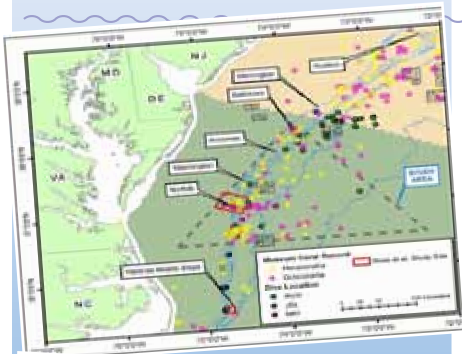
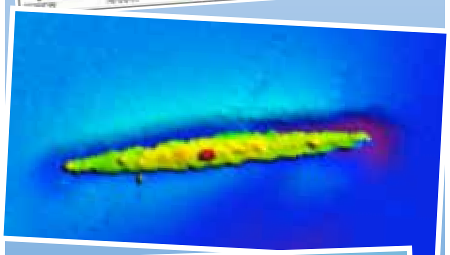
Deepwater Canyons 2012 - Pathways to the Abyss

Design a Benthic Lander!





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lesson plan

Focus

Buoyancy; Engineering Design

Grade Level

5-6 (Physical Science)

Focus Question

How can ocean explorers measure environmental characteristics in the deep ocean over long periods of time?

Learning Objectives

- Students will plan an investigation to identify appropriate materials for a model that will demonstrate the operating principles of a benthic lander

- Students will use a model to communicate the operating principles of a benthic lander, and describe key design constraints and possible solutions.

Materials

- Copies of *Calculating Density and Buoyancy Worksheet*, one copy for each student group
- 100 ml graduated cylinder; one for each student group
- Large containers for testing models (aquarium or plastic storage box)
- Faucet or large container of water with a spigot or siphon to allow controlled dispensing
- Small objects for making models that will fit into the 100 ml graduated cylinders, such as washers or nuts, pieces of modeling clay, corks, fishing weights, Styrofoam™ balls, etc.; students should have a variety of materials available so they are able to select the optimum materials for their designs
- Cotton or nylon thread
- Triple beam balance; one balance may be shared by several groups
- Stiff wire approximately 3 inches long or a straightened paper clip; one for each student group

Audio-Visual Materials

- (Optional) Interactive white board

Teaching Time

Two or three 45-minute class periods

Seating Arrangement

Groups of two or three students

Maximum Number of Students

30

Key Words

Atlantic canyon
Benthic lander
Engineering design
Buoyancy
Density

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

Deepwater canyons are among the most striking features of the continental slope off the east coast of the United States. There are more than 70 of these canyons in depths ranging from about 100 m to about 3,500 m, with steep, narrow walls that make exploration difficult. Research during the 1970's and 1980's (Hecker *et al.*, 1980; Hecker and Blechschmidt, 1979) showed that submarine canyons along the mid-Atlantic continental slope can contain unique hard bottom communities, many of which include high densities of deepwater corals.

Habitat complexity in submarine canyons results from a combination of geological and biological features. Steep canyon walls, rocky outcrops, hard clay formations, boulders, rock rubble, and soft sediments all provide surfaces upon and within which various benthic organisms may grow. Sessile (non-moving) species such as sponges and cnidarians increase the surface complexity and provide additional habitat for other species. Soft sediment is the major substrate type, and most mid-Atlantic canyons have extensive holes and tunnels produced by crabs, tilefish, burrowing anemones, and other animals that further extend the range of available habitats.

Mid-Atlantic canyons may also include chemosynthetic communities whose food webs are based on the energy of chemical compounds, in contrast to photosynthetic communities whose food webs are based on photosynthesis that uses energy from the sun. The first chemosynthetic communities were discovered in 1977 near the Galapagos Islands in the vicinity of underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of

Images from Page 1 top to bottom:
The primary target areas for the Deepwater Mid-Atlantic Canyons Project are in and around the Norfolk, Washington, Accomac, and Baltimore Canyons. This map shows places where deep-sea corals were previously identified (indicated by yellow and pink stars) as well as locations of previous submersible dives (green, blue, and red circles). Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig0_hires.jpg

