Float Your Boat: Sink or Swim?

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Introduction: As an introduction to STEM: Science, Technology, Engineering, and Mathematics, students will conduct a submarine-related interdisciplinary hands-on inquiry unit using the key concepts: buoyancy, density, force and motion, and propulsion. In several activities students apply their knowledge of the Next Generation Science Standards: Crosscutting Concepts for middle school science and engineering, by researching, reading, designing, creating and testing both surface and submersible watercraft. Links to U.S. Navy applications are used for "real world" STEM examples.

Next Generation Science Standards/Common Core State Standards in Math/Literacy:

- **MS-PS2-2 Motion and Stability**: Forces and Interactions. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.

- **CCSS.ELA-Literacy.RST.6-8.9:** Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic.

APPENDIX F – Science and Engineering Practices in the NGSS

The link below expresses a detailed vision in science education that requires students to operate at the nexus of three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas.

http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Instructional Goal:

Students will be introduced to STEM: Science, Technology, Engineering, and Mathematics through an interdisciplinary hands-on inquiry series of activities that introduces key concepts: buoyancy, density, force and motion, and propulsion. This unit and its extension activities have students apply their knowledge of Next Generation Science Standard: Crosscutting Concepts for middle school science and engineering (see Appendix F above) by researching, reading, designing, creating and testing both surface and submersible water craft. These activities have been created to "Prepare the NEXT Generation of STEM Innovators (NSF, 2010) with a "hands-on" or "minds-on" approach to science."

Word Wall: For this unit, chart the key concepts and terms on a word wall to be introduced and discussed throughout the unit. Key concepts and terms should be referred to throughout the lessons and experiments. Entrance tickets should guide students and exit tickets or assessments should reflect students' thinking and learning (observations, reflections, and new questions proposed).

Key Concepts and Terms: Inquiry; Archimedes' Principle; Boyles' Law; Propulsion; Buoyancy (positive, negative, neutral); Density; Forces and Motion; Newton's Laws

Resources for Definitions and Diagrams:

Archimedes' Principle: http://www.onr.navy.mil/focus/blowballast/sub/work2.htm

Boyles' Law: http://www.onr.navy.mil/focus/blowballast/sub/work4.htm

Propulsion: http://www.onr.navy.mil/focus/blowballast/sub/work5.htm

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Entrance Ticket: "Why do some objects float and other objects sink?"

- **Inquiry Focus Questions**: How do ships and submarines stay afloat?
  How do submarines submerge and return to the surface again?
  What materials would be needed to make a vessel float?
- **Note: These questions would also be the given to the students as they enter the room (entrance ticket) for them to brainstorm and answer. (5 min)**

Introductory Activity: STEM is everywhere around us. Since the 1900's inventors: engineers and scientists have been creating and testing different prototypes of water vessels in order to create our Navy's submarine fleet. In order to get a better grasp of where we have come, were we are, and where we are going in science, technology, engineering and mathematics we will start our lesson with a STEM message from the U.S. Navy. (5 min video clip)

- **Videos**: **STEM in the Navy**: http://www.youtube.com/watch?v=mEzcNHkjCB8 (4) Or http://www.navy.com/about/equipment/vessels/submarines.html (2:48)

Today's Goal: We will learn how the Navy uses science, technology, engineering and mathematics to keep our submarines and vessels afloat and how you as students can create, design and test your own submarine and ship using the same scientific principles as the Navy.

Lesson 1: ELA and Literacy Connection/Lesson (30 min):

Divide students into groups (pair/share: 2 people per group or 4) Students will read and annotate (show their thinking in writing in the margins and develop questions) after reading the nonfiction article: ***Submarines: History—How They Work: An Introduction***.

Article: http://www.onr.navy.mil/focus/blowballast/sub/history1.htm

Each student should have their own copy of the article (read and annotate individually) or you could enlarge the article to 11 x 14 and tape it to the center of chart paper for the group to annotate together. Have the students chunk the sections (12 paragraphs total) and share reading the article to the group (2 or 4 per group). After the students have read the article, give them five minutes to discuss together and annotate as a group: each students should get a different color marker in the group so that you know that everyone in the group has participated in the discussion).

