<table>
<tr><td colspan="3">Description
During this lesson, students will design devices that remove garbage from the Pacific Gyre while minimizing the number of animals collected. They will create diagrams of their devices. Students will also gather, analyze and display data to look for patterns. Finally, they will create a video that addresses the problem, their research questions, their process and final solution in order to seek funding to fully develop their solution.</td></tr>
<tr><td>Grade Level
6</td><td>Objectives
Students will:
Design and build a device to propose as a tool for garbage removal.
Explain the purpose of the criteria and constraints in relation to design success.
Explain how materials work together to support the function of their device/ prototype.
Develop clear arguments for the importance of cleaning up the natural world.</td><td>Grade Levels in adaptations (Appendix A)
3, 4, 8, 9-12.
After school/expanded learning</td></tr>
<tr><td colspan="2">Duration
Five to seven 50-minute sessions</td><td>Tech Tips
Our Tech Tips and their accompanying videos can be found here.
Assessment
Data Collection - Reflecting on Your Design
Framing the Challenge
The Language of Engineering
Materials Strategies Engineering Design
Sharing Solutions
What is Engineering?</td></tr>
</table>

Standards Connections

Note: Bolded parts of the standards are fully met by this lesson.

- **NGSS Engineering Performance Expectations (PE)**
  - MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles **and potential impacts on people and the natural environment that may limit solutions.**
- **NGSS Disciplinary Core Idea (DCI)**
  - Defining and Delimiting Engineering Problems ETS1.A:
  - **The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful.** Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)
- **NGSS Science and Engineering Practices (SEP)**
  - Asking Questions and Defining Problems
  - **Ask questions to clarify and/or refine** a model, an explanation or **engineering problem.**
- **NGSS Crosscutting Concepts (CCC)**
- Influence of Science, Engineering, and Technology on Society and the Natural World
- **All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.** (MS-ETS1-1)

Content Standards

- This lesson is written with a connection to the 6th grade CCSS standards and mathematical practices below.
- 6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
- 6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems.

Standards for Mathematical Practice

- MP1. Make sense of problems and persevere in solving them.
- MP3. Construct viable arguments and critique the reasoning of others.
- MP4. Model with mathematics.

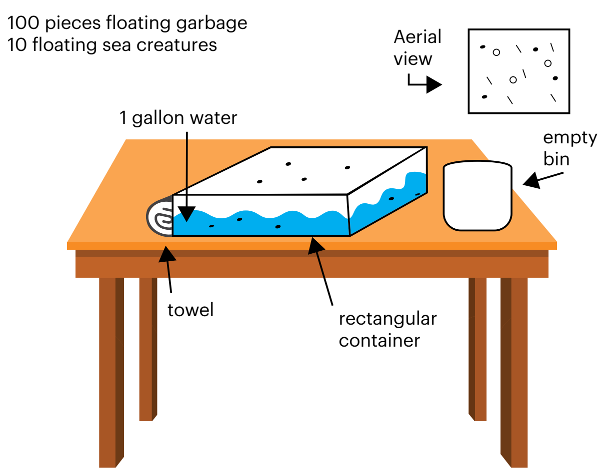
This engineering challenge can be adapted for a variety of CCSS math content standards over many grade levels:

- 3.NF.A.3.D Compare two fractions with the same numerator or the same denominator by reasoning about their size. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with the symbols >, =, or <, and justify the conclusions, e.g., by using a visual fraction model.
- CCSS.MATH.CONTENT.1.OA.A.1 Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem.
- CCSS.MATH.CONTENT.8.SP.A.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.
- CCSS.MATH.CONTENT.HSS.ID.B.6.A Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.
- Quality Standards for Expanded Learning Programs 3. Skill Building. Participants are involved in projects, activities and events that increase their understanding and use of 21st century skills (e.g., creativity, critical thinking and information and communications technology).

Set up and Prep for Classroom

Set up the classroom so students can work in teams of 2-4. Throughout the entire building process, students should have the opportunity to work alone or with others.

- Set up the Test Rig
  - Rig should be a flat, rectangular container that can hold at least 1 gallon of water, with a depth of 8-13 cm (3-5 in).
  - Towels underneath rigs and on the floor to prevent splatter and slipping.
  - Add approximately 100 pieces of a variety of floating garbage-like materials (e.g., cut up pieces of straws).
  - Add approximately 10 pieces of a variety of floating materials to represent animals (e.g., pieces of cork with animal images).
  - Place an empty plastic bin next to Test Rig to scoop garbage into.
  - The Test Rig should be available to students during build time.
- Data collection — Ensure that all groups have copies of the data collection (see Appendix D: Data Collection) to record their prototypes and iterations based on the observations they make. Decide if students will have one copy per team or if all students will fill in individual copies while working with their team. See Tech Tip: [Data Collection](#).
- Possible set-up:



