Lesson: How Many Drops?

With little more than a few pennies, students can learn what hypotheses are all about.

Summary

In this lesson and its associated activity, students conduct a simple test to determine how many drops of each of three liquids can be placed on a penny before spilling over. The three liquids are water, rubbing alcohol, and vegetable oil; because of their different surface tensions, more water can be piled on top of a penny than either of the other two liquids. However, this is not the main point of the activity. Instead, students are asked to come up with an explanation for their observations about the different amounts of liquids a penny can hold. In other words, they are asked to make hypotheses that explain their observations, and because middle school students are not likely to have prior knowledge of the property of surface tension, their hypotheses are not likely to include this idea. Then they are asked to come up with ways to test their hypotheses, although they do not need to actually test their hypotheses. The important points for students to realize are that 1) the tests they devise must fit their hypotheses, and 2) the hypotheses they come up with must be testable in order to be useful.

Engineering Connection

The engineeirng connection in this lesson is when students design experiments to test their hypothesis. Scientists practice engineering whenever they design new experiments to test hypothesis.

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Grade Level: 7 (6-8)

Lesson #: 1 of 2

Time Required: 1 hours

Lesson Dependency :None

Keywords: hypothesis, variables, controls, experimental design, surface tension

Related Curriculum

subject areas Physical Science
curricular units Students As Scientists
activities Wet Pennies

Educational Standards

- North Carolina Science
- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations. (Grade 6) [2004]
- 1.04 Analyze variables in scientific investigations.
  • Identify dependent and independent. (Grade 6) [2004]
- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations. (Grade 7) [2004]
- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations. (Grade 8) [2004]
- 1.05 Analyze evidence to:
  • Explain observations. (Grade 6) [2004]
- 1.08 Use oral and written language to:
  • Defend conclusions of scientific investigations. (Grade 6) [2004]
- 1.02 Develop appropriate experimental procedures for:
  • Student generated questions. (Grade 6) [2004]
- 1.02 Develop appropriate experimental procedures for:
  • Student generated questions. (Grade 7) [2004]
- 1.04 Analyze variables in scientific investigations:
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  • Defend conclusions of scientific investigations. (Grade 7) [2004]
- 1.02 Develop appropriate experimental procedures for:
  • Student generated questions. (Grade 8) [2004]
- 1.04 Analyze variables in scientific investigations:
  • Identify dependent and independent. (Grade 8) [2004]
- 1.05 Analyze evidence to:
  • Explain observations. (Grade 8) [2004]
- 1.08 Use oral and written language to:
  • Communicate findings. (Grade 8) [2004]
- 3.01 Analyze the unique properties of water including:
  • Universal solvent. (Grade 8) [2004]
- 3.07 Describe how humans affect the quality of water:
  • Point and non-point sources of water pollution in North Carolina. (Grade 8) [2004]
- 4.05 Identify substances based on characteristic physical properties:
  • Density. (Grade 8) [2004]

Learning Objectives (Return to Contents)

- Students will be able to give an example of a hypothesis that is based on an observation of a natural phenomenon.
- Students will be able to give an example of an experiment designed to address a specific hypothesis.
- Students will be able to distinguish between the variable and controlled conditions in an experiment.

Introduction/Motivation (Return to Contents)

Students are rarely given the opportunity to be scientists in the classroom, meaning they are seldom asked to generate their own questions about phenomena they observe around them, and conduct controlled experiments aimed at answering those questions. However, in order to understand what the process of science is (and is not), it is important for students to be given opportunities to do the work of scientists.

Whether students are conducting their own investigations, or learning about the scientific method, one of the most difficult concepts for students to understand is the role of a hypothesis. In fact, few people who are not scientists have a clear idea of what a hypothesis actually is. It is commonly, and mistakenly, referred to as an "educated guess". Hypotheses are never made in a vacuum, though - they are always based on some prior knowledge. So, if it is based on education, i.e., knowledge, a hypothesis cannot be a guess, not even an educated one.

Instead, a hypothesis is simply a statement that speculates about the reason for an observed phenomenon, based on some prior knowledge of events or mechanisms related to the phenomenon. For example, if a person is driving a car and the engine sputters and then shuts off completely, a reasonable hypothesis for the fact that the engine stopped is that the gas tank is empty. This hypothesis is based on the knowledge that the engine can't run without fuel, and the hypothesis seems reasonable because the sputtering behavior of the engine just before it stopped is suggestive of the last bits of gas, mixed with air from the fuel tank, flowing into the engine and allowing only partial combustion.

