



LESSON PLAN
DEVELOPED SEPTEMBER 2023

THE GREAT SUBMARINE SALVAGE

GRADES | 4th - 9th

TIME | 60-90 minutes

SCIENCE BRANCH | Engineering

KEY CONCEPTS

Iterative engineering design process;
Generating and comparing solutions
to a problem based on project
criteria and constraints

Lesson Overview

Students will work in teams to design, build, and test a prototype of a device which can retrieve a sunken submarine from the bottom of the ocean. For the engineering challenge, students will build and test a prototype which can pick up and retrieve a 2 oz. fishing weight from a depth of 3 feet.

Learning Goals / Outcomes

Students Will Be Able To:

- Communicate and collaborate with peers to generate and compare multiple design ideas, and then select which design elements best fit the criteria and constraints of the challenge.
- Build a prototype based on their design.
- Test their prototype and use test data to make changes which will improve the prototype's performance and reliability.
- Repeat the iterative engineering design process until they have successfully completed the design challenge and produced a prototype which can pick up and retrieve a 2 oz. fishing weight from a depth of 3 ft.

NGSS Performance Expectations

Grade	Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
4th-5th	Constructing Explanations and Designing Solutions Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.	ETS1.B: Developing Possible Solutions At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.	Scale, Proportion, and Quantity Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
6th-8th	Engaging in Argument from Evidence Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	ETS1.B: Developing Possible Solutions There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	Structure and Function Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.
9th-12th	Planning and Carrying Out Investigations Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variable are controlled.	ETS1.B: Developing Possible Solutions When evaluating solutions, it is important to consider a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	Structure and Function Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Background Information for Teachers

Historical Connections:

This workshop is based on the Central Intelligence Agency's (CIA's) Project Azorian (also known as Glomar). During the Cold War, a Soviet K-129 submarine sank in the Pacific Ocean about 1,600 miles northwest of Hawaii. Project Azorian's mission was to recover the Soviet submarine at a depth of nearly three miles below the ocean's surface – a feat which was well beyond any ship salvage operation ever attempted.

To accomplish this, the CIA enlisted the help of Global Marine, a deep-water offshore engineering group, to design a recovery ship and a large, mechanical claw that could retrieve the sub. Billionaire businessman Howard Hughes provided a cover story for the operation, explaining that the recovery ship (known as Hughes Glomar Explorer) was designed and used for mining manganese from the ocean floor.

Unfortunately, just as the submarine was nearing the surface, the claw began to fracture, causing two-thirds of the submarine to break off and sink back to the ocean floor. Although the claw suffered a catastrophic failure, Project Azorian was not a complete loss. Several items, such as control panels, code books, inventory printouts, instruments, sonar equipment, and two nuclear torpedoes, were allegedly recovered.

While the CIA had planned to retrieve the part of the submarine that had broken away, their efforts were cut short when Jack Anderson, an investigative journalist, revealed the CIA's plans via radio broadcast in March 1975, claiming Navy experts had told him that the project would be a waste of taxpayers' money since there were likely no secrets to be found on the sunken part of the submarine. In response to the leak, the CIA publicly coined the phrase "we can neither confirm nor deny" any involvement related to the Glomar Explorer. This non-responsive reply is known as the "Glomar response."

Prerequisite Skills

Students should understand the **engineering design process**: (1) define the problem and parameters; (2) imagine potential solutions; (3) plan/design a potential solution; (4) prototype the design; (5) test the prototype; (6) improve and iterate the design.

Materials

The idea of these materials is to act as a maker space where students can pick and choose what to use in their design. Feel free to substitute materials as needed (with the exception of the fishing weight).

- | | | | |
|--|--|---------------------------------------|----------------------------------|
| <input type="radio"/> Bottle Caps | <input type="radio"/> Embroidery Floss/
String | <input type="radio"/> Masking Tape | <input type="radio"/> Scissors |
| <input type="radio"/> Brads/Fasteners | | <input type="radio"/> Paper Clips | <input type="radio"/> Straws |
| <input type="radio"/> Cardboard Rolls | <input type="radio"/> 2 oz. Fishing Weights | <input type="radio"/> Pencils | <input type="radio"/> Yardsticks |
| <input type="radio"/> Clothes Pins | <input type="radio"/> Magnets | <input type="radio"/> Popsicle Sticks | |
| <input type="radio"/> Blank Paper for
Sketching | <input type="radio"/> Construction Paper
or Cardstock | <input type="radio"/> Rubber Bands | |

*8th-9th graders will also need the *Supplies Log* worksheet (1 per group) and the *Materials Point Costs Reference Guide* (1 per group).