Materials (per class of ~32 students)*		
Structural pieces (~200 total) • Chopsticks • Caps • Lids • PVC pipe pieces • Sliced cardboard tubes • Straws • Wooden craft sticks • Wooden dowels	**Connectors (~150 total)** • Binder clips • Clothespins • Fabric/netting/tights or stockings • Micro claw hair clips • Paper clips • Pipe cleaners • Rubber bands • String • Tubing • Wire	**Testing materials** • 100 pre-cut 1-2 cm pieces of floating garbage • 4 liters water • Flat, rectangular container that can hold at least 4 L (~ 1 gal) water, with a depth of 8-13 cm (3-5 in). • Empty container to scoop garbage into • Floating materials to represent animals (e.g. pieces of cork with animal images) • Metric rulers • Spoon (to create a whirlpool) • Towels • 10 second timer
Make materials accessible to students so they can see what is available and organize by type. Send teams to the table one at a time or have one member from each team access the materials. See Tech Tip: Materials Strategies for Engineering Design for more materials management suggestions. *Many of these materials are suggestions based on what students have found useful. It is not necessary to have all building materials. Feel free to use materials you have on hand that may be useful for your learners. Think creatively!		

A. Introduction

This unit is designed to be used as either an inquiry-based learning experience, with the content standard introduced and taught after the initial design challenge, or as an application of previously covered content material. Part C gives guidance on connections to the content standard. Appendix A provides suggestions on modifications for connections to other grade level content standards.

1. Lead a discussion to introduce the concept of engineering with students. Tech Tip: What is Engineering? provides information on discussing engineering, problem solving and creative thinking with youth.
2. Explain to students that they are going to solve a problem as design engineers. See Tech Tip: Framing the Challenge for suggestions on facilitating students through this process. Discuss the students' prior knowledge of ocean garbage.
    - Hook the students by showing pictures, videos or websites that show the large floating garbage patch located in the middle of the Pacific Ocean known as the Pacific Gyre. Discuss how the Pacific Gyre harms animals. Some suggested resources may include the following:
        - Suggested articles/websites:
            - Plastic Pollution: https://kids.nationalgeographic.com/explore/nature/kids-vs-plastic/pollution/
            - Ocean Conservancy: https://oceanconservancy.org/
            - "These 5 Countries Dump More Plastic In The Oceans Than The Rest Of The World": www.elitereaders.com/plastic-pollution-ocean/
            - "Irish Teen Wins 2019 Google Science Fair For Removing Microplastics From Water": https://www.forbes.com/sites/trevornace/2019/07/30/irish-teen-wins-2019-google-science-fair-for-removing-microplastics-from-water/#752ce866373f
        - Suggested videos:
            - Ocean Confetti, "The Challenge of Microplastics": https://thekidshouldseethis.com/post/85747435912
            - Kids Take Action Against Ocean Plastic: https://www.youtube.com/watch?v=hKFV9IquMlXA
            - It's OK to Be Smart, "How Much Plastic is in the Ocean": www.pbs.org/video/how-much-plastic-is-in-the-ocean-jpfpsf/
        - Suggested photos:
            - Slideshow of animals interacting with plastic in "Learn about Plastic and How to Reduce Your Use": https://kids.nationalgeographic.com/explore/nature/kids-vs-plastic/
            - Sperm Whale in "Microplastic discovered in the bodies of every dolphin, whale, and seal studied": https://www.indiatoday.in/science/story/microplastic-discovered-in-the-bodies-of-every-dolphin-whale-and-seal-studied-1445298-2019-02-02
            - Albatross photo in "Seabirds Are Eating Plastic Litter In Our Oceans – But Not Only Where You'd Expect": https://www.iflscience.com/plants-and-animals/seabirds-are-eating-plastic-litter-our-oceans-not-only-where-you-d-expect/
            - "Otter Be Ashamed - Otter Uses Plastic As Blanket Instead Of Kelp": www.catersnews.com/stories/animals/otter-be-ashamed-otter-uses-plastic-as-blanket-instead-of-kelp/.
            - "How a Photographer Snapped This Tragic Photo of a Seahorse Lugging a Q-Tip": www.theverge.com/2017/9/15/16314928/justin-hofman-seahorse-plastic-pollution-photography.
            - "Photos of Animals Navigating a World of Plastic": www.nationalgeographic.com/photography/proof/2018/06/animals-wildlife-plastic-pollution/.
3. Discuss what students already know about water pollution, trash cycles and ocean care.
    - *Where does the garbage that ends up in the ocean come from?* Possible answers include: from humans littering, from products that go down the drain, from garbage from the landfill being blown away. (CCC)
    - *Why is it important to clean up the ocean?* Possible answers include: so that the animals are safe, so that humans are not affected by ocean pollution.
    - *Have you ever heard of an ocean engineer, and if so, do you know what they do?* Possible answers

include: people that design and build structures, equipment and instruments that help advance our understanding of the sea, which we call **marine** science.
- *What kinds of devices can you think of that clean up other places (such as your house, a pool, the street)?* Possible answers include: vacuums, pool nets, street sweepers.

