Surface Tension Inquiry with Soap Films – Daniel Sinkovits

Purpose
Surface tension is responsible for a wide variety of phenomena, including bubbles, sand castles, the motion of water striders, and the attraction of Cheerios floating in milk. However, the concept of surface tension is not easy for high school students to fully grasp, nor is it usually covered within a typical curriculum in any depth. This allows students to explore a topic for which they will not be expected to know the answers, and their inquiry will be rewarded with an understanding of an impressive phenomenon.

Overview
The lesson begins with a guided discussion of the origin of surface tension and how a detergent acts to reduce the surface tension. This is used to gauge prior knowledge and bring every student to the necessary understanding. Using this background knowledge, the students break into small groups to explore the different shapes of soap film that are formed when wire frames are dipped in the soap solution. Premade frames as well as the materials to make new frames are available, and the worksheet will guide the students to explore a variety of phenomena. Using their observations, the groups discuss what rules govern the formation of the soap films, and, finally, how the action of surface tension leads to those rules. As a reinforcement activity, the students break into groups once more to work on the four cities problem: What network of roadways connects four cities in the corners of a square to one another with the minimum total length of roadway?

Student Outcomes
Students will be able to illustrate surface tension using a diagram showing the difference between a molecule on the surface and one in the bulk.

Students will be able to explain the shapes of the films observed using the concept of surface tension as a tension.

Students will be able to explain the connection between the soap film and the minimum-roadway problem.

Illinois State Science Standards identified

12.C.3b Model and describe the chemical and physical characteristics of matter (e.g., atoms, molecules, elements, compounds, mixtures).

12.D.4b Describe the effects of electromagnetic and nuclear forces including atomic and molecular bonding, capacitance and nuclear reactions.

Time
One 90-minute double-period or two 45-minute periods

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Level
High school or middle school science

Materials and Tools
Soap solution in a bucket or bowl, enough to fill at least 15 cm (6 inches) deep.
The recipe is 50 parts water, 10 parts glycerine, 1 part dish detergent by volume.
Insulated solid-core wire, approximately 1 m (3 ft.) per group
Twisties for building certain frames
Wire cutters
Rulers
Protractors

Preparation
Prepare the soap solution. Some suggest that it helps to let the solution sit overnight. Build example frames, particularly the cube and the octahedron. The octahedron can be formed with one long wire held in place with twisties, but the cube must be created with at least two wires. Ensure that there is adequate accessibility and supervision of the materials, including the wire cutter(s) and the soap bucket(s).

Prerequisites
None.

Background
The students will need an understanding of the molecular theory of matter and the concept of intermolecular forces. To understand detergent, they must understand the distinction between polar and nonpolar, or else the discussion of detergent could be skipped. The students must also know the geometric concepts of face, edge, and vertex to describe the soap films. The concept of curvature is helpful but not necessary. For the minimum-roadway problem, advanced mathematics is not necessary, since the students can simply measure the length of roadway in their sketches using a ruler, but advanced students could be shown the use of calculus to prove the minimum-length network.

Teaching Notes
Ask leading questions to guide the students toward an understanding of surface tension. These are for more advanced students, but middle school students can also be led in a similar way.

1. What have you heard about surface tension?
2. Do water molecules prefer to be next to other water molecules or next to a different kind of molecule? Why? *Draw diagram of bonds formed between water molecules.*
3. Therefore water molecules are attracted towards one another. Which direction is one in the bulk pulled? (nowhere) How about one on the surface? (toward the inside) Why? (unbalanced pull)
4. What does this mean for the whole surface? (It's being pulled inward as much as possible.)
5. Looking at energy, do bonded particles have higher or lower energy? (lower, more stable)
6. What is the energy of a molecule on the surface compared to one in the bulk? (higher energy, fewer bonds)
7. What is the lowest energy of the system? (When the surface is as small as possible.)

Describe the soap solution recipe. Draw a diagram of the surfactant, showing polar and nonpolar. Ask where it will go in the water. Show how the surfactant prefers to straddle the surface. Ask if students can say what will happen to the surface tension because of this, and why. Explain that the surfactant lowers the surface tension so that we can stretch it into thin sheets without breaking up into droplets (since bubbles in pure water don't last long). Dip one frame into the soap solution to demonstrate.

Group the students and explain goal, for them to carefully observe the soap films and to figure out what rules govern their formation. Encourage the students in any observations. Some will notice the interference pattern from the varying thickness of the film. Others will try to blow and combine bubbles. For inspiration, one can play youtube videos of soap bubble artists while they work.

Check to see what the students are doing and ask them about what features they see in common. When the groups are brought back together, ensure that each major feature is identified: flat unless boundary is curved, then it curves inward, three films meet at 120 degrees, and four edges meet at 109.5 degrees, like the arrangement of sp^3 orbitals in chemistry. In general, they are symmetric and as far apart as possible. Point out that the cube has different film possibilities for the same frame.

Introduce the four cities minimum-roadway problem. Give the students access to rulers so that they can measure their patterns without calculating at first. Many students will settle on the X arrangement and assume that it's the best. Tell them that they can do better, that they need to think outside the box a bit and brainstorm. Have the students articulate the connection between the soap films and this problem. If the students are advanced and time permits, show how to demonstrate mathematically the minimum-length network using calculus.

Assessment

The worksheet that the students complete will be enough information to assess student outcomes.

Additional Information

http://www.soapbubble.dk/en/