Preparation

Each group (2-4 students per group) needs:

- | | | |
|--|--|--|
| <input type="radio"/> 2 Bottle Caps | <input type="radio"/> At Least 7' of Embroidery Floss/String | <input type="radio"/> 4 Rubber Bands |
| <input type="radio"/> 2 Brads/Fasteners | <input type="radio"/> 2 Magnets | <input type="radio"/> 1 Pair of Scissors |
| <input type="radio"/> 2 Cardboard Rolls | <input type="radio"/> 4 Paper Clips | <input type="radio"/> 10 Straws |
| <input type="radio"/> 2 Clothes Pins | <input type="radio"/> Pencils (1 Per Person) | <input type="radio"/> 1 Yardstick |
| <input type="radio"/> 2 Pieces of Sketch Paper | <input type="radio"/> 10 Popsicle Sticks | <input type="radio"/> 1 Fishing Weight (2 oz.) |

- Before the class arrives, have each group's materials sorted into a bin. Keep material bins away from students/tables until it is time for students to begin building their prototypes.
- Set up a table with additional materials. Students will be able to use additional materials, if needed.

Instructions

- 1 Explain to students they are a team of bright engineers which has been assembled to complete a top-secret mission that is of the utmost importance for maintaining our national security. Introduce yourself as the "Project Manager" whose role is to support the engineers, monitor time, and ensure the engineers have all the supplies they need.
- 2 Read the Introduction Script (page 7) which sets up the engineering challenge. After, review the following information:
 - The mission is to design, build, and test a **prototype** of a device that will be used to rescue a submarine from the bottom of the ocean.
 - **Prototype:** *A preliminary, small-scale model of a new machine/product that is used for testing a concept or process.*
 - A 2 oz. fishing weight will be used to simulate the submarine.
 - The prototype will need to accomplish 3 tasks:
 - ☐ Reach the 2 oz. fishing weight which is located 3 ft. below the "surface." (Students can use a yardstick for reference OR they can simply place the weight on the ground and their prototype on the table which is approximately 36" off the floor.) *Note: All parts of students (hands, head, etc.) must stay above the "surface."*
 - ☐ Securely grab the fishing weight.
 - ☐ Lift the fishing weight up 3 ft. to the "surface."

- 3 | Introduce students to the materials they will be able to use to build their prototype.
- 4 | Pass out sketch paper and give students 5-10 minutes to sketch some initial design ideas. Students should share their thoughts/ideas with the rest of their group.
- 5 | Groups begin drafting a team prototype. During this time, pass out a materials bin to each group.
- 6 | Remind students that if they need additional supplies, they can visit the materials table. (Depending on the age/maturity of the students, you may consider stationing yourself or another teacher near the materials table to monitor supply distribution.)
- 7 | Give groups about 20-30 minutes to build and test their prototypes. Be sure to give them a “halfway” warning and a “five minutes left” warning to help them pace their progress. During this time, visit each group and use questioning techniques to help point out any obvious design flaws. Check-in with each group during the last 5 minutes to observe their final prototype iteration and whether it can successfully complete the challenge.

Note: It is totally normal to have some groups successfully complete the challenge, and others to not complete the challenge within the given time frame. Remind students that the engineering process often takes several iterations and encourage them to take what they have learned during the workshop and continue building iterations at home using whatever supplies they have available to them. The learning doesn't have to stop just because the time ran out!
- 8 | Invite groups to present their prototypes to the class, explain their design process, and summarize how their prototype performed on its final test. Groups should reflect on what aspects of their design and process were a success and which aspects were particularly challenging.
- 9 | Debrief: Lead the class through a discussion about their engineering process:
 - What challenges did students face that they didn't initially anticipate?
 - What part of their designs were effective? Which were ineffective?
 - Which materials were most useful? Which materials (if any) would have been helpful during this challenge if they were available?
 - Point out the various ways each group decided to attack this challenge – there are so many ways to retrieve the fishing weight!
 - Compare the designs which were able to successfully retrieve the fishing weight. How are they alike? How are they different? As a class, decide which prototype should be scaled up and manufactured for this mission?

