Distribute additional materials and ask students to discuss their observations with their partner or group.

- How do the liquids look when dropped onto each material?
- How does each liquid react when you move it around with a toothpick on the material?
- What happens to each liquid when you tilt the material to one side?

Have students use rulers to measure how far each liquid spreads out on the coffee filter.

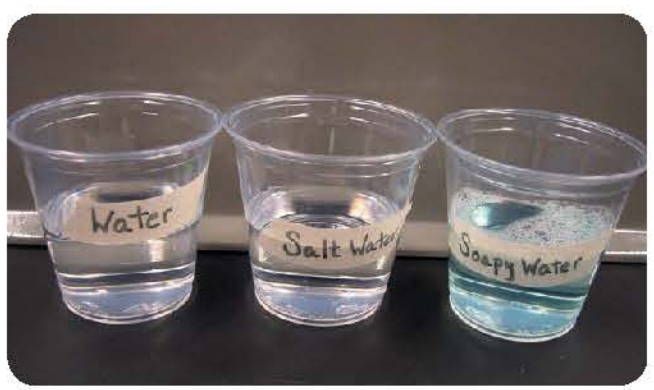
- If you quickly wave the coffee filter back and forth, do any of the liquids begin to disappear?
- Why do you think this is occurring?
- If the liquids do disappear, try adding additional drops and time how long they take to disappear completely.

Part 4
Drop, Plop

Distribute additional materials and ask students to select three objects for this experiment. Use additional cups and liquid, if necessary.

Have students drop their three selected objects into each of the liquids, making observations as they go. Students can discuss their results with their partner or group.

- What happens when each material is dropped into the various liquids?
- Which material floated? Which sank?
- Which disappeared?
- Which caused a reaction?



experimental cup set-up

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water in comparison to other liquids?
- Which liquids behaved similarly/differently?
- What surprised you?
- What other liquids would you like to test?
- What new questions do you have?

The "Why" and The "How"
At first glance, the various liquids tested in this lesson look quite similar, but each has different characteristics, or properties, that make them unique. Each liquid reacts differently during a particular test. Just as each liquid has different properties, so do the other materials used in each part of the investigation. This is why the same liquid may have reacted differently on waxed paper as opposed to on a coffee filter. For example, some liquids are thin and flow or pour easily. Other liquids are thick and gooey. Honey, shampoo or corn syrup flow or move more slowly than water because of a unique property called **viscosity.** Viscosity is a liquid's resistance to flowing.

Curriculum Match-Up

- Create charts showing properties of each liquid.
- Create charts or graphs comparing how the different liquids behaved during each test.
- Create a graph for the distance each liquid spread out on the coffee filter.
- Create a graph or chart of the evaporation time for each liquid.
- Make a chart or graph of the group's findings for a particular liquid.
- Investigate other liquids and objects.
- Identify and list five ways that you use water in your daily life.

References
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www.delta-education.com/science/dsm/samples/InvestigateWaterLink2.pdf

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Let's Look at Water & the Scientific Method

Learning Objectives

Students will:

1. Identify the physical and chemical properties of water.
2. Compare and contrast water to other liquids.
3. Use and demonstrate the scientific method.

Vocabulary Ventures

chemical property
field journal
hydrogen
hypothesis
liquid
observations
oxygen
physical properties
predictions
properties
scientific method
scientist
water

Water is all around us. It is the most common substance on the Earth's surface, covering nearly three-quarters of the planet. Water comes in many different forms such as rain, snow, and water vapor. It can be found in many different places such as the air, glaciers, and the human body.

All living things need water to survive. Humans need 2.5 quarts of water every day, which we get from drinking water, eating food, and breathing and absorbing moisture in the air. Did you know that up to 75% of the human body is water? Every day, the average American uses 100 gallons of water for cooking, drinking, bathing, and washing clothes, dishes and cars.

But what is water? Water is a colorless, odorless, tasteless **liquid** made of two elements called **hydrogen** and **oxygen.**

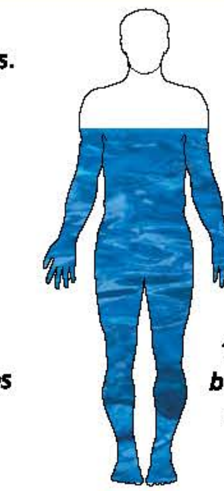
What is a liquid? A liquid is one of the three states or forms of **matter.** Any object that takes up space and has mass is called matter. Everything around you is made of matter, including the air you breathe, the water you drink and the chair you are sitting in. Liquids are fluids that typically take the shape of the container they fill. Water is different from other liquids. It is unlike any other substance on Earth, and we know this because of its unique properties or characteristics.

All matter has **properties.** Water has two basic types of properties: **physical properties** and **chemical properties.** A physical property is a characteristic that can be identified through one of our five senses (sight, touch, taste, smell, and hearing). A chemical property describes the way a substance will change or react to form another substance.

A **scientist** is a person who explores the natural world in order to better understand it. Scientists investigate different areas of science such as biology, physics or the environment. There are many different types of scientists who study the different properties of water. Some examples of scientists who study water include chemists who examine how water interacts with other elements; meteorologists who study how water interacts with the atmosphere to create weather conditions; and ecologists who study how water is connected to the environment.

The **scientific method** is a set of techniques that scientists use to investigate something interesting or puzzling. You can follow these steps to research almost anything:

1. Develop a question about something interesting, puzzling or problematic.
2. Gather information about your questions.
3. Form a **hypothesis** (a proposed explanation or an educated guess) and make **predictions** based on the information gathered.
4. Perform experiments and make observations to test the hypothesis and predictions.
5. Analyze your findings or results of the experiments.
6. Make conclusions based on the findings.
7. Share the results of your investigation.



The human body is made up of 75% water.

Good scientists use their senses to investigate the topics they are studying; however, because some substances are harmful, we will not be using our sense of taste during these experiments. Scientists also record their **observations,** questions, predictions, results and diagrams in a **field journal** so they may refer back to them at a later time.

Time Needed to Conduct Investigation
This investigation has four parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 10 minutes
Conduct the investigation: 30 – 40 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 60 – 70 minutes

Investigation: Getting Our Feet Wet

Materials

For groups of four
Student journals and writing tools

Part 1
- Ten 9 oz clear plastic tumblers
- 200 mL measuring cup or beaker
- Masking tape
- Pen
- ½ liter bottle with tap water
- Paper towels
- Sponges for cleanup

Choose two of the following liquids:
- ½ liter white vinegar
- ½ liter baby oil
- ½ liter seltzer
- ½ liter salt water (¾ cup of salt mixed with ½ liter of water)
- ½ liter soapy water (½ liter of water mixed with liquid soap)
- Karo syrup

Part 2
- All materials from Part 1
- Popsicle sticks
- Plastic spoons

Part 3
- All materials from Parts 1 and 2
- Straws or eyedroppers
- Waxed paper
- Aluminum foil
- Brown coffee filters
- Dry sponges (no scrubber side)
- Toothpicks
- Rulers

Part 4
- All materials from Parts 1, 2, and 3
- Additional 9 oz cups

Students will choose three of the following objects:
- Raisins
- Biodegradable starch packing peanuts
- Styrofoam packing peanuts
- Beads
- Corks
- Sugar
- Salt
- Baking soda

TIP
Familiarize yourself with the lessons before you do them with your students. This way, you will know what outcomes to expect.

TIP
This lesson can be done over two days. Gather all materials before you begin.

Part 1
Making Sense of Water

GET READY!

Brainstorm
Ask students what they think of when they hear the word "water". Record your students' answers on a flipchart or blackboard. Your students will record ideas in their student journals.

Ask students to share what they know about water:
1. What is water?
2. Where does water come from?
3. Why is it important?
4. What makes water different from other types of liquids?
5. Who studies water, and how?

PROCEDURE

Inform your students that they will be conducting several experiments using parts of the scientific method to learn about some of water's unique physical properties. Ask students to identify the steps to the scientific method as they conduct the investigation.

After your students complete this investigation, bring them together for a group discussion to reflect upon their results before moving on to the next part. Remind students that, as a good scientist would do, they should share their findings for each activity, and record the results in their student journals.

1. Before you begin the investigation, ask students to choose two liquids from the materials list to compare with water.
2. Fill each of the cups with 100 mL of the three liquids (two choices plus plain water).
3. Label each cup of liquid with masking tape.

SAFETY TIP
Instruct students NOT to stick their noses directly into the cups because some materials are hazardous to inhale directly. Use the wafting technique by holding the cup with one hand and waving the other hand over the opening of the cup to draw the odors towards the nose.

the wafting technique

PREDICT

Much in the same way that scientists use the scientific method to investigate something interesting, students will make predictions in this experiment based on what they already know about water.

Have your students predict what differences and similarities they expect to find between water and the other liquids in this experiment.

OBSERVE

Ask students to make some simple observations and record them in their student journals in the chart format provided:

- How does each liquid look?
- What is the color?
- Is it runny or thick?
- Do any of the liquids have an odor?
- What is the texture? How does each liquid feel when you rub the liquid between your fingers?

SAFETY TIP
Explain to students that they should never touch any substance in these experiments unless the facilitator informs them that it is safe to do so.

Part 2
This Way and That Way

Distribute additional materials and ask students to use the popsicle sticks and plastic spoons to make various observations.

- How does each liquid look when you stir it with a popsicle stick?
- What does each liquid do when you swirl it around in the cup using a circular motion?
- How does each liquid behave when you scoop it up with a spoon?
- What happens when you drop each liquid back into the cup from the spoon?
- Do the liquids make a sound?

Part 3
A Little at a Time

Have students use eyedroppers or straws to pick up the liquids and drop, a little at a time, onto the various materials provided.

TIP
To pick up liquid using the straw, have students dip one end of the straw into the liquid and place a fingertip over the other open end of the straw, then lift the straw out of the cup.

straw dropper technique

When students have reached the number of paperclips they initially predicted, invite them to pause and make observations about their results. Ask students to make a new prediction and continue to drop paperclips into the cup, counting from where they left off, until the water spills over. Ask students:

- How many paperclips fit into the cup before the water spilled?
- What do you think was holding the water in the cup as the level rose?
- What happened when the cup couldn't hold any more paperclips?
- How did your results compare to your revised prediction?

Part 2
What If?

Ask students to select ONE new variable to test (different-sized cups, different-sized paperclips, plastic-coated paperclips, marbles, beads or pennies). Based on their first observation, students should predict how many objects will fit into the cup before the water spills over.

- Did you get different results with different items?
- What surprised you?
- What new questions do you have?

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion

Scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, students will now come together as a group to share thier results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What were your results?
- Which variables did you test?
- What did you learn about the cohesion of water?

The "Why" and The "How"

Water molecules are attracted to each other and tend to clump together. This is why water drops take the shape of... water drops! Several variables affect the number of drops that will fit on the surface of a penny, such as:

- the size of the straw or water dropper hole;
- the distance between the dropper and the surface of the penny;
- the time allowed between the release of each drop; and
- the condition of the penny (for example, is it clean, oily, dirty, etc.?).

When the amount of water on the surface of the penny becomes too great for the "skin" or surface tension to hold the dome shape, water spills over the rim of the penny.