Looking at the fuel gauge to see if the tank is empty would be a good test of the hypothesis. A gauge reading empty would support the hypothesis, while a non-empty tank would refute it. An important feature of a hypothesis is that it must be testable if it is to be useful. An alternative hypothesis for why the engine stopped might be "divine intervention", but that would not be a hypothesis that could be tested objectively. Other hypotheses could be tested objectively, such as foreign material clogging the fuel line, although testing it would take require more effort than merely consulting the fuel gauge.

This lesson is intended to help de-mystify the idea of what a hypothesis is (and isn't), give students opportunities to form their own hypotheses, and to help students realize that hypotheses must be testable in order to be useful. The best way to introduce the lesson is simply to provide the materials needed and have them conduct the Wet Pennies activity.

Lesson Background & Concepts for Teachers

Water is notable because of the presence of hydrogen bonds within its molecular structure. Although hydrogen bonds are the weakest of the chemical bond types, they are of sufficient strength to make water unusually cohesive. This cohesiveness gives water its high degree of surface tension, which is visible in the small indentations made by the legs of certain insects that can literally walk on water. It is also water's cohesiveness that allows it to form a nearly spherical "bead" when a single drop is placed on a flat, nonporous surface.

In contrast, oils have few, if any, hydrogen bonds amongst their large, organic molecules. When oil is dropped onto a flat, nonporous surface, it quickly spreads and forms a thin layer coating considerably more surface area than would a drop of water. Rubbing alcohol, on the other hand, is a mixture consisting of 70% isopropyl alcohol and 30% water. It does contain some hydrogen bonds within its structure, but not nearly as many as occur in pure water. Rubbing alcohol will form a bead when dropped onto a flat, nonporous surface, but the bead will be slightly flatter and larger in diameter than a corresponding bead of pure water.

When water is dropped carefully onto the surface of a penny, it can pile up into a dome shape before spilling over the small lip around the penny's perimeter. Rubbing alcohol can pile up as well, but will spill over before forming a well-rounded dome. Oil will not pile up much at all, as students will discover.

Vocabulary/Definitions (Return to Contents)

hypothesis: a tentative explanation for a fact or set of observations, which can be tested objectively
cohesion: the chemical attraction between adjacent molecules of the same type
surface tension: the relative strength of the film-like surface on a liquid due to the cohesive forces of its molecules

Associated Activities

- Wet Pennies - Students conduct a simple test to determine how many drops of each of three liquids -- water, rubbing alcohol, and oil -- can be placed on a penny before spilling over.

Lesson Closure

Start the discussion by asking the class which aspects of the penny-dropping experiment were controlled and which were variable. It will not be difficult to generate substantial lists for each. Controlled aspects could include the use of same coin type and side of the coin, all tests were done at the same temperature, humidity, time of day, etc., and all used the same liquids and identical pipettes. Variable aspects include the age and condition of the pennies, how quickly or from what height students dispensed the liquids from the pipettes, and how well they cleaned the pennies and pipettes before changing liquids.

Put a chart on the board such as the one shown below. Have the recorders for each group fill in the chart before beginning the discussion. Ask the reporters from each group to elaborate or answer questions about their hypotheses and proposed tests as necessary. It is important to check that 1) their hypotheses are consistent with their data, and 2) their tests fit their hypotheses.

	Average number of drops				
Team Name	Water	Alcohol	Oil	Hypothesis	Test of Hypothesis

It is especially important to realize that middle school students are not likely to have prior knowledge of hydrogen bonding, cohesion, or surface tension, and so are not likely to get the "right" answer for their hypotheses. Instead, they will use what knowledge -- or misconceptions -- they do have. For example, students might attribute their observations to the different densities of the liquids. In this case, they will probably say that oil is the densest of the liquids, and so the penny could not hold very much of it, and water, being the least dense, could pile up high on the penny. A reasonable test would be to carefully pour the three liquids, one at a time, into a glass beaker, and see if the liquids form layers. This can be done simply, especially if the rubbing alcohol is the kind that is already colored (it is often available in green). Students will find, however, that oil is the least dense, thus disproving their hypothesis. The fact that they did not "get it right" does not matter; what is important is that their hypothesis fit the data and their test is appropriate. For this, they should be commended!

