MSCOPE Final Project Report
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Sink or Swim

Type of Project: Facilitated activity with optional demonstration
Target Museum: SciTech Hands-On Museum, Aurora, IL
Target Audience: 8-11 year old visitors

Sink or Swim. Photo: M. Leighton

Big Idea

The aim of *Sink or Swim* is to teach the principles of density and buoyancy through guided experimentation. Aimed at an 8-11 year old age group and therefore highly suitable for SciTech, this activity takes a highly interactive approach. Children predict what will happen when different types/sets of objects are placed in a tank of water, carry out the experiment, then discuss with the facilitator a) what happened, b) their prediction and c) the explanation. Following this, the children use what they have learned to make objects that float sink and objects that sink float. The strength of the activity comes from the directed but still open-ended nature of the experimentation that can be tailored to the

audience, from the hands-on approach, and from the ability to directly address preconceptions. It differs from similar activities that teach density in the context of sinking and floating objects because it invites visitors to design combinations which change the results of the experiments.

Description

Sink or Swim is highly flexible and can function as a demonstration, "directed play", or both. In all three situations, it needs at minimum a low level of supervision by nearby volunteers or museum staff because of the open tanks of water. The physical components remain the same in all situations, and consist of tanks of water and a selection of contrasting objects. These are listed below.

The exhibit is designed to be easily transportable, able to be set up in school classroom, in the classroom area of SciTech, or potentially on the floor of SciTech near the other water exhibits on a low table.

Suggested Materials

Suggested materials are for 15 visitors at one time (5 visitors per aquarium). The objects have been selected to serve as contrasts to each other. Some objects will have Velcro and rubber bands, to allow attachment of other objects to make them sink/float.

3 5-gallon aquariums
1 sealed[1] plastic container filled with sand
3 additional sealed plastic containers filled with sand with Velcro[2] (one set per aquarium)
1 empty sealed plastic container
3 additional empty sealed plastic containers with Velcro
2 pieces of the same type of wood but different sizes [small: 1x2x4.5 inches; large: 4.5x4.5x2 inches]
Acrylic container, [4.5x4.5x2 inches], for use comparing the weight of the larger piece of wood to the same volume of water
Additional pieces of wood of different sizes
One ball of Plasticine (waterproof molding material) and one Plasticine cup made of the same amount of clay as the ball
Ping-pong balls with Velcro
Weights (metal nuts) with rubber bands or Velcro attached
Plastic boat
Sponge
Plastic dolphin
Pumice stone

[1]Containers should be sealed with epoxy to prevent leaking and keep visitors from opening them.
[2]Velcro should be attached to objects with epoxy to extend lifespan.

Rock
Golf ball
Piece of rope
Additional Plasticine
High precision digital scale (5-gram increments)
Papertowels
Water

Supplementary visual material

To aid the facilitator in the explanation of the science principles, visual materials will be included (see Supplementary Materials). These include labels which briefly introduce the activities, two explanations of density, and one explanation of buoyancy.

Some suggested materials. Photo: M. Hopkins

Directions

One to three tanks are partially filled with water and objects arranged in no particular way around tank the (s). One of two challenges is posed to the visitor: I) Predict which objects will sink or float; and/or II) Make the objects which sink float and the objects which float sink.

I). Predicting which of the objects will sink or float

1. Introduce the concept of density: The container of sand sinks because it is heavier than the same amount of water. A container of air, on the other hand, floats because it is lighter than the same amount of water.

2. Invite visitors to divide up the objects into two groups: one of objects they think will sink and one of objects that will float.
3. Once the visitors have made two piles, have them place all objects from one into the water. Did all of the objects float or sink as predicted? Which objects were surprising to the visitors? Why did the visitors choose certain objects to sink or float?
4. Repeat with the other pile of objects.

