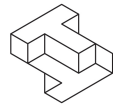


Exploring Buoyancy

Design Challenge Learning



The Tech
Museum of Innovation

201 S. Market St.
San Jose, CA 95113
1-408-294-8324
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How low can you go? Students are challenged to use their understanding of buoyancy, density, and pressure to design and build ocean exploring devices. As students iterate through this design challenge, they gain firsthand experience in the design process.

Grades 3-8

Estimated time: 90 minutes

Student Outcomes:

1. Students will be able to demonstrate the difference between positive buoyancy, negative buoyancy, and neutral buoyancy.
2. Students will be able to apply the key concepts of buoyancy, density, and the balancing of forces to create a device that is capable of diving and surfacing.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards

Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3

Grade 3: *Physical Science* 3-PS2-1

Grade 5: *Physical Science* 5-PS1-1,

Grade 6-8: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4; *Physical Science* MS-PS2-2

Common Core Language Arts-Speaking and Listening

Grade 3: SL.3.1b-d, SL.3.3, SL.3.4a

Grade 4: SL.4.1b-d, SL.4.4a

Grade 5: SL.5.1b-d, SL.5.4

Grade 6: SL.6.1b-d

Grade 7: SL.7.1b-d

Grade 8: SL.8.1b-d

California Science Content

Grade 3: *Investigation and Experimentation* 5.a-b, 5.d

Grade 4: *Investigation and Experimentation* 6.a-d

Grade 5: *Investigation and Experimentation* 6.b-e, 6.h

Grade 6: *Investigation and Experimentation* 7.a-b, 7.d-e

Grade 7: *Investigation and Experimentation* 7.a, 7.c, 7.e

Grade 8: *Physical Science* 2.a-f, 8.a-d; *Investigation and Experimentation* 9.a-b

Vocabulary:

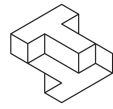
Familiarity with these terms and concepts will enhance students' experience in the activity.

- Archimedes Principle: The relationship between buoyancy and displaced fluid: An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.
- Boyle's Law: At a constant temperature, the volume of a given quantity of gas is inversely proportional to the pressure upon the gas.
- Buoyancy: An upward force acting on an immersed or floating body by the supporting fluid.
- Equilibrium: A state of balance between opposing forces.

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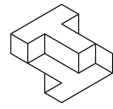
- **Force:** A push or a pull. An influence on a body or system, causing or tending to cause a change in movement or shape.
- **Mass:** The amount of matter that is contained by an object.
- **Negative Buoyancy:** Exists when the weight of the body is greater than the weight of an equal volume of the displaced fluid. The body sinks.
- **Neutral Buoyancy:** Exists when the weight of the body is equal to the weight of an equal volume of the displaced fluid. The body remains suspended – neither rising nor sinking – unless acted upon by an outside force.
- **Positive Buoyancy:** Exists when the weight of the body is less than the weight of an equal volume of the displaced fluid.
- **Pressure:** The force per unit of surface area; exerted perpendicular to the surface; measured in Pascals.
- **Volume:** The amount of space enclosed by a shape or object; how much 3-dimensional space (length, width, and height) it occupies.
- **Weight:** The downward force caused by gravity on an object.

Resources:

- How Submarines Work: Provides a background on submarines from how they dive and surface to how they maintain hospitable conditions for the people who live and work on the vessel. It includes an animated graphic on how submarines use vents and a network of hulls to dive and surface. <http://science.howstuffworks.com/transport/engines-equipment/submarine.htm>
- Buoyancy: A quick overview of how things float and key buoyancy concepts. www.seaperch.org/article?article_id=313
- Mythbusters: “Let’s Talk Buoyancy”: A video where the Mythbusters explain buoyancy and relate it to a pirate myth of turning a rowboat into a submarine. www.discovery.com/tv-shows/mythbusters/videos/lets-talk-buoyancy/
- Buoyancy Playground: A buoyancy simulator supported by the University of Colorado Boulder that allows you to manipulate different experimental parameters including mass, volume, and density of the object and the fluid. The simulator provides quantitative measurements and allows you to overlay force vectors onto the simulation. http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy_en.html
- Underwater Exploration: A National Geographic website that provides information on the many expeditions and discoveries made by National Geographic explorers. Includes articles, videos, and other multimedia sources. <http://ocean.nationalgeographic.com/ocean/underwater-exploration/>

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Design Challenge Process:

The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.