As paperclips were placed in the cup, the water level began to rise because it was being pushed out of the way and upwards by the paperclips, a property known as **displacement**. When the first few paperclips were placed in the cup and the water rose, the strong cohesive forces at the surface of the water caused it to form a dome shape and kept it from spilling over. However, when too many paperclips were added to the cup, bonds between the molecules at the surface were broken, causing the water to overflow.

Curriculum Match-Up

- Use the same variable ten times and find the average number of drops / paperclips for your results.
- Using the group results from Part One, find the range, the mode and the median.
- Create a small pile of sand or soil and pour water over the pile to observe what the water does once it hits the sand. What does this tell you about how bodies of water are formed?
- Find the ratio between your prediction and your result.
- What percentage of your predictions was correct? What percentage of your predictions was incorrect? Calculate the percentage of your prediction in relationship to your result.
- Create a story using water drops as characters. Tell how water drops are attracted to each other.

TIP

A ratio is a way compare two things. For example if you have 20 dimes and 5 nickels, the ratio of dimes to nickels is 20 to 5, or 20:5.

References
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wow.osu.edu/experiments/statesofmatter/psm2/ls_the_Glass_of_Water_Full.pdf

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

A Little Drop of Water: Cohesion

Learning Objectives

Students will:

1. Identify and diagram the structure and atoms that form a water molecule.
2. Describe why water forms a dome shape on a flat surface.
3. Test and explain the circumstances that will break the cohesion of water.

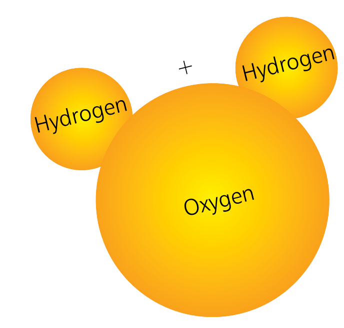
Vocabulary Ventures

atom
attraction
cohesion
displacement
hydrogen
meniscus
molecule
oxygen
sphere
surface area
surface tension
teddy bear molecule
variable
water molecule

Have you ever wondered why water forms little beads on the surface of a car after it rains? It has to do with a property of water called cohesion.


beads of water on glass

Everything on the planet is made of something smaller. The smallest unit of water is called a **molecule**. A molecule is made up of several small particles called **atoms** that are joined by a chemical attraction. In a **water molecule**, two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge. When these atoms attach to each other, they form a shape that looks like the head of a teddy bear. That is why the water molecule is known as the **"teddy bear molecule"**.



the "teddy bear" molecule

Water molecules behave much like a magnet, with a positive end and a negative end. The **oxygen** atom in one molecule of water is attracted to the **hydrogen** atom in another water molecule. This attractive force causes water molecules to be attracted to one another, a property known as cohesion. This is how little drops of water form into a larger pool of water.

The **attraction** between water molecules causes water to pull itself into the shape with the smallest amount of surface area, which is a **sphere**. On a flat surface, water pulls itself into a dome shape called a **meniscus**.

On the surface of water, the attraction between water molecules is very strong. This strong attraction creates an invisible "skin" on the surface of the water that helps hold it together. This property of water is known as **surface tension**.


drops on a penny

Time Needed to Conduct Investigations

Investigation 1: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 45 minutes

Investigation 2: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 10 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 – 15 minutes
Total estimated time: 50 – 55 minutes

Investigation 1: Drops on a Penny

Materials

For groups of one or two
Student journals and writing tools

Introduction to Cohesion
Build a Water Molecule
- Different types of marshmallows: multi-colored or large and small
- Toothpicks

INVESTIGATION 1
Part 1
- 9 oz cup of water
- Eyedropper or straw
- Paper towel
- Penny
- Sponges for clean-up

Part 2
- Assortment of new, old, shiny, dirty and discolored pennies
- Two ½ liter water bottles filled with tap water
- Other liquids to serve as **variables**: Soapy water, salt water, white vinegar, Karo syrup, baby oil, isopropyl alcohol, seltzer water
- Waxed paper
- Paper towel
- Aluminum foil
- Wood block or cardboard

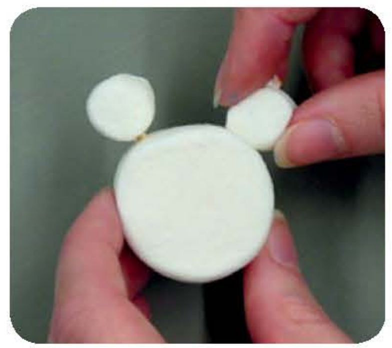
INVESTIGATION 2

Part 1
- ½ liter water bottle
- 9 oz clear hard plastic tumbler
- Boxes of small metal paperclips, 100 - 150
- Paper towels
- Sponges for clean-up

Part 2
- 12 oz clear plastic cup
- 3 oz paper cup
- Boxes of large metal paperclips
- Boxes of plastic-coated paperclips
- Bags of marbles
- Hundreds of pennies
- Different liquids

Introduction to Cohesion
Build a Water Molecule

Discuss the make-up of water molecules and the difference between atoms and molecules with students. Have them diagram pictures of water molecules in their student journals and create a model of a water molecule using different colored marshmallows (or different shaped marshmallows) and toothpicks. Review any relevant concepts/vocabulary from the background information.



marshmallow model of water molecule

TIP
Gather all necessary materials prior to the start of the activity. Students can help prepare salty and soapy water solutions.

Part 1
How Many?

GET READY!

1. Break your students into groups of two.
2. Explain to students that they will be doing an experiment to investigate why water forms into droplets.
3. Ask students to make some hypotheses (educated guesses) as to why water behaves in this way.
4. Provide students with an eyedropper (or a straw) and a penny.
5. Have students place their pennies “heads up” on a piece of paper towel on a flat surface.
6. Before they start, have students practice using the eyedropper by making drops of water in the cup.

PREDICT

Ask students to predict how many drops of water will fit on the head of the penny before it spills over. Ask them to explain why they made that prediction. Students should record their predictions in their student journals.

TIP
Have students be careful not to shake the table. Students can help prepare salty and soapy water solutions.

OBSERVE

Ask students to begin by placing one drop of water at a time on the head of the penny, counting drops as they go. Encourage them to make some observations, such as:
- What is happening to the drops as you place them on the penny?
- How do the drops move?
- What shape are the drops taking on the penny?
- How does the water look from the top? From the side? Invite students to diagram what they see in their journals.
- Does the way you drop the water affect your outcome? Allow students to practice different dropping techniques and observe the results.

When students have reached the number of drops they initially predicted, invite them to pause and make observations about their results. Ask students to make a new prediction and continue to place drops on the penny, counting from where they left off, until the water spills over. Ask students:
- How many drops fit on the surface of the penny?
- What do you think was holding the water on the penny?
- What happened when the penny couldn’t hold any more drops on its surface?
- How did your results compare to your revised prediction?

Part 2
What If?

Ask students to share questions that might have come up during the investigation. Do they have any other questions they would like to explore?

Explain that when we change one aspect of an experiment to see how it affects our results, this change is known as a **variable**. If we repeat the experiment and change just one variable, will we get the same results? Distribute additional materials and allow students to select ONE new variable to test at a time. Some possibilities are:
- What if we used soapy water? Salty water? Cold water? Hot water? A different coin?

Feel free to try these investigations, or take suggestions from your students. Encourage students to share their questions and results with the class and record them in their student journals.

Investigation 2: Filled to the Brim

meniscus on cup

Part 1
What Happens?

GET READY!

Explain to students that they will conduct another experiment to explore the cohesive properties of water. Review any relevant concepts/vocabulary from previous investigations.

1. Have students place a cup on top of a paper towel and fill the cup to the very top with water, until it almost spills over.
2. Gather the paperclips and explain to the students that they will be placing the items into the cups of water.

PREDICT

Ask students to make predictions. What will happen as they start placing paperclips in the cup? How many paperclips will the cup hold before the water spills over?

OBSERVE

Invite the students to slowly begin placing paperclips in each cup, and make the following observations:
- What is happening to the water? Why do you think this is happening?
- What shape is the water taking in the cup?
- How does the water look from the top? From the side? Invite students to also diagram what they see in their student journals.
- Why do you think the water is taking that shape?
- What happened when too many paperclips were placed in the cup?
- Why did this happen?

OBSERVE

Have students make observations about the drops of water inside each loop and discuss their observations with their group or partner.

- What do you notice as you look through the loop?
- What words would you use to describe this effect?
- What is the property of water that helps the water to collect in the loop?

Part 2
Reading Through Water

GET READY!

Students will now try to read small and large letters on the newspaper or magazine using the drops of water inside the wire loop.

PREDICT

Ask students to make some predictions. Do you think you can read through the drops of water in the wire loop? Why or Why not?

OBSERVE

Have students make observations about the drop of water inside each different-sized loop and discuss their observations with their group or partner:

- Which loop is the better magnifier, the loop with more water or less water? Is it the larger loop, or the smaller loop?
- Why does the water act as a magnifier?
- Describe and draw the shape of your waterdrop lens.
- Try to place more or less water on the loop and read the letters again.

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion

Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- How did your predictions differ from your results?
- What did you learn about the magnifying effects of water?
- What new things did you learn about water from this investigation?
- How do you think light and water work together to magnify objects?

Answer: Proper lighting will provide a better view of the objects you want to magnify. The better the quality of light used with a magnifying lens, the less power is needed.

The "Why" and The "How"

A water drop is a **plano-convex** lens, which means it has one surface that is flat, and one surface that is curved out. The **surface tension** of water causes the molecules to create a rounded surface on the water drop. The rounded shape of the drop bends the light and the image of the letters outwards. As it spreads out, the image of the letters gets larger. If the water drop moves or changes shape, the image will be **distorted**.

The image is also **magnified**, or enlarged. As magnification increases, any distortions are also exaggerated. The water drop works as a magnifying glass by refracting light. A magnifying glass is a single **convex** (curved outward) lens that is used to produce a larger image of an object. The water drop in the wire loop also curves outward. A magnifying glass, is the simplest form of a microscope – a tool that scientists use to see small organisms better. Light passes through a convex lens and converges, or comes together, from different directions to a point.

A **concave** lens curves inward. Light passing through a concave lens branches out in different directions from one point. Concave lenses can be used in telescopes, binoculars, microscopes, and eyeglasses.

When light traveling through air touches a glass surface at an angle, some of the light reflects. The rest of the light keeps going, but it bends or refracts as it goes through the glass of water. When light travels through water, it slows down. This change in speed causes the light to reflect and refract as it moves from one material (air) to another (glass and water).

Curriculum Match-Up

- Try this investigation again using glasses or binoculars in place of the wire loop.
- Draw the way the printed words look through the drop of water inside the loop.
- Repeat the investigation using different liquids (**variables**.) For example, what would happen if you used oil instead of water?

References
Adapted from information from: The H20 Files-A Teacher's Guide (©Liberty Science Center)
Arizona State University Department of Physics and Astronomy

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Water Illusions: Refraction & Magnification

Learning Objectives

Students will:

1. Demonstrate how water distorts light to make objects look different.
2. Identify water's refractive and magnifying qualities.
3. Observe how water interacts with light.

Vocabulary Ventures

concave
control
convex
distort
lens
magnify
physics
plano
reflection
refraction
submerge
surface tension
variable

Water is an amazing molecule. It absorbs light and scatters light in three dimensions (back and forth, side to side, and up and down). Water is unique because it absorbs colors at different rates, or speeds. For instance, water absorbs red and orange before it absorbs other colors.

