Civil Air Patrol's ACE Program

Bernoulli Bubbles

Grade 4 Academic Lesson #1

Topics: air, pressure, scientific method (science, language arts, math)

Lesson References:

- *Bubble-ology, Teacher's Guide*, LHS-GEMS: Great Explorations in Math and Science, Lawrence Hall of Science, University of California at Berkeley.
- MaryAnne Nelson, Needham Elementary, Durango, CO

Length of Lesson: 30-60 minutes

Objectives:

- Students will use the scientific method to help determine a way to keep a bubble in the air for a longer period of time.
- Students will define and apply Bernoulli's principle.
- Students will describe the force of lift and its effect on an airplane.

Next Generation Science Standards:

- 4-PS3-1-Use evidence to construct an explanation relating the speed of an object to the energy of that object.
- 4-PS3-3-Ask questions and predict outcomes about the changes in energy that occur when objects collide.

CCSS ELA Standards:

- RI.4.1-Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
- RI.4.3-Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.
- RI.4.7-Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages), and explain how the information contributes to an understanding of the text in which it appears.
- RI.4.10-By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4-5 text complexity band proficiently, with scaffolding as needed at the high end of the range.

Background Information:

Lift is the force that directly opposes the weight of an airplane and holds the airplane in the air. The wings generate most of the lift on a normal airplane. Lift is a force produced by the motion of the airplane through the air. Because lift is a force, it has both a magnitude and a direction associated with it. Lift works roughly perpendicular to the wing.

In an airplane, lift occurs when the wings deflect a moving flow of air. For most airplanes, the wings generate lift through two different means: 1) impact lift and 2) lift through the Bernoulli Effect.

Impact lift is the simplest to understand and is responsible for most lift generated by an airplane at low speeds. As a plane moves forward, its nose is pitched slightly upward into the oncoming airflow, forcing the wings to meet the air at an angle. The angle an airplane's wings make with the oncoming air is called the angle of attack. The angle of attack can be changed by pitching (moving) the airplane's nose up or down. As the airplane's wings strike the air at an angle, the airflow is turned downwards. Lift is generated in the opposite direction, in keeping with Newton's third law of motion. This law states that for every action there is an equal and opposite reaction. For an aircraft wing, both the upper and the lower surfaces contribute to deflecting airflow.

Bernoulli's law states that fluids (such as air) exert less pressure at higher speeds than at lower speeds. Most airplanes have wing shapes (airfoils) that force air to move over their top surfaces more quickly than their bottom surfaces. When a wing is designed in this way, air presses on the bottom of the wing harder than on the top. This difference in pressure results in lift that helps keep the airplane in the air.

The Bernoulli Effect increases at higher airspeeds when the airplane is flying at a smaller angle of attack. When airspeed is low and the angle of attack is high, or in an airplane with airfoils that are not curved properly, or that may be curved the wrong way (as is the case when an airplane flies upside down), there may be little or no lift generated by Bernoulli's law.

Lift is a mechanical force. It is generated by the contact of a solid body with a gas such as air. For lift to be generated, the solid body must be in contact with the air—no air, no lift. A spacecraft in Earth orbit like the Space Shuttle does not stay in space because of lift from its wings but because it is traveling at a velocity sufficient to keep it in orbit around the planet. Space is nearly a vacuum, and the shuttle's wings cannot generate lift until the shuttle re-enters Earth's atmosphere. Without air, there is no lift.

Lift is generated by the velocity difference between a solid object and the air. There must be some relative motion between the object and the air; without motion, there is no lift. It makes no difference whether the object moves through a calm air or wind moves past a stationary solid object. For example, airplane wings generate lift when they move forward, pushing their fixed wings through the air. A kite, on the other hand, is tied to the ground (or someone standing still on the ground), and on a windy day air is forced over the kite's structure to create lift. There must be some relative motion between the air and the object to be lifted for lift to be created.

The above information on this page is adapted from NASA Glenn Research Center's Beginner's Guide to Aerodynamics.

You may wish to watch this video (or share it with your students): "Floating Balls - Bernoulli's Principle Visualized."