The process consists of three interconnected steps:

Conceptualize

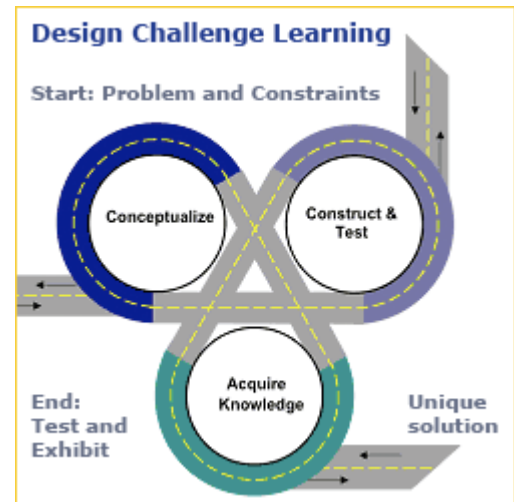
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

Construct and Test

- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

Acquire Knowledge

- Research
- Share solutions
- Reflect and discuss



Through the try, fail, learn approach, students develop skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

Materials:

Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. "Recycled items" are really useful: old mouse pads, wood scraps, boxes, cardboard tubes, strawberry baskets, etc.

One Set Per Pair of Students:

Float, Hover Sink

- 3 Film Canisters
- 1 Plastic Container Filled with Water

One Set For Every Team of 4 Students:

Buoyancy Controlled

- 1 Half Pint Water Bottle or Film Canister
- 1 Small Plastic Container to Act as a Shelf
- 1 Large (66 qt.) Plastic Container
- Objects for Retrieval

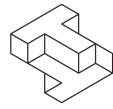
Class Supplies to Share:

- Balloons
- Rubber Bands
- Film Canisters
- Tape
- Drinking Straws
- Plastic Aquarium Tubing
- Hot Glue Guns
- Weights (beads, pennies, etc.)
- Paper Clips
- Duct Tape
- Bubble Wrap
- Pipe Cleaners
- Syringes
- Corks
- Styrofoam Peanuts

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Directed Instruction:

- Lego™ Rescue Submarine
- 30 Gallon Fish Tank or Large Plastic Storage Box
- Small Airtight Plastic Container Filled with Marbles
- Large Airtight Plastic Container (~16 times larger than small container)
- Cartesian Diver
- Various Objects Displaying Positive, Negative, and Neutral Buoyancy

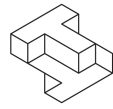
Lesson Plan:

Introduction (5 minutes)

1. While underwater exploration began in 1797 with the invention of the Helmet Suit by Karl Klingert, the underwater environment continues to remain a vast frontier. Scientists continue to discover new species and understand our planet and human civilizations better because they are able to dive deeper and stay submerged longer.
2. What challenges do scientists have to overcome in order to explore the underwater environment? What technology do scientists use to explore oceans?
3. Scientists use new advances in technology to explore more remote locations, such as the use of underwater remotely operated vehicles (UROVs). How do you think these vehicles work? How are they able to dive and surface?

Float, Hover, Sink: Mini Design Challenge (15 minutes)

1. Introduce the Challenge: Design a set of simple devices that will house instruments to take water samples for the Water Quality Monitoring Project. You will need to collect samples at the surface, middle, and bottom of the body of water in front of you. You will need to design 3 instruments, each varying in density so that one will float, one will hover, and one will sink.
2. Introduce the Constraints:
 - You can use any materials provided or found at the class resource table.
 - Each member of your group must participate in solving the design process.
 - You will need to use a different film canister for each challenge (floating, sinking, and hovering).
 - The hovering canister should be free to move around (i.e. not tethered or anchored).
3. Build: Give students about 10 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
4. Demonstration: Have students demonstrate their act for the class. If students have not completed their device ask them how the act would have worked. This should last no more than 5 minutes.
5. Reflection: Each group of students will explain their design strategy and how they were able to make their canisters float, hover, and sink. Instructors should ask leading questions to get at the science behind the designs.
 - Teaching Points:
 - A force is a push or a pull. Buoyancy is an upward force acting on an immersed or floating body by a fluid.
 - There is more to designing a device than building it. You must consider the resources available and the limitations of a design.
 - Brainstorming, teamwork, and testing are important parts of the design process.
 - Complex problems and machines can be simplified by looking at smaller aspects of them.
 - Questions:



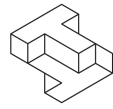
- How are your three instruments different?
- What did you do to make your instrument obtain a low level in the water?
- How did you achieve an instrument that was suspended in the water?
- If you had more time, is there anything that you would have done differently with your designs?
- What connections can you make between this experiment and what you may have experienced elsewhere (i.e. in a pool, bathtub, lake)?