Adaptations to Increase Accessibility and Extend the Learning:

For younger students and students in need of extra support:

Before giving students time to sketch their ideas, first lead the class through some observations which may help them during the design phase. Here are some questions to ask:

- **Are there any features of the fishing weight that may be useful?**
Possible answer: *hollowed center - can be used to secure/hook the weight to the prototype.*
- **Are there any features of the fishing weight that may prove to be extra challenging?**
Possible answer: *it's smooth, fusiform shape may make it difficult to keep it in one spot and not roll away.*

For older students and students in need of an additional challenge:

- Limit the number of materials students have available to them. For example, if a group needs two more straws for their build, they will need to exchange two of the materials originally given to them for the two extra straws.
- Hand out heavier fishing weights (or weights with different shapes/sizes)
- Find out which group can build a successful prototype for the smallest materials cost. In addition to building successful prototypes, groups must keep track of the materials used to build their prototype. Provide each student with the **Points Cost Reference Guide** and **Supply Log**. Each material costs "points" so after groups have built their prototype, they must add up how many "points" it would cost to build their prototype. The goal is to keep material costs as low as possible while still being able to build a successful prototype. Also, enforce supply parameters. Each material has a "maximum quantity" available to students. Students may not use more than the maximum quantity for their build. Use the chart in the Accompanying Worksheets section to determine material costs and maximum quantities.

Note: Print one copy of the Reference Guide for each group as well as one for the materials table. Consider laminating these charts so they can be reused with future groups.

Building Real World Connections

Social Studies Connection:

Play the "[Glomar Video](#)" which explains Project Azorian and how the CIA was able to (partially) retrieve a Soviet submarine from 16,500 feet below the surface of the water.

Career Connection:

Most people falsely assume our intelligence agencies are primarily made up of spies and analysts, however it takes a team of skilled individuals with widely varying backgrounds and skills to keep us safe. This workshop simulates the important role engineers play in retrieving intel.

Introduction Script

Read aloud to the class by the teacher.

Hello engineers. You have all been gathered here today because you are the best and brightest engineers, and we desperately need your help. Early this morning, we received an urgent message from Rear Admiral Smith, Commander of the U.S. Navy's Pacific Submarine Fleet. Let me read it to you:

Around 0100 hours this morning, our radars picked up on a foreign submarine about 100 nautical miles north of Hawaii. Upon further inspection, it appears the submarine has sunk to the bottom of the ocean to a depth of approximately 17,000 feet. We have reason to believe this submarine was sent to gather intelligence on one or more of the submarines in the Pacific Fleet. It is imperative we recover this sunken submarine to find out which country is responsible for entering these waters undetected.

Further, their ability to travel undetected poses a serious threat to our national security. We must recover this submarine so we can study its stealth technology. We are standing by awaiting your recommendation for how to proceed.

As you have just heard, this is why you are all gathered here today. We have never faced a situation like this, and it is crucial that we recover the submarine before anyone else.

Your mission is to work in small teams to determine how we can recover this foreign submarine. Each team must design, create, and test a prototype of a machine that we can use to recover the submarine. Remember, we have never had to retrieve something this large from 17,000 feet below the ocean's surface. Using the materials provided, including a fishing weight that will serve as your submarine, you must create a prototype that accomplishes the following tasks:

- Reach a 2 oz. fishing weight that is 3 ft. below you (the ocean surface).
- Securely grab the fishing weight.
- Lift the fishing weight up 3 ft. to the "surface."

Once you have determined the most robust prototype, we will send it to be built to scale. Good luck engineers. The fate of this mission is now in your hands.

THE GREAT SUBMARINE SALVAGE

ACCOMPANYING WORKSHEETS

Materials Point Costs Reference Guide

Material	Points Cost	Maximum Quantity
Bottle Caps (Qty 2)	1	10
Brads/Fasteners (Qty 2)	1	20
Cardboard Roll	5	6
Clothes Pin	5	6
Embroidery Floss/String (36")	5	10
Magnet	5	10
Paper (1 sheet)	1	20
Paper Clips (Qty 2)	1	20
Popsicle Stick	5	20
Rubber Band	1	20
Straw	5	20
Optional: Miscellaneous Bin Random items such as: plastic bottles, fabric swatches, hole puncher, wrapping paper roll, paper towel roll, rope, etc.	5	6
DO NOT CALCULATE COSTS FOR: <ul style="list-style-type: none"> Yardstick Fishing Weight Scissors Pencils Sketch Paper Masking Tape (unlimited) 		

Supplies Log

Calculate the total cost of your prototype.

Material	Points Cost	Quantity	Total Cost Points Cost x Quantity = Total Cost
Grand Total			