Materials:

- Teachers need a free account with Newsela in order to meet the ELA standards attached to this lesson.
- Teachers need to print the article from Newsela called "Four Forces on an airplane."
- bubble solution - store bought, or make enough bubbles for your class using the following recipe: Combine 1 gallon of water, 1 cup of dishwashing liquid, and 50-60 drops of glycerin (optional, but creates stronger bubbles). Place the resulting liquid in individual containers for student use
- Bubble wands – can use straws or make wands by rolling paper into a cone or making a loop using a pipe cleaner or wire
- index cards
- straws
- "Bubble Experiment" copies for students (copies included)
- dry erase board/marker or chalkboard/chalk
- stopwatches or watches with second hand (or have students count aloud, such as "one Mississippi, two Mississippi," etc., if no watches are available)
- cleaning wipes to clean surfaces (optional)

NOTE: If time is an issue, you may omit direct instruction and reference to the scientific method and the "Bubble Experiment" sheets. You can determine the average time a bubble stays aloft together as a class, writing information on the board. Then, you may ask students to take a sheet of notebook paper and list at least 3 strategies to make a bubble stay in the air longer. Once the students test their strategies a few times, they can document on their notebook paper whether or not the idea worked.

If you go outside to conduct this activity, choose a mild, non-windy day. If conducting the experiment in the classroom, provide explicit rules to students and have cleaning wipes on hand. Also, if using the experiment sheets, consider copying making double-sided copies.

Lesson Presentation:

1. Divide students into small groups, such as groups of 2 – 4 members per group.

2. Pass out passages and questions to small groups of students. Allow students to work through the passage "Four Forces that Act on an Airplane."

3. Ask students what the forces are that act on an airplane and briefly talk through what each force is/what it does.

4. Blow a bubble and ask students what questions come to mind when they see the bubble.

5. Ask students if they are familiar with the scientific method. Review the steps of the scientific method:
   1) State the problem; ask a question.
   2) Research; learn about the topic.
   3) Form a hypothesis, an educated guess, regarding the problem/question.
   4) Conduct an experiment to test the hypothesis.
   5) Analyze the results of the experiment.
   6) Draw a conclusion. Determine whether or not your hypothesis was correct.

6. Tell students that today's science question is, "What can be done to make a bubble float in the air longer without touching it?" Tell students that they will develop ideas as to how to keep a bubble in the air for a longer amount of time compared to blowing a bubble and doing nothing to it. They will test their ideas to see what works and what does not.

7. Tell students that there is really one question that has to be answered before they can start on the science experiment. Ask if anyone knows what that question is. Guide students to realization that they should have an idea of how long a bubble stays in the air when NOTHING is done to it!

8. Distribute the "Bubble Experiment" sheets. Tell students that they will go through the steps of the scientific method together to determine the average amount of time a bubble stays in the air when nothing is done to it. Complete the following with students:

1) On "Bubble Experiment 1" sheet, ask students to write their hypothesis as to how long they think a bubble will stay in the air when nothing is done to it. Ask some students to share their hypothesis.
2) Ask students what they should do to test their hypothesis. Have them write that the teacher will blow a total of three bubbles, each about the same size. The class will record how long each bubble stays in the air before bursting. Then, conduct the experiment.
3) Have students record how long each bubble "lived" and discuss the results.
4) Determine the average amount of time a bubble will stay in the air given its current environment.

9. Tell students to go to "Bubble Experiment 2" sheet. Tell students to notice the next question, "What can be done to a bubble to make it stay in the air longer?" Tell students they may brainstorm ideas in their groups and come up with one to three things to try. If they have more than one hypothesis, they should number them in the "hypothesis" section. Tell students the only thing they may NOT do is actually touch the bubble. They may think of ways to use the index card, straw, or themselves in some manner without actually coming into contact with the bubble to try to keep it in the air. Remind them to follow the steps of the scientific method, making sure to record their information. Also, remind them that they may want to test a particular idea a few times to see if they get the same result or a similar result each time. Tell students that once they are finished, they may continue to try other ideas until the teacher states that it is time to stop.

10. Ask students if there are any questions. If there are no questions, allow them to begin.

11. After sufficient time, call the students back together. Ask students to share some things that did not work. Ask students to share something that did work. Consider allowing a group to demonstrate something that did or did not work.

12. Confirm whether or not anyone found that blowing air or waving air over the TOP of the bubble helped it stay in the air longer. Demonstrate the concept to the students. Ask if anyone understands why this works.

13. Explain Bernoulli's principle to the class. (Bernoulli is pronounced "burr-new-lee.") Daniel Bernoulli was a scientist in the early 1700s. He learned things about air and pressure. Bernoulli's principle states that faster moving air creates a lower pressure and slower moving air creates a higher pressure. So, if air moving over the top of the bubble is moving faster than the air below the bubble, there is a lower

pressure above the bubble and a higher pressure below the bubble. The higher pressure below the bubble helps push or keep the bubble up, while the lower pressure above the bubble kind of creates a suction effect, or a "pull" upwards.

