name____ Date_______________ Period __________

3.C Water Scarcity Information

Each of the following countries is at risk of suffering from water scarcity by the year 2040. Choose one of them to research and fill in the following information.

Armenia Azerbaijan Bahrain Chile Iran	Iraq Israel Jordan Kazakhstan Kuwait	Kyrgyzstan Lebanon Libya Macedonia Morocco	Oman Pakistan Palestine Qatar San Marino	Saudi Arabia Singapore Syria Turkmenistan Yemen

Country Name:

Continent:

Population:

Language:

Climate:

Why might they be at risk of experiencing water scarcity? Provide at least two reasons.

Name________________________________ Date_____________ Period __________

3.D Water Scarcity Key

Country	Continent	Population	Official Language(s)	Climate	Reasons for Risk of Water Scarcity
Armenia	Asia	2.8 million	Armenian	Markedly continental	Irrigation systems lose 70% of water before it reaches farmers' fields due to outdated infrastructure.
Azerbaijan	Asia and Europe	10.1 million	Azerbaijani	Hot summers, mild winters	Climate change has led to reduced rainfall and diminished runoff. Agriculture uses 70% of the country's water but results in huge losses.
Bahrain	Asia	1.5 million	Arabic	Hot summers, mild winters	Seawater entered their aquifer system, making it non-potable. Agriculture has inefficient use of water.
Chile	South America	19.5 million	Spanish	Tropic, Mediterranean, or Antarctic	Agriculture, mining operations, and urban expansion all fight against one another for decreasing water sources.
Iran	Asia	87.9 million	Persian	Arid	Lake size is decreasing due to mismanagement of water and climate change impacts.
Iraq	Asia	43.5 million	Arabic, Kurdish	Subtropical, Mediterranean	Climate change, inefficient water use, internal disputes over water, financial deficit in the water sector.
Israel	Asia	9.4 million	Hebrew	Hot summer, cool winter	Climate change results in drought, water sector policies
Jordan	Asia	11.2 million	Arabic	Mediterranean or desert	Population growth, rapid urbanization, inflow of refugees increases demand for water. Climate change.
Kazakhstan	Asia	19 million	Russian, Kazakh	Continental	Limited rivers and lakes, climate change, poor infrastructure, inefficient use of water.
Kuwait	Asia	4.3 million	Arabic	Arid/Desert	No surface water (no rivers or lakes).

Name____ Date________________ Period ___________

3.D Water Scarcity Key

Country	Continent	Population	Official Language(s)	Climate	Reasons for Risk of Water Scarcity
Kyrgyzstan	Asia	6.7 million	Kyrgyz, Russian	Warm summers, cold winters	Rising sea levels and increased flooding, drought, increasing water demand, poor infrastructure.
Lebanon	Asia	5.6 million	Arabic	Subtropical	Population growth, rapid urban expansion, influx of refugees.
Libya	Africa	6.7 million	Arabic	Arid	Limited access to surface water, little rain, very inefficient use of water.
Macedonia	Europe	2.1 million	Macedonian, Albanian	Moderate	Climate change, increased competition for water, increasing water withdrawals.
Morocco	Africa	37.1 million	Arabic	Tropical	Environmental changes, growing population, too much water use in agriculture.
Oman	Asia	4.5 million	Arabic	Subtropical	Low rainfall, drought, high population growth.
Pakistan	Asia	231 million	Urdu, English	Dry and hot	Rapid population growth, climate change causes floods and droughts, poor management, inefficient infrastructure, water pollution.
Palestine	Asia	4.9 million	Arabic	Varies	Climate change, drought, growing city population, overconsumption of water, raw sewage pollution.
Qatar	Asia	2.7 million	Arabic	Subtropical	High water usage by agriculture, aquifer competition between Qatar and neighbors.
San Marino	Europe	34,000	Italian	Subtropical	Full dependence on foreign water supplies.
Saudi Arabia	Asia	36 million	Arabic	Desert	Excessive water use, population increase, reckless agriculture policy.
Singapore	Asia	5.5 million	Malay, Tamil, English	Tropical	Heavily dependent on rainfall, lack of natural resources, drought.

Name________________________________ Date_____________ Period __________

3.D Water Scarcity Key

Country	Continent	Population	Official Language(s)	Climate	Reasons for Risk of Water Scarcity
Syria	Asia	21.3 million	Arabic	Desert	Crumbling infrastructure, drought, climate change, wartime destruction, energy shortages, weaponization of water access.
Turkmenistan	Asia	6.3 million	Turkmen	Desert	Rapid melting of glaciers, arid desert climate.
Yemen	Asia	33 million	Arabic	Tropical, semiarid	Destruction of infrastructure, lack of water management, climate change.

LESSON FOUR:

Lesson Objectives
Students will be able to:

- Explain the difference between chemical, biological, and physical water treatment methods
- Define environmental justice
- Discuss one method of water treatment that can alleviate environmental injustice

Time Required
One 50-minute lesson

Materials
Per classroom

- EDP poster

Per student

- EDP slider and paper clip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS

- MS-ESS3-3, MS-ESS3-4, MS-ESS3-5

Key Terms
Environmental justice, water treatment

Lesson Summary

The client has sent students a new memo asking them to learn about water treatment methods and environmental justice. Students will then learn about various water treatment methods and the differences between them, as well as environmental justice. Students will finish the lesson by writing a paragraph about environmental justice and water treatment.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem and learned about the water cycle and water scarcity Today, we will be looking at two new topics: water treatment methods and environmental justice.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

Activity

3. **Read the client memo.** Hand out Duplication Master 4.A Client Memo 2. Read together as a group or allow students a minute to read the letter. **Say:** *For the rest of class today, your client would like you to learn about water treatment methods and environmental justice. Let's start by learning about water treatment methods first.*
4. **Discuss various water treatment methods. Ask:** *If you had contaminated water that you needed to treat, how would you do it? What methods can we use to treat water?* **Say:** *Let's learn about how to treat water to make it potable. The term "potable water" refers to water that is safe to drink. It is free of contaminants and does not have any waterborne illnesses that can harm you.* Hand out Duplication Master 4.B Water Treatment Methods and walk through each of the three categories: biological, chemical, and physical treatment.
5. **Write the pros and cons for each water treatment method.** Divide the class into their design teams and provide each group with a large post-it page. Assign each group one of the three water treatment methods. **Say:** *In your group, list the pros and cons for your water treatment method.* Provide a few minutes for

students to complete the activity.

6. **Discuss the pros and cons for water treatment methods.** Allow students to share out what they found. Hand out Duplication Master 4.C Water Treatment Pros and Cons. As the class discusses their answers, have them write down the correct list on the worksheet so they have the data in their engineering notebook.
7. **Introduce the idea of environmental justice. Ask:** *What would you do if you found out that the drinking water in your town is contaminated? What if the treatment plant cannot remove the toxins in the water? What if moving further away from it is not an option?* Help students understand that not everyone is able to move away from the problem, and there is not always funding to treat every toxin in your drinking water if the city does not have extra money. **Ask:** *Is it fair that some people have no choice but to drink contaminated water?* **Say:** *This is why it is so important that we help our client! Even if some people are safe and some people are in danger, EVERYONE should have access to a clean and healthy environment.*
8. **Show an environmental justice video.** Show the video linked below (4.5 minutes) that will teach students about the importance of pursuing environmental justice.
    - https://youtu.be/0L2xCwD5RNI?si=TM7uTVFEpnDOants
9. **Facilitate a discussion about environmental justice.** Either on the board or a projector, show the definition of environmental justice: every person, regardless of race, color, national origin, income, socioeconomic status, or religion, has the right to a clean and healthy environment. **Ask:** *How does this definition relate to our client's problem?*

    NOTE: The answer to this question is that people who live in lower income areas are more like to experience poor water quality because their city does not have the funding to improve their water resources. This relates to the client's problem because water filtration can help improve the water quality of people in areas of low socioeconomic status.
10. **Write the environmental justice paragraphs.** Hand out Duplication Master 4.C Paragraph Requirements. **Say:** *Follow the guidelines from our client to write your letter.*

    NOTE: Ideally, at least one or two students use the recommendation of focusing on water filtration. This provides the context for Client Memo 4 where the client states that students will use filter media based on the research they did during this class activity.

Assessment

Activity Embedded Assessment

Review students' definitions of environmental justice and the paragraphs they have written. Do they understand how serious the issue is? Where their arguments in the paragraph persuasive?

Duplication Masters

- 4.A Client Memo 2
- 4.B Water Treatment Methods
- 4.C Water Treatment Pros and Cons
- 4.D Justice Paragraph

Educator Resources

- 4.E Water Treatment Pros and Cons KEY

Closure

9. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? Why is environmental justice an important problem to solve?* **Say:** *We will continue in the Learn stage during our next class.*

4.A Client Memo 2

Dear Engineers,

Thank you for continuing to learn relevant information for our engineering design challenge. One important role of an engineer is to adhere to the Engineering Code of Ethics. This code states that we will not harm people or the environment with our work. These are very important codes to follow. Therefore, I have asked your teacher to introduce you to environmental justice and climate justice. I have also asked your teacher to teach you about different methods of water treatment to help us solve our engineering design challenge.

For the rest of today's class, please spend time researching methods of how to alleviate water quality injustice. Choose one method that you think is best, and then come up with a few reasons why you think your method is a good idea and write at least one paragraph defending your choice. A few common water treatment methods are chemical treatment, biological treatment, or physical filtration. I have attached guidelines for you to follow while writing your paragraph.

