Submarine Technology

Grade Band: Middle School and High School	**Topic:** Engineering

Brief Lesson Description: Students design and optimize a prototype submarine.

Performance Expectation(s):

HS ETS 1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

MS ETS 1-3: 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.

Specific Learning Outcomes:

Students will be able to…

-identify and explain the key technological components and systems involved in submarine design, including buoyancy control, propulsion systems, and structural materials.

-evaluate and compare various submarine designs based on their efficiency, safety, and effectiveness in addressing underwater challenges.

-apply principles of engineering and physics to design and create a model submarine that demonstrates an understanding of buoyancy, pressure, and propulsion.

-analyze the impact of different design features on the performance and functionality of a submarine, using evidence from their research and experiments.

-collaborate with peers to integrate various design ideas and strategies into a cohesive submarine model, reflecting on how teamwork and problem-solving contribute to successful engineering solutions.

Narrative / Background Information

Students will benefit from background knowledge in the following areas:

-Understanding of basic forces (gravity, friction, buoyancy).

-Archimedes' principle: The concept of buoyant force and how it relates to the displacement of fluid.

-Density: How the density of an object compared to the density of a fluid determines whether it will float or sink.

-Properties of common materials used in engineering (e.g., strength, density, corrosion resistance).

-Steps in the engineering design process (ask, imagine, plan, create, improve).

-Concepts of structural design and the importance of shapes (e.g., spherical and cylindrical shapes for pressure resistance).

-Understanding how systems are made up of interconnected subsystems. For example: How different systems in a submarine (propulsion, buoyancy, navigation) work together.

Science & Engineering Practices:

Analyzing and Interpreting Data

Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.

- Design a solution to a complex real-world problem, based on scientific knowledge,

Disciplinary Core Ideas:

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. (MS-ETS1-3)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)

Crosscutting Concepts:

No Crosscutting Concepts are attached to the performance expectations in this lesson.

student-generated sources of evidence, prioritized criteria, and trade off considerations. (HS-ETS1-2)	• Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	

Possible Preconceptions/Misconceptions:
Students may…
-think that submarines either float on the surface or sink directly to the bottom without any intermediate states.
-assume that materials used for building structures on land are equally suitable for underwater construction.
-believe that submarines function just like regular boats but are simply capable of going underwater.
-underestimate the effects of water pressure and assume it's a minor issue for submarine design.
-believe that all submarines are designed for the same purposes and have similar capabilities.
-think that submarine propulsion systems are straightforward and similar to those of surface ships.
-assume that submarines are entirely safe and immune to accidents or failures.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
Begin the lesson by asking students, ***"What do you know about submarines and how they work?"*** Have students create a concept web to document their ideas individually. Then have them share their concept web with a partner.

Introduce students to the idea that our Navy uses submarines for a variety of tasks and then show the video to introduce them to one Navy officer and her thoughts on submarines.:
https://www.youtube.com/watch?v=jrGTggtuEWI&list=PLDQ1SztOjkOk_rt_XJdJ6kIumYoNNVOY7&index=23

Explain that this lesson will focus on how engineers design submarines. Explain that they will watch a short video to learn a little about the technology of submarines. Then show the video "Exploring the Depths: The Incredible technology behind submarines."

After the video, discuss the following prompts as a class:
What are some purposes of submarines?
What factors might engineers consider when designing a submarine?
How do submarines navigate and stay underwater for extended periods?

EXPLORE Lesson Description – Materials Needed / Probing or Clarifying Questions:
Tell students that in order to understand the basic design of a submarine, they will build and test their own submersibles. Provide each student with a Student Handout and put students into groups of 4. Review the directions and then provide students with time to complete the activity.

Teachers Note: This video shows an example of how this type of submarine can work.

After students complete the activity, discuss the following prompts as a class:
What challenges did you encounter while designing and building your submarine model, and how did you overcome them?
How did the different materials and design choices affect the buoyancy and stability of your submarine model?
What similarities and differences did you observe between your model and the real submarines discussed during the lesson?
If you were to redesign your submarine model, what changes would you make and why?