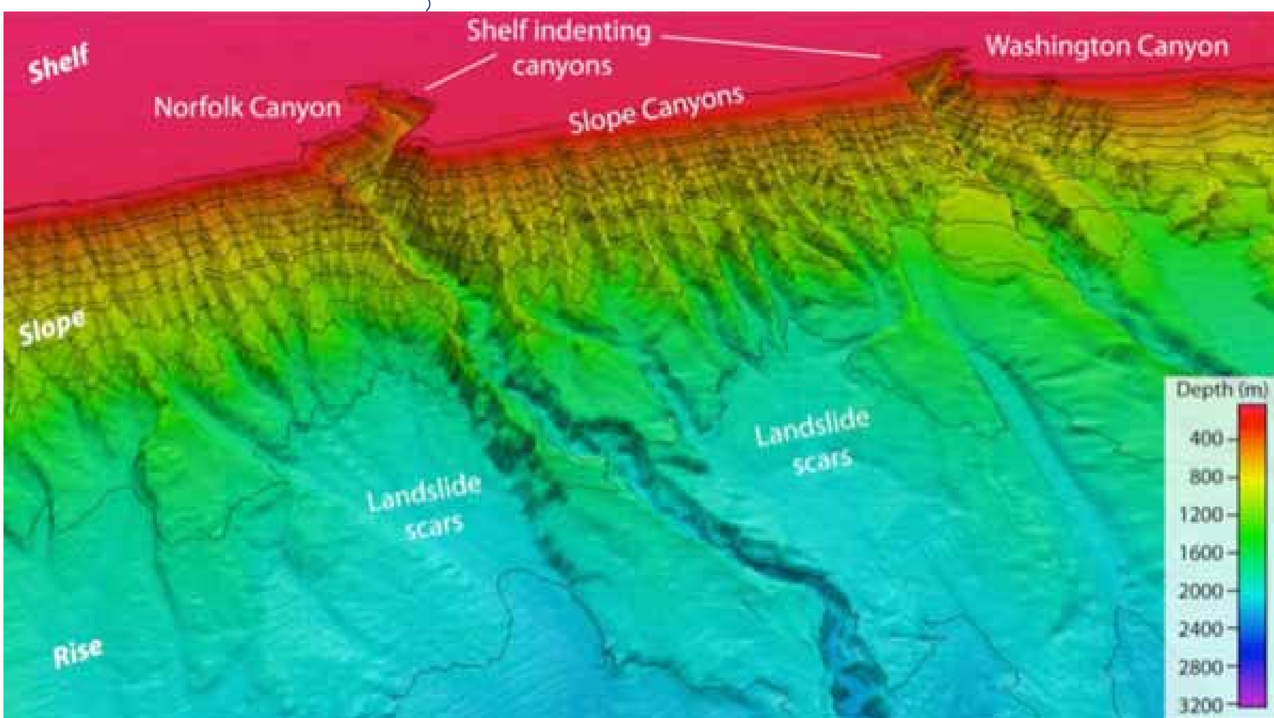
High-resolution multibeam sonar image of a shipwreck on the continental shelf near Norfolk Canyon. Image courtesy R Mather, URI.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig1_hires.jpg

Benthic landers, designed at the University of North Carolina – Wilmington, will be used during Deepwater Mid-Atlantic Canyons Project. They provide a way to deploy multiple instruments and experiments to the deep-sea floor and collect precise time-series data on environmental variability that is typically unattainable. Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig6_hires.jpg

3D rendering of a submarine canyon system just north of Cape Hattaras, NC which illustrates both the rugged canyon topography and the kind of detail that is possible to obtain from multibeam sonar mapping. Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig4_hires.jpg

the vent community food web. Another type of chemosynthetic community is found in areas where gases (such as methane) and liquid hydrocarbons seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth.

Cold-seep communities have been found at two locations on the east coast continental slope. These communities may signal the presence of other unusual ecosystems, potentially important energy resources and areas that may be susceptible to submarine landslides that can trigger tsunamis. An historic example of this hazard was the 1929 Grand Banks submarine landslide, which produced a tsunami 3 to 8 m high. That tsunami killed 28 people along the Newfoundland coast, even though this area was sparsely populated at the time. A similar tsunami along the present-day Atlantic coast might be much more devastating.