Sincerely,

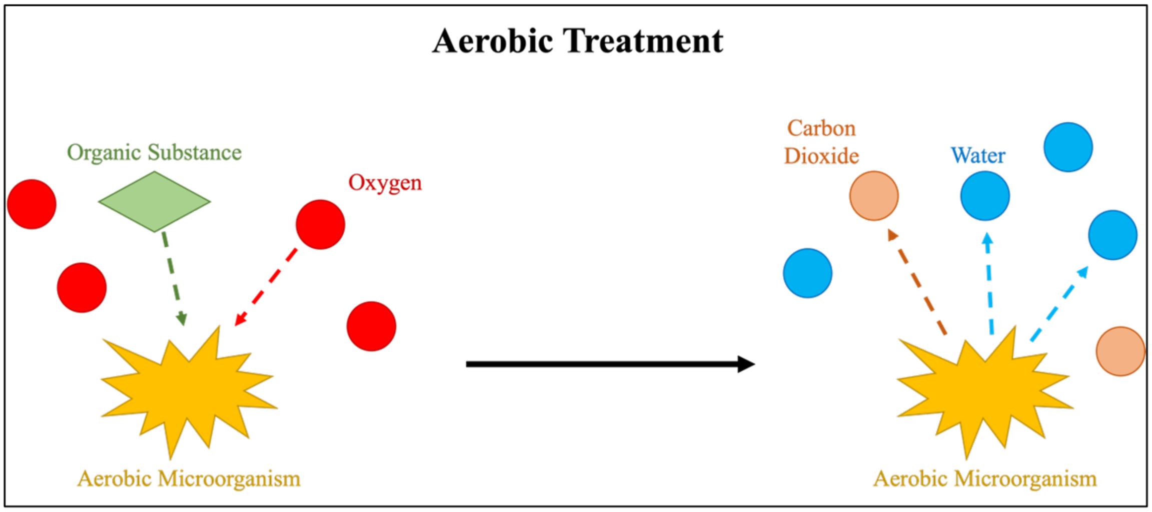
Brooks Eaton

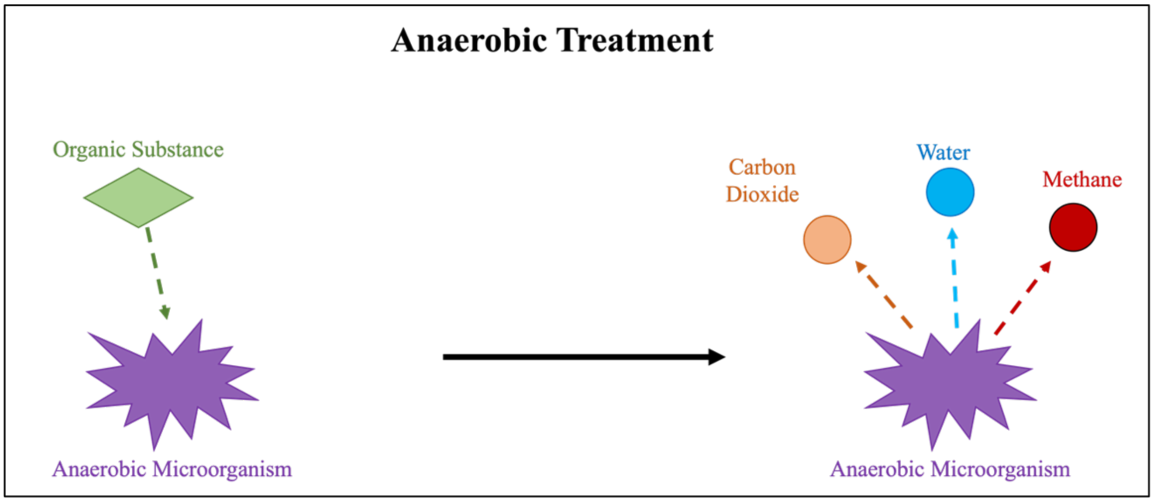
Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

Biological Water Treatment

Biological water treatment uses microorganisms to remove organic material from water. While some organic material is ok, other organics are unnecessary or harmful and need to be removed. The two primary biological processes are aerobic and anaerobic. **Aerobic** means that oxygen is present while **anaerobic** means that oxygen is not present.

The advantages of biological water treatment are that it is an efficient process, it successfully removes 70% - 98% of organic contaminants, and it can be used on large volumes of water. The disadvantages of biological water treatment are that it may require a large amount of electricity, it results in a large amount of waste that must be disposed of, it is not commonly used for drinking water (only wastewater), and it cannot treat many chemical contaminants.

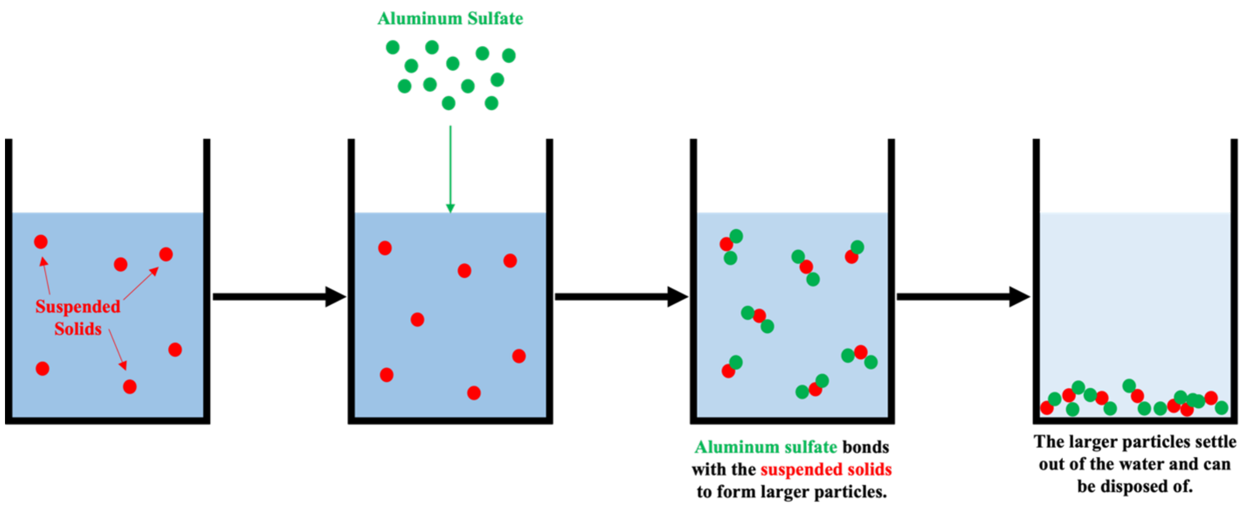




Chemical Water Treatment

Chemical water treatment uses different compounds to chemically transform contaminants in drinking water into a chemical that is not harmful. There are many different chemicals that can be added to water depending on what you would like to treat. For example, aluminum sulfate can be added if you would like to remove suspended solids, which will improve your turbidity. Chlorine can be added if you want to disinfect the water, removing any bacteria or viruses.

The primary advantage of chemical water treatment is that it is highly effective in removing chemical and biological contaminants from water. The disadvantages are that the chemicals can often be difficult to handle, there are many safety hazards with storing and using these chemicals, and some of the chemicals are expensive.

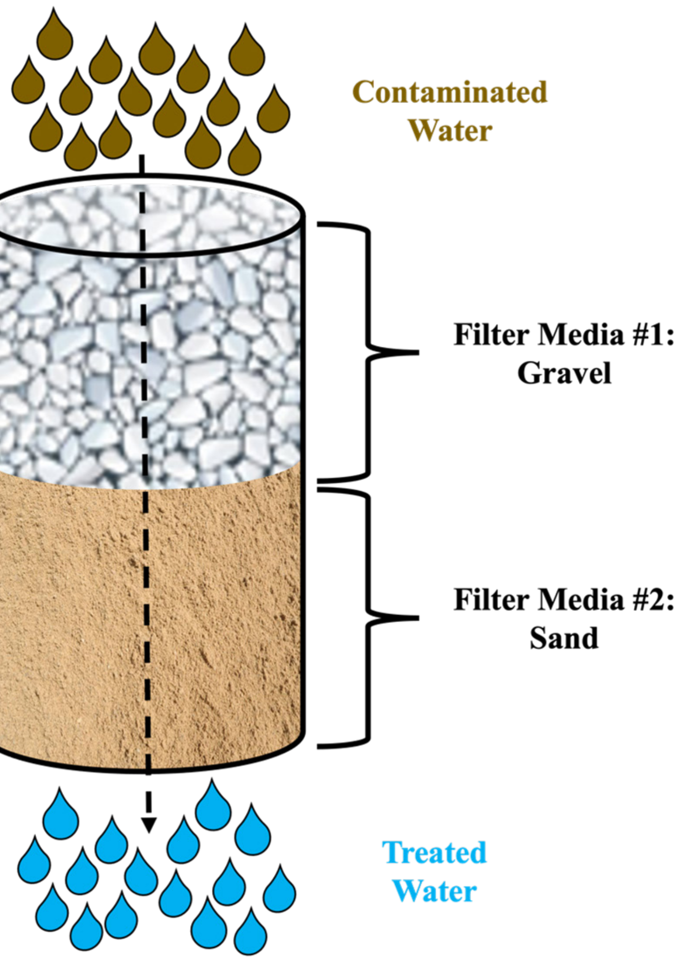


4.B Water Treatment Methods

Physical Water Treatment

Physical water treatment is the filtering of water through different filter media. The filters can range in size. Many filters will start with a very large filter media to remove bigger contaminants and then progress to smaller filter media to remove the smallest contaminants last. This makes the process more efficient. Examples of filter media used in drinking water treatment are fine sand and anthracite (a type of coal). You can also use special types of filters that have a very very small opening in them, allowing only water (and NO contaminants) to pass through them. These are often called cartridge or reverse osmosis filters.

