Make a critter that can walk on water

SC Academic Standards: 4.L.5A; 4.L.5B; 5.L.4B; 6.L.4A; 6.L.4B; 6.L.5A; 7.L.3A; 7.EC.5A; 8.E.6B; H.B.2B; H.B.3; H.B.6

NGSS DCI: 4-LS1.A; MS-PS1.A; MS-LS1.A; MS-LS2.C; HS-LS1.A; MS / HS-ETS1.A-C

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.6; S.1A.7; S.1A.8

Crosscutting Concepts: Patterns, Cause and Effect: Mechanism and Explanation; and Structure and Function.

Focus Question(s): What properties of water make it so water striders don't sink? What properties of animals allow them to "walk on water"?

Conceptual Understanding: Structural adaptations within groups of plants and animals allow them to better survive and reproduce (4.L.5B).

Classification of animals is based on structures that function in growth, reproduction, and survival. Animals have both structural and behavioral adaptations that increase the chances of reproduction and survival in changing environments (6.L.4B).

Background: If you've ever looked carefully at a full glass of water or a water droplet, you may have noticed that the water forms a thin, stretchy layer at its surface. This phenomenon is called surface tension. Surface tension is caused by the attraction, or cohesion, of individual molecules to one another in a liquid, especially when they are near repulsive air molecules. Water on the surface has a tendency to be tight with the water around it, resulting in a property that pulls it together. This is called surface tension. Lightweight objects, even ones that do not typically float, may be able to rest on the surface tension of a liquid. This happens when the weight of the object is distributed over a large area so that it doesn't tear apart the cohesion between molecules. Surface tension is one of water's most important properties. It is the reason that water collects in drops, but it is also why water can travel up a plant stem, or get to your cells through the smallest blood vessels.

Some insects, such as water striders, are able to stand and travel on the surface of water because of surface tension and spend much of their lives gliding across ponds and streams. Water striders use the surface tension of water to their advantage so they can "walk on water".

Water acts different at the surface. Water molecules are attracted to each other, and like to stay together, especially on the surface where there is only air above. The attraction between water molecules creates tension and a very delicate

membrane. Water striders walk on this membrane. Water striders are about a half inch long with a thin body and three sets of legs. A water strider's front legs are much shorter than the two sets of back legs. The secret of the water strider is its legs! The water strider's legs are covered with thousands of hairs that repel water and capture air, rendering them effectively non-wetting. This property allows it to freely remove its legs from the surface to row. A water strider's weight is balanced by a surface tension force of more than ten times its weight. This large margin of safety allows the strider to freely lift its legs from the surface during rowing or to support the weight of a companion without falling through the surface. By repelling water, the tiny water striders stand on the water's surface and the captured airs allows them to float and move easily.

Water striders can move quickly along the water's surface. These true bugs look as if they are "skating" on water. They don't sink because of the way they spread out their long, thin back legs. Their weight is spread over a large area, so these bugs can actually slide along the surface of water. The shorter legs are used for catching and holding onto food.

Water striders eat insects and larvae on the surface of water, such as mosquitoes and fallen dragonflies. Water striders are about 3/4 inch (19 millimeters) long. Many live on freshwater ponds and streams. These bugs use waves to find food. When insects fall in the water, they make tiny ripples. Water striders feel the ripples with their feet. They skate to the source and stab their victims with their beaks.

Some species of water striders live on the ocean. In fact, they are the only insects that can live their entire lives on the ocean. These bugs skate around and feed on dead fish and other animals they find.

In this lab exercise, we will engineer (or design) a critter made from wire that will float on the surface of a bowl of water, suing surface tension to support its body. We will then add liquid soap, a surfactant, to see how surfactants affect surface tension.

Materials: *per group*: Large bowl of cold water, a roll of think plastic coated wire (30 gauge: 50-Ft. White Insulated Wrapping Wire (30AWG) $6.00 at RadioShack), sharp scissors or wire cutters, paper clips, and (for **extension**) a coffee mug / pennies / water dropper.

Previous Knowledge: (physics). Surface Tension - At liquid-air interfaces, surface tension results from the greater attraction of water molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion). The net effect is an inward force at its surface that causes water to behave as if its surface were covered with a stretched elastic membrane. Because of the relatively high attraction of water molecules for each other, water has a high surface tension (72.8 milli-newtons per meter at 20°C) compared to that of most other liquids.