Have you ever seen a rainbow? After it rains, water can put on an amazing light show by **refracting** (bending) light from the sun and separating all of the colors of light – red, orange, yellow, green, blue, indigo, and violet – into the shape of a bow.

Scientists use **physics** (the science of matter, or stuff, and energy and how they interact with each other) to understand how light passes more slowly through water than through air. The "bending" that occurs is a side effect of the light slowing down in water.

Water can play lots of tricks with your eyes, especially when it takes on the shape of a sphere. Let's see how!

TIP
To help students remember the colors of the rainbow, the Rainbow Man's name is
ROY G. BIV = Red, Orange, Yellow, Green, Blue, Indigo, Violet.

R	RED
O	ORANGE
Y	YELLOW
G	GREEN
B	BLUE
I	INDIGO
V	VIOLET

colors of the rainbow

Time Needed to Conduct Investigations

Investigation 1: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 45 minutes

Investigation 2: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 45 minutes

Investigation 1: Underwater Differences

Materials

For groups of two to four
Student journals and writing tools

- Small and large clear glass jars (120 mL, 600 mL to 1000 mL), 2 of each
- A gallon of water

INVESTIGATION 1
Part 1:
- Clear glass jar (holds 600 mL)
- Pencil

Part 2:
- Clear glass jar (holds 125 mL)
- Sticker about 1-inch in length and width

INVESTIGATION 2

Part 1
- 10 inch #22 gauge bare wire
- Nails of different sizes (5mm, 7mm, 9mm)
- Small jar of water (125 mL)
- Magazine or newspaper clipping

Part 1
Broken Pencil

GET READY!

1. Ask students if they've ever looked in a fish tank or pond from above to get a close view of the fish. Did they notice that the water made the fish appear in a different location than where they really were?
2. Tell students they will be doing an investigation to test how water bends (refracts) light and changes the images we see.
3. Break up the students into groups of 2 or 4 for this investigation.
4. Fill a large jar with water.

broken pencil effect in water

PREDICT

Ask your students to predict what will happen when they place the pencil in the water. Do they expect the pencil to look the same in and out of the water? If not, why?

OBSERVE

Have students place pencils into their beakers of water, and look at the pencils from the top and the sides of the beakers. Ask students to make the following observations:
- How does the pencil appear in the water?
- Look at the pencil below the surface and then at the surface of the water. What appears to happen to the pencil at the water level?
- Describe any changes to the pencil's appearance.
- Diagram what you observe about the pencil in the water.

Part 2
Stick it to the Bottom

PROCEDURE

1. Place a sticker on the table. (NOTE: don't remove the sticker from its coated backing!)
2. Then, place a small jar over the sticker.
3. Fill the jar completely with water.
4. Look through the water as you slide the jar back and forth over the sticker. What do you observe?

OBSERVE

Ask students to make the following observations:
- What happened when you placed the jar over the sticker?
- What ideas do you have about these illusions?
- Diagram what you see.
- How do you imagine we see examples of this illusion in everyday life?

Answer: rainbows, shadows at the bottom of a pool, contact lenses and glasses, when the setting sun looks flat at the horizon, twinkling stars, and halos (a ring of light around objects in the sky) are all examples of what happens when light is refracted or bent.

WRAP-UP

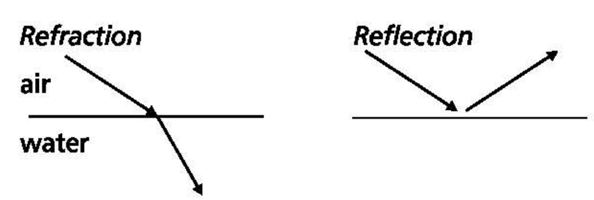
To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you notice about the objects in and under the water?
- How did your predictions differ from your results?
- What did they learn about water's refraction ability?
- What surprised you?
- What new questions do you have about water?
- What did you like about this activity?

The "Why" and The "How"
A property of water known as refraction creates the "broken pencil" effect. Light travels at different speeds through different materials. In fact, light travels slower through water than it does through air. This optical (eye) illusion causes light to refract, or bend, when it passes through materials of different densities -- in this case air, glass and water. In order to see the pencil under the water's surface, light must be reflected, or redirected, off the pencil and then travel through the water, the glass, and the air before it reaches your eyes. **Reflection** occurs when light bounces from a surface back toward the source, like a mirror reflects your image. Traveling through these materials slows the light just enough so that the image reaches your eyes just after the light reaches the top part of the pencil above the surface of the water. The combination of slower travel speed, and the density of the water and the glass distorts the image of the pencil. The water and the glass also magnify the submerged part of the pencil, making it appear larger than it really is -- just as a magnifying lens would do.

This diagram can help illustrate the effects of reflection and refraction:



Curriculum Match-Up

- Diagram the angles of refraction and reflection that occur in this experiment.
- Draw two fish of the same size (2 inches in length and ½ inch in width) on the line of a piece of lined paper. Place a glass or beaker filled with water over one of the fishes. Notice that the "underwater" fish looks higher up and a little further back than where you know it is on the paper. Predict what will happen. The second fish acts as a control to help you make the comparison.
- Shine a flashlight through a glass filled with salt water and a glass filled with fresh water. Add some drops of food coloring to the beakers and predict which transmitted light will be brighter. Which glass transmitted more light? Record your observations.

Investigation 2: Bigger Through Water

Part 1
Water Through a Loop

GET READY!

Inform students that they will be conducting an experiment that shows how water can magnify, or enlarge, objects.

PROCEDURE

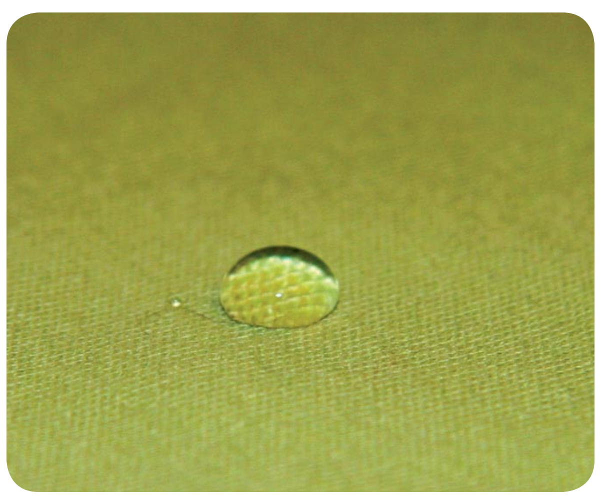
1. Have students choose two (2) nails of different sizes.
2. Using one of two nails, wrap one end of the wire tightly around the nail. Tighten the wire by twisting it.
3. Carefully slide the wire loop off the nail.
4. Dip the wire in a cup of water so that water collects in the loop.
5. Repeat these steps with the second, different-sized nail.

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water in comparison to other liquids?
- What were your results from the fabric activity?
- Which fabric did the water adhere to most? The least?
- How did this compare with your prediction?
- Which liquids behaved similarly/differently?
- What surprised you?
- What other liquids would you like to test?
- What new questions do you have?



meniscus on a flat surface

References:
www.uark.edu/~k12info/teacher/workshops/AIMS-lessons/Water_Olympics.pdf
www.bpa.gov/Corporate/KR/ed/sold/water/k1/drip_drop.pdf

The "Why" and The "How"
The bonding or adhesive forces vary between water and different fabrics. Water does not have a strong attraction to nylon, which is why it is often used to make outerwear to protect people from the rain. However, water is strongly attracted to cotton, which is why it is used in items like mops. Materials such as cotton become wet when water bonds or adheres to the surface and spreads through the fibers of the fabric. A material such as nylon has much stronger bonds between its molecules, making it difficult for water to penetrate. Instead, water will form droplets that bead or fall off when it is unable to soak through a material.

Curriculum Match-Up

- Repeat the investigation and find the ratio of the weight of the fabric to the amount of water the fabric absorbed.
- If you dropped a cup of water on the floor in your kitchen and wanted to clean it up fast, which fabric would you use?
- Watermelon is a fruit that is made up of 85% water. Using the following words, can you explain how water can stay inside of the skin of a watermelon?
    - Attraction
    - Molecules
    - Adhesion
- Imagine that it is raining outside and you need to get from your home to the car without getting wet? What materials would you use to keep dry? How will this object keep you from getting wet?

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Stuck on You: Adhesion I

Learning Objectives

Students will:

1. Learn that water molecules can also stick to molecules found in other materials, a property known as adhesion.
2. Measure and record how water adheres, or sticks, to different fabrics.
3. Explore how the adhesive forces of water vary for different materials.

Vocabulary Ventures

molecule
atom
teddy bear molecule
attraction
cohesion
adhesion

Have you ever wondered how water sticks to a window pane when it rains? What keeps the water in a watermelon? Why does water roll off a duck's back? It has to do with a property of water known as adhesion.

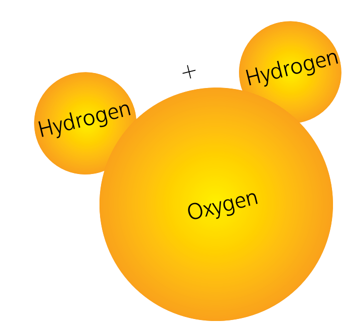
Everything on the planet is made of something smaller. The smallest unit of water that can exist by itself and still have the same chemical features or properties is called a **molecule**. A molecule is made up of several small particles called **atoms** that are joined by a chemical **attraction**. In a water molecule, two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge. When these atoms attach to each other, they form a shape that looks like the head of a teddy bear. The water molecule is known as the **"teddy bear molecule".**

Water molecules are polarized, behaving much like a magnet, with a positive end and a negative end. The oxygen atom in one molecule of water is attracted to the hydrogen atom in another water molecule.

adhesion of water to leaf

This attractive force causes water molecules to stick together, a property known as **cohesion**. Cohesion helps little drops of water form into a larger pool of water.

Water can also be attracted to molecules found in other materials such as glass, plants or soil. This property of water is known as **adhesion**.



the "teddy bear" molecule

The forces of adhesion between water and other materials can vary. Water may be strongly attracted to some materials and not attracted to others. For example, water is not very strongly attracted to the oils found on duck feathers. This is why water does not stick to duck feathers and instead rolls off in droplets. Stronger adhesive forces also keep water inside the tissues of the human body and in fruits and vegetables.

Time Needed to Conduct Investigation
This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 10 minutes
Conduct the investigation: 25 – 30 minutes
Student journaling/group reflection: 10 – 15 minutes
Total estimated time: 55 – 65 minutes

Investigation: Fabric Frenzy

Materials

For groups of 3 or 4
Student journals and writing tools

Part 1

Note: fabric samples / swatches should all be the same size *(suggestion: 4 x 4 in. square):*

- Cotton fabric
- Nylon fabric
- Polyester fabric
- Linen fabric
- Twill fabric
- Wool fabric
- Magnifying lenses

Part 2

- ½ liter bottle with tap water
- Tongs
- 1000 mL (1 liter) jar
- Balance
- Sponges for clean-up

fabric under magnifying lens

Part 1
Exploring Fabrics

GET READY!

Brainstorm
Explain to students that they will conduct activities to understand why water stays on a window pane after it rains and why watermelons are so juicy. Ask students to brainstorm what kinds of things they might use to clean up a water spill:
1. Why are these materials so good at soaking up water?
2. Where do you think the water goes?
3. Why wouldn't you use a material like plastic wrap to clean up a spill?
4. Invite student volunteers to try out the various materials to clean up a spill, and discuss their findings.

