ICE FLOATS!

Concept Overview:
This Lesson develops precursor understanding about how and why ice floats. Water is less dense in its solid phase than in its liquid phase. Ice displaces less water than its volume.

Concepts:
- Buoyancy
- Density
- Floating
- Displacement

This activity provides a concrete experience of:

- Archimedes' principle of displacement
- Ice floating in water
- Measuring displacement of floating ice
- Near-freeing water sinks

Grade 3 – 5 Concepts
- The random motion of water molecules creates water pressure; floating is a result of upthrust (buoyancy), the upward direction of water pressure.

- As water changes into ice, it takes up more space than it does as liquid water, which is to say, ice is less dense than water.

- Ice floats. Ice is about 91% as dense as liquid water. This means that about 91% of floating ice is underwater and about 9% of the ice is above the water line.

Lesson Summary & Objectives:
Young Children know that ice floats. One objective of this lesson is to invite students to understand why it happens. This leads us into the relationships of several concepts: displacement, buoyancy, and density.
Objective 1: Notice that if you push down on water, the water pushes back. The random motion of water molecules produces water pressure in all directions. The combination of gravity, air pressure, and water pressure results in a net upward force that you can feel, called upthrust.
Objective 2: Notice that ice floats in water. Anything that floats in less dense than the liquid it is floating in. Ice floats in liquid water. Unlike most substances, water is denser in its liquid phase than in its solid phase. There are more molecules per unit volume in liquid water than in solid ice.
Objective 3: Notice that ice sinks part way into water. When ice is floating in water, a small portion of the ice emerges above the water level while most of it is submerged.

Objective 4: Notice that liquid water close to the freezing point actually sinks. Cooler water is denser than warmer water and is most dense just above freezing.

STANDARDS
Project 2061 Benchmarks
1B-The Nature of Science: Scientific Inquiry
Grade 3 – 5 Page 11
• Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological and social questions.
4D The Physical Setting Structure of Matter
Grades 6 – 8, Page 78
• Equal volumes of different substances usually have different weights
Content Standard B Physical Science: Properties and changes of properties in matter
Grade 5 – 8, Page 154
• A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances by using one or more characteristic properties.

ESSENTIAL QUESTION: Why is it important that ice floats? What can we learn by studying the floating of ice in natural conditions such as lake ice, river ice, pond ice, sea ice, and icebergs? What can we say, draw or write about ice floating?

ACTIVITY QUESTION: Why does ice float? What can we learn about ice by watching how ice floats? What observations about ice floating can we record? What can we say, draw, or write about ice floating? What can we say, draw, write about ice floating that we look at, touch, and examine in class?

BACKGROUND
This activity connects to the principles of buoyancy, displacement, and gives students a tool to measure relative density of ice compared to liquid water. The notion of relative density has to do with the proportion of a floating object that will be submerged. If the body is two thirds as dense as the fluid, then two thirds of its volume will be submerged, displacing it the process a volume of fluid whose weight is equal to the entire weight of the body.
In the case of a submerged body, the apparent weight of the body is equal to its weight in air less the weight of an equal volume of fluid. The fluid most often encountered in applications of Archimededs’ principles is water, and the specific gravity of a substance is a convenient measure of its relative density compared to water, where water has a specific gravity of 1.

Archimedes (287 – 212 BC)
Archimedes was a Greek scientist who lived in Syracuse on the island of Sicily. The classic story of Archimedes is that he spent all day thinking and thinking. After a long day of thinking, Archimedes decided to take a bath. As he stepped into the water. . .

something interesting happened. He noticed that as he immersed himself in the water, the water level rose. When he put his whole body into the water, the water level rose even more than before. When he stepped out, the water level dropped back down to where it was before. T hen he made the great leap of understanding: the water level rose by exactly the amount of space that his body volume took up – he displaced the water by exactly the amount of his own volume!
This was so amazing that he leaped out of the bath and shouted “Eureka!! Which means I’ve got it! I found it! I discovered it! Historically, this resulted in Archimedes writing a thesis On Floating Bodies, which influenced scientific thought even today.

How can we apply this to understand more about ice floating in water?
Archimedes’ principle describes buoyancy, or upthrust, the upward direction of fluid pressure   A body immersed in water experiences an upward force equal to the mass of the fluid displaced by the body. If the weight of an object is greater than the weight of displaced fluid, it will float. If the two are equal, it is suspended, neither floating nor sinking. For example, when an object is placed in water, it will displace its own volume of water, and that water will push back against it proportionally, producing an upthrust.

Water has a weight density of 62 pounds per cubic foot. It an object weighing 62 pounds has a volume that displaces 2 cubic feet of water, it will float. The displaced water will weigh 124 pounds and the pressure of that water would be enough to keep the object floating. Another more densely packed object, also weighting 62 pounds, has a volume that displaces ½ a cubic foot of water. This object will sink. The displaced water will weigh 31 pounds and the pressure of that water would not be enough to keep the object afloat. We can also explain this example in metric units. One liter of water has a mass density of 1 kilogram.