The advantages of physical water treatment are that it is effective in removing contaminants, very inexpensive, and typically very easy to install. The disadvantages of physical water treatment are that is does not remove every contaminant and some filters move water very slowly through them, making it a time consuming process.



Name________________________________ Date______________ Period __________

4.C Water Treatment Pros and Cons

Water Treatment Method	Pros	Cons
Biological	Number of Pros:	Number of Cons:
Chemical	Number of Pros:	Number of Cons:
Physical	Number of Pros:	Number of Cons:

Name____ Date_______________ Period __________

4.D Justice Paragraph

Our client would like you to write a paragraph about environmental justice. Your paragraph must include the following information:

- Explain why it is important to have potable water.
- Provide definitions (in your own words!) for environmental justice and climate justice.
- Describe your chosen method of water treatment.
- Explain why this water treatment method is effective in pursuing environmental justice.

4.E Water Treatment Pros and Cons KEY

Water Treatment Method	Pros	Cons
Biological	• Efficient • Successfully removes 70% - 98% of organic contaminants • Can be used on large volumes of water Number of Pros: 3	• May require a large amount of electricity • Results in a large amount of waste that must be disposed of • Not commonly used for drinking water • Cannot treat many chemical contaminants Number of Cons: 4
Chemical	• Highly effective in removing chemical and biological contaminants from water Number of Pros: 1	• Can often be difficult to handle • There are many safety hazards with storing and using these chemicals • Some of the chemicals are expensive Number of Cons: 3
Physical	• Effective in removing contaminants • Very inexpensive • Typically, very easy to install Number of Pros: 3	• Does not remove every contaminant • Some filters move water very slowly Number of Cons: 2

LESSON FIVE:

Lesson Objectives

Students will be able to:

- Use sensors to measure water quality parameters
- Discuss the importance of water quality standards
- Discuss the qualitative difference in various types of water sources

Time Required

Two 50-minute lessons

Materials

Per classroom

- EDP poster
- Vernier LabQuest 3
- Vernier pH Sensor
- Vernier Turbidity Sensor
- Vernier Temperature Sensor
- Vernier Salinity Sensor
- pH test strips
- Salinity test strips
- Thermometer (not digital)
- Turbidity tube with secchi disk
- Water from various sources (bottled, tap, filtered, etc.)
- Several drinks (lemonade, soda, juice, milk, etc.)
- Four gallon-sized jugs
- Small plastic cups
- Lab wash bottle

Per student

- EDP slider & paper clip
- Laptop/Chromebook
- Engineering notebook
- Pencils and erasers
- Small disposable plastic cup

Lesson Summary

Have you ever noticed that water tastes different depending on where it's from? Students will learn about this concept as they work through tasting and sensor stations. Each design team will taste several types of water and drinks to describe the difference between them. Design teams will use LabQuest sensors and their analog tools to compare the difference in the values collected.

Before the Activity

Set up the stations for tasting, sensor testing, and analog testing. Depending on the number of groups in the classroom, the station set up may vary. A recommendation for stations based on number of groups is provided in a table on the next page.

- **Water Tasting Station(s):** Set up four gallon-sized jugs, each full of a different type of water: tap, well, spring, and mineral. Clearly label the jugs: Water A, Water B, Water C, and Water D.
- **Drink Tasting Stations(s):** Set out your drinks in their containers: juice, lemonade, milk, and soda.
    - **NOTE**: Please ensure that none of the chosen drinks will irritate classroom allergies or restrictions.
- **Sensor Testing:** Set up the Vernier LabQuest 3 with the four sensors: pH, salinity, temperature, and turbidity. Set up eight cups with each cup containing Waters A – D, and the four drinks. Clearly label each plastic cup. Fill a squeeze bottle with DI water and clearly label it. Have a few empty cups available for rinsing the probes.
- **Analog pH:** Set out the pH strip container. Set up eight cups which each cup containing Waters A – D, and the four drinks. Clearly label each plastic cup.
- **Analog Salinity:** Set out the salinity strip container. Set up eight cups which each cup containing Waters A – D, and the four drinks. Clearly label each plastic cup.
- **Analog Temperature:** Set out a thermometer. Set up eight cups which each cup containing Waters A – D, and the four drinks. Clearly label each plastic cup.
- **Analog Turbidity:** Set out a turbidity tube with secchi disk and the instructions (Duplication Master Set up eight cups which each cup containing Waters A – D, and the four drinks. Clearly label each plastic cup.

Station	4 Groups	5 Groups	6 Groups	7 Groups	8 Groups
1	Water Tasting	Water Tasting	Water Tasting	Water Tasting 1	Water Tasting 1
2	Drink Tasting	Drink Tasting	Drink Testing 1	Drink Tasting 2	Drink Tasting 2
3	Sensor Testing	Sensor Testing	Drink Testing 2	Drink Tasting 1	Drink Tasting 1
4	Analog Testing	Analog: pH, salinity, temp.	Sensor Testing	Drink Tasting 2	Drink Tasting 2
5	-	Analog: turbidity	Analog: pH, salinity, temp.	Sensor Testing	Sensor Testing
6	-	-	Analog: turbidity	Analog: pH, salinity, temp.	Analog: pH, salinity
7	-	-	-	Analog: turbidity	Analog: temperature
8	-	-	-	-	Analog: turbidity

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client and learned about the water cycle, water scarcity, and environmental justice.* Point out the "problem" block on the Engineering Design Process and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

Standards Addressed
NGSS
- MS-ETS1-1

Key Terms
Water quality, pH, salinity, temperature, turbidity, sensors

Assessment
Pre-Activity Assessment
Check students' responses as they recall the client's problem and brainstorm possible topics they need to learn about to understand the problem. Check that students understand the problem itself.

Activity Embedded Assessment
Listen to students' responses during the classroom discussion about what factors could impact the taste of water, and why water quality parameters are important.

Post-Activity Assessment
Check students' responses in their engineering notebooks for Duplication Master 5.A Tasting and Testing Experiment.

Duplication Masters
- 5.A Tasting and Testing Experiments
- 5.B Water Quality Standards

Educator Resources
Additional information about the water quality parameters can be found here:

- pH: https://www.epa.gov/goldkingmine/what-ph
- Salinity: https://www.epa.gov/national-aquatic-resource-surveys/indicators-salinity
- Temperature: https://www.epa.gov/caddis-vol2/temperature
- Turbidity: https://www.epa.gov/system/files/documents/2021-07/parameter-factsheet_turbidity.pdf

3. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about water scarcity.* **Ask:** *What other ecosystem information will you need to know in order to solve the problem?*

Activity

4. **Discuss the taste of different drinks. Ask:** *What does lemonade taste like? What about milk, soda, or juice?* Let students define the characteristics that determine how a drink tastes. **Ask:** *Why does lemonade taste different than milk?* Lead the discussion to help students reach the conclusion that the ingredients in a drink determine its taste and may change factors like pH or salinity/sweetness.
5. **Discuss the taste of water. Ask:** *What does water taste like? Does all water taste the same? Does bottled water taste the same as river water? What kinds of things might be the ingredients in water that makes it taste different sometimes?*
6. **Introduce the activity. Say:** *We are going to taste different kinds of water, as well as different drinks. You are also going to measure the water quality using different types of sensors and testing equipment. Take your plastic cup and carry it to each tasting station – you will use the same cup for each drink!*
7. **Gather into pre-determined design teams.** Allow students to gather with their team and work through each station as a group. Students should fill out Duplication Master 5.A Tasting and Testing Experiments while working through each station.

   NOTE: The teacher may want to remain at the sensor station(s) to ensure that students are properly using the tool.
8. **Discuss the taste experiment. Ask:** *Why do you think different types of water do not taste the same? What is the chemical formula for water?* Ensure students answer H_2O. *What is in your water other than hydrogen and oxygen? Can someone remind us what the term potable water means?* Tell students what Water A – D are. Discuss the different tastes. Discuss the different tastes of the drinks briefly.
9. **Discuss the sensor experiment. Ask:** *What sort of differences did you see across the measurements you made? Did any of the measurements surprise you?*

10. **Introduce water quality standards. Say:** *Water that is safe for you to drink is called potable water. However, drinking water can have bacteria or viruses in it that can make you very sick. This is called waterborne illness. It is important that all of the water that comes out of our taps is regulated to ensure that it is potable.* **Ask:** *Who regulates our drinking water?* **Say:** *The United States Environmental Protection Agency, or the USEPA, works alongside the Indiana Department of Environmental Management, or IDEM. These two organizations set standards for water quality to ensure that our drinking water is potable.*
11. **Discuss if the eight drinks from the tasting experiment meet Indiana water quality standards.** Hand out Duplication Master 5.B Water Quality Standards and allow students a few minutes to read the information. **Ask:** *Did all of the water types we measured today meet the standards? What about the drinks? Why do you think it is ok for some drinks to not meet these standards, but water must for it to be potable?*

Closure

12. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? How does the taste of water impact water quality? What do these water quality tests tell us, and why do they matter?*

Name________________________________ Date______________ Period __________

5.A Tasting and Testing Experiment

Tasting Experiment

Drink	What does it look like?	How does it taste?	What does it smell like?	How does it feel in your mouth? (e.g., bubbly, smooth, thick, etc.)
Water A				
Water B				
Water C				
Water D				
Juice				
Lemonade				
Milk				
Soda				

Name______________________________________ Date_______________ Period __________

5.A Tasting and Testing Experiment

Testing Experiment

Drink	pH		Salinity (mg/L)		Temperature (°F)		Turbidity (NTU)	
	ME Sensor	Analog Tool	ME Sensor	Analog Tool	ME Sensor	Analog Tool	ME Sensor	Analog Tool
Water A								
Water B								
Water C								
Water D								
Juice								
Lemonade								
Milk								
Soda								

Water Quality Standards

United States Environmental Protection Agency (USEPA) website:

pH

pH is an expression of hydrogen ion concentration in water. Acidic and alkaline (or “basic”) are two extremes that describe substances, usually liquids or chemicals, just like hot and cold are two extremes that describe temperature. A substance that is neither acidic nor alkaline is neutral.

