RESOURCE LIBRARY
ACTIVITY : 1 HR 50 MINS

Under Pressure: Creating a Model

Students build a testable model of a submersible based on their own designs.

GRADES

9 - 12+

SUBJECTS

Earth Science, Oceanography, Engineering, Geography, Mathematics, Physics

CONTENTS

3 PDFs, 1 Video

OVERVIEW

Students build a testable model of a submersible based on their own designs.

For the complete activity with media resources, visit:
http://www.nationalgeographic.org/activity/under-pressure-creating-model/

Program

DEEPSEA CHALLENGE

DIRECTIONS

1. Activate prior knowledge by having each group summarize how its concept design from Activity 2: Under Pressure: Defining the Problem addresses the extreme pressure present at the bottom of the ocean.

Have students bring out the Engineering Process handout from the previous activity and refer to it for their summary. Have groups keep the handout handy. Briefly review the concept of pressure and how pressure changes as water depth increases.

2. View and discuss "The First Launch" video.

Provide students with the following focus questions prior to viewing the video: What role did the dummy sub play in preparing for the actual dive? Why was lowering the sub so dangerous? Have students use these questions to take notes during the video, and then use the questions as a focal point to discuss the video.

3. Explain that groups are going to build simplified models, or prototypes, of their concept designs that can be tested.

Distribute the Prototype Parameters handout to students and read the activity information to students. Make sure students understand that their ultimate goal will be to create prototypes that can rise slowly to the surface from a depth of 3 meters (10 feet) under water, but that in this activity they will be testing their prototypes in shallow water. Go over with students the constraints of the testing environment as described on the handout. Review step 5 on the Engineering Process handout. Distribute and review the Submersible Modeling Rubric with students so they know what is expected in this activity.

4. Review neutral buoyancy and positive buoyancy with students.

Ask students to share what they know about buoyancy. Ask: *What is buoyancy?* (Buoyancy is the upward force exerted by a fluid on an object.) *How does an object that is positively buoyant in water behave when submerged in water?* (It rises to the surface and floats.) *How does an object that is neutrally buoyant in water behave when submerged in water?* (It hovers.) Be sure students understand these concepts before moving forward. Ask students to identify what type of buoyancy their prototypes will need to have in order to meet the parameters described for this activity. Make sure students understand that the prototypes will need to be slightly positively buoyant in order to rise slowly, rather than sinking, staying in place, or rising quickly to the surface.

5. Give students an opportunity to experiment with the buoyancy of various materials.

Provide students with a tub of water and a variety of objects from the materials list that they can use to construct their submersibles. Give students time to explore the buoyancy of these objects.

6. Have students sketch their prototypes.

Have groups discuss which aspects of their concept design from the Under Pressure: Defining the Problem activity will need to be present in their model in order to test it for the given parameters. For example, they will not need video cameras, but they will need to construct a basic shape for their submersible vehicle and will need to add foam, weights, etc. Have students create a simple sketch of their prototypes and list the materials they will use based on the ones they experimented with in step 5 above.

7. Have students build their prototypes.
Have each group build a physical prototype based on their design and using the available materials. Remind students of the size constraints for their prototypes. Have students list the materials they use, including amounts, per step 5 of the Engineering Process handout. Have them include step-by-step instructions for how to build the prototypes. Point out that these instructions must be specific and thorough enough that someone else could use them to replicate the prototypes.

