

Lesson 2: How can a ship carry all these taconite pellets and still float?

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Target: Grade 8 standards but applicable for grades 6-10.

Time: 1-2 class periods depending on depth and detail research, modeling, extensions, etc.

Lesson Overview

The goal of this lesson is to get students thinking about how ships are designed. The lesson will allow students to extend their understanding of floating, sinking, density, and buoyancy and apply it to the design and testing of boats.

This lesson will fit nicely into a geology and/or mining in Minnesota unit as an extension activity of lesson 1 on how do you ship taconite on the Great Lakes.

Objectives

To design, build, and test the specifications (water displacement and load line) for a model boat. The lesson will focus on integrating design principles with inquiry-based experimental skills. Students use what they have learned about ship design (along with some additional information on the Web about how ships are built) to design and build a small model boat, using limited materials. They then develop a procedure to determine how much their boat can hold (the load line) while it is in “calm” vs. “rough waters.” Finally, they test their boat in water to determine whether their design is a practical one. Through this activity, students will learn that every design involves trade-offs and decisions. This will also spur decisions on other Great Lakes limitations such as minimum depth of the seaway and lock systems.

Minnesota Science Standards Addressed:

1. History and Nature of Science. B. Science inquiry, 3. The student will use appropriate technology and mathematics skills to access, gather, store, retrieve and organize data.
2. History and Nature of Science. D. Historic Perspectives 2. The student will cite examples of how science and technology contribute to changes in agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing, or communication.
3. Earth and Space Science. A. Earth Structure and Processes, The student will investigate the impact humans have on the environment.

Materials:

- A pan, or tub of water. This container should be at least twice as deep and twice as long as the maximum size of the boat. You can use one large common plastic pool or tub for testing. You will need at least one set of a smaller container (e.g., plastic shoebox) within a larger one (plastic dish pan or 13 x 9 cake pan) to allow students to check the water displacement of their boats.
- Beakers of graduated cylinders with milliliter markings.
- Aluminum foil, 2 large sheets of 3-foot-long.
- A roll of waxed butcher paper, 3-foot-long sheets.
- Wooden splints, pipe cleaners, plastic straws, match sticks, toothpicks, etc. Anything that can be used as support for the skin of the ship.
- Glue, hot glue gun, duct tape or other tape.
- Taconite pellets
- Permanent markers for marking load lines

- Ship Specifications student sheet

Note: The amount of materials needed by each group depends on the maximum allowed size of the boat; the materials listed above are for a boat that is 12 inches or less in length.

Attention Getter

Show pictures of some of the ore ships and some of the “salties” on the Great Lakes. The students may discuss: “How can the captains of these ships be sure they will not sink, especially when they are loaded with thousands of tons of iron ore?”

Vocabulary

Load line- the safe freeboard of the ship

Freeboard- the distance between the water line and the deck or gunwale

Archimedes- Greek Mathematician/physicist 212 B.C.

Keel- the centerline on the ship’s hull

Hull- the body or skin of the ship

Ribs- the support structure of the hull

Displacement- the weight of water displaced by the ship’s hull

Procedure

Assign students to teams of 2-4 (or whatever works for your particular class size). Tell students that each team will be in charge of designing, building, and testing a boat.

Each boat should:

- Include the three major parts of all of the ships (a keel, ribs attached to the keel, and a hull).
- Be less than or equal to the maximum specified length (you specify the length). For example using a 13x9 inch cake pan ship length should be 12 inches or less.
- Be capable of carrying a load at least as heavy as the boat itself.
- Be “seaworthy” in both calm and rough waters. This will be a good place to re-introduce the Edmond Fitzgerald they learned about previous.
- The boat must be constructed from the materials provided.

After the boats are built, the students will develop a procedure for determining the boats' maximum safe load. Each group will float its boat in a tub or container of calm water and add taconite to the boat until it sinks; this weight represents an “overload” for the group's boat. Then students should repeat the procedure, adding taconite only until they feel the boat has reached a safe load. Using a permanent marker, they should mark the safe load line.