Salinity

Salinity is the dissolved salt content of a body of water. It is a strong contributor to conductivity and helps determine many aspects of the chemistry of natural waters and the biological processes within them. Salinity, along with temperature and pressure, helps govern physical characteristics of water such as density and heat capacity.

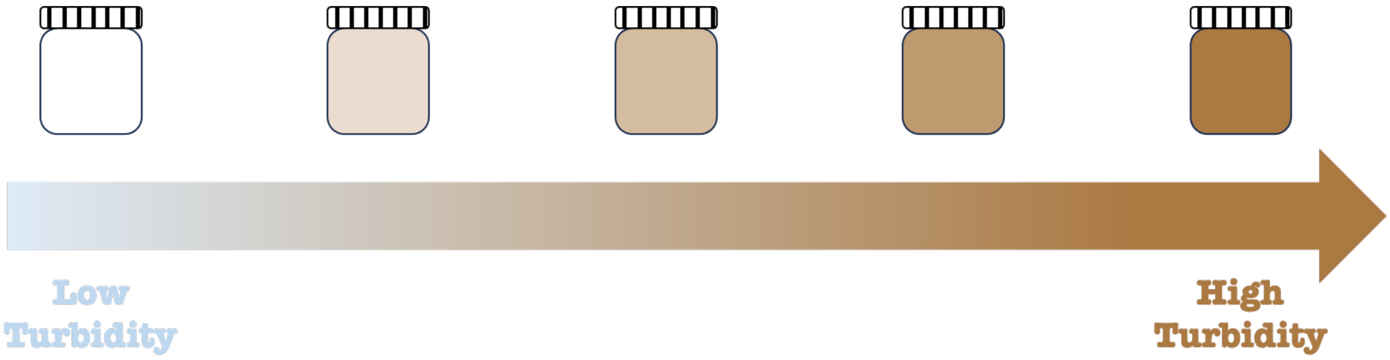
Temperature

Temperature is the concentration of thermal energy in a substance such as water. Temperature plays a fundamental role in shaping the structure and function of aquatic systems.

5.B Water Quality Standards

Turbidity

Turbidity is a measure of water clarity. High turbidity makes water appear cloudy or muddy. Turbidity is an optical property of water rather than a chemical or biological measurement. Caution should be exercised when using turbidity as a water quality parameter because high turbidity levels do not necessarily indicate poor water quality, and low turbidity levels do not necessarily indicate good water quality. Values should, therefore, be evaluated alongside other parameters.



Standards for This Class

Parameter	Acceptable Range
pH	6.0 – 9.0
Salinity	< 600 mg/L
Temperature	60°F – 75°F
Turbidity	< 1.0 NTU

LESSON SIX:

Lesson Objectives
Students will be able to:
- Explain how a turbidimeter works
- Define the term microelectronics

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP poster

Per group
- Light Sensor

Per student
- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS
- MS-ESS3-3

Key Terms
Microelectronics, sensors

Lesson Summary

The last learn lesson will allow students to explore the microelectronics component of water quality sensors. Students will review a diagram of a turbidimeter and look at a microchip with a light sensor on it. Students will complete a turbidity calculation to understand the relationship between voltage and turbidity.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem and learned about the water cycle, water scarcity, environmental justice, and the taste of water. Today, we will study how sensors work.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.
3. **Read the client memo.** Hand out Duplication Master 6.A Client Memo 3. Allow students a few minutes to read the memo.

Activity

4. **Introduce the topic of microelectronic sensors. Ask:** *What differences did you see in the measurements you made yesterday when using the Vernier sensors and their analog measuring tools?* See if students identify that there was a variation in values when using the analog tools while the sensors provided a more consistent value. **Ask:** *What is the difference between these types of tools we can use to measure water quality?* Help students identify that electronics are the difference.
5. **Discuss the importance of microelectronics. Say:** *Microelectronics are devices that use microchips. Microchips are tiny wafers that are used to build a circuit. Using these microelectronic tools allow us to make very accurate measurements. This is important, as our client pointed out, to ensure water meets regulations and is potable.*
6. **Review the turbidimeter diagram. Say:** *Yesterday, we measured turbidity with our Vernier sensor. How does the sensor work to help us measure turbidity?* Allow students to try and answer the question. Pass out Duplication Master 6.B Turbidimeter Diagram. **Say:** *This is a diagram of a turbidity*

sensor (or turbidimeter). A light source shines through the sensor past a lens and through the water sample. Some of the light will bounce off of the particles in the water and be caught by the Scattered Light Detector. The rest of the light will pass through the water and is measured by the Transmitted Light Detector – the amount of light that is measured here is converted to turbidity.

7. **Discuss how the light sensor works. Ask:** *How do you think the light sensor converts light to turbidity?* Pass out one light sensor to each group. **Say:** *The microchip in the sensor actually detects the light it is receiving in units of voltage. The voltage is then converted to turbidity units.*
8. **Complete the calculation activity.** Pass out Duplication Master 6.C Turbidity Calculation Worksheet. The teacher can decide if students will work individually or in groups. Allow students time to complete the worksheet, then review it before ending class.

Closure

9. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? Why is important to use sensors to measure water quality instead of their analog measurements?* **Say:** *We will continue in the Learn stage during our next class.*

Assessment

Activity Embedded Assessment

Review students' worksheets and their calculations to determine if they found the correct answer. Listen to their thoughts on the turbidity sensor and how it works to see if they understand the microelectronic components.

Duplication Masters

- 6.A Client Memo 3
- 6.B Turbidimeter Diagram
- 6.C Turbidity Calculation Worksheet

Educator Resources

- 6.D Turbidity Calculation Worksheet Answers

6.A Client Memo 3

Dear Engineers,

Thank you for taking the time to learn the important background information for this engineering design challenge. I wanted to provide you with one final lesson before you begin designing your solutions. In your previous lesson, you saw the difference between using microelectronic sensors and their analog measuring tools. It is important to have very accurate water quality data to ensure the water is potable and nobody will contract waterborne illness. Please use the activities I sent to learn about how microelectronic sensors work.

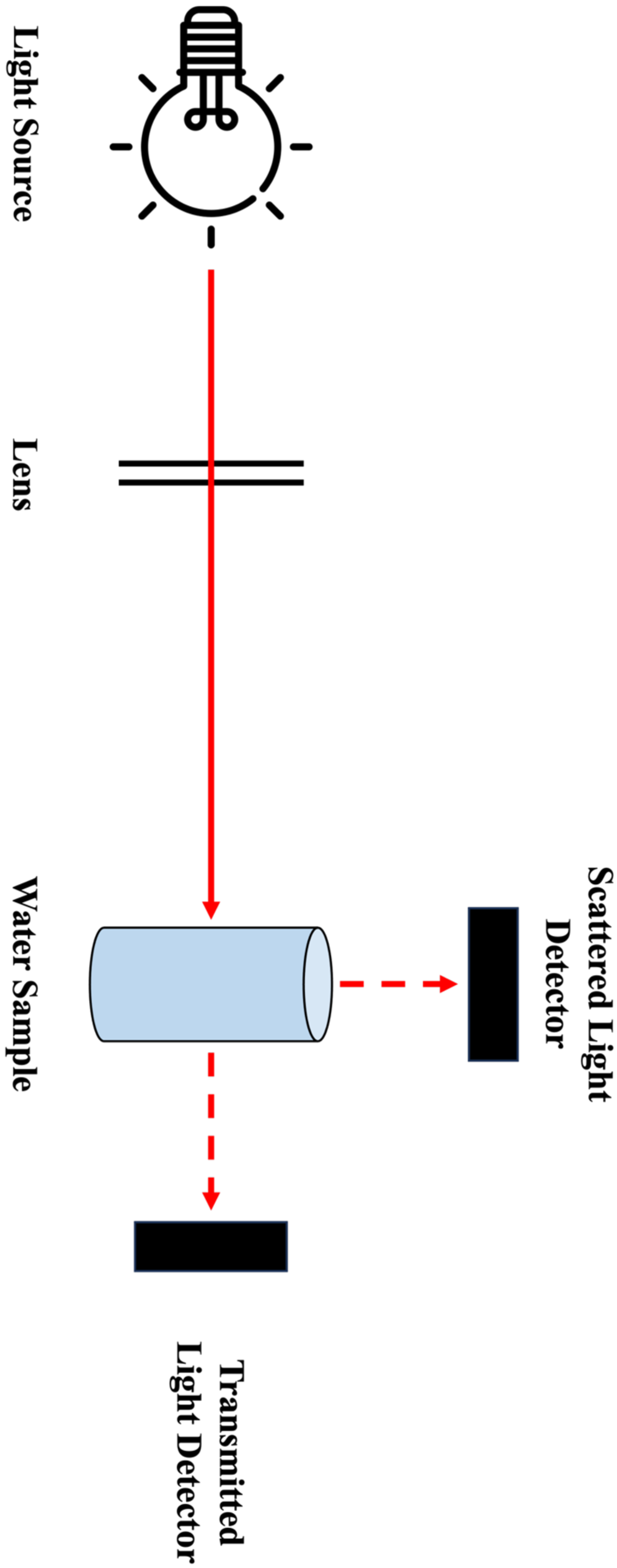
Thank you for your hard work!

Sincerely,

Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

6.B Turbidimeter Diagram



Name______________________________________ Date______________ Period __________

6.C Turbidity Calculation Worksheet

This equation converts voltage to turbidity for a specific type of turbidimeter.