OBSERVE

Invite students to examine each of the fabrics by looking at them with the magnifying lenses and by touching them with their fingers. Students should record their observations in the chart in Part 2 of their student journals.
Ask students:
- Which fabric would make the best raincoat? Why?
- Which fabric would make the best mop? Why?

Part 2
Testing the Fabrics

pan balance

TIP
Review proper use of a pan balance. Remind students that the balance needs to be balanced (needle in center) prior to the investigation and at the start of each fabric test.

GET READY!

1. Students should weigh each dry piece of fabric on the balance and record the weights in their journals.
2. They should then pour 200 mL of water into the beaker.

PREDICT

Ask students to predict how water will affect the weight of the fabric. Why have they made this prediction? Students should write their predictions in their journals.

PROCEDURE

1. Have students pour 200 mL (7 oz or 14 Tbsp) of water into the jar.
2. Using the tongs, students should place one of the fabrics into the water until it becomes completely wet.
3. Once it is wet, students should lift the fabric out of the jar with the tongs, holding it over the jar until it no longer drips.
4. Next, students should place the wet fabric on the balance and weigh it again.
5. Calculate how much water each piece of fabric absorbed by subtracting the dry fabric weight from the wet fabric weight.

TIP
Students should be sure to dry the balance before testing a new fabric as any extra water in the pan will influence their results.

Remind students to record these observations in the charts in their student journals. The groups should repeat this process with the remaining fabrics and record their observations and results.

Testing Fabrics

	Cotton	*Nylon*	*Polyester*	*Linen*	*Twill*	*Wool*
Look						
Feel (touch/texture)						
Dry Weight						
Wet Weight						
Amount absorbed *(wet weight-dry weight)*						

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water from the string investigations?
- What did you expect your results to be?
- What surprised you?
- What other liquids would you like to test?
- What new questions do you have?

The "Why" and The "How"
The adhesive properties of water cause it to cling to the string. Wet string works better than dry string because cohesive properties also help the water move along the string. When the string is wet, water clings to both the string (adhesion) and to itself (cohesion). If the water is poured too quickly, there is not enough string for all of the water to stick to, so gravity pulls the excess water down. When we change one aspect of an experiment to see how it affects our results, this is known as a variable. In order to compare results, we only change one variable at a time for each experiement to make sure that other factors aren't affecting the outcomes.

adhesion, cohesion, and surface tension of water on a spider web

Curriculum Match-Up

- Repeat the experiment and create a graph of the time it took for water to travel along the different types of string.
- Calculate the ratio of length to speed for different strings.
- Calculate the average speed for different trials or different types of string.
- Create a graph for how long it took to get water across the room for the entire class.
- List five ways that you might observe the property of adhesion as you walk home on a rainy day.

References:
www.uark.edu/~k12info/teacher/workshops/AIMS-lessons/Water_Olympics.pdf
www.bpa.gov/Corporate/KR/ed/sold/water/k1/drip_drop.pdf

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Stick to It: Adhesion II

Learning Objectives

Students will:

1. Learn that water molecules can also stick to molecules in other materials, a property known as adhesion.
2. Develop a procedure to solve a problem.
3. Test the adhesion of water to different types of string.

Vocabulary Ventures

molecule
atom
teddy bear molecule
attraction
cohesion
adhesion

Note: This introduction is repeated from the previous lesson on adhesion.

Have you ever wondered how water sticks to a window pane when it rains? What keeps the water in a watermelon? Why does water roll off a duck's back? It has to do with a property of water known as adhesion.

Everything on the planet is made of something smaller. The smallest unit of water that can exist alone and still have the same chemical characteristics or properties is called a **molecule**. A molecule is made up of several small particles called **atoms** that are joined by a chemical **attraction**. In a water molecule, two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge. When these atoms attach to each other, they form a shape that looks like the head of a teddy bear. The water molecule is known as the **"teddy bear molecule"**.

water droplets showing cohesion and adhesion

Water molecules are polarized like a magnet, with a positive end and a negative end. The oxygen atom in one molecule of water is attracted to the hydrogen atom in another water molecule. This attractive force causes water molecules to be drawn to one another, a property known as **cohesion**. Cohesion helps little drops of water form into a larger pool of water.

Water can also be attracted to molecules found in other materials such as glass, plants or soil. This property of water is known as adhesion.

The forces of **adhesion** between water and other materials can vary. Water may be strongly attracted to some materials and not attracted to others. For example, water is not very strongly attracted to the oils found on duck feathers, and is actually more attracted to itself. This is why water does not stick to duck feathers and instead rolls off in droplets. Stronger adhesive forces also keep water inside the tissues of the human body and in fruits and vegetables.

Time Needed to Conduct Investigation
This investigation has four parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 25 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 50 minutes

Investigation: Walking the Tightrope

Materials

For groups of three or four
Student journals and writing tools

Part 1:
- ½ liter water bottle with tap water
- Plastic tablecloths
- Two 16 oz plastic cups (label one cup 'A' and the other cup 'B')
- Scissors
- White cotton string
- Measuring tape
- Masking tape
- Sponges

Part 2:
- Additional white cotton string

Part 3:
- Fishing line
- Thick clothesline
- Twine
- Thread
- Yarn
- Wax-coated string

Part 4:
- Long lengths of white cotton string

Part 1
Water on a String

GET READY!

In this investigation, your students will discover that the adhesive and cohesive properties of water enable it to travel on a string. Place plastic tablecloths on the surfaces where students will be working. Review any relevant concepts/vocabulary from previous investigations.

set-up for water on a string

PROCEDURE

1. Explain to students that their task is to try to get the water from cup "A" to cup "B" while keeping them 60 cm apart.
2. Only materials provided may be used. Hands and mouths cannot be used.
3. Students should measure 60 cm using the measuring tape.
4. Next, have students mark this distance on the table with masking tape.
5. Students should cut 70 cm of cotton string to use in the experiment.
6. Fill Cup A ¾ full of water.

Let students experiment with different methods of transporting the water, but don't immediately provide the solution. Instead, ask questions that will help get students on the right track. Invite students to discuss their methods, observations and results with their partner.

TIP
Wet the string first to get the water from one cup to another.

How it Works!
One person grasps the cup containing the water and uses his index finger to hold one end of the string inside the cup submerged in the water. A partner grasps the empty cup and uses her index finger to hold the other end of the string inside the cup while keeping the string taut. Next, lift the cup containing the water above the level of the empty cup and slowly tilt the cup so that the water begins to flow from the cup and onto the string. Remind students to keep the cups 60 cm apart!

OBSERVE

Invite the students to make the following observations:
- How did you come up with the method that you are testing?
- How is the water behaving on the string?
- What techniques are working/not working?
- Does the speed at which the water is being poured have an effect? Why?
- Why do you think some water sticks to the string while some falls to the table?
- Which works better: wet string or dry string? Why?
- How many tries did it take for the water to travel from one cup to the other?

water drop traveling on a blade of grass

Part 2
A String of Strings

Invite students to repeat the procedure from Part 1, experimenting with different lengths and types of string such as thread, yarn, twine, waxy string and fishing line.

Ask students to record the following observations:
- How does the experiment work when using a longer string?
- How does the water behave on different types of materials? Why?
- Which material transports the water the fastest? The slowest?

twine, yarn, kite string, and fishing line

Part 3
One String or Two?

Invite students to experiment with two strings instead of one to create a water bridge. Ask students to discuss the following observations with their partner or group:
- How did your results change with two strings versus one?
- Did the water move faster or slower? Why?

Part 4
Going the Distance

Invite students to see if they can transport water across the entire room using the string of their choice. Ask students to make the following observations:
- How far can you get the water to travel?
- Which material works best for a long distance?
- How long did it take for the water to travel across the room on the string?
- How much water can you transport from one cup to the other?

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

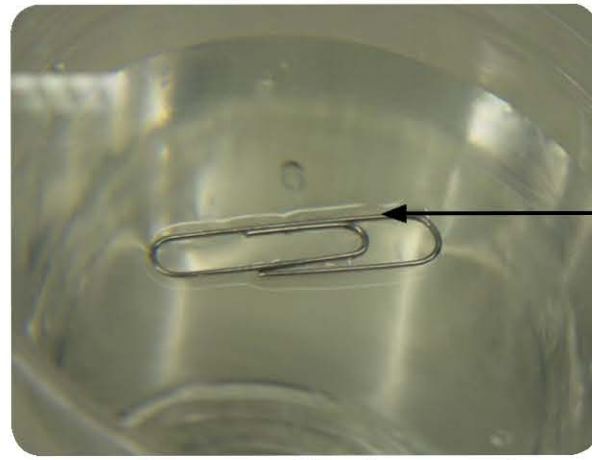
Group Discussion

Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water from this experiment?
- Did everyone have the same results?
- How were you able to float the paperclip?
- How did the detergent affect the water?
- What surprised you?
- What new questions do you have?

The "Why" and The "How"

Surface tension is the strength of the force that controls the shape and movement of water. Water molecules on the surface of water feel a strong force of attraction from all of the molecules under the water's surface. The molecules at the surface are attracted to each other. This attraction also contributes to the strength of the skin. The stronger the bonds are between the molecules in water, the greater the surface tension. However, the surface tension of water can be broken by adding certain substances such as detergents. Soaps and detergents are useful for cleaning because when they break water's surface tension, they are able to spread out onto dirty surfaces and soak into laundry, breaking up dirt and oil.



meniscus around floating paperclip

Adding detergent to water weakens the bonds between the surface molecules, making them spread apart. This causes the water's invisible skin to break and pull off to the sides, similar to the popping of a balloon. When the surface tension of water was broken in this experiment the weight of the paperclip floating on the surface could no longer be supported, causing it to immediately sink to the bottom.

Curriculum Match-Up

- Draw a water strider using surface tension to help it walk on water.
- Create a chart or graph for the results of different sized paperclips.
- Try the investigations again with different water solutions: saltwater or carbonated water, for example.

References:
www.coolscience.org/CoolScience/KidScientists/FloatDivePaperClip.htm
launchpadscience.com/experiments.htm
pbskids.org/zoom/activities/phenom/soappoweredboat.html

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Breaking the Tension: Surface Tension I

Learning Objectives

Students will:

1. Explain why certain objects are able to float on the surface of water.
2. Explain how detergents break the surface tension of water.
3. Observe that the attractive forces between water molecules cause an invisible "skin", known as surface tension, to form on the surface of water.

Vocabulary Ventures

atom
attraction
cohesion
elastic
hydrogen bonding
meniscus
molecule
sphere
surface area
surface tension
teddy bear molecule
water strider

Have you ever looked at a pond or a large rain puddle and wondered how some insects are able to walk on water? What enables these organisms to accomplish such an incredible feat? Have you ever thought about raindrops and wondered why they aren't square or triangular? These phenomena are actually due to an amazing property of water known as **surface tension**.

Aquarius sp.* *(Water Strider)

Everything on the planet is made of something smaller. The smallest unit of water is called a **molecule**. A molecule is made up of several small particles called **atoms** which are joined by a chemical attraction. Atoms are the building blocks of eveything on the planet. In a water molecule, opposites attract: two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge, forming a shape that looks like the head of a teddy bear. The water molecule is known as the **"teddy bear molecule"**.