Deep submarine canyons are perhaps the most striking feature of the continental margin of the eastern United States. Most of these canyons are relatively minor features, but several are incredibly extensive and cut quite deeply into the seafloor. This image shows the Norfolk and Washington Canyons along the continental margin offshore of Virginia. Image courtesy of USGS.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/background/seafloormapping/media/seafloormapping_fig3.html

Methane is produced in many environments by a group of Archaea that obtain energy by anaerobic metabolism through which they break down the organic material contained in once-living plants and animals. When this process takes place in deep ocean sediments, methane molecules are surrounded by water molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form. Extensive deposits of methane hydrates and methane gas have been found on the Blake Ridge, on the continental slope off the coast of South Carolina and Georgia. Scientists are interested in methane hydrates for a variety of reasons, including their potential as an energy source, their association with unusual biological communities, and their possible role in tsunamis and climate change (for more information about methane hydrates, please see the Expedition Education Module for the Deepwater Canyons 2012 - Pathways to the Abyss expedition).

Shipwrecks are another type of substrate known to be present in mid-Atlantic canyons, and have historical as well as ecological significance. The mid-Atlantic coast of the United States has a maritime history that spans more than 400 years, and is marked by numerous shipwrecks that are neither well-documented nor well-understood. Shipwrecks, like many other human artifacts, can provide hard surfaces that may be associated with a high biomass of biologically diverse organisms. Deterioration of shipwrecks can enhance the settlement of some organisms (e.g., corals; see "Corrosion to Corals." http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/corrosion.pdf), but the importance of artificial substrates to natural ecosystems is not clear. In areas with a low percentage of natural hard substrates (such as mid-Atlantic submarine canyons), shipwrecks may represent a significant habitat resource for benthic organisms.

The purpose of the Deepwater Canyons 2012 - Pathways to the Abyss expedition is to explore and investigate deepwater coral and hard bottom communities and shipwreck sites on the continental slope off of Virginia, Maryland, and Delaware. These studies are expected to discover new coral areas and other significant canyon habitats and provide information about processes that control their distribution, abundance, and ecological functions. Selected shipwreck sites will be studied to determine their historical significance and their ecological function as artificial substrates for deepwater organisms.

To achieve these goals, expedition explorers will:
- Prepare detailed bathymetric maps of the three canyons in the study area using a multibeam sonar system;
- Collect video and still imagery from the survey area that will provide information about the presence, identity, and distribution of living organisms, as well as structural characteristics (size, shape, complexity, area covered) of various habitats resulting from biological and geological components;
- Collect samples for genetic, biological, ecological, and geological studies; and
- Measure temperature, salinity, turbidity, dissolved oxygen, and bottom currents in the three canyons and adjacent locations in the study area.

Many of these activities will be part of a series of surveys using the *Kraken 2* remotely operated vehicle (ROV; underwater robot).

Long-term measurements of physical and chemical environmental characteristics will be made with a combination of moorings and benthic landers installed at both ends of the canyons to be studied, as well as other areas of particular interest (such as seeps and hard substrates).

Moorings typically consist of several floats capable of withstanding deep-ocean pressures, a steel cable, and a heavy weight. Instruments to make desired measurements are attached to the cable. Often several sets of instruments are attached at different locations along the cable so that data can be recorded at different depths or distances from the bottom. Moorings for the Deepwater Canyons 2012 - Pathways to the Abyss expedition will carry sediment traps, current meters, and temperature data loggers.

Benthic landers, designed at the University of North Carolina – Wilmington, will be used during Deepwater Mid-Atlantic Canyons Project. They provide a way to deploy multiple instruments and experiments to the deep-sea floor and collect precise time-series data on environmental variability that is typically unattainable. Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig6_hires.jpg

Benthic landers are instrument-carrying platforms that are placed on the seafloor to record data. Typically, these platforms consist of a metal frame, floatation, and a ballast weight to keep the platform oriented in the desired position. The weight is attached to the platform with an acoustic release device that will release the weight and allow the platform to surface when an appropriate acoustic signal is received from scientists aboard a surface ship. If an acoustic release system is installed, the platform will also carry signaling devices such as a radio beacon, strobe light, or large flag to help scientists locate the benthic lander after it reaches the ocean surface. Benthic landers will carry instruments to measure currents, temperature, salinity, turbidity, dissolved oxygen, fluorescence, and suspended sediment, as well as data loggers to record measurements made by these instruments. Moorings and benthic landers are typically left in place for at least a year, so that seasonal variations in parameters can be detected. For more information about benthic landers, see http://www.lophelia.org/scientific-techniques/landers.