Students that don't yet know about density might offer a very similar explanation: that oil is the heaviest and water is the lightest, and so the penny held the least and most of these liquids, respectively. They may propose the same test as above, or they may want to weigh the liquids. In the latter case, it would be important to help them realize that the volumes of the liquids need to be the same before weighing. (This could lead into an introduction or discussion of the concept of density.)

Another explanation students might offer is that the size of the drops coming from the pipette might differ depending on the liquid. This is a reasonable hypothesis, and one that is also easily tested, for example, by counting the number of drops needed to fill a small graduated cylinder to the 5 ml mark.

These are not the only explanations student groups may come up with, but they are the most common ones we've experienced. It is up to you whether you want to give the "real" answer after all the groups have reported their ideas. It is quite possible that they will demand to know the right answer, however, and you can answer with as much detail as you feel is appropriate. A good way to explore surface tension is to add a few drops of liquid dish washing detergent to the water. Detergents lower the surface tension by disrupting the hydrogen bonds, making the water less able to pile up on a penny.

If you do provide the class with the "real" answer, you can then ask them why it was important to conduct the penny-dropping experiment in the order of water, alcohol, and oil. It is important to do oil last because the oil will coat the penny and the pipette. The thin layer of oil might affect how well the other two liquids adhere to the penny, or the oil might mix with and thus contaminate the other two liquids in the pipette. Once oil is present on the penny or in the pipette, it can only be removed with soap, which could also contaminate the other liquids. The rubbing alcohol should be done second because it is already 30% water, and so will not be noticeably affected by any tiny water droplets remaining from the first part of the experiment. Because it evaporates more quickly than water, it is also not likely to appreciably affect the subsequent oil-dropping part of the experiment.

For students who are fairly sophisticated in their thinking and knowledge of science, you could ask if the detergent-adding experiment would prove that it was surface tension that caused the penny to hold the most water and the least oil in the initial experiment. The answer is no. Using drops on a penny provides only an indirect comparison of surface tensions at best. It could be argued that something else entirely allows the penny to hold the most water, and the fact that water's surface tension is the highest of the three liquids is mere coincidence. Adding detergent to the water and finding that the penny now holds fewer drops of it only supports the notion that surface tension is at work, but it cannot prove it. This is an important lesson in science: hypotheses can only be supported by evidence, not proven. There is always a chance that new evidence will come to light in the future to disprove a hypothesis.

Assessment (Return to Contents)

- Describe a simple experiment and ask students to state a hypothesis that could be tested by the experiment. An example of such an experiment could be that a student tested the effects of adding fertilizer to the soil of a bean plant grown in a flowerpot. (A suitable hypothesis would be, "Adding fertilizer causes the plant to grow taller than it would without the addition of fertilizer.) Then ask students to describe a test of the hypothesis. (Growing two plants under identical conditions, one with fertilizer added and one without, would be an appropriate test of the hypothesis.)

Lesson Extension Activities (Return to Contents)

- Students can follow up on the ideas presented in the Lesson Closure section with some simple experiments. For example, they can test to see which liquid is the densest, and they can test the volumes of the drops of each liquid. They can also test to see if detergent will lower the surface tension of water and thus allow fewer drops to sit on the penny than can when plain water is used.
- This lesson can serve as an introduction to the unique chemical properties of water. It is the polarity of water that provides its high surface tension and creates phenomena such as the meniscus formed at the wall of a container, and the ability of certain insects to walk on the water's surface. Students might also be interested in what happens when detergent is added to water, from the point of view of the structure of the molecules involved. Detergent has both polar and non-polar aspects, which is what makes it useful as a cleaning agent, and students can easily find out how it works with some Internet research.

Other Related Information (Return to Contents)

Acknowledgement:

- This lesson and its associated activity were originally published, in slightly modified form, by Duke University's Center for Inquiry Based Learning (CIBL). Please visit the website http://www.biology.duke.edu/cibl for information about CIBL and other resources for K-12 science and math teachers.

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Supporting Program (Return to Contents)

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