4. Introduce the engineering challenge. For modifications for grades 3, 4, 8, and 9-12 Math Content Standards and after school standards, see Appendix A.
   - *You are an ocean engineer studying the* Great **Pacific Gyre,** which is an area of the ocean so full of trash that it is damaging the wildlife and their habitat. *Your goal is to create a device that will help clean up the trash from the ocean without catching or harming the animals that live there.*
   - Tell students they will have access to the materials at the table to create their devices. Because ocean engineers work with scientists on research vessels, space is limited, so the device must be smaller than 15 cm x 20 cm (6 in x 8 in).

B. Design Challenge

1. Discuss necessary background information with students.
   - *Currently, there are over one hundred million tons of garbage floating in our oceans. This garbage has a significant effect on the health of marine wildlife. You are engineers who are on a mission to clean up the ocean.*
   - Introduce concepts of criteria and constraints. Tech Tip: Framing the Challenge provides guidance on the subtle differences between criteria and constraints.
2. Introduce the engineering design challenge

Design Problem Build a device that can remove the garbage from the polluted ocean rig without harming the included animals.
Criteria (Design Requirements/Desired Features)* • Students must pick up 10% (**percent** is a ratio over 100, so 10 out of 100) of the garbage pieces in the sample of ocean water. • The device must pick up no more than 10% (1 out of 10) of total animals from the sample of ocean water. • Students will have 10 seconds to retrieve garbage pieces. • Students will record their capture data on a data chart.
Constraints (Design Limitations)* • Budget: Students may only use the provided materials. • Devices must be no larger than 15 cm x 20 cm. • Student hands may not touch the water. • Schedule: Students have only 10 minutes to build their device
Testing • Timekeeper will track 10 seconds for testing of the device. • At the end of each attempt, students will count the number of pieces and the number of sea animals their device removed from the ocean. These numbers will be recorded in a data table, along with iterations for adjustments. See Tech Tip Data Collection - Reflecting on Your Design. • After testing, all students should have sketched a diagram of a device that includes labels and measurements.

*If the class has determined different criteria and constraints through discussion, use those in addition or instead.

3. Help students to co-develop criteria and constraints by facilitating a class discussion on criteria and test design. Students will use critical thinking to answer these questions. Some questions to use when guiding the discussion could include:

- *What challenges do you think real-world engineers face when dealing with the problem of ocean pollution?* Possible answers include: Creating a device that is well-made and does not break down in the ocean.
- *How should we take these challenges into account when making our designs? What criteria might we add?*
- *Our oceans are being polluted every minute of every day, which means we must act quickly. How much time should we allow ourselves to complete this challenge?* (Divide time into planning, building, iteration, etc.)
- *What size constraints do you think we should work within? Why?* Possible answers include: The device must be transported to its location.
- *What do we need to know before we start to design our devices and are able to test them?*

4. As teams work throughout the 20-minute build time, walk around and ask questions. Suggested questions:
    - *What kind of materials do you think you would need in order to create your device?*
    - *Why did you choose the materials that you did? How are you using them?*
    - *What criteria or constraints are you having the hardest time meeting? What are the easiest to meet? (DCI)*
    - *What changes might we want to make to our criteria and constraints to help us be more successful in our next challenge? (DCI)*
    - *Can you tell me about your design and how it works?*
5. Share solutions

- When build time is over, lead the class in final testing and demonstration of their designs. For ideas on a possible facilitation protocol see Tech Tip: Sharing Solutions. Suggested share-out questions:
    - *What parts of your device did not work like you had planned?*
    - *Looking at our data chart, how were you successful? How were you not successful?*
    - *What parts of your device do you think you can change to make your device more successful?*
    - *How can you change your device to have less impact on sea animals? (CCC)*
    - *What part of another team's design would you like to incorporate into your design to improve it? How would this improve your design?*
    - *Did you meet all criteria for the challenge? How do you know?*

6. Have students reflect on the materials they used to develop their design solution and the properties and functions of the materials.
    - *What do you think might happen if we did not clean up the ocean? How might this impact humans?* Possible answers include: All life forms that live in the ocean will be impacted by the plastic which will affect humans. *(CCC)*
    - *How might the materials used in your solution impact the pollution of the ocean? (CCC)*
    - *If you could talk to an ocean engineer, what types of questions would you ask them about modifications you could make for your device? (SEP)*
    - *What questions would you ask your fellow classmates about their device design? (SEP)*

C. Content Learning

1. Circle back to the original scenario and design problem with students. Spend time on the mathematical context of the design challenge, ensuring students make connections between the data collected during the first design challenge and the use of ratios and rates in thinking about their engineering data.
    - If this activity is being used as an inquiry-based approach, this is the time to introduce new content material and learning connected to the content standard.
    - If this activity is being used as an application of previously covered material, review and expand on students' knowledge and understanding.
    - After introduction or review of content material, spend time connecting the engineering challenge that students just completed and the iteration they will do next with the aligned content standards.
2. The following are suggested strategies for helping students use ratios to analyze data from the engineering challenge and plan for iteration of their solutions.