In this lesson, students will use the engineering design process to create model benthic landers based upon their investigation of buoyancy properties in a variety of materials.

Learning Procedure

1. To prepare for this lesson:
   a. Review the background essays for the Deepwater Canyons 2012 - Pathways to the Abyss Expedition (http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html). Download an image of a benthic lander (http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig6_hires.jpg).

b. If students are not already using some form of journal, you may want to consider using engineering design journals for this activity. This type of journal is a daily record of activities that are pursued in designing, developing, and constructing an invention. The journal is a complete log that should include research, testing, diagrams, and ideas about the invention and the problem that is being solved (ITEEA, 2006). Typical requirements for an engineering design journal include:
- The journal is a bound book;
- All pages are numbered;
- All entries are dated;
- A pen is used so ideas cannot be altered; and
- Sketches are made to scale.

c. Review the remaining Learning Procedure steps, and procedures described on the *Calculating Density and Buoyancy Worksheet*.

2. Briefly introduce the Deepwater Canyons 2012 - Pathways to the Abyss expedition and describe deepwater canyon habitats. Describe the various types of technology used by the expedition, including multibeam sonar, remotely operated vehicle (ROV), moorings, and benthic landers. Ask students why moorings and benthic landers are necessary when the scientists can make the same measurements during ROV dives. Students should realize that ROV data are only a "snapshot" and do not provide any information about how measurements might vary at different times or in different seasons of the year.

   Show students the image of a benthic lander (Step 1a), and briefly describe the overall concept. If necessary review the concepts of density and buoyancy, and ask students how these ideas are involved in benthic landers.

3. Tell students that building devices such as benthic landers involves a process called Engineering Design. If students are not already familiar with this concept, explain that Engineering Design is a process that engineers use to create solutions to problems. There are many versions of the process, but the basic steps are:
   - Define the problem;
   - Gather relevant information;
   - Brainstorm possible solutions;
   - Analyze possible solutions and select the most promising;
   - Test the solution;
   - Repeat these steps as needed until a satisfactory solution is achieved;
   - Communicate the solution to those who will use it.

Testing the solution often involves building models of simplified designs to be sure an idea will work before investing a lot of time and money to construct something more elaborate. This step is sometimes called prototyping or "proof of concept." If the prototype works, the designers will continue to develop their solution with the same materials and techniques. If the prototype does not work, then designers must go back to a previous step and consider solutions that use other materials and techniques. This entire process may be repeated several times to improve the solution until results are satisfactory. For complex projects, these steps may be done by teams that work on different parts of the problem. A benthic lander might have a design team working on the instrument systems, another working on the buoyancy control system, and another working on control electronics.

You may also want to point out that explorers often encounter unexpected problems or challenges during an expedition. A famous example is the Apollo 13 mission during which engineers on Earth had to design a "scrubber" that would remove carbon dioxide from the air that the astronauts had to breathe, using only materials that were already aboard the spacecraft. To find solutions for these kinds of challenges, explorers often turn to Engineering Design.

4. Tell students that their assignment is to design and construct a model that demonstrates the overall concept of a benthic lander. The assignment includes making a presentation using their model to explain this concept, describing how density and buoyancy are related to the concept, and calculating the density and buoyancy of all materials used in the model. Models should include a frame system, ballast weight, floatation, release mechanism, signaling device, and instrument package. The signaling device and instrument packages do not have to operate, but the model should include something that indicates their presence on the model lander. Ballast, floatation, and release mechanism should be operational on the model. That is, there should be enough ballast to overcome the model's buoyancy and cause it to sink, and there should be a way to release the ballast so that the model will float. A length of thread can be attached to the release mechanism so that students may activate the mechanism while the model is submerged. You may want to specify limits for the overall size of the models, depending upon the size of aquarium or container available for testing. It is a good idea to list all requirements for the model on a whiteboard, and have students record these in their journals.