Directed Instruction (Buoyancy, Density, and Pressure) (15 minutes)

1. Ask questions to encourage teaching points:
 - What did you do to get the canisters to the correct locations?
 - Can you tell me why one of your canisters will float while the other canister sinks?
 - What forces are acting on the canister? (*Gravity is pulling down and the buoyant force of water is pushing up.*)
 - How did you get a canister to hover? Was it difficult? (*Hovering is the most difficult because you need to balance the forces of gravity and the buoyant force. Most solutions require adding mass to get it to sink but then increasing the volume with a floatable material to get it to float.*)
2. Density is the amount of mass per unit volume. If you increase the mass but keep the volume the same, the density increases. If you increase the volume but keep the mass the same, the density decreases
 - Demonstration: Show students a small (1-2 cup) plastic container filled with marbles. Discuss that it has a lot of stuff (mass) in a small shape (volume). Ask them to predict whether it will sink or float. Empty the marbles into a larger container (16 times larger than the smaller container). Stress that this is the same amount of mass in a larger volume. Ask them to predict whether it will sink or float.
 - Questions:
 - How does the submarine dive down? How does it become denser?
 - How does the submarine surface?
 - Why does this work?
 - Does anyone know how a scuba diver is able to dive and surface?
3. When something is denser than water, it is negatively buoyant. When it is less dense than water, it is positively buoyant. When it has the same density of water, it is neutrally buoyant. The density of water is greater than air. When the density of a submarine (or scuba diver) is greater than water it will sink, when it is less than water it will surface.
 - Demonstration: Demonstrate for the class the Lego™ Rescue Submarine. Show how air is pulled out to allow it to dive and air is pumped back in to allow it to surface.
 - Questions:
 - Can you think of real life applications for being positively buoyant (floating)? Negatively Buoyant (sinking)? How about being neutrally buoyant (hovering)?
 - Can you think of anything that might make use of all three forms of buoyancy?
 - How does the submarine dive down? How does it become denser?
 - How does the submarine surface?
 - Does a submarine change its mass or volume to change its density? (It changes its mass. The shape or volume doesn't change).
 - Does anyone know how a scuba diver is able to dive and surface?
4. Pressure is directly related to density as described by Boyle's Law. As the density of a neutrally buoyant object increases, its buoyancy decreases.

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- Demonstration: Create a Cartesian Diver as explained by Steve Spangler Science (<http://www.stevespanglerscience.com/lab/experiments/eye-dropper-cartesian-diver>). Demonstrate for the class that when the bottle is squeezed the pressure increases, increasing the density of the eyedropper, and the eyedropper sinks. When the pressure is released the density of the eyedropper decreases and the eyedropper rises.
- Questions:
 - Why does the eyedropper's density increase under increased pressure and decrease under decreased pressure?
 - How do you think the pressure of deep-sea exploration effects buoyancy?
 - What practical applications does this have for scuba divers and submersibles?

Buoyancy Controlled Design Challenge (55 minutes)

1. Introduce the Challenge: Design and create a vessel that can become negatively buoyant to retrieve an object located at the bottom of the tub, then become positively buoyant to bring the object back to the surface.
2. Introduce the Constraints:
 - Your vessel must retrieve the object provided by the teacher.
 - Your vessel must maintain buoyancy control (no uncontrollable sinking or floating).
 - You must control the vessel from outside the tank.
 - You can only use the materials provided.
 - Each group member must participate in the design, construction, and operation of the vessel.
 - You will be allowed to test your vessel as you work.
3. Build: Give students about 40 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
4. Discussion/Demonstration: For about 10 minutes have students demonstrate their device for the class at their tables. If students have not completed their device ask them how the device would have worked.
5. Reflection: Each group of students will explain their design strategy and how their vessel controls buoyancy in relation to density, mass, volume, etc. Instructor should ask leading questions to point out facets of the student's designs.
 - Teaching Points:
 - A force is a push or a pull. Buoyancy is an upward force acting on an immersed or floating body by a fluid.
 - Density and buoyancy are related.
 - Density and weight are related.
 - Density and pressure are related.
 - Brainstorming, teamwork, and testing are important parts of the design process.
 - Complex problems and machines can be simplified by looking at smaller aspects of them.
 - Questions:
 - How is your vessel's buoyancy controlled?
 - How does your vessel increase its density in order to dive and retrieve objects?
 - How does your vessel decrease its density to become more positively buoyant?
 - If you had more time, is there anything that you would have done differently with your design?