- Introduce and/or practice ratios and rates after students create their first round of solutions to the design problem:
  - *A **ratio** compares two amounts. For example, if a team has 2 girls and 3 boys, then the ratio of girls to boys is 2:3.*
  - ***Rates** are ratios comparing two terms of different units. Often the second number is a unit of time. For example, 10 miles per hour is comparing miles to hours.*
  - Introduce students to ratios and rates by recording data of collected garbage, total garbage and sea animals on a data chart, to use when demonstrating how to create ratios.
  - Use timed collections to determine rate of garbage retrieval.
- Apply ratios to student solutions. This could be by analyzing data, describing or explaining their solutions with more content-specific vocabulary, in-depth explanations, or by connecting their solutions to other areas of the content skill:
  - Challenge students to improve the ratio of garbage collected to total garbage from the Test Rig by iterating on their original devices.
  - Ask students to explain the success of their attempts using ratios.
- Have students use their understanding of ratios to plan iterations, develop data collection plans or connect to a deeper use of ratios.
  - Have students use the data they collected in the first challenge to determine what ratio they will focus on improving. (i.e., Device picked up three pieces of garbage and three sea animals. Which part of their device might they change to pick up the same amount of garbage and fewer sea animals?)

3. To help students apply their knowledge of ratios, review the solutions different teams came up with during build time. Suggested questions to facilitate a discussion:
   - *What are some ratios that can be created from the data?* Possible answers include: The ratio of the number of pieces of trash collected to the total pieces of trash.
   - *What are some ways ratios are used in the real world.* Possible answers include: To compare values, make predictions, find rates, or give values more meaning.
   - *How can we compare our rate of garbage cleanup to another group's rate?* Possible answers include: We could compare the number of pieces of trash collected to the total number of pieces of trash.
   - *The term for marine animals that are accidentally caught is **bycatch**. How can we compare the rate of bycatch to garbage collected?* Possible answers include: Calculate the ratio of the number of animals collected to the number of pieces of trash collected.
   - *How can percent be used to compare different ratios?* Possible answers include: Percent is a ratio out of 100. They make comparisons easier because you are always using the same whole.
   - How can we use ratios to help make data visual? Possible answers include: We can use test data to make coordinate graphs that show the relationship between two different variables such as the amount of trash picked up over time.
   - *How will knowing ratios help with other world problems?* Possible answers include: Ratios can be very helpful because they are a way of comparing the relationship between two values, like the number of miles traveled in one hour or the number of miles traveled on one gallon of gas.
4. You can use the data from the design challenge and student knowledge of how to use ratios and percentages by having teams write ratios, rates and percentages from their data and answer questions using that data. Questions include the following:
   - *What was the ratio of number of animals collected to number of pieces of trash collected?*
   - *What percent of the total trash did your group collect?*
   - *What percent of the total animals did your group collect?*
   - *What was the rate for collecting trash?*
   - *What was the rate for collecting animals?*

5. Lead students in a discussion about the data they collected and what it might tell them about their designs.
   - *Which rates, ratios, or percentages do you think best represents the results of their design?* Possible answers include: The percent of trash or animals collected or the ratio of trash collected to animals collected.
   - *Which ratio or rate would you like to focus on improving during the iteration phase of the project?* Possible answers include: Focus on the rate of trash collected so that it is more pieces per minute, or fewer animals per minute.
   - *How will you know if the ratio or rate improves?* Possible answers include: If the rate improves, we will have more pieces of trash over the same length of time, so the first number in the rate will increase while the other stays the same.

D. Iterate Design Solutions

1. After a class share out and discussion about the content, allow students to return to their work area and work on further iteration of their device. Make students aware of the following changes:
   - Changes to challenge/criteria: Students iterate their device to remove more garbage than was collected during the first trial from the polluted ocean rig without harming the included animals. Their devices also must fit in a smaller footprint than the first challenge and, as a class, students will agree on adding or changing any criteria and constraints, based on the prototype working in the real world.
   - Real-world problem connection/reasoning for change: The investor in this device is not willing to produce the device unless it can collect enough plastic and be easily transported by a standard boat. In defining the problem they are trying to solve, engineers refine their criteria and constraints to ensure that they are very specific.
2. Remind students of the problem they are working to solve and the criteria and constraints of the challenge. Make sure students are aware of and understand any changes to the criteria and constraints as they iterate on their designs.

Design Problem Improve on your device to remove more garbage from the ocean without harming the animals.
Criteria (Design Requirements/Desired Features)* • Must remove a larger percentage, or ratio, of garbage from the Test Rig than previous attempts. • The device must pick up no more than 10% (1 out of 10) of total animals from the sample of ocean water. • Students have 10 seconds to retrieve garbage pieces. • Students will create a diagram of their device and gather data.
Constraints (Design Limitations)* • Budget: Only use the materials provided. • Devices must be no larger than 15 cm x 15 cm. • Student hands may not touch the water. • Schedule: Students have only 10 minutes to iterate their device. • Students will add or delete limitations.
Testing • The timekeeper will track 10 seconds for testing of the device. • At the end of each attempt, students will count the number of garbage and the number of sea animals their device removed from the ocean. These numbers will be recorded in a data table, along with iterations. See Tech Tip: Data Collection - Reflecting on Your Design.