Turbidity = –111.3 * Voltage + 506.4

Assume that the voltage detected by your turbidimeter is 4.54 volts. Would this meet the turbidity regulation of < 1.0 NTU? Answer the question in a full sentence.

6.D Turbidity Calculation Worksheet Answers

This equation converts voltage to turbidity for a specific type of turbidimeter.

Turbidity = –111.3 * Voltage + 506.4

Assume that the voltage detected by your turbidimeter is 4.54 volts. Would this water meet the turbidity regulation of < 1.0 NTU? Answer the question in a full sentence.

Turbidity = –111.3 * (4.54 volts) + 506.4

Turbidity = –505.302 + 506.4

Turbidity = 1.098 NTU

The water does NOT meet the turbidity regulation because it is greater than 1.0 NTU.

LESSON SEVEN:

Lesson Objectives
Students will be able to:
- Discuss different water filter media
- Explain the difference between different types of filter media

Time Required
Two 50-minute lessons

Standards Addressed
NGSS
- MS-ETS1-2, MS-ESS3-3

Key Terms
Water treatment methods, filtration

Assessment
Activity Embedded Assessment
Listen to students' observations about the cross-sections of water filters. Do they understand how each of them works?

Duplication Masters
- 7.A Client Memo 4
- 7.B Filter Media Testing

Lesson Summary

Students will learn about different types of water filters and how they work to remove contaminants from drinking water. Students will then work in their design teams to test different filter media and see what is most effective at improving water quality.

Before the Activity

- **Prepare the filter cross-sections.** Cut the LifeStraw and Brita filter in half so that students can view the cross-section. The teacher may want to put the Brita filter halves in a container or bowl so that students do not get the black activated carbon dust everywhere.

  NOTE: If the teacher prefers not to purchase these filters, there are many images of their cross-sections online that can be used instead.
- **Prepare the untreated water.** To make 8 oz of untreated water, add 1 oz (2 Tbsp) soy sauce to 7 oz of tap water. Ensure that there is enough for each group to have about 16 oz of untreated water.
- **Take water quality measurements of the untreated water.** Measure the pH, salinity, temperature, and turbidity of the untreated water to save time during class. These can be recorded in Duplication Master 8.A Filter Media Information.
- **Prepare the sponges.** Cut the sponges into circles so that they will fit into the water bottles.
- **Prepare one 1-liter plastic water bottle for each design team.**
  - Cut the bottom of the bottle off.
  - Unscrew and remove the cap from the bottle.
  - Take a coffee filter and cut out a circle that is larger than the bottle's cap. Use a rubber band to tightly secure the coffee filter to the bottle.
  - Draw a line with a Sharpie that is 4 inches above the cap of the bottle. This is the line students will use to determine how much filter media they will add to their bottles.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem and learned about the water cycle, water scarcity, environmental justice, and sensors. Today, we are going to talk about water treatment methods.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.
3. **Read the client memo.** Hand out Duplication Master 7.A Client Memo 4. Allow students a few minutes to read the memo. **Ask:** *How has our engineering design challenge changed based on this memo? Do we have any new criteria or constraints?*

Activity

4. **Discuss the different types of water filters. Say:** *There are many different kinds of filters that can be used to remove contaminants from water.* **Ask:** *Does anyone have an example of a water filter?* A common filter that may be mentioned is the Brita filter. **Ask:** *What is inside of these filters that allows them to remove contaminants of water? How do filters work?*
5. **Look at different types of water filters.** Pass around the cross-sections of the Brita and Life Straw filters. **Ask:** *What is inside these filters that help them remove particles and contaminants from drinking water?* Facilitate a discussion about how filtration works.
   - **Brita Filters:** A Brita filter is simply activated carbon, which is tiny pieces of purified charcoal. This charge on the charcoal attracts organic compounds to attach it, which pulls them out of the water that is passing through the filter. Brita filters help remove organic material from water in addition to any added chlorine.
   - **Life Straw:** The inside of a Life Straw is a hollow fiber membrane. Essentially, it looks like a tiny paper towel roll, but is actually a membrane with microscopic pores in it. These tiny pores only allow water molecules to pass through. They trap bacteria, parasites, and microplastics.

Materials

Per classroom

- EDP poster
- 1 Vernier LabQuest 3
- 1 Vernier pH Sensor
- 1 Vernier Turbidity Sensor
- 1 Vernier Temperature Sensor
- 1 Vernier Salinity Sensor
- 1 LifeStraw
- 1 Brita filter
- Soy Sauce
- Cheesecloth
- Cotton Balls
- Gauze
- Gravel
- Paper Towel
- Rice
- Sand
- Sponge

Per group

- One 100-mL beaker or graduated cylinder
- One 1-liter plastic water bottle
- Ring stand
- Coffee filter
- 2 plastic cups (that can hold 8 oz or more)
- Stopwatch

Per student

- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

6. **Test different types of household items for filtration. Say:** *Our client would like us to use household items to create water filters. Each design team will be assigned one or two different items to use as filter media so we can collect information about how well they work.* Hand out Duplication Master 7.B Filter Media Testing. **Say:** *As you test your filter media, record how long it takes to pass through and the water quality afterward. This will help us decide what items will work best for filtration.*
7. **Have students construct their filters.** Have students secure their bottle using the ring stands. Once the bottle is secured, students may add their filter media to the line the teacher drew on the bottle. Below the bottle, students should set their 100-mL beaker or graduated cylinder to collect the filtered water.
8. **Allow students to "wet" their filter systems. Say:** *Since some of the materials we are using are absorbent, everyone can run one cup of untreated water through their system to "wet" their filter media.* Allow students time to run the water through their system.
9. **Explain to students how the testing process will work. Say:** *When I say you can start, each group should simultaneously pour all 16 oz of their untreated water into their filter system AND start their timer. Once you have collected 50 mL water in your beaker, stop the stopwatch. Use the equation the client gave you – which is 50 mL divided by the number of seconds it took – to calculate your flow rate. If your water is filtering VERY slowly, you may stop your stopwatch at 5 minutes and record how much water went through your filter system.*
10. **Allow students time to test their filter systems.** Remind students to use their stopwatch to measure the time it takes for the water to pass through their filter so they can calculate flow rate. If time permits, students may try testing multiple filter media or using different amounts. For example, what is the water quality difference when using one layer of sponge as opposed to using two layers of sponge?
11. **Measure the effluent water quality.** When a group is ready, they may test the effluent water quality of their filter and record it on Duplication Master 7.B Filter Media Testing.

Closure

12. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? Why did we test our filter media before designing our filter systems?* **Say:** *We will move to the Plan stage in our next lesson.*

7.A Client Memo 4

Dear Engineers,

Thank you for continuing to work hard on preparing your solutions for providing safe water access! Now that you have learned all relevant information, I would like you to get started on brainstorming your designs. One of the water treatment methods you learned about was physical water filtration. Several of you wrote your environmental justice paragraphs about filtration due to its low cost and ability to be implemented with basic household items. Filtration is a great treatment method because you do not need certain chemicals or expensive components to make a successful filter.

To help pursue environmental justice, I would like you to design a water filter out of common household items. Your filters should be made out of a 1-liter plastic bottle, so all of your filter media will need to fit inside of that. Each filter should have a coffee filter at the bottom to ensure your filter media does not fall out the bottom. You will want to consider water quality, flow rate, and the cost of your filter. To calculate the flow rate of your filter, you can use the following equation:

$$\text{Flow rate} = \frac{\text{50 mL}}{\text{Time in seconds for 50mL to come out of your filter}}$$

Sincerely,

Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

Name_______________________________________ Date_______________ Period __________

7.B Filter Media Testing

Record the flow rate and effluent water quality for the filter media(s) that your group tests.

Filter Media	Flowrate (mL/second)	pH	Salinity	Temperature (Fahrenheit)	Turbidity (NTU)

LESSON EIGHT:

Lesson Objectives
Students will be able to:
- Design solutions to an engineering design challenge
- Use evidence-based reasoning while designing a solution to a problem

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP poster

Per group
- One 1-liter plastic water bottle
- Coffee filter

Per student
- EDP slider and paper clip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS
- MS-ETS1-2

Key Terms
Brainstorm, evidence-based reasoning, water filter

Lesson Summary

Now that students have learned about the water cycle, water scarcity, environmental justice, sensors, and water treatment methods, they are ready to develop their ideas and brainstorm a solution to the engineering design challenge. Students will work individually and then in teams to brainstorm different water filter systems. Using evidence-based reasoning, they will make a decision as a design team.

Before the Activity

- **Prepare information about filter media results.** Compile the data students collected in Lesson 7 and add it to Duplication Master 8.A Filter Media Information. This is important for students to consider how each filter media impacted water quality.
- **Prepare one 1-liter plastic water bottle for each design team.**
  - Cut the bottom of the bottle off.
  - Unscrew and remove the cap from the bottle.
  - Take a coffee filter and cut out a circle that is larger than the bottle's cap. Use a rubber band to tightly secure the coffee filter to the bottle.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Plan). Say:** *So far, we have defined the problem and learned about the water cycle, water scarcity, environmental justice, sensors, and water treatment methods. Today, we will begin brainstorming ideas for the engineering design challenge.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Plan" stage.

Activity

3. **Review the filter media information.** Hand out Duplication Master 8.A Filter Media Information and allow students a few minutes to read through the results from the previous class.

What should our filter look like?