II. Make the objects which sink float and the objects which float sink

1. The ball of clay sinks because it is heavier than the same amount of water. A container of air, on the other hand, floats because it is lighter than the same amount of water. Demonstrate that even though a ball of clay will sink, we can change the clay (by remolding it into a cup) in order to make it float. We change the shape of the clay so that it (plus the air it contains) takes up more space than when it was a ball.
2. Invite the visitors to try to make the additional objects (see materials list above) which sink float and vice versa but attaching objects to one another via the Velcro and rubber bands.

In addition to directed play, the exhibit may also be treated as an interactive demonstration where the visitors are led through a series of comparison experiments. See Supplementary Materials at the end of this report for example scripts for two demonstrations. Depending on the setting, a demonstration may also precede or follow directed play.

Science Background

Density is mass over volume. Mass is the amount of matter contained by an object. Mass is measured using its weight, which is the gravitational pull of the earth on an object due to its mass. Volume is the amount of space in three dimensions that an object occupies and is often measured as the volume of water the object displaces when completely submerged. If you keep the mass the same but increase the volume, density

decreases. If you keep the volume the same but increase the mass, density increases. Objects which are made of the same material have the same density, despite their individual volumes. Two objects made of a material which is less dense than water will both float but the larger one will displace more water than the smaller object. The larger object will also float such that its top surface is above that of the smaller object and its bottom surface is below that of the smaller object. This effect is due to buoyancy.

Buoyancy is the net upward force exerted by a fluid on a submerged object. This force is equal to the weight of the displaced fluid (known as Archimedes Principle). The direction of the buoyant force is opposite that of gravity. An object which floats is said to be positively buoyant; that which sinks to be negatively buoyant. If the object hovers in the water column, it is neutrally buoyant.

A container filled with air floats because the total mass of the container and the air is less than the mass of the same volume of water; therefore the container of air is less dense overall than the water. An open cup of boat floats by the same principle. Engineers must balance the amount of air space within a ship with the mass of the ship itself plus any cargo in order to insure that the ship will not sink or ride low enough on the water's surface to start taking on water (which eventually replaces the air).

Evaluations

Evaluations were conducted on the floor at SciTech and at the Museum of Science and Industry, Chicago, (MSI). The atmosphere of each museum is quite different: MSI is large and targets all age groups. Evaluations were conducted on weekday mornings, however, when a larger proportion of the visitors are school-groups. SciTech is a small space whose primary target age is 5-12 year olds. Evaluations were conducted on weekday mornings, when all attendance

13-14 year olds during evaluations.
Photo: M. Leighton

consists of school-groups.

Four evaluations were performed with locations specified: 1) Demonstration closely following script 2 (see Supplementary Materials) where visitors were asked to predict the outcomes of three experiments demonstrated for them (MSI); 2) Facilitated activity where visitors were asked to divide the objects into two groups, one of objects they predicted would float, and one predicted to sink and then helped to test their predictions (SciTech); 3) Facilitated activity where visitors are asked to use the materials given to them to make the objects which sink float and vice versa (MSI); 4) Demonstration of the three experiments followed by directed play where visitors are asked to make objects which sink float and vice versa (MSI).

Results: Target age range

The target age range for *Sink or Swim* was determined during the first evaluation. Audiences for the demonstration consisted of three major age groups, Kindergarten and younger, 9-10 year olds, and 13-14 year olds. The results of this evaluation suggested that Kindergarten-age children have a difficult time deciding which object is heavier and which is lighter. Often they do not make the connection between the results of a previous experiment (whether the heavy object sank or floated) and what they think will happen when it's their turn to guess which will sink and which will float—though some learn after the experiment has been repeated a few times. Chaperones were surprised that the children had a hard time guessing which would sink even after seeing multiple experiments. One group was able to guess correctly only with intervention from the chaperone. Nonetheless, the children enjoy experimenting with the objects and everyone wants a chance to hold the objects and predict which will float and sink. They also seem to enjoy the competitive aspect of the experiment (who predicts correctly and who does not).