*If the class has determined different criteria and constraints through discussion, use those in addition or instead.

3. Facilitate a class discussion to help students to develop their skills in refining their criteria, constraints and testing procedures as they prepare to iterate on their designs. Students will use critical thinking to answer these questions. Call attention to observations that align with the engineering DCI of focus in this lesson so that the more precisely a design task's criteria and constraints are defined, the more likely it is the designed solution will be successful. Questions may include:
   - *Which criteria or constraints were hardest to achieve in the first challenge? Why?*
   - *Are there any criteria or constraints that we want to make more specific? (DCI)*
   - *Which criteria or constraints will push us to have less impact on animals? (CCC)*
   - *What questions do you have about your device that you want answered by this next iteration? What changes to the criteria, constraints or to how we test/ collect data will help you answer those questions? (SEP)*
4. Begin the second round of iterations. Give teams 15 minutes to build and test. As student teams work:
   - Facilitate the sharing of the Test Rig.
   - Ensure that all teams are testing their devices appropriately and using their final prototype to record data.
   - Circulate to ask guiding questions that support their building experience. Possible questions include:
     - *Can you tell me about your design and how it works?*
     - *Which parts of your design will ensure that fewer animals are collected? How? (CCC)*
     - *Which criteria or constraints are you having the hardest time meeting? What are the easiest to meet? (DCI)*
     - *What new questions do you have about your device that you want to test next? (SEP)*
   - Ensure that teams are collecting data for every prototype they make of their design. Teams may be able to test multiple prototypes during the iteration period, and they should capture the data for each iteration using the Data Collection sheets.
5. Lead a second class share-out and discussion. Be sure to have students explain the improvements they made, why they made them and if other teams designs helped inspire their changes. For ideas on facilitation see Tech Tip: Sharing Solutions.
   - Questions to evaluate results:
     - *Did you meet all criteria for the challenge? How do you know?* Possible answers include: We met the garbage collection criteria but not the animal collection criteria.
     - *Which constraints were the most difficult for your team? Why? (DCI)*
     - *Looking at our data chart, which designs were most successful?*
     - *What effect did your device have on sea animals in the ocean?* (Possible answers include: Some sea animals were captured.) *(CCC)*
     - *How large do you see your device in the real world? What limitations would there be in scaling up what you have designed?* Possible answers include: If the device was made large enough to impact ocean trash, it would be more expensive, difficult to transport, or fragile.

E. Evaluation

Formative assessments and evaluation of student learning is integrated throughout the lesson. This section summarizes suggestions for implementing summative evaluations, as well as creating authentic experiences for the students around the design challenges and their learning by making work public. For guidance on assessment, see Tech Tip: Assessment.

Having students participate in an authentic presentation or discussion of their work is a great way to reinforce that they are engineers and their work should be shared with the community and public in similar ways. Finding a way to bring students' work to a larger audience helps build on the idea that engineers help people in creative ways and are part of something larger than themselves.

1. Review the final assessment project with students.
    - As oceanic engineers, they are requesting federal funding from the National Oceanic and Atmospheric Administration to fund the building of their device at scale for use in the ocean.
    - Students will create a group video recording that demonstrates "class selected" devices and their ability to accomplish the job required. They must explain the importance of the problem and how it relates to real world issues.
    - Videos and letters will be sent to organizations that are currently involved in ocean clean-up with an explanation of how their device can be helpful to the organization's goals.
2. What are we assessing?
    - Remember, students are not being graded on whether or not their design was successful in meeting all the criteria and constraints. The important part of design challenge learning is the process, helping students develop their skills in working through difficult problems and persevering through failure.
3. Introduce and explain the details about the final assessment project.
    - As a class, students choose the five most successful devices, supported by data.
    - Remaining students then join with each of the selected prototype teams, creating five groups that will complete one final iteration that will be featured in the videos.
    - Lead the class in a discussion about how to use the data to decide which devices were most successful.
    - The class will decide on the top five most successful devices. Ask the following questions:
        - *Which data values are most important?*
        - *If a device did well in one category but not another, was it successful?*
        - *If two devices are very similar, should both be included?*
    - Groups of five (flexible) will be assigned around these devices.
    - Groups will work together to assist the student who created the device to iterate further.
        - Often, engineers have more than one design, then come together and choose the most successful model based on data, meeting criteria and constraints. The chosen model is further iterated as a group to make an even better device.
    - Have students create a final diagram, data analysis, and any other visuals needed for the video.
4. It is important to allow students to begin with the end in mind, just as most projects are planned in the real world. Students should use standards, assessments, or rubrics to create a successful device.
    - Review the "Ocean Clean Up Video" assignment sheet so students understand the requirements of the video.
    - Review the rubric so students understand the learning goals of the project.
    - Brainstorm questions to connect the design challenge to the assessment project and/or project goals:
        - *How did you decide on the type of design you chose?*
        - *What was your most important consideration when choosing your design?*
        - *In what way were you able to use your data to show the success of your design?*
        - *How important was peer feedback when creating the final iteration?*
        - *How feasible is your design to function in a real-world situation? Why? Why not?*
        - *What is the purpose of writing the letters and sending videos to ocean organizations? (CCC)*
        - *In what ways did you take the environment into consideration when designing your device? (CCC)*

Appendix A – Grade Level Modifications

While written for 6th grade standards focused on ratios and rates, this unit is applicable to other grade level standards. Below are ways to modify the scenario and design problem to address different grade level standards.