14. Ask students if they can explain what helps an airplane stay lifted into the air - now that they know about the bubble and Bernoulli's principle. Draw an airplane on the board. Illustrate faster moving air going over the curved part of the top of the wing and slower air moving under the bottom of the wing. The air molecules going over the top of the wing have a greater distance to travel, but the molecules will meet up with the air molecules traveling below the wing at the same time when they reach the other side of the wing. So, faster moving air on the top of the wing creates a lower pressure, which results in a "pull" upward, while the slower moving air under the wing creates a higher pressure, resulting in a push upward. This occurs as long as the plane is moving forward through the air.

15. Ask students why a bubble might eventually burst. Explain that an outside force such as a gust of wind or someone's finger can easily break the "skin" of the bubble. Explain that the "connection" of the bubble molecules eventually may become too weak to keep it together. Just like when a person is hanging on to a bar overhead and lifting himself or herself up, eventually the person's muscles get tired and he/she has to let go of the bar. The same can happen with the "connection" of the molecules in the bubbles; it gets weak, and eventually, they "let go." A plane is made up of much stronger material than water and soap molecules.

Summarization:

Ask students what they learned today. Ask students what Bernoulli's principle means. Ask students if they can explain what helps an airplane to stay in the air using the following words: wings, air, and pressure. Ask students to talk through the four forces that act on a plane. Teachers can give the definition of each force and have the students verbally match it to either lift, thrust, gravity/weight, or drag. Ask students how Bernoulli's principle is related to flight or how an airplane works?

Example teacher explanation:
Air exerts pressure in all directions, at all times. Bernoulli's principle states that the slower the air moves, the greater the air pressure. The faster the air moves, the lower the pressure. This means that still air has a higher pressure than faster moving air. Higher pressure likes to push while lower pressure creates a suction effect. Also, higher pressure likes to move toward areas of lower pressure.

The upper surface of an airplane's wing is designed to have a greater curvature. This greater curvature causes the oncoming air to flow much faster over the curved upper surface of the wing. As the airflow speeds up, the pressure drops on top of the wing and this creates "suction." Newton's action-reaction forces work on the bottom of the wing. This means that there is high pressure below and low pressure above. With low pressure on top and high pressure underneath, the wing has nowhere to go but up. (information from CAP's Dimensions)

Character Connection: Remind students that in life, we often have pressure coming from different directions just like an airplane. Tell students that even the uneven pressures in life make us who we are each day. We have to be like airplanes and decide to use everything that comes our way to soar! Students can take time to talk through good things and hard things that worked together for good.

Assessment:

- teacher observation
- student answers to class discussion questions
- "Bubble Experiment" sheet
- Newsela article question sets

Additional activity ideas to enrich and extend the primary lesson (optional):

- Discuss variables that may affect their experiment if they conducted it in a different location. (e.g. temperature, wind) Discuss why scientists try experiments numerous times to see if they come up with the same results each time. Reliability and validity in science experiments are important. Allow students to see if they obtain different results when conducting the experiments in a different environment.
- Allow students to experiment to see what might make a bubble move forward. (Consider what happens if air is moving faster in front of the bubble than behind the bubble.)
- Designate a "start" and "finish" line and have bubble races! Consider having a "turn" in the bubble race course.

Associated Websites:

- Making bubbles in space isn't quite as easy as you might think. Read the article "Space Station Bubble Blowing" about an astronaut who was going to try making bubbles on the International Space Station.

Bubble Experiment 1

Name____

What is the question?
What is the average amount of time a bubble stays in the air when nothing is done to it?
What do you know or what have you learned about the topic?
What is your hypothesis (best educated guess) as to the answer to the question? ______________________________ ______________________________ ______________________________
What is your experiment plan? ______________________________ ______________________________ ______________________________

Think about the results of your experiment. (Write the results in this space.)

What is the answer to your question? (Was your hypothesis supported?)

Bubble Experiment 2

Name____

What is the question? What can be done to a bubble to make it stay in the air longer without touching it?
What do you know or what have you learned about the topic? We learned that the average amount of time a bubble stays in the air (in our classroom or outside today) is__________________________________when nothing is done to it.
What is your hypothesis (best educated guess) as to the answer to the question? ____ ____ ____ ____
What is your experiment plan? ____ ____

Think about the results of your experiment. (Write the results in this space.)

What is the answer to your question? (Was your hypothesis supported?)