Ice is water. By observing ice closely, we can measure the displacement of the ice: 91% of ice is submerged; 9% emerges above the water line. Ice is 91% as dense as water. A cubic foot of ice displaces a cubic foot of water. A cubic foot of ice is only 91% of weight density of a cubic foot of water, or about 56 pounds. So 56 pounds of ice displaces 62 pounds of water. The 62 pounds of water pushes back with a resultant upthrust that floats the ice so that the difference in the two weight densities is up out of the water, 9%, or about 6 pounds.

If an object displaces more than its weight in water, it will float; if an object displaces less than its weight in water, it will sink.

Water within 4 degrees C of its freezing point is at its most dense, denser than warmer water. Near-freezing water displaces less than its weight in warmer water and it will sink. This can also be observed. At this temperature, the colder, denser, water sinks toward the bottom, and the warmer water (less dense) moves up toward the top. On Earth, this process helps the oceans circulate, as cold water descends in Arctic regions and invigorates the ocean depths. In nature, as air gets colder, ice crystals form (and float), eventually, the top freezes over, and the ice floats, creating an insulating layer. This dynamic system makes it possible for liquid water to remain below the surface of ice in ponds, lakes, rivers, and oceans – which also means that life can survive in those conditions.

Frozen Lake Density

When the surface temperature in a lake reaches 0 degrees C, ice forms and floats on top of the lake. The ice becomes an insulating layer on the surface of the lake; it reduces heat loss from the water below and enables life to continue in the lake When ice absorbs enough heat for its temperature to increase above 0 degrees C, the hydrogen bonds can be broken and allow the water molecules to slip closer together. If ice sand, lakes would be packed from the bottom with ice, and many of them would not be able to thaw out, since the energy from the air and the sunlight does not penetrate that very far.

Density Relationships of Water

A lake's physical, chemical, and metabolic dynamics are governed to a very great extent by differences in density. Ice is almost ten percent less dense than liquid water. Liquid water's density is at a maximum at 3.98 degrees C, and its density decreases as its temperature increases. Therefore, warmer waters are always found on top of cooler water in lakes and produce layers of water called strata. This is typical of a lake that is stratified during the summer. In winter the density differences in water cause a reverse stratification where ice floats on top of warmer waters.

MATERIALS

The activity enables students to experience the buoyancy of ice in water. The activity works best when a variety of see-through containers are selected in order to observe below the waterline.

Demonstration:
• Several see-through containers
• 12 –gallon or larger plastic or Plexiglas aquarium tank(s)
• Several 10, 20, or 25-lb blocks of ice
• Water
• Collection of objects that float or sink
• Select items such as: bathtub toys, wood, coins, rocks, foil opened flat, foil balled up, foil folded like a boat.

Main Activity
Whole Group:
• Varied large blocks of ice, as well as ice cubes
Small Groups:
• Plastic trays large enough to hold water and let ice float without touching the bottom of the container.
Individual or Pairs:
• Clear plastic cups to place water and an ice cube
• Food coloring & eyedropper
• Thermometer sensitive at the freezing point of water.

Demonstration: The purpose of this demonstration is to provide an opportunity for students to observe objects float and sink and to think about how and why things float. By comparing a variety of objects of different shapes and materials, patterns, emerge. Through guided discussion, students can gain insight into concepts of buoyancy, upthrust, density, and displacement. Fill a 12 gallon aquarium about ¾ full with water to use for the demonstration.

Grades 3 – 5:

Invite students to collect 2 or 3 objects for the sink or float test. Show them the size of the aquarium that will be used. Let them know that it will be filled about 3/4 with water. Show them a few of the items you have already selected. Form active inquiry teams of 3-5 students. Invite them to organize a selection of objects for testing in some sensible way. Notice what patterns of comparison seem sensible to the students. Invite them to discuss their reasoning. For example, relative size, relative weight, density, what they are made of, what shape they have, how much air may be in or part of the object (connects to ideas about density).

Once they have arranged objects for testing, have students select and prepare to test several items. As part of the preparation, ask students to predict whether an object will sink or float and explain why they think so. Have students record their predictions and explanations in their science notebooks. Then invite them to design a way to conduct their investigation and to do it, and to keep track of their results. Regroup as a whole and lead a discussion, inviting students to share findings.

Procedures:

Part 1

Observe the dynamics of ice floating.

This can be done in several ways, depending on the dynamics of the class, whichever allows students the most direct experience, while also remaining as orderly as a scientific laboratory. Be prepared, water is likely to spill at any rate.