In comparison, the oldest children (13-14 years old), found most of the experiments trivial. The outcome of the wooden block experiment is still less obvious than the containers filled with sand and air (not all predicted correctly) but students generally appeared uninterested. The children felt that the concepts were "basic" and "review" for them.

The demonstration was most successful for the 9-10 year old groups. Children correctly predicted which of the plastic containers would float and which would sink. Introduction of the concept of density seemed appropriate. Children did not predict unanimously that both wooden blocks will float; in fact all four possible outcomes (that both will float, that both will sink, that the smaller one will float and the larger one will sink, and vice versa) were often suggested. Children appeared to understand the explanation that both are made of the same material, so both would act in similar fashion (here floating), once the experiment has been performed. In fact, one student came up with this explanation himself. They were able to notice (with help) that the larger block was riding lower in the water (and higher above the surface) than the smaller block. This is a good point to reiterate the concept of density and introduce the term buoyancy. It was clear that the children were interested because they wanted to see the experiments repeated and suggested their own modifications to the experiments, such as placing one of the plastic containers on the wooden block to see what happened.

10 year olds comparing objects during evaluations. Photo: M. Leighton

Results: How directed should the activity be?

Including a demonstration at the start of *Sink or Swim* insured that all visitors heard words such as "density" in the context of the experiments but did increase the length of time the visitors must be engaged with the activity. Visitors needed extra prompting to start experimenting themselves following a demonstration (perhaps they did not believe that they were allowed to play in the water themselves after so much structured experimentation). With or without a demonstration, visitors first tried to attach every object to every other object with no clear objective as to why they were choosing particular objects. However, this quickly and consistently gave way to more deliberate experimenting. The challenge to manipulate the objects in order to make the ones that

sink float and vice versa held older visitors' attention longer than simply dividing up the objects into two groups. In fact, children did not stop experimenting with the objects unless 1) There was not enough room around the aquariums; or 2) Their parents or chaperones decided it was time to stop. Nonetheless the challenge to simply divide the objects into two groups may be more appropriate for SciTech's youngest visitors. This "directed play" part of *Sink or Swim* allowed the facilitator to interact with individual visitors, reiterating or emphasizing concepts as visitors experiment with the objects in different ways.

Evaluations suggested that 5 is the maximum number of students per 5-gallon tank.

Educational Standards

Sink or Swim meets science standards regarding learning about properties of objects as well as methods of scientific inquiry set out by the National Research Council for both younger and older children (grades K-8)[3] as well as those set out by the Illinois Learning Standards of Science[4]. The activity is able to meet standards for a large age range because it may be tailored to a particular individual or audience by varying the level of experimentation, independence, and explanation. Younger children are exposed to concepts regarding the properties of objects, such as weight and material, and learn how to qualitatively describe the objects and their behaviors through interaction with the facilitator. Older children are exposed to more advanced concepts regarding the properties of objects such as density and the contribution of different components to the properties of an object. Older children are also exposed to the tools necessary for scientific inquiry, such as making predictions, testing those predictions through experimentation, and then communicating their results through interaction with the facilitator.

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[3]National Committee on Science Education Standards and Assessment, National Research Council, 1996, *National Sciences Education Standards*: Washington D.C.: National Academy Press, 272 p. Also available online at: http://www.nap.edu/readingroom/books/nses/.

[4] As specified in State Goal 11-A, available at http://www.isbe.state.il..us/ils/science/standards.htm.

Other Similar Exhibits

Sink or Swim was inspired by other exhibits which directly or indirectly incorporate floating and sinking properties of objects into them but do not explain why those objects sink or float. For example, the Field Museum has an exhibit entitled "What travels on ocean currents?" within their permanent exhibition, *Traveling the Pacific*, which lowers objects into water to demonstrate which are more likely to be dispersed along ocean currents. *Sink or Swim* incorporates the simplicity of the exhibit at the Field Museum (lowering objects into water and observing the outcome) into a more interactive context by conferring some of the decision of which objects are to be tested to the visitors as well as encouraging manipulation of the objects by allowing access to the tank of water. Because visitors are able to interact with the objects and the water themselves, they come away from the activity with a strong experienced-based understanding of why objects sink and float.