4. **Show the class what their container looks like.** Hold up a 1-liter plastic water bottle that has been prepared for the design challenge. **Say:** *You will be filling this bottle with filter media to treat the water. Note that you cannot go any higher than the two holes at the top of the bottle, as we will be tying string through those holes to hold up your filters.*
5. **Brainstorm ideas individually.** Hand out Duplication Master 8.B Evidence-Based Reasoning. **Say:** *Come up with ONE idea that you think would do the best job of filtering unclean water. Answer the questions for your idea only under Design Idea #1: Individual Idea.*
6. **Gather into pre-determined design teams to discuss their designs. Say:** *Now that you have come with an idea on your own, work in your teams to share your ideas and determine what the best possible idea you have is. Answer the questions for Design Idea #2: Team Idea.* Allow the students a few minutes to discuss.
7. **Prepare a materials list.** Hand out Duplication Master 8.C Materials List. **Say:** *Now that you know what your filter will look like, create a materials list so you know exactly what you will need to build it.*

Closure

8. **Connect the activity to the engineering design challenge. Ask:** *What did we do today that will help us provide a recommendation to the client? How is brainstorming a helpful tool in engineering?*

Assessment

Pre-Activity Assessment

Listen to students' answers to the questions about the engineering design process and challenge. Determine if they understand the importance of the problem and what they have learned so far to help solve the problem.

Activity Embedded Assessment

During the activity, observe how students use the filter media information to determine what their filter system should look like.

Post-Activity Assessment

Review Duplication Master 8.B Evidence-Based Reasoning to see if students utilized the provided information to design their filter system.

Duplication Masters

- 8.A Filter Media Information
- 8.B Evidence-Based Reasoning
- 8.C Materials List

Educator Resources

- 8.D EBR Example

Name____ Date_______________ Period __________

8.A Filter Media Information

Below is important information for you to consider about each of the household items that can serve as your filter media.

Filter Media	Cost	Flow Rate (mL/min)	Initial Water Quality	Final Water Quality
Cheesecloth	$0.03 per layer of cloth		pH = Salinity = Temperature = Turbidity =	pH = Salinity = Temperature = Turbidity =
Cotton Balls	$0.01 per cotton ball			pH = Salinity = Temperature = Turbidity =
Gauze	$0.05 per layer of gauze			pH = Salinity = Temperature = Turbidity =
Gravel	$0.10 per cup*			pH = Salinity = Temperature = Turbidity =

Name____ Date_______________ Period __________

8.A Filter Media Information

<table>
<tr><th>Filter Media</th><th>Cost</th><th>Flow Rate (mL/min)</th><th>Initial Water Quality</th><th>Final Water Quality</th></tr>
<tr><td>Paper Towel</td><td>$0.01 per layer of towel</td><td></td><td rowspan="4">pH =
Salinity =
Temperature =
Turbidity =</td><td>pH =
Salinity =
Temperature =
Turbidity =</td></tr>
<tr><td>Rice</td><td>$0.40 per cup*</td><td></td><td>pH =
Salinity =
Temperature =
Turbidity =</td></tr>
<tr><td>Sand</td><td>$0.34 per cup*</td><td></td><td>pH =
Salinity =
Temperature =
Turbidity =</td></tr>
<tr><td>Sponge</td><td>$0.80 per layer of sponge</td><td></td><td>pH =
Salinity =
Temperature =
Turbidity =</td></tr>
</table>

*Using a standard 8-oz measuring cup

Name______________________________________ Date______________ Period __________

8.B Evidence-Based Reasoning

First, think about the problem, criteria, and constraints to focus your brainstorming.

Then, using the filter media information, brainstorm which filter media or combination of filter medias you would like to use for your design. Come up with your two best options and think through your justification for these choices.

- What is the client's problem?

- Why is the client's problem important to solve?

- What are the criteria for the design challenge?

- What are the constraints for the design challenge?

- A simplifying assumption means that while something might be important, you have decided not to worry about it in order focus on the solution (or to make the solution easier to approach). Do you have any simplifying assumptions? If yes, what are they?

Name______________________________________ Date_______________ Period __________

8.B Evidence-Based Reasoning

Design Idea #1: Individual Idea	
How many filter media will you use for your design? What are they?	
Why did you choose this/these specific filter media? List scientific evidence and/or test results that support your design idea.	
If you have more than one filter media, how will you choose to layer them? Feel free to write out the layers or draw a picture of your idea.	
Why do you think this design idea will work? Explain how your data and evidence support your design idea in order to meet criteria/constraints.	
What negative or unintended consequences could emerge from your design idea being implemented?	

Name________________________________ Date______________ Period __________

8.B Evidence-Based Reasoning

Design Idea #2: Team Idea	
How many filter media will you use for your design? What are they?	
Why did you choose this/these specific filter media? List scientific evidence and/or test results that support your design idea.	
If you have more than one filter media, how will you choose to layer them? Feel free to write out the layers or draw a picture of your idea.	
Why do you think this design idea will work? Explain how your data and evidence support your design idea in order to meet criteria/constraints.	
What negative or unintended consequences could emerge from your design idea being implemented?	

Name________________________________ Date______________ Period __________

8.C Materials List

With your team, write a list of materials that you will need to build your filter design.

Material List

Filter Media	Quantity

8.D EBR Example

First, think about the problem, criteria, and constraints to focus your brainstorming.

Then, using the filter media information, brainstorm which filter media or combination of filter medias you would like to use for your design. Come up with your two best options and think through your justification for these choices.

- What is the client's problem?

  Providing safe water access for people that do not have potable water.

- Why is the client's problem important to solve?

  All people should have access to a safe and healthy environment.

- What are the criteria for the design challenge?

  The recommendation should be reliable, cost effective, ethical, and demonstrate the use of scientific reasoning.

- What are the constraints for the design challenge?

  These communities cannot afford to install and maintain complex, expensive systems.

- A simplifying assumption means that while something might be important, you have decided not to worry about it in order focus on the solution (or to make the solution easier to approach). Do you have any simplifying assumptions? If yes, what are they?

  There is no correct answer to this question and students may choose to leave it blank. Examples of simplifying assumptions include not worrying about the flow rate, cost, or a particular water quality parameter.

8.D EBR Example

Design Idea	
How many filter media will you use for your design? What are they?	**I will use three filter media for my design – gravel, sand, and cheesecloth.**
Why did you choose this/these specific filter media? List scientific evidence and/or test results that support your design idea.	**I chose these filter media because they performed the best in the water quality testing. The gravel and cheesecloth had a high flow rate and low turbidity. The sand had a low flow rate, but also decreased turbidity.**
If you have more than one filter media, how will you choose to layer them? Feel free to write out the layers or draw a picture of your idea.	**I will layer the sand on the bottom, the gravel in the middle, and the cheesecloth on top.**
Why do you think this design idea will work? Explain how your data and evidence support your design idea in order to meet criteria/constraints.	**I think this idea will work because the materials are fairly inexpensive and all produced great effluent water quality. It meets the criteria of being an inexpensive, quick, and efficient water filter.**
What negative or unintended consequences could emerge from your design idea being implemented?	**Some of the materials may be wasted if they don't work. If the filter does not work properly, the user may drink low quality water that could make them sick.**

LESSON NINE:

Lesson Objectives
Students will be able to:
- Work as a design team to construct a filter system
- Calculate a product's total cost from a bill of materials

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP poster
- Cheesecloth
- Cotton Balls
- Gauze
- Gravel
- Paper Towel
- Rice
- Sand
- Sponge

Per group
- One 1-liter plastic water bottle
- Ring stand

Per student
- EDP slider and paper clip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS
- MS-ETS1-2, MS-ESS3-3

Key Terms
Water filtration, filter media, teamwork

Lesson Summary

Now that students have designed their filtration systems, they will physically build it using the household materials available to them. During the building process, teams are required to fill out a Bill of Materials to keep track of the quantity used of each item. At the end, the team will have to calculate the total cost of their filtration system.

Before the Activity

- **Setting up materials:** The teacher may choose to provide each design team with the specific materials they requested in Lesson 8. Or, they can have the materials out for students to come gather themselves. It is up to the teacher what will work best for their specific classroom.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Try). Say:** *So far, we have defined the problem, learned relevant information, and planned our design. Today, we are going to build our designs.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Try" stage.

Activity

3. **Explain how the building process will work. Say:** *While you are building your filter systems, it is important to keep a bill of materials, or a list of items that you use to create your product.* Hand out Duplication Master 9.A Bill of Materials. **Say:** *While you build, mark down how many of each item you use. Before leaving today, you will need to find the total cost of your filter.*
4. **Allow students time to build their filter systems.** Set out the materials for students to use to build their systems and allow them time to construct. Remind them to fill out their Bill of Materials as they work. When students are finished, they can put their bottle on the ring stand until next class.

5. **Have students find their total cost.** Once students are finished building their filter systems, give them a few minutes to add up the total cost of their filter systems.

Closure

6. **Connect the activity to the engineering design challenge.** **Ask:** *What did we do today that will help us provide a recommendation to the client?* **Say:** *We will move to the Test stage during our next class.*

Assessment

Pre-Activity Assessment

Listen to students' answers about the engineering design problem and where they are in the EDP. See if they understand the design process.

Activity Embedded Assessment

Watch how students work together in their teams to build the filtration systems. Are they working as a team or is one student taking over? Are there clear roles among the team?

Post-Activity Assessment

Look at the teams' Bill of Materials to see if they properly calculated the total cost of their filtration system.