3rd Grade

Standard: CCSS.MATH.CONTENT.3.NF.A.3.D

Compare two fractions with the same numerator or the same denominator by reasoning about their size. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with the symbols >, =, or <, and justify the conclusions, e.g., by using a visual fraction model.

A – Intro and Scenario

- Hook students by displaying videos, articles and pictures of garbage in the Pacific Gyre and/or animals that have been harmed in the Pacific Gyre due to pollution. *See A1 for suggestions.
- You are an ocean engineer studying the Great Pacific Gyre, which is an area of the ocean so full of trash that it is damaging the wildlife and their habitat.
- Your goal is to create a device that will help you clean up the trash from the ocean while minimally harming the animals that live there.
- You will be counting the amount of trash collected by your device and writing a fraction of the amount of trash collected out of the total amount of trash in the test ocean. You will then compare the fractions from each test run.

B – Design Problem

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices.
- Data will be compared using <, >, =.
- Students will then justify their thinking.

C – Content Connections and Adaptations

- Guide the classroom conversation or activity to assess fractions and comparing fractions with symbols.
- *On the first test, you removed 25 pieces of garbage from the ocean, and the ocean originally had 100 pieces. How would you write that as a fraction?*
- *On the second test, you removed 30 pieces of garbage from the ocean. The ocean originally had 100 pieces of garbage. How would you write that as a fraction?*
- *Compare the fraction from the first test to the fraction in the second test using symbols.*

D – Iterating Design Solutions

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices.
- Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged.

E – Assessment

- An option for an alternate assessment is to replace the group video discussing a chosen device to create a video to present each group's individual device.
- Students could also create pamphlets with information about the pollution in the ocean and ways people can help. These pamphlets can be copied and distributed around the school and/or town.
- Depending on the structure of the school, students can present/teach this information to younger students.

4th Grade
Standard: CCSS.MATH.CONTENT.1.OA.A.1
Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem.

A – Intro and Scenario

- Hook students by displaying videos, articles and pictures of garbage in the Pacific Gyre and/or animals that have been harmed in the Pacific Gyre due to pollution. *See A1 for suggestions.
- You are an ocean engineer studying the Great Pacific Gyre, which is an area of the ocean so full of trash that it is damaging the wildlife and their habitat. Your goal is to create a device that will help you clean up the trash from the ocean while minimally harming the animals that live there. You will be counting the amount of trash collected by your device and subtracting it from the total amount of trash in the testing area.

B – Design Problem

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then use addition and subtraction, within 20, to solve word problems.
- The rig should only have 20 pieces of garbage and 5 animals.

C – Content Connections and Adaptations

- Guide the classroom conversation or activity to assess addition and subtraction.
- *If there are 20 pieces of garbage and 6 were removed, how many are left?*

D – Iterating Design Solutions

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices.
- Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged.

E – Assessment

- An option for an alternate assessment is to replace the group video with a class video or presentation of the successful devices.
- Students could also create ocean awareness posters to be displayed around the school and public spaces in town (such as libraries, post offices, etc.).

8th Grade Standard: CCSS.MATH.CONTENT.8.SP.A.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.
A – Intro and Scenario • Hook students by displaying videos, articles and pictures of garbage pollution in the Pacific Gyre and/or animals that have been harmed in the Pacific Gyre due to pollution. *See A1 for suggestions.
B – Design Problem • Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected. • Students will then analyze data gathered from the timed test trials. • Data will be displayed in scatter plots and students will look to see what patterns, if any, have emerged.
C – Content Connections and Adaptations • Connect the students' discussion and design solutions to the variables that change based on the device. • Device A would plot the amount of garbage collected and compare to the number of animals collected. • This would be displayed using a scatter plot. • *Compare the amount of garbage collected to the amount of ocean animals collected.* • Students could also create a formula to predict one variable based on the data collected.
D – Iterating Design Solutions • Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected. • Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices. • Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged.
E – Assessment • Students will create a group Public Service Announcement. • The PSA will need to explain the importance of the problem and how it relates to real world issues. • Videos and letters will be sent to organizations that are currently involved in ocean clean-up with an explanation of how their device can be helpful to the organization's goals.