Water molecules behave like a magnet, with a positive end and a negative end. The oxygen atom in one molecule of water is attracted to the hydrogen atom in another water molecule, a process called **hydrogen bonding**. This force causes water molecules to be attracted to one another, a property called **cohesion**.

The **attraction** between water molecules also causes water to pull or curve itself inward into the shape with the smallest amount of **surface area** (the outside surface of the shape) which is a **sphere**, or on a flat surface, a dome shape called a **meniscus** (from the Greek word for "moon").

Within a body of water, water molecules are in a constant tug of war with other surrounding water molecules. A water molecule is constantly pulled in every direction by other water molecules, canceling out the forces and causing it to remain stationary. This is known as "no net force".

However, on the surface of the water, molecules are being pulled by other molecules everywhere except from above. This causes the surface molecules to be pulled down strongly and held together very tightly, creating an invisible "skin" on the water's surface known as surface tension.

This stretchy, **elastic** skin on the surface of water is strong enough to support some insects like **water striders**. If you look closely at an insect walking on water you will notice that the insect's feet make dents in the skin but do not break it. Amazing!

Time Needed to Conduct Investigation

This investigation has two parts.

Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 25 minutes
Student journaling/Group reflection: 10 minutes
Total estimated time: 50 minutes

Investigation: Walk on Water

Materials

*For groups of two**
Student journals and writing tools
Picture of a water strider

Part 1
- ½ liter water bottle
- Pie tins or 16 oz clear plastic cups with a wide brim
- Paperclips of varying sizes
- Plastic fork
- Magnifying lenses
- Sponges for clean-up

Part 2
- Liquid dish detergent

*Students can each get their own set of materials if available.

Part 1
Floating Paperclips

GET READY!
In this investigation students will learn that attractive forces between water molecules cause an invisible "skin", known as surface tension, to form on the surface of water. Students will conduct an experiment to determine whether water can support a paperclip.

TIP
Gather all necessary materials prior to the start of the activity.

1. Break students up into groups of two.
2. Ask students if they have ever seen an insect, such as a water strider, walk across the surface of a pond. Show them a picture. Ask students how they think the water strider and other insects are able to walk across water without falling in?
3. Explain that the students will be doing a series of experiments to determine how this phenomenon is possible. Review any relevant concepts/vocabulary from previous investigations.

PREDICT
Invite students to predict whether they think a paperclip will float or sink in the water and why. Have students record their predictions and explanations in their student journals.

PROCEDURE
1. Students should pour water into the pie tin or cup.
2. Tell students they will next try to float a paperclip on the water, but they should first make some predictions.
3. Using the materials provided, try to get the paperclip to float on the surface of the water in the pie tin or cup. Start with the small paperclips first before trying paperclips of larger sizes.

TIP
Let the students experiment with different methods of floating the paperclip. If they are having difficulty, ask questions to help get them on the right track. An easy way to get the paperclip to float is to balance the paperclip on the prongs of the fork and then lower the fork into the cup or pie tin until the paperclip moves off the fork and rests on the water. This may take a bit of practice.

lowering paperclip into water

OBSERVE
Once students have been able to get their paperclips to float, invite them to examine the floating paperclip with a magnifying glass. Students may then experiment with different sizes of paperclips. Circulate around the room and ask students to make the following observations:
- Which methods were successful in getting the paperclip to float?
- Which methods were not effective?
- What do you think is keeping the paperclip afloat?
- How did the water around the paperclip look under the magnifying glass?
- How large of a paperclip can you float? (Students can measure them.)

Part 2
Sink to the Bottom

PREDICT
Next, ask students what they think will happen to the floating paperclip if they add some dishwashing detergent to the water?

OBSERVE
Have students place a drop of dish detergent onto the surface of the water, and make the following observations:
- What happened when you added the detergent to the water? Why do you think this occurred?
- Could you float another paperclip on the water after you added the soap? Why do you think this is?
- How do you think adding detergents or pollutants to a pond would affect organisms such as water striders that live in water environments?

TIP
Rinse all materials between investigations to remove soap residue.

leaf supported by surface tension

Part 2
What If?

Ask students: If you could change one thing about this investigation to learn something new, what would you try? When we change one part of an experiment to see how it affects our results, this change is known as a variable. What if we used different liquids? Use the chart in your journal to record your ideas about what might happen if you change some of the variables. Some possibilities are:

- What if you used different liquids in this experiment?
- Different spices (oregano, sugar, salt, flour, basil, rosemary)?
- How about different types of soaps? Different amounts of soap?
- Different temperatures of water? Salty water?
- How would your results change?

TIP
Rinse the pie tins and cups between each variable investigation to remove soap residue.

We encourage you to try these variables or other ideas suggested by the students. Invite students to share their questions and results with the group and record them in their student journals.

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water from this experiment?
- Did everyone have the same results?
- How did the detergent affect the water?
- Based on your observations from this experiment, how does dish detergent help clean dirty dishes?
- What did you like about this investigation?
- What variables did you try?
- What surprised you?
- What new questions do you have?

The "Why" and The "How"
Surface tension is the strength of the force that controls the shape of water. Water molecules on the surface of water are strongly attracted to each other, and feel a strong force of attraction from the molecules under the water's surface. These forces pull the surface molecules closely together and back towards the body of water creating an invisible skin. The stronger the bonds are between the molecules in water, the greater the surface tension.

Adding detergent to water weakens the bonds between the surface molecules, making them spread apart. When this occurs, the water's invisible skin breaks or pulls apart, similar to the popping of a balloon. When the detergent was added to the water, ths invisible skin at the surface was broken, and both the boat and the pepper were pulled along with the popping skin. Once the skin was broken, the weight of the paper boat and the pepper floating on the surface could no longer be supported, causing them to sink to the bottom.

Curriculum Match-Up

- Try changing one variable and test your paper boats again. Add oil to the water in place of detergent, or try using saltwater instead of freshwater.
- Create additional boats of your own design using different materials. Test your new boat and document your results.
- Create a chart or graph for different liquids, soaps, spices or water temperatures that you used.

References:
www.coolscience.org/CoolScience/KidScientists/FloatDivePaperClip.htm
launchpadscience.com/experiments.htm
pbskids.org/zoom/activities/phenom/soappoweredboat.html
www.wikimedia.com

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Below the Surface: Surface Tension II

Learning Objectives

Students will:

1. Demonstrate that the attractive forces between water molecules cause an invisible "skin", known as surface tension, to form on the surface of water.
2. Explain why certain objects are able to float on the surface of water.
3. Explain how detergents break the surface tension of water.

Vocabulary Ventures

atom
attraction
cohesion
elastic
hydrogen bonding
meniscus
molecule
sphere
surface area
surface tension
teddy bear molecule
water strider

We are learning that we can identify water by its physical and chemical properties. A **molecule** is made of several **atoms**, which are joined by a chemical attraction. Molecules behave depending on the atoms they contain and how these atoms bond to each other. In a water molecule, two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge, with the resulting shape looking like the head of a teddy bear. The water molecule is known as the **"teddy bear molecule"**.

Water molecules behave much like a magnet, with a positive end and a negative end. The oxygen atom in one molecule of water is attracted to the hydrogen atom in another water molecule, which is known as **hydrogen bonding**. This force causes water molecules to be attracted to one another, a property referred to as **cohesion**.

Within a body of water, water molecules are in a constant tug of war with other surrounding water molecules. The water molecule is constantly pulled in every direction by other water molecules, canceling out the forces and causing it to remain stationary. This is known as "no net force".

However, on the surface of the water, molecules are being pulled by other molecules everywhere except from above. This causes the surface molecules to be pulled down strongly and held together very tightly, creating an invisible "skin" on the water's surface known as surface tension. The **attraction** between water molecules also causes water to pull itself into the shape with the smallest amount of **surface area** (the outside surface of the shape) which is a **sphere**, or on a flat surface, a dome shape called a **meniscus**.


hand breaking surface tension of water

This stretchy, **elastic** skin on the surface of water is strong enough to support insects like **water striders**. If you look closely at these insects walking on water you will notice that their feet make dents in the skin but do not break it. Amazing!

Time Needed to Conduct Investigations

Investigation 1: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 25 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 50 minutes

Investigation 2: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 25 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 50 minutes

Investigation 1: A Soapy Sloop

Materials

For groups of two
Student journals and writing tools

INVESTIGATION 1
Part 1
- ½ liter water bottle
- Pie tin
- Index cards
- Boat template (See Appendix)
- Ruler
- Scissors
- Liquid dish detergent
- Sponges for clean-up

Part 2
- Construction paper
- Aluminum foil
- Wax paper
- Cardboard
- Brown paper bag
- Printer / Copy paper
- Sandpaper
- Wrapping paper

INVESTIGATION 2
Part 1
- ½ liter water bottle
- 9 oz clear plastic cup
- Ground black pepper
- Liquid dish detergent
- Sponges for clean-up

Part 2
- Different types of soap (dish detergent, bar soap, liquid hand soap)
- Electric teapot (to make hot water)
- Bottles filled with other liquids (Salty, soapy, hot and cold water, white vinegar, Karo syrup, mineral oil, isopropyl alcohol, seltzer water)

Part 1
Floating Along

GET READY!

Explain to students that they will be conducting another experiment about surface tension, this one involving a boat. Review any relevant concepts/vocabulary from previous investigations, specifically the floating paperclip activity.

1. Break students up into groups of two.
2. Instruct students to create their boats by cutting a 2 ½ inch high and 1 ½ inch wide triangle out of their index cards.
3. Students should then cut a smaller triangle directly in the center of the back edge of the boat for the "motor." This is also where the boat's "fuel" (dish detergent) will go.
4. Students may use the template provided to create their boats.

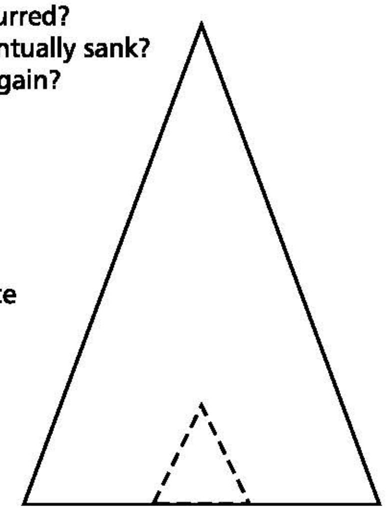
PREDICT

Invite students to make some predictions.
Ask students:
- What will happen when you place your boats in the water?
- Do you think that the boat will float or sink? Why?
- What do you think will happen when you add detergent to the water?
- Will you get the same results as with the floating and diving paperclip from the previous investigation?

OBSERVE

Students should then place their boats in the water near the edge of the pie tin and make observations.
Ask students:
- What happened to the boat when you first placed it in the water?
- Why do you think this happened?