Duplication Masters

- 9.A Bill of Materials

Name________________________________ Date______________ Period __________

9.A Bill of Materials

Filter Media	Cost	Quantity Used	Total Cost
Cheesecloth	$0.03 per layer of cloth	Layers:	
Cotton Balls	$0.01 per cotton ball	Cotton Balls:	
Gauze	$0.05 per layer of gauze	Layers:	
Gravel	$0.10 per cup	Cups:	
Paper Towel	$0.01 per layer of towel	Layers:	
Rice	$0.40 per cup	Cups:	
Sand	$0.34 per cup	Cups:	
Sponge	$0.80 per layer of sponge	Layers:	
		TOTAL COST:	

LESSON TEN:

Lesson Objectives
Students will be able to:

- Filter untreated water through filtration systems
- Analyze water quality data to determine if it has been properly treated

Time Required
One 50-minute lesson

Materials
Per classroom

- EDP poster
- 1 Vernier LabQuest 3
- 1 Vernier pH Sensor
- 1 Vernier Turbidity Sensor
- 1 Vernier Temperature Sensor
- 1 Vernier Salinity Sensor
- Soy Sauce

Per group

- Constructed Filter System
- 1 cup water
- 2 plastic cups (that can hold 8 oz or more)
- Stopwatch
- Ring stand

Per student

- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
NGSS

- MS-ETS1-4

Key Terms
Water quality, data, filter systems

Lesson Summary

Students will test their constructed filter systems by running "untreated" water through them. Design teams are required to test the water quality before and after treatment to determine if they were successful.

Before the Activity

- **Prepare the untreated water for students.** Each group should be provided 24 oz of untreated water to run through their filter system. To make 8 oz of water, add 1 oz (2 Tbsp) soy sauce to 7 oz of tap water. Ensure that there is enough untreated water for each group to have at least 24 oz.
- **OPTIONAL – Test untreated water quality.** To save time, the teacher may choose to test the untreated water for pH, turbidity, temperature, and salinity. These numbers can then be provided to students.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Test). Say:** *So far, we have defined the problem, learned relevant information, planned our design, and build our filter systems. Today, we will see if the systems work.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Test" stage.

Activity

3. **Introduce the activity.** Hand out Duplication Master 10.A Filter System Data. **Say:** *To determine if your filtration system can successfully treat water, we need to compare water quality parameters before and after filtering. To measure flow rate, you will use a stopwatch to measure how long it takes for your 50 mL water to pass through the filter.*

4. **Allow groups to test initial water quality.** Have each group test one water quality parameter on the untreated water. The parameters that should be tested are pH, turbidity, temperature, and salinity.

   NOTE: To save time, the teacher may choose to test the quality prior to the lesson and provide these values to students.
5. **Allow students to "wet" their filter systems. Say:** *Since some of the materials we are using are absorbent, everyone can run one cup of unfiltered water through their system to "wet" their filter media.* Allow students time to run the water through their system.
6. **Allow students time to test their filter systems.** Remind students to use their stopwatch to measure the time it takes for 50 mL untreated water to pass through their filter so they can calculate flow rate.
7. **Measure the effluent water quality.** When a group is ready, they may test the effluent water quality of their filter and record it on Duplication Master 10.A Filter System Data.

Closure

8. **Connect the activity to the engineering design challenge. Ask:** *What did we do today that will help us provide a recommendation to the client? Do you think your filter system is successful at solving the problem? If you had the chance to improve your filter system, what would you do to make it better?*

Assessment

Pre-Activity Assessment
Listen to students' answers about the engineering design problem and where they are in the EDP. See if they understand the design process.

Activity Embedded Assessment
Watch how students work together in their team. Are they filling out their worksheet? Do they understand how to calculate flow rate?

Activity Embedded Assessment
Look at the Filter System Data sheets to see if students understand water quality parameters and if the water improved after filtration.

Duplication Masters

- 10.A Filter System Data

Name_______________________________________ Date_______________ Period ___________

10.A Filter System Data

Water Quality Data

Parameter	Water Quality Requirement	Untreated Water	Treated Water	Did it improve?	
pH	6.0 - 9.0			Yes	No
Salinity	< 600 mg/L			Yes	No
Temperature	60°F - 75°F			Yes	No
Turbidity	< 1.0 NTU			Yes	No

Flow Rate:

Time for 50 mL water to pass through the filter: ____________ seconds

Flow Rate: ___________ mL/second

LESSON ELEVEN:

Lesson Objectives
Students will be able to:
- Redesign based on acquired data
- Use evidence-based reasoning to improve filter design

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP poster
- Cheesecloth
- Cotton Balls
- Gauze
- Gravel
- Paper Towel
- Rice
- Sand
- Sponge
- 1 Vernier LabQuest 3
- 1 Vernier pH Sensor
- 1 Vernier Turbidity Sensor
- 1 Vernier Temperature Sensor
- 1 Vernier Salinity Sensor
- Soy Sauce

Per group
- One 1-liter plastic water bottle
- Ring stand
- Coffee filter

Per student
- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Lesson Summary
Now that students have tested their filters, they have seen how they perform and what could be improved. This lesson allows students to repeat the process of planning, building, and testing their filters. The iterative design process will allow students to use evidence-based reasoning and water quality data to design an improved filter.

Before the Activity
- **Prepare the untreated water for students.** Each group should be provided 24 oz of untreated water to run through their filter system. To make 8 oz of water, add 1 oz (2 Tbsp) soy sauce to 7 oz of tap water. Ensure that there is enough untreated water for each group to have at least 24 oz.

Classroom Instruction
Introduction
1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Retry/Retest). Say:** *So far, we have defined the problem, learned about relevant information, planned our filter systems, built the systems, and tested them. Today, we are going to see if we can improve upon our filter system designs.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Retry/Retest" stage.

   NOTE: The words "Retest" and "Retry" are not on the EDP sliders and poster. Show the students the arrows that move from test back to other stages of the EDP. Explain that sometimes engineers have to take a few steps back to improve upon their current design.

Activity 1 - Plan Filter 2.0
3. **Consider how the filter system can be improved.** Hand out Duplication Master 11.A Evidence-Based Reasoning. **Ask:** *How well did your filter system perform? How could it be improved? Fill out the worksheet with your team to design a second filter that will hopefully work better than the first one. Remember that you are being evaluated on flow rate, water quality, and cost of your filter. If you have met all of the required water quality*

parameters, you should focus on improving the cost and flow rate of your filter.

Activity 2 - Build Filter 2.0

4. **Explain how the building process will work. Say:** *While you are building your filter systems, it is important to keep a bill of materials, or a list of items that you use to create your product.* Hand out Duplication Master 11.B Bill of Materials. **Say:** *While you build, mark down how many of each item you use. Before leaving today, you will need to find the total cost of your filter.*
5. **Allow students time to build their filter systems.** Set out the materials for students to use to build their systems and allow them time to construct. Remind them to fill out their Bill of Materials as they work.
6. **Have students find their total cost.** Once students are finished building their filter systems, give them a few minutes to add up the total cost of their filter systems.

Activity 3 - Test Filter 2.0

7. **Allow students to "wet" their filter systems. Say:** *Since some of the materials we are using are absorbent, everyone can run one cup of unfiltered water through their system to "wet" their filter media.* Allow students time to run the water through their system.
8. **Allow students time to test their filter systems.** Remind students to use their stopwatch to measure the time it takes for the water to pass through their filter so they can calculate flow rate.
9. **Measure the effluent water quality.** When a group is ready, they may test the effluent water quality of their filter and record it on Duplication Master 11.C Filter System Data.
10. **Ask students if their filter design improved. Ask:** *How did your new filter designs perform? Were they better than your original design, or was your first design a more efficient filter? What are the differences between the two?* Facilitate a class discussion about the redesign process.

Closure

11. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? Did your second filter design work better than your first one?* **Say:** *We will move to the Decide stage during our next class.*

Standards Addressed
NGSS
- MS-ETS1-2, MS-ETS1-3

Key Terms
Redesign, iteration, water filtration

Assessment
Activity Embedded Assessment
Observe students as they work through the redesign process of planning, building, and testing their second filter iteration. Are they thinking critically about their design? Are they using evidence and test results to make decisions about their new design? Review Duplication Masters 11.A and 11.C to review their evidence-based reasoning and new filter data.

Duplication Masters
- 11.A Evidence-Based Reasoning
- 11.B Bill of Materials
- 11.C Filter System Data

Name____ Date_______________ Period __________

11.A Evidence-Based Reasoning

Think about your first filter. What went well? What did not go well? Use this sheet to improve your design.

Filter Redesign	
What would you like to improve about your first filter? Consider the importance of water quality, cost, and flow rate.	
How can you fix these issues? What changes should be made to your filter design? List scientific evidence and/or test results that support your design idea.	
If you have more than one filter media, how will you choose to layer them? Feel free to write out the layers or draw a picture of your idea.	
Why do you think this design idea will work better than the first one? Explain how your data and evidence support your design idea in order to meet criteria/constraints.	

Name____ Date________________ Period ___________

11.B Bill of Materials

Filter Media	Cost	Quantity Used	Total Cost
Cheesecloth	$0.03 per layer of cloth	Layers:	
Cotton Balls	$0.01 per cotton ball	Cotton Balls:	
Gauze	$0.05 per layer of gauze	Layers:	
Gravel	$0.10 per cup	Cups:	
Paper Towel	$0.01 per layer of towel	Layers:	
Rice	$0.40 per cup	Cups:	
Sand	$0.34 per cup	Cups:	
Sponge	$0.80 per layer of sponge	Layers:	
		TOTAL COST:	

Name____ Date_______________ Period __________

11.C Filter System Data

Water Quality Data

Parameter	Water Quality Requirement	Untreated Water	Treated Water	Did it improve?	
pH	6.0 - 9.0			Yes	No
Salinity	< 600 mg/L			Yes	No
Temperature	60°F - 75°F			Yes	No
Turbidity	< 1.0 NTU			Yes	No

Flow Rate:

Time for 50 mL water to pass through the filter: ____________ seconds

Flow Rate: ___________ mL/second

LESSON TWELVE:

Lesson Objectives

Students will be able to:

- Communicate science, technology, engineering, and mathematics ideas by giving presentations
- Use evidence-based reasoning to support their engineering decisions

Time Required

Two 50-minute lessons

Materials

Per classroom

- EDP poster

Per student

- EDP slider and paper clip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed

NGSS

- MS-ETS1-2, MS-ETS1-3

Key Terms

Criteria, constraint, decision matrix, communication, evidence-based reasoning

Lesson Summary

In this lesson, students will report out their group findings to provide a holistic, evidence-based recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client.