Share out/Debrief: Each group takes three minutes to share out what they learned, wondered, or questioned. Common questions that come up should be charted and investigated later during the inquiry lab/experiment. (5-10 min)

Homework/Extend the Lesson: Ask the students to research materials that can float and are buoyant. Have them look around their house and bring in materials over the next two days that they think they could use in designing and creating a surface ship or submarine. It is helpful if you email staff and parents earlier in the week to get enough materials for the experiment. All materials that the students plan to use should fit in a grocery bag.

Teacher Note: The teacher should also provide materials that could be used for the experiment. (Collect materials like empty juice containers, milk jugs, soda bottles, foam egg cartons, plastic or glass test tubes, empty cigar containers or empty make-up/perfume tubes, marbles, jars, small weights, play-dough or molding clay, straws, toothpicks, styrofoam, popsicle sticks, glue sticks, waxed string, index cards, construction paper, and empty towel and toilet paper rolls).

Lesson 2, Cross- Cutting Lab: Energy and Propulsion, Transfer of Energy

Entrance Ticket/Inquiry Questions: What type of materials or types of energy could you use to propel a vessel? Where does this energy come from? How does energy transfer? What types of energy will be used? Where does the energy go?

Types of **Inquiry questions** that should prompt your discussion should be developed with the focus on the NEXT Generation of Science Standards:

Next Generation of Science Standards:

Grades 6-8	Grades 9-12
Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. ☐**Ask questions** **o that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.** **o to identify and/or clarify evidence and/or the premise(s) of an argument.** **o to determine relationships between independent and dependent variables and relationships in models.** **o to clarify and/or refine a model, an explanation, or an engineering problem.** **o that require sufficient and appropriate empirical evidence to answer.** **o that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when**	**Asking questions and defining problems in 9–12** builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ☐**Ask questions** o **that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.** **o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.** **o to determine relationships, including quantitative relationships, between independent and dependent variables.** **o to clarify and refine a model, an explanation, or an engineering problem.** ☐ Evaluate a question to **determine if it is testable and**

The table was taken directly from the Next Generation of Science Standards.org website.

Instructional Objective: Students will use classroom and materials from home (if collected) to design and create a surface vessel which uses energy to propel itself in the water. Students will brainstorm and pose questions (min. ten questions) that they would like to have answered by the end of inquiry lab. (Note: During inquiry investigations students should develop questions before design, during development, during test, and after the experiment to show their thinking. Observation and questions should be documented by members of the group just like a scientific lab experiment to show their progression in design to concept model experiment.)

Background Knowledge: Student should have current articles, magazines (with pertinent information on energy and propulsion) or computers available to them to refer to gather more information on energy and propulsion if needed. This unit would work in conjunction with the seventh grade science standards for energy and the Next Generation Science Standards for Renewable Resources.

Show Video/Interactive Board Activity to Review Types of Energy and Energy Transfer: http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/energy_transfer_storage/activity/ (5 min) or http://www.youtube.com/watch?v=xniW3_afO-0 (buoyancy)

Below I have included links to **non-fiction articles** for students to gain background knowledge in types of energy, energy transfer, propulsion, sustainability, and ingenuity.

Types of Propulsion: http://www.onr.navy.mil/focus/blowballast/sub/work5.htm (historical)

Navy Uses Seawater for Fuel: http://www.usatoday.com/story/news/nation/2014/04/13/newser-navy-seawater-fuel/7668665/ (Low Level Reader)

http://www.voanews.com/content/us-navy-lab-turns-seawater-into-fuel/1919512.html (Med Level)

http://news.discovery.com/tech/alternative-power-sources/us-navy-game-changer-seawater-turned-into-fuel-140408.htm (High Level/Enrichment)

Key Terms/Concepts: Renewable Energy: Wind, Solar, Water (Hydroelectric or Steam), nuclear, fission, biomass; heat energy, heat transfer, battery; turbines (fans), generator; fossil fuels: coal, natural gas, diesel, petroleum/oil/petrol, diesel- electric, chemical energy, variable, reaction, propulsion, propeller, buoyancy, drive, acceleration, weight transfer, force and motion, load, distribution of weight, cost and sustainability.

A **propeller** is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces (www.bing.com)

The twin propellers from USS *Nautilus* (SSN 571) at the Submarine Force Museum, Groton, CT. USS *Nautilus* was the first nuclear-powered ship, using the energy from the fission or "splitting" of the Uranium 235 atom to generate heat from a nuclear reactor core, which in turn heated water to make steam to spin turbines to rotate the propellers.