Whole Group Activity or as a Small Group Exploratory Zone

1. Fill a 12-gallon aquarium tank about ¾ full.
2. Draw a line to mark the water level
3. Place a 10, 20 or 25 lb block of ice in the water.
4. Notice the water level rises. Mark the level.
5. Push the ice to the point that the top of the ice is even with the top of the water. Mark that level.
6. Observe and record what happens.
7. Pose questions about what happened.
8. Measure how much of the ice floats and how much is submerged.

Part 2

Observe the dynamics of near-freezing water sinking. Lead off a discussion with questions such as:

‘Have you ever noticed that when you put cold ice cubes into a warm soft drink, a moment later the liquid at the bottom is colder than the liquid at the top? You can get to that refreshing coldness with your straw.’ ‘Or when you go swimming, have you ever noticed that the water down below is cooler than near the surface?’ ‘What’s going on?’

Pick out tow different colors of food coloring. Keep one at room temperature or warmer. Place the other color near the ice to get close to freezing. Obtain two see-through containers large enough to hold sufficient water to enable a 10 pound block of ice to float. Fill each container with water at room temperature. Test out how the war food coloring behaves when a small droplet is placed in the water at room temperature. Then test out how the cold food coloring behaves. Do they behave differently?

Now place a 10 pound block of ice in the other container. Notice that it floats. Notice also that this is like a big ice cube in soft drink. Now place a droplet of each food coloring (warm and cold) near the big ice block. What happens?

Proposed explanations may emerge from discussion. Here's the scoop:
The cold liquid next to the ice cube cools down to close to the freezing point and then sinks to the bottom. As water gets colder, the molecules get closer together. Just above freezing point 0 to 4 degrees C, the water is at its MOST DENSE – that NEAR FREEZING WATER actually SINKS (that's why you see the food-coloring sink in next to the ice. The warm food coloring might take just a moment longer to first cool and then sink. Near-freezing water will SINK. Frozen water (ice) will float.

DISCUSSION AND REFLECTION

What explains the buoyant pressure of water?

The molecules in a fluid, in this case, water, move about and create a pressure in all directions. Because of the Earth's system as a whole, with its gravitational field always present, water experiences a downward pressure that increases with depth. The combination of forces, including air pressure, results in a net upward force, so things weight less in water. The mass has not changed; the upthrust just counteracts against gravity. The result is that the water pushes upward on an object immersed in it.

Why is it important to living things that ice floats?

One observation that might trigger discussion and reflection on this point is that when puddles, ponds, lakes, rivers, and oceans freeze, the upper surface freezes first. Liquid water persists beneath the ice, especially in larger bodies of water, where living things abound. What would be different if ice were heavier than water? What would happen to life if bodies of water froze from the bottom up? How does this affect our thinking about a place like Europa, a moon of Jupiter, covered with a surface of ice, harboring an ocean beneath that surface?

CURRICULUM CONNECTIONS

This lesson presents a marvelous opportunity for literacy connections. The meanings of words to express science concepts, such as weight, volume, density, mass, buoyancy, pressure, and upthrust – all depend on both an experiential context and an interpretive explanatory context.

Have students tell and write about situations that use these words. Guide them toward exploration and understanding of the nuances of meaning. For example.

• How do boats stay afloat?

• How do fish maneuver underwater?
• How do hot air balloons maneuver through the atmosphere?

ASSESSMENT CRITERIA

Exemplary:

• Students write and illustrate a personal ice floating experience and share it dynamically with both a small group and whole group.
• Students display drawings, constructions, and dynamic kinesthetic models drawn from
• Students identify and extend science questions drawn from direct observation and extended research about ice floating.
• Students explore a rich range of observations about ice floating and relate it to prior shared experiences.
• Students ask a rich and extensive range of questions about ice floating.
• Students extend learning by considering implications of the molecular structure of H2O as explanation for ice floating.
• Students relate ideas to the whole context of exploring ice in the Solar System.

Emerging:

• Students write and illustrate a description of ice floating and share it with both a small group and the whole group.
• Students pose science questions drawn from their observations and research of ice floating.
• Students observe examples of ice floating.
• Student display results using a variety of ways to represent examples of ice floating.
• Students ask a rich range of questions about density and buoyancy.
• Students make speculations about possible explanations for ice floating.

Formative:

• Students recognize that ice floats and that the features of ice floating can be measured.
• Students identify characteristics of density and buoyancy, connected to ice floating.
• Students pose science questions drawn out of the context of observing ice float.

Adapted from **EXPLORING ICE IN THE SOLAR SYSTEM, MESSENGER, 'MErcury, Surface, Space ENvironment, GEochemistry, and Ranging' Education Modules: comparative Planetology, "Ice in the Solar System."**
http://btc.montana.edu/messenger/teachers/MEMS_CompPlanetology.php