Previous knowledge: (chemistry): Hydrogen bonding. Water is a polar molecule. When the two positively charged hydrogen atoms attach to the negatively charged oxygen atom, a stable water molecule is created. The atoms attach in a "bent" shape. This does not allow for an equal "pulling" or sharing of the electrons between the three atoms, allowing the hydrogen atoms to develop a slight positive charge and the oxygen atom to develop a slight negative charge. The difference in charge across the molecule is called a "dipole".

The slightly positive hydrogen side of one water molecule attracts the slightly negative oxygen side of another water molecule, creating a natural "attraction" between the molecules. Water molecules on the surface of a bowl of water are attracted to each other as well as to the water below them, which creates a strong and flexible film on the water's surface. This is the surface tension that allows the paperclips to float.

When you add soap to water, however, the surface tension breaks. Soap molecules consist of nonpolar, dipole-free bodies and a polar head. When soap mixes with water, the polar heads attach to the surface of the water and the nonpolar bodies tend to point upwards, away from the water, reducing the water's surface tension. Thus, the paper clips sink and it becomes difficult to float new clips!

Procedure:

1. Watch the video https://www.youtube.com/watch?v=mCd6zIuACLw and/or https://www.youtube.com/watch?v=K4uoj9_mqBU and/or http://vimeo.com/30598419

2. Cut a 30 cm piece of 30-gauge plastic coated wire.

3. Bend the wire into a unique, flat shape. This will be your water-walking critter.

4. Fill a large bowl with cold water and let it rest until the surface is still.

5. Gently place the wire shape on the surface of the water. If it sinks, pick it up, shake off the water, and try again (once water surface is still again). This can be tricky – you may need to try putting the paperclip on a small piece of toilet paper or paper towel – in a few seconds, the paper toweling will sink and the paperclip should float.

6. Take your wire critter out of the water and try placing it on the water vertically. What changed?

7. Change the shape of your critter so that it can hold a paperclip above the water surface. Modify your design and try to get your critter to hold as many paperclips as you can.

Group Name	# paperclips held above water surface

8. Now take your best design for a floating wire critter. Add a few drops of liquid soap to the bowl of water. Try to place your wire critter in so that it floats, as you did in step 5. What happens now?

Data Analysis: Record how many paperclips each student was able to keep above the water surface on top of their wire critter. Make a frequency histogram with # students who achieved "X" number on Y versus Number of paperclips on X.

Extensions: a great pre-lab for this activity is to try to float a paperclip in a glass of water. The complete protocol for the activity "Break the Tension" is here, on the TEACH Engineering resources for K-12 website: http://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_earth/cub_earth_lesson2_activity4.xml and the website by David Hu (http://www-math.mit.edu/~dhu/Striderweb/striderweb.html)contains amazing photos of water striders plus some neat ideas if you have a live water strider in an aquarium, with pH sensitive powdered Thymol Blue.

Secondly, you could do the "how many drops of water can I get on a penny" exercise as seen on The Science Spot http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0CDcQFjAD&url=http%3A%2F%2Fsciencespot.net%2FMedia%2Fpennylab.pdf&ei=f1IcVKXfJsWcyAS0_YGQCg&usg=AFQjCNGauQzuo7ui0VKrcAqJcyrKBAKkyg&bvm=bv.75774317,d.aWw

Reflection Questions:

- **What happened to the surface tension when we added soap?** Well, soap is what we call a *surfactant*. This word comes from two words: surface and active. (Write these on the board.) Surface, because soap acts on the surface, and active because it *acts* on the *surface*. Surfactants act on the surfaces of liquids, in this case water, to reduce surface tension.

- **In what ways have engineers used the property of surface tension to design things to help people?** Engineers understand how surface tension

works and use it in many ways. They design printers and printing presses in which surface tension is used in the ink application process. Environmental engineers who clean water and air pollution take advantage of surface tension. They design systems that use the condensation of water, for example, to make drinking water from salty ocean water, or use water vapor to remove pollutants from dirty air. Surface tension determines whether things can float or not, which applies to many everyday situations. Surface tension is a consideration in space flight (zero gravity) — liquids cannot be stored in open containers because they will run up the vessel walls.