See the whole process at: Reactor Operations: This video on the reactor operations of nuclear submarines is part of the Covert Submarine Operations Exhibit, located in the Cold War Gallery, Washington Navy Yard.

Introduction to Lesson 2 Energy and Propulsion, Transfer of Energy LAB :

Energy can come from several sources and used in many ways. Today you will use potential and kinetic energy and observe the transfer of energy from one item to the next in order to propel a surface vessel or ship. You will use your background knowledge and ingenuity to design and create a surface vessel that can be propelled using different types of energy. (Note to Teacher: There are many sites, videos, and levels of articles that can be used to guide your instruction on energy if needed and boat propulsion lab videos if needed.)

Energy basics

Energy can be stored or transferred from place to place in different ways. This website can help students understand the basics or flip classroom lesson for home if needed to gain background knowledge.

http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/energy_transfer_storage/revision/7/

Materials for LAB Activity:

Graph paper, pencils, rulers and protractors for design concept Styrofoam, epoxy or hot glue gun, 1/8 inch copper wire (steam engine), tea lights (heat energy), Alka-Seltzer tablets, cigar tubes or perfume/make-up metal tubes, tinfoil, soda can, soda or juice bottles, paint- if desired, straws, toothpicks, twine, small elastic bands, paper clips, index card (large), construction paper to make sail, propeller (computer fan and electrical wire), wood panels (pre-cut), water for testing ships and a flower box or long plastic trough for water, stop-watch .

Let students use their own creativity as a group in order to brainstorm and problem solve:

Inquiry question: What materials would work best to make our ship?

Here's a video for you (the teacher) to view to get ideas on which materials you will need. Videos range from easy to more complex design concepts. Students will only be limited by the materials that are provided.

Remember: Lab Safety: goggles/eyewear and heat resistant protective gloves are needed if students will be using heat.

Provide the rubric/expectations for the activity

STEM Project Rubric:
https://classes.svvsd.org/pluginfile.php/99367/mod_resource/content/1/STEM%20Project%20Rubric.pdf

Video to Inspire Creativity: Kite Propelled Ships
http://www.solidworks.com/btd/innovations/wind-propelled-ships.htm

When students brainstorm ideas the teacher should be observing and taking notes on groups' thinking: students participating in the discussion and design process can be noted each day for final effort/participation grade.

Inquiry Design Model:

Inquiry Starters: Learners explore materials, make observations, and raise questions related to content goals.

Focused Investigation: Learners plan and carry out investigations based on their questions

Sharing Understanding: Learners share investigation results with each other to further their understanding of scientific concepts.

DESIGN CONCEPT/NAME: _____DAY: _____

GROUP MEMBERS/PARTICIPANTS PRESENT:

Materials we need:	**Procedures:** Steps we need to take to make design.	**Questions we have:**	**Problems we encountered:**	**Solutions & Observations:**

In order to keep students on task for each day of your lab, provide each group with a TASK card for that day. Their task would dependent on what you as the teacher observed the day before and where their group is in the design process. You may include questions on the card for the group to answer (questions you have about their concept/idea).

Each table should have a folder with the expectations for that day (task card), inquiry question, copy of rubric and observation chart, group member roles (time keeper, group leader, materials/resource person, reporter, recorder, engineer/design- jobs should rotate daily) and graph paper for students to draw their design. Mini-lesson for each day should only take 5-10 min to guide the inquiry lab; the rest of the time should be used for students to collaborate, design, build and test their design. This activity should take one week to go from design to concept. If schema/background information needs to be taught first, this inquiry lab could take two weeks.

Once ship or surface vessels are built, have the groups test the vessels for buoyancy. If the vessel takes on water the team needs to go back and secure the seals (problem-solve). Once the ship is buoyant they can attempt to add propulsion. *Variable: Add salt to water: Does the density or buoyancy change? Add Karo syrup to change density of water.

