Clay Boats

Synopsis

Each student uses a small quantity of modeling clay to make a boat that will float in a tub of water. The object is to build a boat that will hold as much weight as possible without sinking. In the process of designing and testing their boats, students discover some of the basic principles of boat design and gain first-hand experience with concepts such as buoyancy and density.

This exercise can stand alone as a process skill activity, or it can be used as an introduction to the topics of density and/or buoyancy, which are addressed in the exercises **Floaters and Sinkers** and **What Floats Your Boat?** We recommend that the exercise **Paper Towers** be done prior to this one, since the concept of center of gravity may be helpful to students when they analyze their successful and unsuccessful boat designs.

Objectives

Like the **Paper Towers** exercise, this exercise provides students with another opportunity to use model-building as a way to help understand the forces and phenomena at work in the world around them. Both successful and unsuccessful models allow students to make inferences, refine hypotheses, and draw conclusions about the behavior of materials and structures. All of these are important aspects of the type of inquiry we call science. As such, this exercise addresses the Science as Inquiry strand of the *NC Standard Course of Study for Middle School Science*: "Mastery of integrated process skills: formulating models." In addition, after completing this exercise students will be able to describe some of the relationships between form and function in man-made structures, using elements of boat design as examples.

Materials

- One half stick (about 2 ounces) of modeling clay (non-hardening) per student
- One tub of water, at least six inches deep, per four or five students
- 100+ large washers, *e.g.*, 1.5" fender washers (available from hardware stores)
- paper towels

Procedure

Part I: Write on the board, "Create an object out of clay that will float." Give each student a half stick (2 oz.) of clay, and have several tubs of water placed throughout the classroom. Let them know they can test their objects as often as they like. (The paper towels can be used to pat the clay dry before shaping into new designs.) Part I should take no more than 5 minutes.

Part II: As students successfully complete Part I, challenge them with a new goal. Write on the board, "Design an object out of clay that can carry the largest load of washers possible." Show students the washers that will be used to make up the load.

Allow about 15-20 minutes for Part II. As students work, encourage them to continue making improvements every time their boats sink. Students may become competitive and want to declare a winning boat, but it is possible that a tie for the number of washers supported will occur. Should this happen, you could try using a balance to determine the actual mass of the washers held, since there will be slight variations in the masses of individual washers.

Discussion and Extensions

Stimulate a discussion by asking questions referring to experiences the students had while designing their boats. Some examples include:

- What did you notice while building your boats?
- Why did you make the changes you made?
- What boat designs seemed to work best? What is it about these designs that made them successful?
- What boat designs didn't seem to work well? What is it about these designs that made them less successful or unsuccessful?
- How did your boat change throughout the activity?
- How does the process of building a boat relate to the way the scientific process works?

The last question may take some guidance in order for students to formulate an answer. The point is to lead students to realize that:

- each boat design they tested reflected a hypothesis they had about what would help the boat float;
- each test produced data -- either the boat sank or it didn't;
- the data was used to formulate a new hypothesis, which led to yet another test.

This exercise can stop here, or it can go on in two or more different directions. Most likely, students will have a number of observations about the shapes of successful boats, and express some curiosity about "real" boats and their design features. They may also wonder what it is that allows a boat to float in the first place. Thus, the principles of boat design and the principles of density and buoyancy are two obvious directions for extending this exercise. What follows is information about the shapes of boat hulls or the parts of the boat that are underwater, since this is what students were experimenting with in this exercise. The principles of density and buoyancy are left to the exercises **Floaters and Sinkers** and **What Floats Your Boat?**

Boat Hulls -- Form and Function

With photographs from books and magazines, students can compare their own designs to boats commonly used for trade and recreation, both past and present. They can be guided through observations about the trade-offs between speed (how fast the boat can go with a given power source), stability (how likely the boat is to tip over under a given sideways force), draft (how deeply the boat rides in the water), and cost (how expensive a given design is to build). As students consider the different types of boats and their features, try to emphasize the relationships between the design, or form, of the boat, and its function.

The more successful of the student-designed clay boats probably resembled a flat-bottomed bowl. This design will hold many washers -- as long as the weight is carefully distributed in the boat. This is a feature of flat-bottomed boats: they require careful balancing of the cargo and passengers, or else they become unstable and prone to tip and take on water. A distinct advantage of flat-bottomed boats is that they have a shallow draft, meaning their hulls do not extend very far down below the surface of the water compared to other hull shapes (see Figure 1). Flat-bottomed boats are thus desirable for moving around in shallow water. Their simple shape also makes them the least expensive type of boat to build. Flat hulls are typically found in small utility boats such as Jon boats, and were commonly used in the last century as barges to transport goods on the quiet waters of canals in this country and in parts of Europe.