8. Have students test their prototypes in shallow water.
Describe the basic testing procedure to students. Explain that in this activity, they will conduct shallow-water tests in water about 30 centimeters (1 foot) deep. Students will be able to test, evaluate, and adjust their prototypes, and retest as long as time permits. Per step 6 of the Engineering Process handout, have students list the data they need to collect in order to evaluate their solutions and describe how they will use the data to improve their designs. At a minimum, students should include the depth and the time it takes to reach the surface. Have students specify how they want to conduct the tests. Ask: *How will you collect data from the tests? What role will each group member play in the testing process?* Have students create tables to record the data for each test. Provide students with a large tub, cooler, or trashcan full of water at least 30 centimeters (1 foot) deep. Have students conduct the test in about 30 centimeters (1 foot) of water, record their data, and use it to evaluate the success of their designs. To conduct a test, students will need to push their prototype to the bottom of the container and then let go of it to determine whether it is positively buoyant and thus able to rise to the surface on its own. The slower the prototype rises, the closer it is to neutrally buoyant. A negatively buoyant prototype will remain on the bottom of the container. Ask students to determine what, if any, changes need to be made to their designs in order to better solve the problem, and have them record that information. Give students time to re-make their prototypes and make any adjustments needed. Then have them test again. Give students as many opportunities as time permits to test and retest their prototypes in about 30 centimeters (1 foot) of water.

9. Have groups evaluate their shallow-water tests and prepare for deep-water testing.
Have each group review their test data and summarize their shallow-water testing. Have them

list factors that could affect their designs in deeper water. Have students consider how changes in pressure in deeper water will affect the buoyancy of their designs. Read aloud to students the section of the Background Information on buoyancy. Have them brainstorm adjustments they will need to make to their designs to have the prototypes remain slightly positively buoyant when they test it in deeper water.

10. Have students reflect on the modeling process.

Discuss the modeling process as a class. Ask: *What worked and what didn't work? What was the most difficult part of the process? The most helpful? What would you do differently next time?* Note that students should keep all documentation from this activity in preparation for the Under Pressure: Testing a Model activity.

Tip

Hand-held PVC pipe cutters can be used to cut PVC pipe to whatever length necessary. Consider pre-cutting the pipe into 5 cm (2 in) segments for students. For safety reasons, do not allow students to handle the pipe cutters.

Tip

If you opt to test the materials and prototypes in shallow water in the classroom, keep in mind that many of the designs are likely to retain water. Surround the coolers or buckets with towels; give each group a towel for drying materials; and have students place their materials directly into a plastic bag after testing.

Tip

Review your standard lab safety procedures with students before they begin creating the prototypes.

Alternative Assessment

Use the Submersible Modeling Rubric to assess students' testable prototypes.

OBJECTIVES

Subjects & Disciplines

Earth Science
  - Oceanography
- Engineering
  Geography
- Mathematics
- Physics

Learning Objectives

Students will:

- create a physical submersible model and assess its buoyancy at different depth and pressures
- analyze essential components of a testable submersible model

Teaching Approach

- Learning-for-use

Teaching Methods

- Cooperative learning
- Discussions
- Hands-on learning
- Reflection

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Creativity and Innovation
- Critical Thinking Skills

    - Analyzing
    - Applying
    - Creating
- Geographic Skills
    - Analyzing Geographic Information

National Standards, Principles, and Practices

NATIONAL GEOGRAPHY STANDARDS

• **Standard 15**:
How physical systems affect human systems

NATIONAL SCIENCE EDUCATION STANDARDS

• **(9-12) Standard B-2**:
Structure and properties of matter

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

• **Principle 7a**:
The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
• **Principle 7d**:
New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

ISTE STANDARDS FOR STUDENTS (ISTE STANDARDS*S)

• **Standard 1**:
Creativity and Innovation
• **Standard 2**:
Communication and Collaboration
• **Standard 4**:
Critical Thinking, Problem Solving, and Decision Making

Preparation

What You'll Need

MATERIALS YOU PROVIDE

- Bubble wrap
- ½-inch PEX pipe cut into 5-centimeter (2-inch) length
- ½-inch PVC pipe [A1] cut into 5-centimeter (2-inch) length
- Cups, clear plastic
- Cups, Styrofoam
- Hand towels
- Large bucket, cooler, trash can, or other container, at least 30 centimeters x 30 centimeters x 30 centimeters (1 foot x 1 foot x 1 foot)
- Plastic garbage bags
- Pennies or washers
- Plastic ball
- Plastic egg
- PVC pipe cutters
- Several types of foam (for example, cushion foam, pipe insulation foam, packing foam)
- Waterproof duct tape
- Scissors