- **Is soap ever added to natural water systems?** Storm drains: washing cars
- **In what ways have engineers used surfactants to design things to help us?** Engineers figure out ways to use surfactants to break up surface tension. For example, surfactants, like soaps and detergents, break up all kinds of oil, which helps in cleaning up messes. Environmental engineers use surfactants to clean hazardous waste areas or spilled airplane fuel on runways or spilled oil on the surface of the ocean. Chemical engineers design cleaning products using surfactants — everything from laundry soap to shampoo.

Models and Explanations: In this lab we explored surface tension and designed a wire critter that, like the insect water strider, could float on the water even though it is more dense than water. **A student who demonstrates understanding** of these concepts can explain why dense things should sink in water, but due to the shape of the wire critter, or water strider, the weight is spread out and the water's surface tension (caused by Hydrogen bonding) will keep the water critter from sinking.

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Student Worksheet:

Surface tension is one of water's most important properties. It is the reason that water collects in drops, but it is also why water can travel up a plant stem, or get to your cells through the smallest blood vessels. Surface tension is caused by the attraction, or cohesion, of individual molecules to one another in a liquid, especially when they are near repulsive air molecules. Water on the surface has a tendency to be tight with the water around it, resulting in a property that pulls it together. This is called **surface tension**. Lightweight objects, even ones that do not typically float, may be able to rest on the surface tension of a liquid. This happens when the weight of the object is distributed over a large area so that it doesn't tear apart the cohesion between molecules. Some insects, such as water striders, are able to stand and travel on the surface of water because of surface tension and spend much of their lives gliding across ponds and streams. Water striders use the surface tension of water to their advantage so they can "walk on water".

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- **How many paperclips could your wire critter hold without sinking?**

- **What happened to the surface tension when we added soap?**
- **Is soap ever added to natural water systems? Surfactants?**

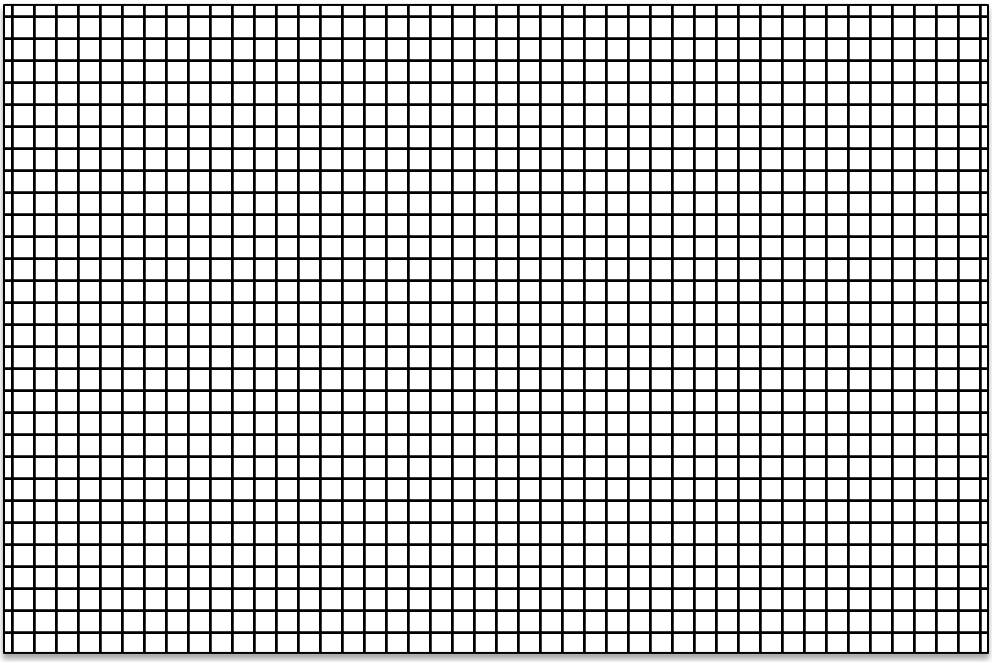
- **In what ways have engineers used the property of surface tension to design things to help people?**

- **In what ways have engineers used surfactants to design things to help us?**

Group Name	# paperclips held above water surface

Table 1. Number of paperclips the wire water critter could hold above the surface without sinking

 # groups (frequency)



0 1 2 3 4 5 6 7 8 9 10

 # paperclips held above surface