"What travels on ocean currents?", an exhibit in the Traveling the Pacific *exhibition at the Field Museum, Chicago. Photo: M. Hopkins*

Supplementary Materials—Example demonstration scripts

The goal of the first script is to teach the concept of density in the context of why different objects sink or float in water. The goal of the second script is to teach both the concept of density and buoyancy and then apply these two concepts to how boats float. Both scripts use the same set of materials and the same sequence of experiments; the difference is only in the level of explanation, particularly in part 11 and at the end of the demonstration.

Demonstration Script I: Density

1. Begin by welcoming guests and tell them that in this demonstration, we will do a series of experiments to learn about why some things sink and others float.
2. Hold up the two plastic containers. Note that they are the same size and shape but that they are filled with different materials—in this case, one has air and one has sand.
3. Ask for a volunteer to predict whether each object will sink or float (you may hand the objects to them).
4. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.
5. Repeat with as many visitors in the group as desired.
6. While repeating the experiment, explain that the reason that the container with air floats in water is because it is lighter than the same amount of water. This property is called density; here the container with air is less dense than the water. The container with the sand sinks in water because it is heavier than the same amount of water. Here the container with sand is denser than the water. In general, things that float are less dense than water; things that sink are denser than water.
7. Next hold up the two pieces of wood. Note that they are made of the same material but are a different size and shape from one another.
8. Ask for a volunteer to predict whether each object will sink or float.
9. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.
10. Repeat with as many visitors in the group as desired.
11. When the two pieces of wood are in the water, explain that even though the larger block of wood is heavier than the lighter block of wood, it does not sink because is still lighter than the same amount of water.
12. Next hold up the ball of clay and the clay cup. Announce that the two objects are made of the same amount of the same material. Now they differ in shape. You may prove this to the audience by weighing each on the scale (and have a volunteer help you with this).
13. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.
14. Note that because the ball sinks, the material each object is made out of must be denser than the water. So why doesn't the cup sink also? Ask the visitors what is

in the cup. Once the audience (or you) have identified that the cup is filled with air, explain that it the combined weight of the cup and the air is less than the same volume of water.

Demonstration Script II. Density and buoyancy

1. Begin by welcoming guests and tell them that in this demonstration, we will do a series of experiments to learn about why some things sink and others float.
2. Hold up the two plastic containers. Note that they are the same size and shape but that they are filled with different materials—in this case, one has air and one has sand.
3. Ask for a volunteer to predict whether each object will sink or float (you may hand the objects to them).
4. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.
5. Repeat with as many visitors in the group as desired.
6. While repeating the experiment, explain that the reason that the container with air floats in water is because it is lighter than the same amount of water. This property is called density; here the container with air is less dense than the water. The container with the sand sinks in water because it is heavier than the same amount of water. Here the container with sand is denser than the water. In general, things that float are less dense than water; things that sink are denser than water.
7. Next hold up the two pieces of wood. Note that they are made of the same material but are a different size and shape from one another.
8. Ask for a volunteer to predict whether each object will sink or float.
9. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.
10. Repeat with as many visitors in the group as desired.
11. When the two pieces of wood are in the water, show the visitors that if they bend down to the level of the water, they'll see that the bottom of the larger piece of wood is lower in the water than the smaller piece of wood. Note that the weight of the entire block of wood is the same as the weight of the volume of water that the wood is displacing. Because the larger piece of wood weighs more, it must displace a larger amount of water than the smaller block of wood and for this reason, "sits" lower in the water than the smaller piece of wood. This is called buoyancy. Buoyancy is a force which works in the opposite direction of gravity.
12. Next hold up the ball of clay and the clay cup. Announce that the two objects are made of the same amount of the same material. Now they differ in shape. You may prove this to the audience by weighing each on the scale (and have a volunteer help you with this).
13. Once the volunteer has made his/her predictions, hold up the two objects again and announce what the predictions are for each object. Then place both in the water and announce the results.