   Encourage students to use their density measurements to calculate the amount of ballast that will be needed to cause their model to sink. This involves determining the total density of the model without ballast from the mass and volume of the individual components, then determining the amount of ballast that will be needed to make the total density of the model slightly more than 1.0gm/cm^3. Students can achieve the same result experimentally by adding ballast to their model until it sinks, but doing the calculation first will help ensure that the underlying concepts are understood. Some class discussion may be needed to help students understand how they can calculate the total density of their model.

You may want to require that this information be recorded in engineering design journals (if you a using them) or in separate written reports. Provide each student groups with a copy of the *Calculating Density and Buoyancy Worksheet* and with access to materials for constructing benthic lander models.

5. When students have completed their models, allow each group to test their models in an aquarium or plastic storage container partially filled with water. The ballasted model should sink, and when the ballast is released by pulling the thread the model should float to the surface. The results of the test should be recorded in students' journals.

Have each group present their results and explain the model's operation to the rest of the class. There are many ways to construct a model that meets the design requirements. The essential points are:
- Design requirements are clearly identified;
- Several options are considered;
- The selected option fulfills the design requirements;
- If the model does not fulfill the design requirements, students identify necessary modifications.

Each group's report should also include the density of the materials used to construct their model. Students should realize that they need to know mass and volume to find the density of an object. Since the volume of many substances change in response to temperature, it is also true that the density of an object also depends upon temperature. But temperature changes usually have very small effects on density compared to the effects of changing mass and volume. Students should observe that objects that float have lower densities than objects that sink. Students should also realize that increasing the volume of an object will increase the volume and weight of fluid displaced when the object is immersed, and thus will increase the buoyant force acting on the object.

Most science standards do not expect elementary students to distinguish between mass and weight, but middle school (grades 6-8) students are expected to make this distinction. These concepts can be easily confused when dealing with density and buoyancy, because when students use a balance to determine mass they are actually measuring weight (mass multiplied by the force of gravity). This works out because the balance is calibrated to take gravity into account, but under zero gravity conditions the balance would not give an accurate estimate of mass. So, if we want to calculate the buoyant force acting on an object based on the weight of displaced fluid, we have to use units of weight such as pounds. If we want to use metric units of force (Newtons) we have to multiply the mass of the displaced fluid (in kg) by the acceleration of gravity (about 9.81 m/sec2). Since these metric units, as well as the concepts of gravitational acceleration, are usually taught in higher grade levels, we do not have students calculate actual buoyant force in this lesson. But if students discuss buoyant force in terms of "grams" or "kilograms," it is important to remind them that these are units of mass and that buoyancy involves units of weight.

The BRIDGE Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, scroll over "Ocean Science Topics," then "Human Activities," then click "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay describing how being able to calculate buoyancy might be of personal benefit.

Connections to Other Subjects

English Language Arts, Mathematics

Assessment

Student analyses and report prepared in Step 5 offer opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html to find out more about the Deepwater Canyons 2012 - Pathways to the Abyss Expedition.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, 6, and 8 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Ocean Currents.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

The Big Burp: A Bad Day in the Paleocene
(from the 2003 Windows to the Deep Expedition)
http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_badday.pdf

Focus: Global warming and the Paleocene extinction (Earth Science)

Students describe the overall events that occurred during the Paleocene extinction event, describe the processes that are believed to result in global warming, and infer how a global warming event could have contributed to the Paleocene extinction event.

Animals of the Fire Ice
(from the NOAA Ship *Okeanos Explorer* Education Materials Collection - Volume 1: Why Do We Explore?)
http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_fireice.pdf

Focus: Methane hydrate ice worms and hydrate shrimp (Life Science)

Students define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

A Piece of Cake
(from the 2003 Charleston Bump Expedition)
http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_cake.pdf

Focus: Spatial heterogeneity in deep-water coral communities (Life Science)

Students explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deep-water hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Charleston Bump.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html – Web site for the Deepwater Canyons 2012 - Pathways to the Abyss expedition

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Relationship to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*

The objectives of this lesson integrate the following Practices, Crosscutting Concepts, and Core Ideas:

Objective: Students will plan an investigation to identify appropriate materials for a model that will demonstrate the operating principles of a benthic lander.