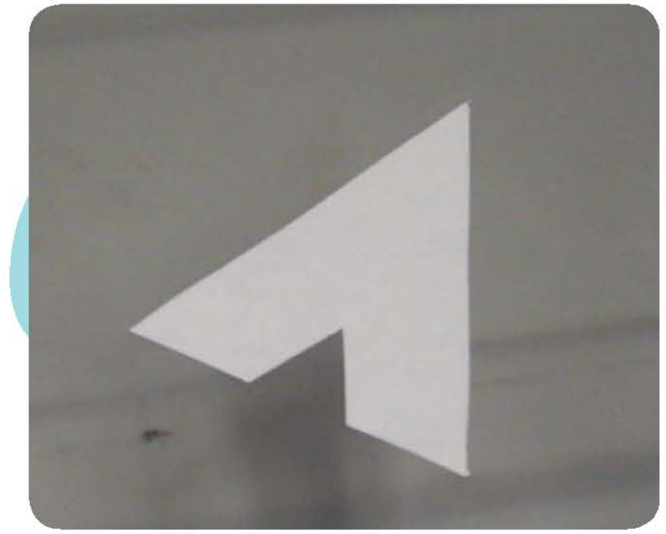
Next, have students place a small drop of fuel (liquid dish detergent) in the boat's motor (notch at the back of the boat).
Ask students:
- What happened to the boat just after adding the detergent?
- Why do you think that this occurred?
- Why do you think the boat eventually sank?
- Can you get the boat to float again?



boat template
(full size template
in Appendix)

Part 2
A Different Boat

Try this investigation again with a different type of paper. Have students choose a different paper from the materials list and build a new boat. Have students conduct the investigation with the new boat and compare their findings.



boat floating on water

Investigation 2: Petrified Pepper

Part 1
A Dash of Pepper

GET READY!

Explain to students that they will be conducting another experiment to explore the surface tension of water. Review any relevant concepts/vocabulary from previous investigations.

pepper floating on water

PREDICT

- What will happen if you sprinkle some black pepper into the cup?
- Do you think it will float or sink?
- What do you think will happen to the pepper if you drop some dish detergent onto the surface of the water?

PROCEDURE

1. Have students fill their cups halfway with water.
2. Next, sprinkle some pepper on the surface of the water.

OBSERVE

Invite students to make observations about the pepper and the water. Next, have students place a drop of dish detergent in the center of the floating pepper. Invite students to record their observations.
- What happened to the pepper when you added the detergent to the water?
- Why do you think this occurred?
- Why do you think the pepper eventually sank?

Part 2
What If?

Ask students: If you could change one thing about this investigation to learn something new, what would you try? When we change one part of an experiment to see how it affects our results, this change is known as a variable. Use the chart in your journal to record your ideas about what might happen if you change some of the variables. Some possibilities are:

- Will you get the same results if you use different quantities of water or different amounts of food coloring?
- What if you use soapy water? Salty water? Cold water? Hot water?
- Will it make a difference if you use slightly wilted carnations or celery?
- What if you tried a different type of plant?
- If you use another liquid, will you get the same results?

We encourage you to try these variables or other ideas suggested by the students. Invite students to share their questions and results with the group and record their findings in the chart in their student journals.

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion

Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

References:
www.ed.gov/pubs/parents/Science/celery.html
www.stevespanglerscience.com/experiment/00000144
Toothpick star in Water, water everywhere and not a drop to spare! New Jersey Academy for Aquatic Sciences.

Group Discussion

- Did you get similar results for the celery and carnations?
- Were there different results for different lengths of carnations or celery?
- Where do you think the water goes once it gets to the top of the plant?
- What did you learn about water from this experiment?
- Did everyone have the same results?
- What did you like about this investigation?
- What variables did you try?
- What surprised you?

The "Why" and The "How"

This investigation illustrates the property of water known as capillary action. Capillary action is how trees and plants get water to travel upwards from their roots to their leaves and flowers. All trees and plants have tube-like capillaries called "xylem" (zi-lem). Water molecules like to stick together and to the inside walls of plant capillaries, so they rise up in the tubes until they reach the top of the plant. Water eventually evaporates (changes from a liquid to a gas) from the leaves and petals of the plant by a process known as transpiration.

In this investigation, the colored water climbed up through the narrow capillaries of the celery and carnations. As the colored water moved upwards it outlined the path of the capillaries in each plant's stem/stalk, leaves and petals, resulting in a change of color.

Curriculum Match-Up

- Graph the distances the water traveled in the celery and carnations for a particular time period.
- Create a graph for the time it took for the water to travel all the way up the celery and carnations.
- Graph the speeds or distances for different colored water.
- Repeat the experiment using other materials such as cotton string. What do you observe?

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Moving On Up: Capillary Action I

Learning Objectives

Students will:

1. Explain why water travels through certain materials by capillary action.
2. Investigate how water can travel through the capillaries of different materials.
3. Test variables during the capillary action experiments.

Vocabulary Ventures

adhesion
capillary
capillary action
cohesion
gravity
meniscus
surface tension

Have you ever wondered how water gets from the roots of a tree to its leaves, or why paper towels are able to soak up a soggy spill? It has to do with the property of water known as **capillary action.**

Capillary action is water's ability to move through the narrow tube-like spaces, known as capillaries, within a porous or spongy material. Capillary action even allows water to climb upwards against the force of gravity. This is how water is able to travel from the roots to the leaves of a tall tree.

Plants absorb water from the soil through their roots. When water enters the soil and reaches the roots of the tree, water molecules are attracted to the molecules in the root. This process is known as **adhesion**, and it happens when water molecules are attracted to molecules in other substances. This attraction causes the water molecules to move closer to the root molecules and be drawn through the narrow **capillary** tubes inside the plant. For capillary action to occur, the attraction between the water molecules and the tree molecules (adhesion) must be stronger than the mutual attraction between all water molecules (cohesion).

Water's **surface tension**, the property of water which causes an invisible "skin" to form on the surface of water, also has an important role in capillary action. Inside a capillary, the surface of water forms a concave shape (like the letter C) called a **meniscus**. This is because the force ad adhesion causes surface water molecules near the capillary walls to move through the capillary first. As these molecules move, surface tension keeps the surface of the water together and causes it to form a bowl shape. The water molecules beneath the surface tag along due to cohesion.


mangrove tree with exposed roots

Capillary action is limited by **gravity** and the size of the capillaries or tubes. Water will stop moving upwards through a capillary once it is unable to overcome the force of gravity. The size of a capillary also determines how high the water can go. The thinner the capillary tube, the higher up capillary action will pull the water. Capillary action can draw water up into a tree over 300 feet tall!

Time Needed to Conduct Investigation
This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 10 minutes
Conduct the investigation: 20 - 30 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 50 - 60 minutes

Investigation: Colorizing Carnations

Materials

For groups of three or four
Student journals and writing tools

Part 1

- ½ liter water bottle with tap water
- 200 mL beakers or measuring cups to hold plants
- 3 Fresh stalks of celery with leaves (cut to the same length)
- 3 Fresh white carnations with leaves (cut to the same length)
- Red or blue food coloring
- Sponges for clean-up
- Clock or watch
- Calendar

Part 2

- Rulers
- Magnifying lenses
- Other types of plants with leaves
- Bottles of other liquids (Salty water, soapy water, cold water, hot water, white vinegar, Karo syrup, baby oil, isopropyl alcohol, seltzer water)

Part 1
Color Me Happy

TIP
This activity will take several days to complete. Fresh carnations and celery should be purchased NO SOONER THAN THE DAY BEFORE the lesson is done to prevent them from drying out. Refrigerate the celery and keep the carnations in water to prevent wilting. Have your students help with the prep work.

TIP
Just prior to the start of the lesson make a fresh cut on the carnation and the celery. To make a fresh cut, hold the celery stalks and carnation stems under running water. As you are doing this, cut off the bottom ends of the celery and a bottom portion of the stems of the carnations at an angle using scissors. Cut a number of different lengths of celery and carnations.

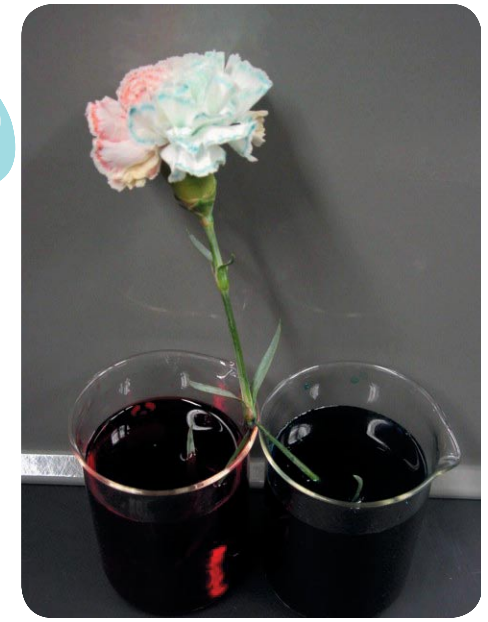
GET READY!

Inform the class that they will do an experiment to understand how a paper towel can soak up a spill, or how water gets from the roots to the leaves of a tree. Review any relevant concepts/vocabulary from previous investigations.

PROCEDURE

1. Have students measure out 75 mL of water.
2. Next, have the students place 20 drops of blue or red food coloring into the beakers or measuring cups. Students should observe what happens after they added the food coloring to the water. Students should record the amount of water and number of drops in their student journals.
3. Have students place the celery stalks and carnations in each of the cups and set them aside. As an option, students can split some of the carnation stems down the middle, keeping them attached to the flower, and placing each half in a different colored container of water.
4. Students should record in their student journals the date and what time it is when they place the carnations and celery in the water.

TIP
Capillary action can sometimes take a few days to occur in these plants, so you may want to prepare final samples in advance of the investigation to show students.



split carnation set-up

celery vessels with food coloring

PREDICT

- What do you think will happen to the celery and the carnations as they sit in the colored water? How did you come to that conclusion?
- What do you think will happen to the split carnations?
- Do you think there will be a difference between the results for the carnations and the celery? Why, or why not?

OBSERVE

Ask students to record their observations in the student journals as they conduct the investigation.

- Do you think there will be a difference between different lengths of celery or carnations?
- Do you think that there will be different results for different colors?

TIP
After a few days, invite students to observe what happened to their celery stalks and carnations. If a visible result has not yet occurred, let students observe the prepared samples.

Students can set up additional celery stalks and carnations and record the results in hour/day-long increments, measuring how far the water traveled at each interval.

- What do you observe about the stem/stalk of the plants? Pick up the carnation/celery and examine the bottom of the stem where it was cut. Diagram what you observe.
- What do you notice about the petals and leaves? How do they look under magnifying lenses? Diagram what you observe.
- Examine the carnations and celery each day and record your observations.
- Measure and record how high the food coloring traveled.

PREDICT

- What do you think will happen if you place a drop of water in the center of the toothpick flower?
- Why do you think this will occur?

OBSERVE

- What happened to the toothpicks?
- Where did the water go?
- How did this compare with what you predicted?
- Draw the "before" and "after" diagrams of the toothpicks in your journals.

Part 2 What If?

Ask the group to share questions that might have arisen as they conducted the "Toothpick Flowers" activity. Invite them to think of other questions they would like to explore. Some possibilities are:

- Will the results of the experiment differ if you use rounded toothpicks instead of flat toothpicks?
- Will you get the same results if you use different quantities of water or different amounts of food coloring?
- What if you use soapy water? Salty water? Cold water? Hot water?
- If you use another liquid, would you get the same results?

Feel free to try these other investigations or ones that are suggested by the students. Invite students to share their questions and results with the class and record them in their student journals. Ask students to record their observations in the chart in their student journals.

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion

Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What happened to the paper flowers?
- What variables did you test?
- How did this investigation remind you of the color blooming carnation and celery activity?
- What surprised you?
- What variables did you test?
- What new questions do you have?