14. Note that because the ball sinks, the material each object is made out of must be denser than the water. So why doesn't the cup sink also? Ask the visitors what is in the cup. Once the audience (or you) have identified that the cup is filled with air, explain that it the combined weight of the cup and the air is less than the same volume of water. In fact, the cup+air weighs exactly the same as the amount of water the cup is displacing.
15. This concept may be further demonstrated by putting something in the cup so that the cup sinks lower in the water but does not sink. Note that this time the combined weight of the cup+air+object is still less than the same volume of water. Continue to fill cup until it sinks.
16. The demonstration can continue with visitors suggesting different experiments to do with the objects available. For example, visitors in the past have suggested putting objects on the wooden block until it sinks.

Supplementary Materials—visual aids

1. Instruction panel for challenge I
2. Instruction panel for challenge II
3. Explanation of density I
4. Explanation of density 2
5. Explanation of buoyancy

TRY IT: Place the containers of sand and air in the tank. Which **floats**? Which **sinks**?

The container of sand **sinks** because it is **heavier** (has more mass) than the same amount of water.

A container of air **floats** because it is **lighter** (has less mass) than the same amount of water.

TRY IT: Divide the rest of the objects into **2** piles:

1 objects that you think will **float**

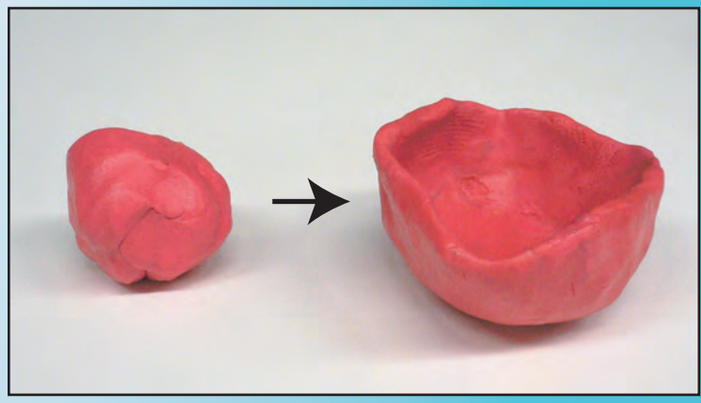
2 objects that you think will **sink**.

Then put the objects in the tank to find out!

Can you make objects which usually sink float?
What about objects which usually float sink?

TRY IT:
Attach objects
to one another

TRY IT:
Change the shape
of the objects



Same volume

with
LESS mass

↓

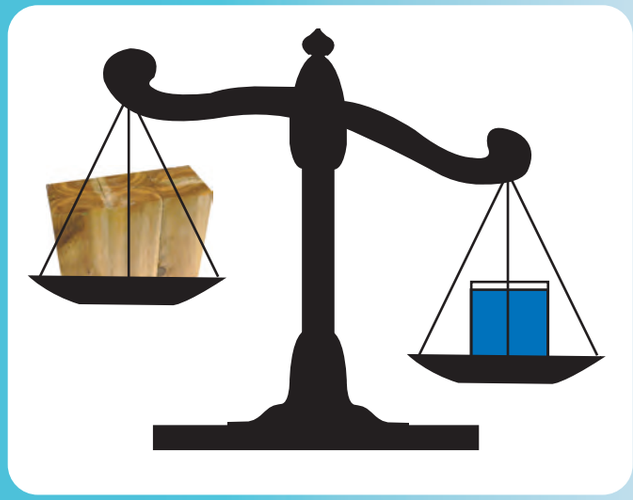
SMALLER DENSITY
(like the container
with air)