9-12th Grade Standard: CCSS.MATH.CONTENT.HSS.ID.B.6.A Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.
A – Intro and Scenario • Hook students by displaying videos, articles and pictures of garbage pollution in the Pacific Gyre and/or animals that have been harmed in the Pacific Gyre due to pollution. *See A1 for suggestions.
B – Design Problem • Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected. • Students will then analyze data gathered from the timed test trials. • Data will be displayed in scatter plots and students will look to see what patterns, if any, have emerged.
C – Content Connections and Adaptations • Connect the students' discussion and design solutions to the variables that change based on the device. • Device A would plot the amount of garbage collected and compare to the number of animals collected. • This would be displayed using a scatter plot. • Create a scatter plot of all designs. • Find the line of best fit and the equation of that line.
D – Iterating Design Solutions • Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected. • Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices. • Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged and use the patterns to make predictions.
E – Assessment • Students will create a group Public Service Announcement. • The PSA will need to explain the importance of the problem and how it relates to real world issues. • Videos and letters will be sent to organizations that are currently involved in ocean clean-up with an explanation of how their device can be helpful to the organization's goals.

After School

Standard: Quality Standards for Expanded Learning Programs

3. Skill Building

Participants are involved in projects, activities, and events that increase their understanding and use of 21st century skills (e.g., creativity, critical thinking, and information and communications technology).

A – Intro and Scenario

- Hook students by displaying videos, articles and pictures of garbage pollution in the Pacific Gyre and/or animals that have been harmed in the Pacific Gyre due to pollution. *See A1 for suggestions.
- You are an ocean engineer studying the Great Pacific Gyre which is an area, of the ocean so full of trash that it is damaging the wildlife and their habitat.
- Elaborate, refine, analyze, and evaluate ideas in order to improve and maximize creative efforts.
- Solve different kinds of non-familiar problems in both conventional and innovative ways.
- Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts

B – Design Problem

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices.
- Data will be displayed in line plots and students will look to see what patterns, if any, have emerged.

C – Content Connections and Adaptations

- Students should be split into groups by age or grade level.
- Guide the program activity and conversation regarding the Pacific Gyre and ocean pollution to gauge prior knowledge.
- Have students work in their groups to design a device using provided materials.
- Ask open-ended questions regarding student group design and material choices.
- Students will record data they collect on a class chart.
- Students will analyze data they collected and iterate on their original design.

D – Iterating Design Solutions

- Students will design devices to remove garbage from the Pacific Gyre while minimizing the number of animals collected.
- Students will then analyze data gathered from the timed test trials and create diagrams in order to iterate their devices.
- Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged.

E – Assessment

- The after school program can create a video to display and explain their work to be shown at parent-nights.

Appendix B – Vocabulary

The following is a suggested list of words to discuss as you progress through this lesson with students. For more in-depth information about vocabulary, see Tech Tip: The Language of Engineering.

Term	Student-friendly definition
bycatch	The unwanted fish and other marine creatures caught during commercial fishing for a different species.
marine	Of or relating to the sea.
Pacific Gyre	Large floating garbage patch in the middle of the Pacific Ocean.
percent	A part out of 100. A ratio whose second term is 100.
rate	A ratio in which the two terms being compared are in different units. Often the second number is a unit of time (i.e., miles per hour).
ratio	Shows the relative sizes of two or more values.

Appendix C – Resources and References

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Appendix D – Lesson Handouts

Data Collection: Iteration 1

Name:______________________________

Date:______________ Class:___________

Draw a diagram of your **device**. Include labels for:

1. all materials and measurements.
2. any failure points observed during testing.

Prototype #____

Quantitative Data:

Iteration #	Plastic collected	Total plastic	Ratio of plastic collected to total plastic	Total number of sea animals collected	Ratio of sea animals to plastic collected

Easiest criteria and constraints to meet. Why?	Most challenging criteria and constraints to meet. Why?

Based on your current prototype, what questions might you ask an ocean engineer to help you further develop your prototype?

____

____

Data Collection: Iteration 2

Name:________________________________

Date:________________ Class:____________

Draw a diagram of your **device**. Include labels for:

1. all materials and measurements.
2. any failure points observed during testing.

Prototype #____
Quantitative Data:
Enter with first prototype data table to keep data together.

Easiest criteria and constraints to meet. Why?	Most challenging criteria and constraints to meet. Why?

Based on your current prototype, what questions might you ask an ocean engineer to help you further develop your prototype?

____

____

____

____

Data Collection: Final Iteration

Name:________________________________

Date:________________ Class:____________

Draw a diagram of your **device**. Include labels for:

1. all materials and measurements.
2. any failure points observed during testing.

Prototype #____
Quantitative Data:
Enter with first prototype data table to keep data together.

Easiest criteria and constraints to meet. Why?	Most challenging criteria and constraints to meet. Why?

Based on your current prototype, what questions might you ask an ocean engineer to help you further develop your prototype?

____

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____

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Name:______________________________

Date:_______________ Class:____________

Pre-Assessment Reflection Questions

1. What is a part of another team's design that you would like to incorporate into your design to improve it? How would this improve your design?

2. Did you meet all criteria for the challenge? How do you know?

3. Looking at our data chart, how were you successful? How were you not successful?

4. What materials do you wish you had access to for this design challenge?

Name:________________________________

Date:_______________ Class:___________

Ocean Clean-Up Video

Your group will be creating a video to share your devices with the National Oceanic and Atmospheric Administration (NOAA) to convince them to use your design. The ocean animals are counting on you to save them! The video must be between **5-8 minutes** and all group members must contribute to the final product agreed upon by the group.