Type of Propulsion:	**Energy Type/Transfer:**	**Variables attempted:**	**Problems**: **Observations**	**Date:**
Observations: **Trial 1:** Weight: Time:	**1.**	1. **Propulsion:**		
Trial 2: Weight: Time:	**2.**	2. **Speed:**		
Trial 3: Weight: Time:	**3.**	3. **LOAD** **Weight tested:** **Type of Load:**		
Trial 4: Weight: **Reflections:**	**4.**	**Acceleration** Time**:**		

Have students present their finding as a group to the whole class. Each group will have an entire block to organize their data to be displayed and presented. Students must graph data appropriately: bar graph or line graph: show progression over time (w/ different variables: trends). They must explain why they used this particular chart.

Reflection: Other groups share out questions they have for presenters or ideas on ways they could have improved or changed their experiment to make it different next time. (All groups share)

Adapt the lesson: Grade Eight: Newton's Laws of Motion (focus questions: inertia, propulsion--distance of glide-depending on load, and opposite force reaction); cost: budget for materials: fuel costs and sustainability. Add a rudder or propeller. Add an opposite force: What happens? Use a fan (wind).

WATER PROPELLED BOAT http://www.youtube.com/watch?v=BbikCnLoAag&app=desktop

STEAM http://www.youtube.com/watch?v=ciMLybJWMhA&app=desktop

HEAT: Making a POP-POP Boat http://www.youtube.com/watch?v=0ki9Kta8g14

Middle School Video

http://www.youtube.com/watch?v=GaCmeJaNiFg

Magneto Hydrodynamic Propulsion using a battery, Styrofoam plates and wires.

How to Build a Submarine by Iridescent Office of Naval Research (ONR):

http://www.youtube.com/watch?v=dslhHVpgkxM

Extension Activities and Experiments:

How Does a Submarine Dive?

> Students will conduct an experiment that simulates how a submarine stays afloat (**positive buoyancy**) and how it submerges (**negative buoyancy**) by creating ballast tanks using available classroom materials. This activity allows students to see how buoyancy and density affects the depth of the submarine. The students will see how the exact depth of the vessel can be controlled by adjusting the water to air ratio in the ballast tanks. The submerged submarine can eventually obtain neutral buoyancy when the weight of the submarine equals the amount of water it displaces.
> **Inquiry lesson**: Students will develop questions and test their hypotheses. Students will chart their observations and observe and measure how their submarine uses ballast tanks to change the depth of their vessel.

Inquiry questions: How does a submarine submerge? How does a submarine resurface? What has to happen in order for the submarine change depth? Students can also view a demonstration of a submarine diving: http://www.navy.com/about/equipment/vessels/submarines.html .

1. **Dive! Dive! The History and Technology of Submarines**(adaptable for STEAM/STEM grades 5-8)**. Follow the link to Field Trip in a Box:** **http://www.history.navy.mil/branches/teach/fieldtrip-dive.htm**

2. **Additional Resource:** Take a virtual tour of the Submarine Force Museum and Historic Ship *Nautilus* (SSN571) at 1 Crystal Lake Drive, Groton, CT http://www.ussnautilus.org/virtualTour/nautilus/_flash/USS%20Nautilus_nautilus.html

3. **Cartesian Diver:** This lesson encourages students to research and read about the way submarines change and maintain depth in the ocean. Students will then model how the taking in of water (ballast) and release of it from a submarine allows the change of buoyancy to rise (positive buoyancy), dive (negative buoyancy), and maintain depth (neutral buoyancy).**http://www.ussnautilus.org/education/pdf/stemlessons/dive-the-cartesian-way.pdf**

4. **For more STEM lessons and resources please go to http://www.ussnautilus.org/education/stemlessonplans.shtml.**

STEM Internship Opportunities:

Students interested in applying for an internship in STEM please go to: http://www.onr.navy.mil/Education-Outreach/undergraduate-graduate.aspx or

http://www.onr.navy.mil/Education Outreach/undergraduate-graduate/NDSEG-graduate-fellowship.aspx for more information.

Inquiry Design and Opportunities for Professional Development:

Connecticut Science Center:
http://www.ctsciencecenter.org/things-to-do/mandell-academy/inquiry/

Additional STEM Activities and Resources:
http://www.solidworks.com/sustainability/sustainable-design-guide.htm

http://teachers.egfi-k12.org/

Engineering Design for Middle School:
http://www.nextgenscience.org/sites/ngss/files/MS%20ETS%20topics%20combined%206.12.13.pdf