The "Why" and The "How"

Capillary action is how trees and plants get water to travel upward against gravity. All trees and roots have tube-like capillaries called "xylem" (zi-lem). Water molecules like to stick together and to the inside walls of the tree's capillaries, so they rise up the tubes against the force of gravity. Capillary action is how water travels from the roots of a plant to its leaves. Water eventually evaporates (changes from liquid to gas) from the leaves in a process called transpiration.

This investigation illustrated capillary action. The water traveled through the capillaries in the paper flower causing the petals to swell and open. Capillary action was also the force that caused water to be absorbed by the toothpicks. This resulted in the toothpicks straightening, which changed the shape of the toothpicks from a flower to a star. The water molecules stick or adhere to the paper flower and the toothpicks. This adhesive force worked with surface tension to pull water through the paper flower and the toothpicks.

Curriculum Match-Up

- Have students tie-dye shirts to see capillary action happen before their eyes.
- Experiment with white paper towels to see which liquids travel the farthest and fastest, and does the print on the paper towel effect the absorption rate.
- Graph the speeds or distances for the different liquids or different colored water.
- Diagram the path of water as it flows through a tree or plant by capillary action.

References:
www.ed.gov/pubs/parents/Science/celery.html
www.stevespanglerscience.com/experiment/00000144

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Moving On Up: Capillary Action II

Learning Objectives

Students will:

1. Explain why water climbs or travels through certain materials.
2. Investigate the process of capillary action using different materials.
3. Select variables to test during the capillary action experiments.

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Vocabulary Ventures

adhesion
capillary
capillary action
cohesion
gravity
meniscus
surface tension

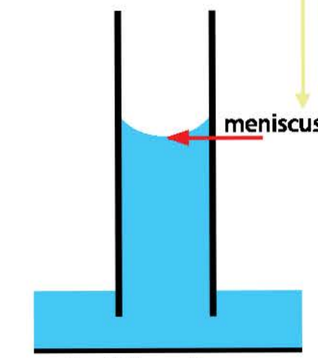
Note: This introduction is repeated from the previous lesson plan on capillary action.

Have you ever wondered how water gets from the roots of a tree to its leaves, or why paper towels are able to soak up a soggy spill? All of these have to do with the property of water known as **capillary action.**

Capillary action is water's ability to move through the narrow tube-like spaces, known as capillaries, within a porous or spongy material. Capillary action even allows water to climb upwards against the force of gravity. This is how water is able to travel from the roots to the leaves of a tall tree.

Plants absorb water from the soil through their roots. When water enters the soil and reaches the tree roots, water molecules are attracted to the molecules in the root. This process is known as **adhesion**, and it happens when water molecules are attracted to molecules in other substances. This **attraction** causes the water molecules to move closer to the root molecules and be drawn through the narrow **capillary** tubes inside the plant. For capillary action to occur, the attraction between the water molecules and the tree molecules **(adhesion)** must be stronger than the mutual attraction between all water molecules **(cohesion).**

Surface tension, the property of water which causes an invisible "skin" to form on the surface of water, also has an important role in capillary action. Inside a capillary, the attraction between water molecules at the surface causes water to pull or curve itself inward, forming a concave or bowl shape (like the letter C) called a **meniscus**. Surface tension keeps the surface of the water together inside the tube. When the surface of the water is pulled through the capillary, cohesion helps pull all of the water molecules through the capillary as well.



liquid traveling up through a tube

Capillary action is limited by **gravity** and the size of the capillaries. Water will stop moving upwards through a capillary once it is unable to overcome the force of gravity. The size of a capillary also determines how high the water can go. The thinner the capillary tube, the higher up capillary action will pull the water. Capillary action can draw water up into a tree over 300 feet tall!

Time Needed to Conduct Investigations

Investigation 1: *This investigation has two parts.*
Organize and set up materials: 5 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 10 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 30 minutes

Investigation 2: *This investigation has two parts.*
Organize and set up materials: 5 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 15 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 35 minutes

Investigation 1: Paper Blooms

Materials

For groups of three or four
Student journals and writing tools

Investigation 1
Part 1
- ½ liter water bottle
- Flower template (See Appendix)
- Pie tins
- Notebook paper
- Scissors
- Food coloring
- Sponges for clean-up

Part 2
- Bottles of other liquids (Salty water, soapy water, cold water, hot water, white vinegar, Karo syrup, baby oil, isopropyl alcohol, seltzer water)
- Various kinds of paper

Investigation 2
Part 1
- ½ liter water bottle
- Different colors of food coloring
- 16 oz plastic cups
- Flat toothpicks
- Sponges for clean-up
- Straw or eye dropper

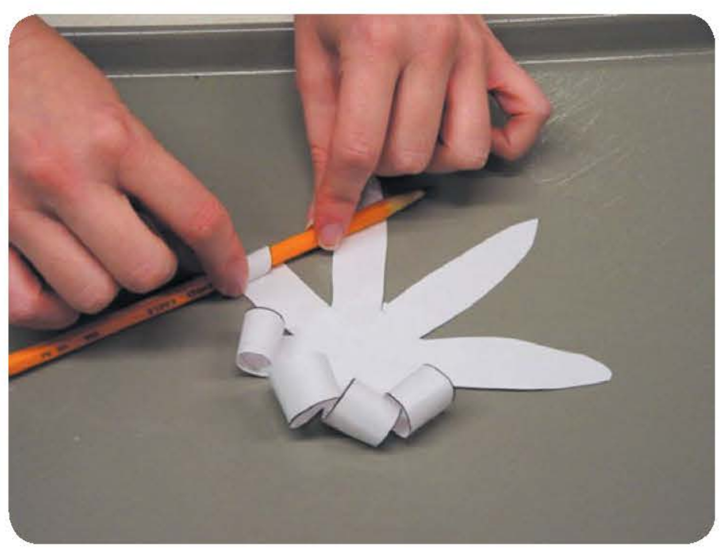
Part 2
- Rounded toothpicks
- Bottles of other liquids (the same liquids used in Investigation 1)

Part 1
Unfurling Flowers

GET READY!
Explain to students that they will be conducting another experiment about capillary action, this one involving paper flowers. Review any relevant concepts/vocabulary from previous investigations, specifically Unit 1, Lesson 8, "Colorizing Carnations".

TIP
Gather all necessary materials prior to the start of the activity. Prepare salty and soapy water solutions in advance. Prepare flower templates for Part 1. Flower templates must have distinct petals that are clearly separated, not layered or overlapping. This makes it easy for the petals to unfurl during the experiment.

PROCEDURE
1. Have students fill their pie tins halfway with water and add two drops of food coloring.
2. Next, have students use the flower template to trace a flower on notebook paper and cut it out.
3. Students should use a pencil to roll up the petals so that it looks as if the flower is closed.
4. Explain that the students will place the paper flower into the water, but first, invite them to make and record their predictions.



curling paper flower petals

PREDICT
- What will happen when the flower is placed into the water? Why?
- Where do you think the water will go?

OBSERVE
After placing the flower in the pie tin of water, ask students to make observations and discuss them with their partner or group.
- What happened to the flower when it was placed in the pie tin?
- What did you observe about the water?
- Where did the water go?

Part 2
What If?
Ask the group to share questions that might have arisen as they conducted the first part of this investigation, "Unfurling Flowers." Invite students to think of other questions they would like to explore. Some possibilities are:
- Would you get the same results if you used different quantities of water or different amounts of food coloring?
- What if you used soapy water? Salty water? Cold water? Hot water?
- If we used another liquid, would you get the same results?
- What about other variables such as different types of paper for the flowers and different size flowers?

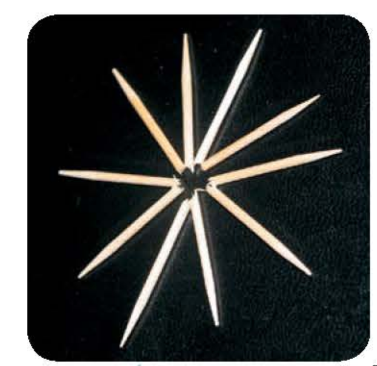
Feel free to try these other investigations or ones that are suggested by the students. Invite students to share their questions and results with the class and record them in their student journals.

Investigation 2: Toothpick Tricks

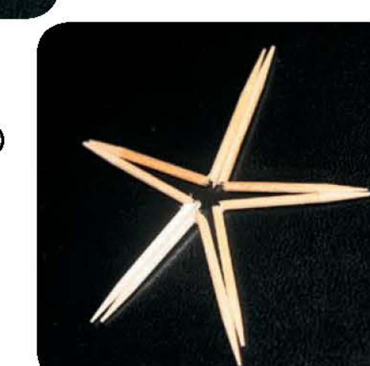
Part 1
Toothpick Flowers

GET READY!
Explain to students that you will be conducting another experiment about capillary action, this one involving toothpicks. Review any relevant concepts/vocabulary from previous investigations.

PROCEDURE
1. Have students prepare their colored water in the 16 oz cups by pouring water into the cups and adding several drops of food coloring to the water.
2. Invite students to bend five flat toothpicks in half without breaking them, so that each one is in the shape of a "V".
3. Students should then arrange the five toothpicks on a waterproof surface with the base of the V's touching, to resemble a flower.
4. Students should place the ends of their straws into the colored water. Holding a finger over the other end of the straw, they should then lift the straw out of the water.
5. Inform students that they will be placing the water into the center of the toothpick flower, but before they do, they should make some predictions.



flower (before)



star (after)

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water from this activity?
- What surprised you?
- What new questions do you have?
- What did you like about this activity?

The "Why" and the "How"
There are several things working together to make each object float or sink. The surface of a liquid acts like an elastic band or skin, caving in slightly when an object touches the surface. When a high-density object (like a marble) is placed in or on water, it breaks the surface tension of the water. Some of the water is then pushed aside or "**displaced**". Because no two objects can occupy the same space at the same time, the water has to make room for the marble by moving out of the way, so the water level rises. If you weigh the marble that sank to the bottom of the container, you will find that it weighs more than the water it displaced.

All objects, whether they sink or float, experience an upward **force** when they are placed in liquid. This force is known as the buoyant force, and it is equal to the weight of the liquid displaced by the object. The properties of buoyancy and density work together, helping an object sink or float.

Density measures how compact (how crowded together) matter is packed into a certain space. If an object is less dense than the surrounding water, the object floats. But, if an object is more dense than the surrounding water, it sinks.

Buoyancy helps low-density objects float and causes them to resist being submerged under water. This is why the sealed bottle of air floats instead of sinking. Air is less dense than water, causing it to float above water.

Think about it: air floats above all the Earth's water, including lakes, rivers and the ocean! If you release air from the bottle while it is under water, water will fill the container, causing it to sink. Every day, you can see examples of some objects that float while others sink. Cornflakes can float in milk because they are less dense than the milk. A raisin may sink because it is denser than milk. Ice is actually less dense than water – this is why icebergs float on water.

Another example is submarines: a submarine floats because the weight of water that it displaces or moves is equal to its weight. When a submarine is placed in the water, **gravity** pulls the submarine downward. But, as water is displaced, it creates the upward (buoyant) force. This buoyant force acts opposite to gravity, which tries to pull the ship down. A submarine can control its buoyancy, allowing it to sink and rise to the surface as it needs. To control its buoyancy, the submarine has tanks that can be filled with water or air. When the submarine is on the surface of the water, the tanks are filled with air, making the submarine less dense than the surrounding water. When the submarine wants to dive, its tanks are filled with water until its density is greater than the surrounding water, causing the submarine to sink.

submarine

Curriculum Match-Up

- Make a chart of the items that sink and float in this investigation.
- Repeat the investigation using a ball of aluminum foil, cornflakes, paperclips or pennies in place of marbles and clay. Predict whether or not these items will sink or float. How many will it take to sink the bottle?
- Add ½ cup of salt to the water and try the investigations again. What do you observe?