EXPLAIN:
Students will work in teams to explore the technologies related to submarine technology and design. Start by dividing the class into small groups of 3-4 students (you can use the same groups from the Explore section). Each group will be assigned a specific topic to research. Topics include:

- Buoyancy and Ballast Systems
- Propulsion Systems
- Materials and Construction
- Pressure Resistance and Hull Design

Each group should find the answers to the following questions:

- ***What is the primary function of this aspect of submarine design?***
- ***What challenges do engineers face when designing this part of a submarine?***
- ***What are some modern technologies used in this area?***

Each group should then prepare a 5-minute presentation to share their findings with the class. Include visuals such as diagrams or pictures

to help explain their topic.

Students should present their findings to the class. After each presentation, students should record their learning for use during the elaborate portion of the lesson.

After student presentations, you may want to elaborate on the following ideas as needed

Buoyancy and Ballast Systems:
- **Principle of Buoyancy:** Explain Archimedes' principle and how submarines control buoyancy using ballast tanks.
- **Ballast Tanks:** Discuss how filling and emptying ballast tanks with water or air allows submarines to sink and float.

Propulsion Systems:
- **Diesel-Electric Propulsion:** Describe how submarines use diesel engines on the surface and electric motors underwater.
- **Nuclear Propulsion:** Explain how nuclear-powered submarines can remain submerged for extended periods due to their energy source.

Materials and Construction:
- **Materials Used:** Discuss the materials used in submarine hulls (e.g., high-strength steel, titanium) and their properties.
- **Importance of Materials:** Highlight why these materials are chosen for their strength, durability, and resistance to corrosion.

Pressure Resistance and Hull Design:
- **Pressure Challenges:** Explain the challenges of underwater pressure and how it increases with depth.
- **Hull Design:** Describe the design of the submarine hull, including the use of spherical and cylindrical shapes to distribute pressure evenly.

Following presentations and elaboration, show the following real-world examples for students to see these technologies in action:
Alvin Submersible, Nuclear Submarine

ELABORATE: Applications and Extensions:

Based on their learning, students will refine their submarine models based on the feedback and observations from the Explore section. They will incorporate specific criteria and constraints to enhance their designs, focusing on functionality, safety, and sustainability. This phase emphasizes critical thinking, creativity, and problem-solving skills.

Procedure:

1. Introduction and Planning:
   - Review the criteria and constraints with the students.
   - Discuss how these criteria and constraints reflect real-world engineering challenges.
   - Allow students time to plan and sketch their refined submarine designs, considering how to incorporate the criteria and constraints.

2. Construction and Testing::
   - Students work in groups to build and refine their submarine models.
   - They test their models in a large water tank, making adjustments as needed to achieve neutral buoyancy, structural integrity, and functional propulsion.

Materials Note:
A variety of additional materials should be provided for students based on what is locally available. Ideas include:
straws, balloons, rubber tubing, masking tape, duct tape, hot glue and glue guns, cardboard, plastic bottles, paper clips, rubber bands, waterproof sealants (such as silicone), etc.

Differentiation Notes:
-For students who need more guided support, provide a detailed set of directions to build a model to be revised. There are many readily available across the internet.
-If time is a constraint, you can simplify the criteria and constraints provided to students. For example, removing the requirements for propulsion and safety will shorten the time needed.

EVALUATE:
Formative Monitoring (Questioning / Discussion):
Prompts throughout the lesson in ***bold and italics*** and student handouts/presentations can be used to check student understanding throughout the lesson.

Summative Assessment (Quiz / Project / Report):
Final Presentation and Reflection:

1. Each group gives a final presentation, highlighting the key features of their submarine, the challenges they faced, and how they addressed the criteria and constraints.
2. Students reflect on the design process, discussing what they learned and how they applied engineering principles to solve problems.