REQUIRED TECHNOLOGY

- Internet Access: Required
- Tech Setup: 1 computer per classroom, Projector, Speakers
- Plug-Ins: Flash

PHYSICAL SPACE

- Classroom

SETUP

The testing portion of this activity is best done outside. If the testing in water is done in the classroom, set up the space so each group has a large container of water surrounded by towels to soak up any drips and spills.

GROUPING

- Large-group instruction

BACKGROUND & VOCABULARY

Background Information

Preparations for James Cameron's historic 2012 solo dive to the bottom of the Mariana Trench took years to complete. Because many aspects of the *DEEPSEA CHALLENGER* were engineered specifically for the unique conditions at the very bottom of the ocean, the *DEEPSEA CHALLENGE* team designed, tested, evaluated, redesigned, and retested parts, components, and systems before assembling them into a whole vessel capable of carrying Cameron deep into the ocean. Testing is a key part of the engineering process, and elements of a design are often isolated and tested before being incorporated into an overall design. This allows for fewer variables at each stage of testing and makes identifying problems much easier. Models and prototypes provide ways to test specific elements of a design.

One of the biggest challenges for the *DEEPSEA CHALLENGE* expedition, as for any deep-sea exploration, was the extreme pressure at the bottom of the ocean. This extreme pressure affects all parts of a deep-sea vehicle and can cause materials to compress or to crack or fail. Pressure is also related to buoyancy. Buoyancy is the upward force exerted by a fluid on an object, equal to the weight of the fluid displaced by the object. (Note that both liquids and gases are considered fluids.) Buoyancy works to make objects float because the pressure at the bottom of the object, which is deeper in the fluid, is greater than the pressure at the top of the object. This creates a net upward force. When an object is placed into a fluid, it displaces a volume of fluid equal to the volume of the part of the object immersed in the fluid. As an object is lowered into a fluid, the volume of the part of the object immersed in the fluid increases, and so does the amount of fluid being displaced. The weight of the fluid being displaced is equal to the buoyant force. The buoyant force reaches a maximum when the object is completely submerged, that is, when the object is displacing a volume of fluid equal to the object's entire volume. If the buoyant force is less than the weight of the object, the object is negatively buoyant and will sink. If the buoyant force is equal to the object's weight, the object is neutrally buoyant and will "hover" under the surface without sinking or moving upward. If the buoyant force is greater than the weight of the object, the object is positively buoyant and will accelerate upward in the fluid. It is not necessary to calculate the maximum buoyant force to determine if an object will float. Simply compare the density (mass/volume) of the object to the density of the fluid. The net force acting on an object placed in a fluid depends on the relative weight of equal volumes of the object and the fluid. With equal volumes, greater density means greater weight. When the density of an object is greater than that of the fluid, it is negatively buoyant in that fluid. When the density of the object is less than that of the fluid, the object is positively buoyant. When the density of the object is the same as that of the fluid, it is neutrally buoyant. In the deep ocean, pressure can also affect buoyancy by compressing materials. This will make those materials more dense (the same mass but a smaller volume), and thus less buoyant.

Prior Knowledge

["Students should have a basic understanding of pressure, particularly as it pertains to water.", "Students should have an understanding of density and buoyancy. "]

Recommended Prior Activities

- Exploring Pressure
- Under Pressure: Defining the Problem

Vocabulary

Term	Part of Speech	Definition
buoyancy	*noun*	the power to float or rise in a fluid.
model	*noun*	image or impression of an object used to represent the object or system.
pressure	*noun*	force pressed on an object by another object or condition, such as gravity.
prototype	*noun*	early version or model.

FUNDER

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