References:
Adapted from information from the U.S. Office of Naval Research
Encyclopedia Britannica

This lesson was funded in (whole or part) with federal funds from Title IV, Part B, 21st Century Community Learning Centers program of the No Child Left Behind Act of 2001 awarded to the New Jersey Department of Education.

Uplifting Force: Buoyancy & Density

Learning Objectives

Students will:

1. Investigate different kinds of force and motion, including buoyancy and other properties of water.
2. Identify the relationship between physical properties of water, specifically buoyancy, **surface tension** and displacement.
3. List common examples of displacement, buoyancy and surface tension in action.

Vocabulary Ventures

buoyancy
density
displacement
force
gravity
mass
surface tension

An ancient Greek mathematician named Archimedes first discovered the law of **buoyancy**. Also known as Archimedes' principle, it states, "the buoyant force is equal to the weight of the displaced fluid".

Archimedes had a gift for making machines, and he served as an advisor to King Hiero of the Greek colony of Syracuse. King Hiero had gold sent to a goldsmith for a new crown. When the king received the finished crown, he thought something was wrong -- it didn't appear as if all the gold was used to make the crown. The king told Archimedes about his problem.

Archimedes went home and filled his tub with water. When he sat in the tub of water, it overflowed. Archimedes realized that the **mass** of the water that spilled out of the tub was equal to the mass of his body.

boy using inner tube float to stay buoyant in water

Archimedes tried the same experiment with the crown, placing it in a bucket filled with water and watching water spill out of the bucket. He observed that the amount of gold that was supposed to be used for the crown was equal to the amount of water that spilled out of the bucket. Archimedes later found out that the amount of gold sent to the goldsmith weighed more than the crown.

Archimedes concluded that the goldsmith didn't use all of the gold he was given to make a new crown. Why? Because the crown had less mass than the amount of gold sent to the goldsmith. The goldsmith was punished when King Hiero found out that the gold was missing from the crown. The legend is told that when Archimedes discovered the property of buoyancy, he ran through the streets yelling "Eureka!" which means "I found it!"

Time Needed to Conduct Investigation
This investigation has five parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 15 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 40 minutes

Investigation: Sink or Float?

Materials

For groups of three
Student journals and writing tools

- Marbles (15 per group)
- Medium to large (shoebox-sized or larger) plastic container with a wide open top, filled with water

½ stick of clay (from a 1 lb. package)

- Small airtight jar or bottle (like a baby food jar or a ½ liter water bottle with cap)
- Pan balance or scale

Part 1
Marble vs. Clay

GET READY!

Review the concept of physical properties with students. Physical properties can be observed using at least one of our five senses (sight, smell, taste, touch, hearing), or they can be measured (using a tool like a scale) without changing the chemical make-up of matter. We use physical properties to describe and understand different objects. Physical properties include observations such as color, texture (rough or smooth), odor, melting point, boiling point, density, solubility (if and when a material dissolves in liquid) and several others.

PROCEDURE

1. Divide students into groups of two or three.
2. Ask students to mold a small piece of modeling clay into a ball the same size as the marble in their supplies.
3. Have students make observations about the properties of the clay ball and the marble. Students should then describe the differences and similarities between the clay and the marble.
4. Next, have students weigh the marble and the ball of clay using the pan balance.

PREDICT

Ask students to make predictions and record them in their student journals:

- What will happen when you put the marble in the water?
- What will happen when you put the ball of clay in the water?

OBSERVE

Ask students to place the marble into the water. Then have them place the clay in the water. Make the following observations:

- What happened to each object after you placed it in the water?
- Did the object sink quickly or take a long time to sink?
- Why do you think that this happened?

Part 2
Bottle Basics

Distribute the small airtight jar or bottle, and have students seal the lid tightly. Have students weigh the bottle using the pan balance.

PREDICT

Ask students to make a prediction about what will happen when they place the bottle in the water. Students should record their predictions in their journals.

OBSERVE

Ask students:

- What happened to the bottle after you placed it in the water?
- Why do you think that this happened?
- What do you notice about the shape of the bottle?
- What's inside the bottle? (HINT: It's something that you breathe. ANSWER: Air!)

Part 3
Marble in a Bottle

Have students take the bottle out of the water, remove the lid and place a marble in the bottle. Students should re-seal the bottle tightly and weigh it using the pan balance. Before the students place the bottle back in the water, have them make some predictions about what will happen to the bottle with the marble in it.

OBSERVE

Ask students:

- What happened to the bottle after you placed it in the water?
- How do you explain what happened?
- How many marbles can you add before you get the bottle to sink?

Part 4
Clay in a Bottle

Have students take the bottle out of the water, remove the lid and the marble, and place the ball of clay in the bottle. Students should re-seal the bottle tightly and weigh it using the pan balance. Students should predict again what will happen before they place the bottle back in the water.

OBSERVE

Ask students:

- What happened to the bottle after you placed it in the water?
- How do you explain what happened?
- How many balls of clay can you add to the bottle before you get it to sink?

Part 5
A Bottle Full of Water

Have students take the bottle out of the water, remove the lid and the ball of clay from the bottle. Students should fill the bottle with water and re-seal the bottle tightly. If you have enough gram counter weights, have the students weigh the bottle of water using the pan balance. Ask students to predict what will happen when the bottle is placed in the water.

OBSERVE

Ask students:

- What happened to the bottle after you placed it in the water?
- How do you explain what happened?

floating bottle with marble

boats floating in the harbor

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Explain to students that scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, they will now come together as a group to share their results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What did you learn about water from this investigation?
- What have you learned about an object's ability to float in water?
- What variables did we use in this investigation?
- What surprised you?
- What new questions do you have?
- What did you like about this activity?

The "Why" and the "How"
There are several things working together to make each object float or sink. The surface of water acts like an elastic band or skin, caving in slightly when an object touches the surface. When a high-density object (like a marble) is placed in water, it breaks the surface tension of the water. Some of the water rises and is then pushed aside or "displaced".

No two objects can occupy the same space at the same time. The water has to make room for the clay boat by moving out of the way, so the water level rises. If you weigh the ball of clay that sank, you will find that the clay weighs more than the water it displaced.

The thing to remember about floating is that the object must displace an amount of water which is equal to its own weight. So, let's imagine that you have a wooden boat that weighs 20 pounds. When you lower that boat into the water, the boat will move down into the water until it has displaced or moved 20 pounds of water out of the way. That means that 20 pounds of water are pushing back up on the boat, causing it to float. In this investigation, the more weight, or cargo, added to the boat, the more water it displaced.

The ball of clay that sank earlier in the lesson will float once its shape is changed to give it enough surface area. The clay boat has more contact with the surface of the water, making it more stable so that it does not tip over easily. **Buoyancy** is the ability of an object to float – an upward **force** (in this case, the water) pushes up on the object (the clay boat), and **gravity** makes the weight of the clay boat push down on the water.

Curriculum Match-Up

- Graph the number of items that it took to sink your clay boat.
- Repeat the investigation using aluminum foil in place of clay, or pennies in place of marbles or paperclips.
- Have students rework the clay into a few different-shaped boats to see which model will carry the most marbles.
- Add salt to the water and try the investigations again. Are the results different? What do you observe?
- Discuss why objects seem lighter in water than they do on dry land.
- Research how a ship's crew knows just how much cargo a ship can hold.

References:
Adapted from information from the U.S. Office of Naval Research

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Above Water: Buoyancy & Displacement

Learning Objectives

Students will:

1. Conduct experiments to find out how objects stay afloat in water.
2. Document the relationship between **surface tension,** buoyancy, density and **displacement.**
3. Demonstrate how shape, size, and type of material affect an object's ability to remain buoyant.

Vocabulary Ventures

buoyancy
density
displacement
force
gravity
surface tension

Water plays such an important role in our lives that we could not live without it. We drink, bathe, clean, and cook with water. Can you think of some other ways that we use water?

You may have seen objects like styrofoam or wood float on water. But have you ever seen concrete and steel float?

freighter with a heavy load

The reason that a steel ship can float is because the ship is made of more than just steel. If you put a solid steel ship in the water, it would sink, but ships are designed with an air floor called a "hull". Air is very light and less dense than steel. The air trapped inside the ship's hull lowers the overall density of the ship, helping it float.

So, while steel is dense and heavy enough to fully submerge the ship in water, the trapped air has a lower density than steel and is light enough to keep the ship from sinking. If there is not enough air in the ship's hull, and the ship sinks too low in the water, some of the water could spill in over the sides of the ship, displacing the air and increasing the overall **density** of the ship. This is why ships sink if they are tipped to one side.

Today, you're going to learn how special properties of water help objects float!

Time Needed to Conduct Investigation
This investigation has three parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 minutes
Total time: 45 minutes

Investigation: Shape It!

Materials

For groups of two or three
Student journals and writing tools

Part 1
- Medium to large (shoebox size or larger) plastic container with a wide, open top filled with water
- ½ stick of modeling clay per student (from a 1 lb. package)

Part 2
- Paperclips (one box per group)

Part 3
- Marbles (one bag per group)

Part 1
Float Your Clay

GET READY!

1. Divide students into groups of two or three.
2. Ask students to mold their ½ stick of modeling clay into a ball.
3. Ask students to think about how they can get their ball of clay to float in the water.

PREDICT

Before students place their ball of clay in the water, they should make some predictions.
Will the ball of clay float, or will it sink? Why?

PROCEDURE

1. Have the students place their ball of clay into the water and make observations.
2. After several tries, have the students make predictions and suggestions about how to shape the clay differently so that it will float.

TIP
If needed after 5 minutes, assist students in shaping their boats to float. Show students how to shape a boat by forming sides and hollowing out the inside.

clay boat

OBSERVE

Ask students to make and record their observations of the following:
- What happened after you placed your re-shaped clay in the water?
- What do you notice about the shape of your molded clay?
- How is this clay different from the original ball of clay?

Part 2
How Many Paperclips Can You Float?

Once students get their clay boats to float, distribute the paperclips.

PREDICT

Have students record their predictions in the student journals.
How many paperclips will the boat hold before it sinks?

PROCEDURE

1. Have students *slowly* begin placing paperclips into the clay boat.
2. Remind students to count the number of paperclips and make observations about the water level as they drop the paperclips into the boat.
3. They should continue adding paperclips until their clay boat sinks and record the number of paperclips used.

boat with paperclips

boat with marbles

Part 3
How Many Marbles Can You Float?

Students will continue using their clay boats for part of this investigation. Distribute the marbles, and ask students to predict and record the number of marbles the boat will hold before it sinks.

OBSERVE

As students begin to *slowly* add the marbles one at a time until the boat sinks, have them make the following observations:
- What effect do the marbles have on the boat?
- What do you notice about the water? *Answer: the water level is rising as more marbles are placed in the boat.*
- How many marbles did it take to sink your boat?
- Do the results differ between the paperclips and the marbles? If so, why do you think this happened?