or with
MORE mass

↓

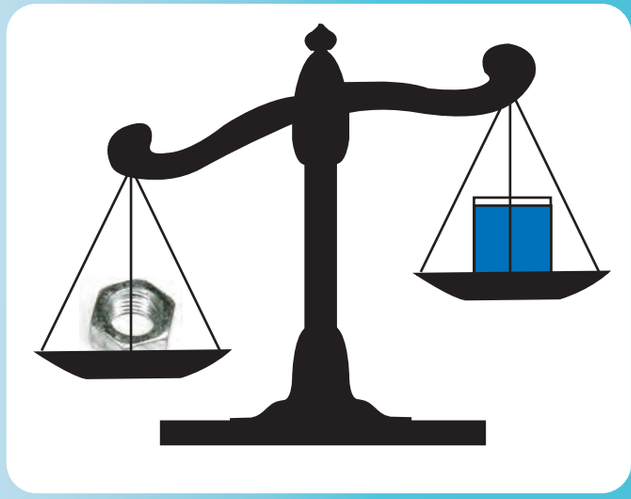
GREATER DENSITY
(like the container
with sand)

If an object is LESS DENSE than water, then it has LESS MASS than the SAME amount of water:



(like the pieces of wood)

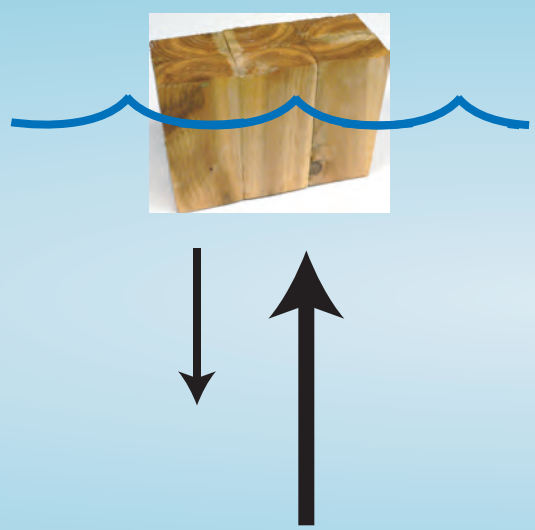
If an object is MORE DENSE than water, then it has MORE MASS than the SAME amount of water:



(like the metal weights)

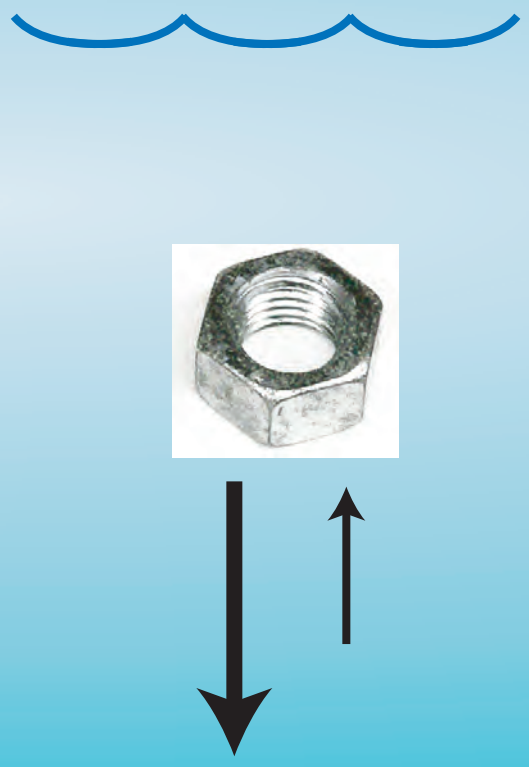
BUOYANCY is the upward force that pushes on an object when it is in water

FLOATER:



upward force
is **greater** than
weight of object

SINKER:



upward force
is **less** than
weight of object