Before the Activity

- In this lesson, students will be making presentations to convince the client that their filter system is the best option, or if they recommend the client does not choose their filter system. The teacher can choose from a variety of presentation options based on the materials and technology that are available. Presentations may be live, video recorded, or use any other technology resources available. Alternatively, the teacher may choose to have students write a letter to the client that includes the same information that would be included in the presentation. This lesson is structured to allow one class period for preparation and one for presentation and conclusion, but this should be adjusted to meet the needs of the class.
- Before distributing Duplication Master 12.E Client Memo 5, it is recommended that the teacher adds feedback specific to the students' presentations. If the teacher wants to do this, they will need to treat 12.E Client Memo 5 as a template and make a new version. They will add feedback specific to the students after the first sentence of the body of the letter.
- After students complete their presentations, the teacher will evaluate their designs based on the 12.B Client Communication Requirements document.

  NOTE: Although some students thrive on competition, it can have a negative impact on the engagement of other students. The teacher will need to decide on the level of competition based on their students.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Decide). Say:** *So far, we have defined the problem, learned relevant information, planned our designs, built our designs, tested our designs, and then redesigned and retested. Today, we are going to provide a recommendation to our client.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Decide" stage.

Activity

3. **Read Duplication Master 12.A Client Memo 5. Ask:** *What is the client asking us to do?* (Prepare a presentation and a written document to convince the client and the rest of the class which design is best.)
4. **Explain what needs to be included in the presentation.** Hand out Duplication Master 12.B Client Communication Requirements. Briefly describe what is required by the client. Share the presentation options that are available to students and distribute the presentation template to students.
5. **Explain the evaluation process. Say:** *A decision matrix is a tool that evaluates and prioritizes your options to help you make the best decision.* Hand out Duplication Master 12.C Decision Matrix Directions. **Say:** *We have been considering water quality, cost, and flow rate when designing and building our filters.* Allow students a few minutes to review the decision matrix and ask any questions.
6. **Prepare design review presentations.** Allow students time to prepare for their presentations (e.g., creating visuals, filming video, rehearsing scripts, etc.). **Say:** *Based on the results you collected, you are welcome to present either your first or second filter design to the class. Choose the filter that you believe is the better option based on the design matrix.*
7. **Use the decision matrix to assess design recommendations.** Hand out Duplication Master 12.D Decision Matrix Activity. While each group is presenting, the students should be using the decision matrix to evaluate their filter system.

Assessment

Pre-Activity Assessment

Have a class discussion about what is important in a presentation.

Activity Embedded Assessment

Ensure that students are using the provided PowerPoint template and are evaluating their classmates during the presentations.

Post-Activity Assessment

Review the final presentations that were assessed using 12.B Client Communication Requirements. Review the students' post-assessment to see if their understand has improved over the course of this unit.

Duplication Masters

- 12.A Client Memo 5
- 12.B Client Communication Requirements
- 12.C Decision Matrix Directions
- 12.D Decision Matrix Activity
- 12.E Client Memo 6
- 12.F Content-Post Assessment

Educator Resources

- 12.G Content Post-Assessment Key

8. **OPTIONAL: Prepare a class report to the client.** This is the final deliverable which must include the formal recommendations to the client with scientific justification behind the choice.
9. **Identify where they are in the engineering design process (Communication). Ask:** *What stage of the engineering design process are we in now?* Facilitate a discussion about why communication with the client is vital to engineering design. Students should identify that they are in the “Communicate” stage.

Closure

10. **Revisit engineering design challenge.** Discuss the client, the problem, what information led to their informed decision, and how criteria and constraints were included in the decision-making process.
11. **Provide feedback from the client.** Hand out Duplication Master 12.E Client Memo 6 and read it as a class. Reflect on the engineering design process and how the process was used throughout the unit.
12. **Complete Duplication Master 12.F Content Post-Assessment.** Note that this is an important step in the process and students should be given time to complete this individually.
13. **OPTIONAL: Review the entire unit.** If time allows, the teacher may choose to review some of the material during the Learn lessons.

12.A Client Memo 5

Dear Engineers,

Thank you for your hard work in developing water filtration systems! As you finalize your decision, I would like each team to prepare a presentation describing your design, your evaluation of it, and whether or not you would recommend the design. This is your opportunity to convince the other design teams that your water filtration system is the best, so please ensure you use the guidelines I have attached when preparing your presentation. This is also your chance to convince ME that your design is the best!

Sincerely,

Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

12.B Client Communication Requirements

- Students introduce themselves.
- Students summarize the client's problem including criteria and constraints.
- Students explain why it is important to create water filtration systems.
- Students describe their solution to the problem:
  - Describe the filtration system.
  - Explain the test results they found.
  - Explain their redesign process.
  - Provide a recommendation to the client about their final design.
  - Include the rating you achieved according to the decision matrix.
- Students show data and evidence gathered and used in their design.
- Students justify their decision using data and evidence.
- All team members have a role in the presentation.
- Students demonstrate in-depth knowledge of their water filtration system.
- Students describe how their filtration system will help people suffering from environmental injustice.

12.C Decision Matrix Directions

A decision matrix is a tool that evaluates and prioritizes your options to help you make the best decision. The row represents your water filtration system, which will be evaluated for each of the three column headings. The three column headings represent important factors to consider when making your recommendation to the client. For this decision matrix, each factor will be rated on a scale from 1 to 5. A rating of 1 indicates that the design does not meet expectations for the category, while a rating of 5 indicates that the design exceeds expectations for the category. An explanation of each category is given below.

Category	Explanation	A rating of 1 indicates…	A rating of 5 indicates…	A rating of 7 indicates…	A rating of 10 indicates…
Water Quality	*Water quality is determined by pH, turbidity, chlorine concentration, and salinity.* *Maximum rating for this category is 10 points.*	*Water quality did not change after filtration.*	*Two out of four water quality parameters met state standards after filtration.*	*Three out of four water quality parameters met state standards after filtration.*	*All four water quality parameters met state standards after filtration.*
System Cost	*How much did the system cost?* *Maximum rating for this category is 7 points.*	*The system cost more than $5.*	*The system cost between $1 and $2.*	*The system cost less than $0.50.*	*Not achievable for this category.*
Flow Rate	*How fast can the water be filtered?* *Maximum rating for this category is 5 points.*	*It took more than 5 minutes for all 250 mL water to be filtered.*	*It took less than 30 seconds for 250 mL water to be filtered.*	*Not achievable for this category.*	*Not achievable for this category.*

Name____ Date_______________ Period __________

12.D Decision Matrix Activity

Take notes while each group gives their presentation on their water filtration system, paying specific attention to the presenters' comments on each of the three categories. Once the presentation is finished, rate the water filtration system for each of the three categories on their given scale. Find the total score for each row. The row with the highest value is what you consider to be the best water filtration system to recommend to the client based on these criteria.

Design Team	Water Quality	Cost	Flow Rate	TOTAL SCORE

12.E Client Memo 6

Dear Engineers,

I received your presentations this morning and have reviewed them. The design you recommend will be extremely helpful in providing water filtration options to people in need.

Thank you for your dedication to this engineering design challenge and for all of the hard work that you did for my company. I hope to have the opportunity to work with you again in the future.

Sincerely,

Brooks Eaton

Brooks Eaton
Environmental Engineer
QUENCH (QUality ENgineering for Community Health)

Name____ Date_______________ Period __________

12.F Content Post-Assessment

1. Name two filter media that may be used in water filtration.

2. Why is environmental justice important?

3. What are some methods of resolving environmental injustice?

4. Why are countries such as Pakistan and Spain are predicted to experience water scarcity in the year 2040?

5. Name at least one component of drinking water other than the chemical components of hydrogen and oxygen.

Name____ Date_______________ Period __________

12.F Content Post-Assessment

6. Why is it important to use microelectronic-based water sensors as opposed to their analogs?

7. What does the term, “microelectronics” mean?

8. How are microelectronics used in the field of science?

9. What jobs would you be interested in that use microelectronics?

10. Provide one example of how microelectronics is used in that job.

12.G Content Post-Assessment Key

1. Name two filter media that may be used in water filtration.

   Answers will vary, but correct answers include sand, gravel, or activated carbon.

2. Why is environmental justice important?

   Answers should vary based on students' personal convictions and opinions. Satisfactory responses should state why it is unfair to receive different treatment from another person based on demographics.

3. What are some methods of resolving environmental injustice?

   There are many answers, but potential ideas include changing policies to be fair and inclusive, stricter limits on factory emissions, or providing public health information to the general public.

4. Why are countries such as Pakistan and Spain are predicted to experience water scarcity in the year 2040?

   Answers will vary, but correct answers include increased consumption by farms and industry, rapidly increasing populations, migration toward cities, and climate change.

5. Name at least one component of drinking water other than the chemical components of hydrogen and oxygen.

   Correct answers include minerals, metals, small particles, and organic material.

6. Why is it important to use microelectronic-based water sensors as opposed to their analogs?

   Microelectronic sensors provide very accurate measurements which ensure water quality standards are met.

12.G Content Post-Assessment Key

7. What does the term, “microelectronics” mean?

   Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

8. How are microelectronics used in the field of science?

   There are many answers to this question, but examples include sensors, controllers, measurement tools, instruments, computers, etc.

9. What jobs would you be interested in that use microelectronics?

   Students’ answers will vary based on interest. Credit may be given as long as at least one job example is provided.

10. Provide one example of how microelectronics is used in that job.

    Students’ answers will vary based on interest. Credit may be given as long as at least one example is provided of how microelectronics is used in the job they provided in question nine.