The rubric for the final project is included in the criteria and constraints document.

Elaborate Further / Reflect: Enrichment:

Option 1: Submarine Mission
Students plan and execute a mock submarine mission. They must consider factors such as mission objectives, environmental conditions, equipment needs, and safety protocols. This could be done as a role-playing activity where students take on different roles (e.g., captain, engineer, navigator).

Option 2: Guest Speaker/Virtual Field Trip
Invite a guest speaker who is an expert in submarine technology, marine engineering, or oceanography to give a talk or conduct a Q&A session. Alternatively, arrange a virtual tour of a submarine or a marine research facility. Possible opportunities include:
Smithsonian Virtual Submarine Dive
Submarine Virtual Tour of HMAS Ovens

SOCIAL-EMOTIONAL LEARNING ACTIVITY

CASEL Competencies addressed: Self-Awareness and Self-Management
Objective:
Help students understand how sailors deal with boredom during long periods underwater on submarines and connect these strategies to managing boredom in their own daily lives.

1. Introduction

- Briefly discuss the life of sailors on submarines, focusing on the challenges of long periods underwater.
- Introduce the concept of boredom and why it can be particularly challenging in confined environments like submarines.
- Relate the topic to students' experiences with boredom in their daily lives (e.g., long classes, waiting for something, lack of engagement in activities).

2. Group Discussion

- Divide students into small groups and have them discuss the following questions:
    - What situations in your daily life make you feel bored?
    - How do you usually respond to boredom?
    - What are some negative and positive ways to handle boredom?

3. Video/Guest Speaker

- Show this short Navy video to talk about life on a submarine and how sailors cope with boredom.
- Encourage students to take notes on specific strategies and techniques mentioned.

4. Brainstorming Session

- Have students brainstorm strategies that sailors use to cope with boredom and write them on the board. Examples might include:
    - Engaging in hobbies (reading, writing, drawing)
    - Physical exercise
    - Socializing with crewmates
    - Structured routines and schedules
    - Learning new skills or studying
- Discuss how these strategies can be applied to their own lives.

5. Activity: Boredom Toolkit

- Have students create a "Boredom Toolkit" that they can use in their daily lives. This could be a physical or digital collection of activities, strategies, and resources.

6. Reflection and Sharing

- Ask students to share one or two items from their Boredom Toolkit with the class.
- Discuss how having a plan for dealing with boredom can improve their overall well-being and productivity.

7. Closing and Takeaways

- Summarize the main points of the lesson.
- Emphasize the importance of recognizing boredom and having constructive ways to handle it.
- Encourage students to use their Boredom Toolkits and share them with friends and family.

INTERDISCIPLINARY CONNECTIONS/IDEAS

History: Evolution of Submarine Technology

Students conduct a Research project on historical milestones in submarine technology. They can produce a timeline creation of key events in submarine history and/or an analysis of the role of submarines in World Wars I and II.

English Language Arts: Submarine-Related Literature

Students can read and discuss "Twenty Thousand Leagues Under the Sea." (Full text or Excerpt). Additional activities include writing a creative short story set in a submarine or Researching and writing an essay on the significance of submarines in literature and media.

Art: Designing and Illustrating Submarines

Possible project ideas include Drawing detailed cross-sectional diagrams of submarine interiors, Creating 3D models of submarines using clay, cardboard, or digital tools, or designing posters or infographics explaining submarine technologies.

Materials Required for This Lesson/Activity

Quantity	Description
1 per group	Plastic bottle
1 per group	Straw
1 per group	Weights (such as washer or nuts)
1 per group	Water tanks or large containers to submerse waterbottles in
Class Supply	Locally available prototyping materials such as straws, Balloons, rubber tubing, masking tape, duct tape, hot glue and glue guns, cardboard, plastic bottles, paper clips, rubber bands, waterproof sealants (such as silicone), etc.

Lesson Created by Jess Noffsinger
For questions please contact
info@usasciencefestival.org