You will create a storyboard that lays out the different scenes in your video and what will be said or explained in each scene. In your video storyboard, you must include the following:

- **The Problem**
  - Explanation of the problem at hand and why it matters
  - Two ways that humans rely on oceans
  - Two short and two long-term consequences of increased plastics in our ocean

- **Research Questions**
  - Two questions explored in developing and refining a device to solve this problem

- **The Solution**
  - Device demonstration
  - Reflection of the criteria and constraints:
    - Why were the criteria and constraints important to your process?
    - What did you notice about the ones that were hardest to meet?
    - What was it about the criteria/constraints that made them difficult to meet?
  - Explanation of what makes a device "successful" based on test data
  - Positive and negative consequences of using your device
  - Explanation of what improvements can be made to our oceans with funding from NOAA.

Name:________________________________

Date:________________ Class:____________

Ocean Cleanup Storyboard

#___	#___

____ ____

____ ____

____ ____

____ ____

____ ____

____ ____

____ ____

***Sample Data table:**

Iteration #	Plastic collected	Total plastic	Ratio of plastic collected to total plastic	Total number of sea animals collected	Total number of sea animals in the rig	Ratio of sea animals to plastic collected
1	4	100	4/100 = 1/25	2	10	2/10 = 1/5
2	7	100	7/100	1	10	1/10

Student Rubric – Ocean Clean Up

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

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
(NGSS DCI) ETS1.A: Defining and Delimiting Engineering Problems **The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. S**pecification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)	*Areas that individual students may need one-on-one support with:* • Defining the meaning of the criteria and constraints. • Identifying which criteria and constraints a design is not meeting based on failure points. • Identifying the cause of a design's failure/difficulty. • Identifying failure points as a decision point for what to try next (rather than starting all over from scratch). • Making design improvement decisions based on the cause of failure.	• Unclear explanation of the purpose of the criteria and constraints. • Explanation includes one challenging aspect of the criteria and constraints when building the prototype and at least one reason for this challenge. The reason may not be tied to the specificity or clarity of the criteria or constraint.	• Explanation of the purpose of the criteria and constraints is accurate and clear (in data collection and final assessment). • Explanation includes two challenging aspects of meeting the criteria and constraints and logical reasons for these challenges particularly as it relates to the lack of specificity or clarity of the criteria and constraints (in data collection and final assessment).	*Areas where students may exceed:* • Thoroughness and detail of documentation. • Accuracy and logical clarity of why the prototype must adhere to size requirements. • Accuracy and logic clarity of why a device used in the real world must be a certain size. • Identifies and explains what was challenging during the building of the prototype. *Ideas for next steps for growth:* • Show students the current devices used to clean up the ocean; research and discuss how they work.
(NGSS SEP) Standard and Topic Asking Questions and Defining Problems (6-8) **Ask questions to clarify and/or refine** a model, an explanation, or **an engineering problem.**	*Areas that individual students may need one-on-one support with:* • Imagining open-ended questions about the problem, device or testing.	• One broad question for expert engineers is documented (e.g., Why did the device fail?).	• Two specific questions for expert engineers to help refine iterations is documented and shared (in data collection and final assessment) *(e.g.. What materials would be more effective in the water?)*	*Areas where students may exceed:* • Thoroughness and thoughtfulness of questions. *Ideas for next steps for growth:* • Allow students to choose and take apart a different rig and determine how that rig was used and can be used in the real world. • Discuss why certain materials may be helpful/not helpful when working in the real world with the ocean.

Student Rubric – Ocean Clean Up (cont.)

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
(NGSS CCC) Standard and Topic Influence of Science, Engineering, and Technology on Society and the Natural World **All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.** (MS-ETS1-1)	*Areas that individual students may need one-on-one support with:* • Understanding of relationship between human and natural world. • Understanding of positive and negative consequences. • Understanding of how human-produced objects can impact the natural world. • How to use data to support an argument.	• Presentation includes one way that humans rely on the ocean. • One short and one long-term consequence of increased plastics in our ocean are included. • Argument for how device impacted the ocean in a positive or negative manner is not clear or well-supported by data and may only include positive or negative impacts but not both.	• Presentation includes two ways that humans rely on the oceans. • Two short and two long term consequences of increased plastics in our ocean are included. • Presentation includes a clear argument for how their device may impact the ocean in both positive and negative ways. These arguments are well supported by data.	*Areas where students may exceed:* • Identify three things that humans use the ocean for. • Explain three+ short and long term consequences of increased plastics in our ocean. • Thorough explanation of the short-term and long-term consequences (positive and negative) of human impact on the ocean and how the device created would contribute. • Thorough explanation of how ocean pollution affects animals as well as humans. *Ideas for next steps for growth:* • Show videos of ocean pollution and how it is affecting habitats, animals and humans. • Discuss ways that we can contribute to stopping ocean pollution. • Encourage participation in a local waterway clean-up effort.