This is only a general procedure. Allow students to develop their detailed procedures. For example, where the load will be distributed on the boat will open a discussion on listing and so on. Remember that the load line should be level when carrying as much taconite as possible, but safe for varying weather conditions.

The procedure of determining their boat’s water displacement is similar to the procedure Archimedes used. The students be more scientific about their measurements (if time allows) by having the students do the following: Set the dish pan on a flat surface and set the plastic shoebox in the middle of the dish pan. Completely fill the shoebox to the very rim with fresh water, making sure not to spill water over into the dish pan. Students should then float their unloaded boat on the water in the shoebox and begin loading it carefully and evenly with taconite until they reach the load line. Water will spill over the side into the dishpan. When their load line is reached, they should carefully lift out the boat, then the

shoebox. Pour the water in the dishpan into the beaker or graduated cylinder. This is the amount of water the boat displaces when fully loaded (the load line).

Remember that water displacement is measured in the weight of water displaced rather than the volume of water displaced. In this case,

1 milliliter of fresh water = 1 gram of water.

Therefore, you can measure your water displacement in grams.

For example, if a ship that displaces 1,000 tons of water, this is equivalent to 1,000 U.S. tons x 1,100,000 grams/ton = 1,100,000,000 grams. It is all about the math.

There are many other questions that may be asked like: 1 ton of water is equal to how many gallons? How many cubic feet of water are in a ton of water? What is the ship's displacement in cubic feet? How many grams in a U.S. gallon? Etc.

Finally, each team can test its boat in "rough" water. Teams should load their boats to full and create waves with plastic lids or small plates. The water should be rough enough to create turbulent seas, but not so rough as to destroy the boats. Ask students what modifications they could make to their boats to make them more "seaworthy" in rough weather. This may lead to a discussion on why container ships look the way they do. The history of the warship is interesting here as well for the stability of the early battle ships.

Distribute the Ship Specifications Student Study Sheet (see attached). Each student will complete this sheet. Each team will also describe to the class how they built their boat, how they determined its load line, and what the water displacement is.

Assessment

Assess student understanding with a class discussion or written answers in a journal to the following questions examples:

- Which boats seemed to hold the most taconite? Were they the biggest boats? Were they shaped differently than the other boats? Was their design similar to the Great Lakes ore ships?
- When you added taconite to your boats, did you put it at one end, side, or along the whole length of the boat? Why?
- How did your boat fare on rough seas?
- How would you improve your boat design if you were planning to build another one?
- What other limiting factors can you think of for shipping on the Great Lakes?

(This last question will lead the class discussion on depth of the seaway and the lock systems on the Great Lakes [Lesson 3]).

Extensions

Discussion on the Edmond Fitzgerald and why it may have sank.

Resources:

Additional resources about sinking, floating, and boats can be found in the following resources:

- The Way Things Work, by David Macaulay, Houghton Mifflin; ISMB 0-395-42857-2; 1988. This book has a good section on boats and submarines.
- NOVA Online's Buoyancy Brainteasers has activities and problems to solve on floating and sinking.
- Hertal, Robert Capt. 1999 The Edmond Fitzgerald Lost with All Hands Spring Lake, Michigan: River Road Publications, Inc.

Websites:

<http://www.nmm.ac.uk/server/show/conWebDoc.153>

<http://www.sciencenetlinks.com/lesson.cfm?DocID=301>

<http://www.greatlakes-seaway.com/>

<http://www.greatlakes-seaway.com/en/seawaymap/index.html#portinfo>

<http://www.gwpda.org/naval/scnavdes.htm>

Ship Specifications Student Study Sheet

Name: _____ Period _____

The ship was christened on this date: _____

The builders were:

- 1.
- 2.
- 3.
- 4.

The name of the ship is: _____

The Specifications

Total length:

Width:

Draft:

Total weight:

Water displacement, fully loaded:

Materials used in hull, keel, & ribs:

Include your design "blue prints" on a separate sheet or sheets.