Science and Engineering Practices:

2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Designing solutions

Crosscutting Concepts:

4. Systems and system models
6. Structure and function

Disciplinary Core Ideas:

PS1.A Structure and Properties of Matter
ETS1.B Developing Possible Solutions
ETS1.C Optimizing the Design Solution

Objective: Students will use a model to communicate the operating principles of a benthic lander, and describe key design constraints and possible solutions.

Science and Engineering Practices:

2. Developing and using models
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts:

2. Cause and effect;
4. Systems and system models
6. Structure and function

Disciplinary Core Ideas:

ETS1.A Defining and Delimiting and Engineering Problem
ETS1.B Developing Possible Solutions

Correlations to Common Core State Standards for Mathematics

6.RP – Understand ratio concepts and use ratio reasoning to solve problems.
6.EE – Expressions and Equations
6.G – Geometry

Correlations to Common Core State Standards for English Language Arts

SL.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. 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.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. 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.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

Calculating Density and Buoyancy Worksheet

A. Density

Background: Density is a physical property of matter that is related to an object's mass (how much matter the object contains) and volume (the object's physical size). You know that a handful of Styrofoam™ weighs much less than a handful of rocks. This is because the density of the Styrofoam™ is less than the density of the rocks. Density is usually defined as "mass per unit volume," and the density of an object or substance is stated in "grams per cubic centimeter."

Do It: Your task is to measure the density of objects that you will use to construct your benthic lander model. What two properties of each object do you need to know to find the object's density?

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Measure the mass of each object using a balance as directed by your teacher. Record these measurements on the *Density and Buoyancy Data Sheet*.

Now measure the volume of each object. The easiest way to do this is to immerse the object in water in a graduated cylinder and measure the increase in water volume. Put water into a graduated cylinder so the cylinder is about half full. Record the volume of the water on the data sheet in the "Volume Without Object" column. Drop the object into the cylinder and record the new volume on the data sheet in the "Volume With Object" column. If the object floats, you will need to push it down with a piece of stiff wire until the object is completely submerged. Subtract "Volume Without Object" from "Volume With Object" and record the result in the "Object Volume" column.

Calculate the density of each object by dividing the mass by the volume, and record the results on the data sheet in the "Density" column. Hint: One milliliter is the same as one cubic centimeter.

Record the buoyancy of the object in the last column.

What do you notice about the density of objects that sink compared to objects that float?

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B. Buoyancy

Background: Read the following explanation of Archimedes' Principle:

The idea of buoyancy was summed up by a Greek mathematician named Archimedes: any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. Today, this definition is called Archimedes Principle.

Archimedes is considered one of the three greatest mathematicians of all time (the other two are Newton and Gauss). Archimedes was born in 287 B.C., in Syracuse, Greece. He was a master at mathematics and spent most of his time thinking about new problems to solve.

Many of these problems came from Hiero, the king of Syracuse. Archimedes came up with his famous principle while trying to solve this problem: The king ordered a gold crown and gave the goldsmith the exact amount of metal to make it. When Hiero received it, the crown had the correct weight but the king suspected that some silver had been substituted for the gold. He did not know how to prove it, so he asked Archimedes for help.

One day while thinking this over, Archimedes went for a bath and water overflowed the tub. He recognized that there was a relationship between the amount of water that overflowed the tub and the amount of his body that was submerged. This observation gave him the means to find the volume of an irregularly shaped object, such as the king's crown. With this information, Archimedes could find out how much the same volume of gold would weigh. If the weight of the same volume of gold turned out to be the same as the weight of the crown, then he would know that the crown was made of gold. But if the weight of the same volume of gold was different from the weight of the crown, then he would know that the crown was not pure gold after all.

Archimedes had solved the problem! He was so excited that he ran naked through the streets of Syracuse shouting, "I have found it!" As it turned out, the crown was not pure gold, so the goldsmith was brought to justice and Archimedes never took another bath...(just kidding!).
(from "Discover Your World with NOAA: An Activity Book;" http://celebrating200years.noaa.gov/edufun/ book/welcome.html)

Thought Experiment: If the volume of an object increases but the mass of the object does not change, how does this affect the buoyant force acting on the object when it is immersed in a fluid?

Density and Buoyancy Data Sheet

Object	Mass (g)	Volume Without Object (ml)	Volume With Object (ml)	Object Volume (ml)	Density (g/cm3)	Buoyancy S = sinks F = Floats N = Neutral