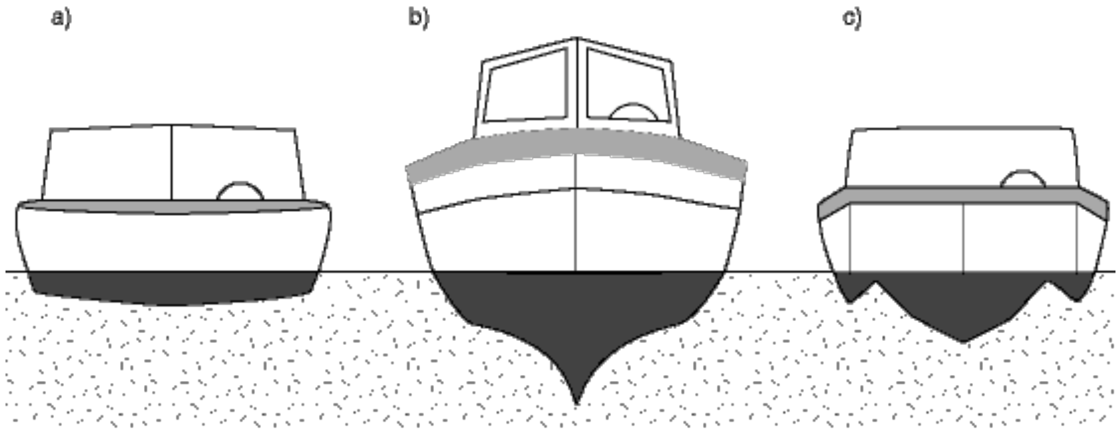

Figure 1. Hull designs: flat (a), round with keel (b), and multi-hulled (c).

The more contemporary use for flat-bottomed boats is as high-speed runabouts for recreational purposes. In this case the flat hull is designed to rise up and ride on top of the water rather than cutting through the water, thereby encountering the reduced friction of moving through air instead of water (see Figure 2). Although it takes a lot of engine power to get the hull up, at which point the boat is said to *plane*, it can then travel at very high rates of speed. A disadvantage of flat hulls is that they give a rough ride if any waves are present, because the entire width of the boat's bottom is in contact with the water. (Even when planing, the back, or stern, of the boat is still in the water.)

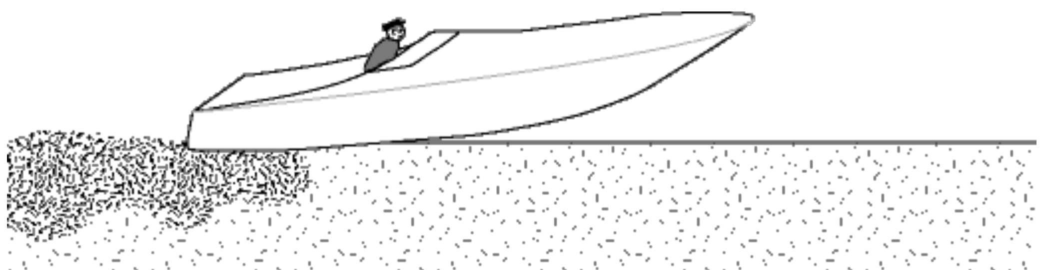

Figure 2. A planing speedboat.

Some students may have tried making boats from their clay that were shaped more like canoes, with tapered ends and rounded hulls. Tapered ends certainly let a boat move through the water more efficiently than a bowl-shape, since water can easily flow around the front (bow) of the boat if it is tapered. The rounded hull, however, presents a problem because such boats roll easily and take on water or capsize. Large sailboats, fishing trawlers, and cargo ships, which do have rounded hulls, generally also have *keels*. A keel is a narrow V-shaped extension of the hull along the boat's centerline that helps prevent excessive rolling (see Figure 1b). Because the keel extends down into the water, these boats cannot travel in shallow water the way boats with flat bottoms can. With their complicated hull shapes, these boats are also expensive to build.

Multi-hulled boats, such as catamarans, trimarans, pontoon boats, and some house boats, are very stable due to their wide stance in the water. Each of the hulls can be flat, but usually they are either round or V-shaped. Multi-hulled boats are usually the most expensive to build.

Superstructures and Center of Gravity

The hull shape is the main determinant of how the boat interacts with the water, but real boats carry structures and cargo above their decks, too. Structures such as cabins, masts, cranes, booms, and communications towers that are found above the deck are known collectively as the boat's *superstructure*. If students have done the **Paper Towers** exercise, they should have a good working knowledge of center of gravity and how it affects tall structures, particularly in the face of a sideways force such as a strong wind.

Ask students how they think a tall superstructure would affect a ship when strong winds blow from the side. Also ask how a tall superstructure would affect a ship if it rolled to one side due to large waves. If there is time and student interest, you could provide materials such as Popsicle sticks and white glue, and challenge students to make the tallest floating superstructures they can for their boats. Just as in **Paper Towers**, you could blow on the boats from an arm's length away to test each boat's *seaworthiness*.

Students should be able to realize that it is necessary to keep the center of gravity as close to the midline of the ship as possible. Once the center of gravity is beyond the deck of the ship, it will tip over (just as the towers tipped over once their centers of gravity got beyond their bases). Ask students where they think heavy cargo should be placed on a ship. Point out that ships carry *ballast*, or extra weight (usually in the form of scrap metal), in their keels for the purpose of keeping the center of gravity low and along the midline of the ship. You can also ask students to speculate on the comparative keel depths of ships with lots of superstructure versus those with little superstructure.

Acknowledgement

Figures 1 and 2 and some of the information about boat hulls have been adapted from information provided by the *Nautical Know How, Inc.*, website, found at www.boatsafe.com/nauticalknowhow.

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