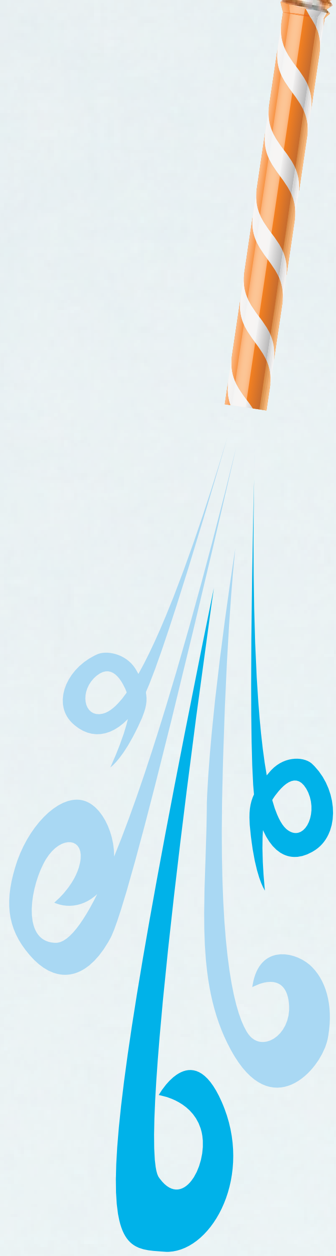
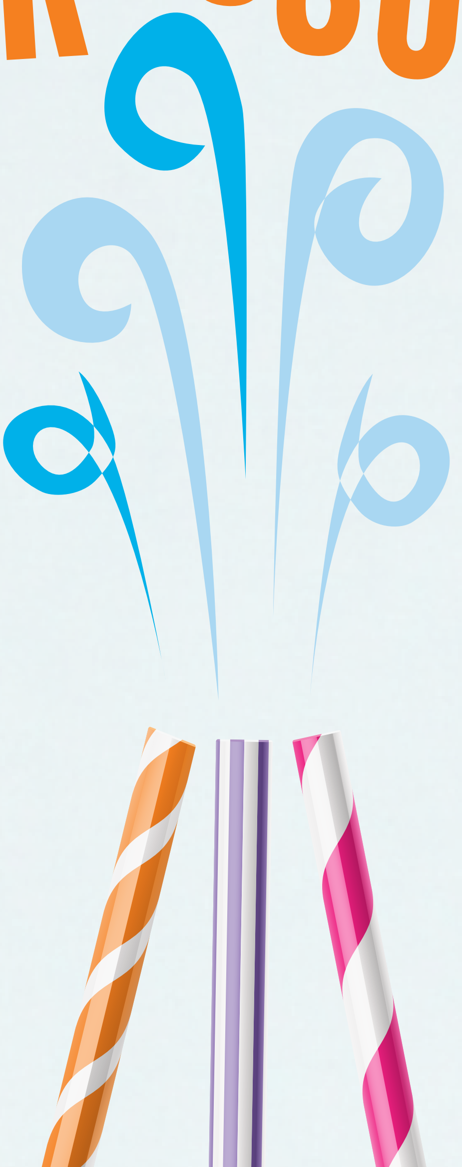
STRAWS AND AIR PRESSURE





Using an Everyday Object to Explain Air Pressure

by Deborah McCarthy

How can the use of a simple straw help students understand the effects of air pressure on their daily lives? As a middle school science teacher with almost 30 years of experience, I have witnessed the positive impact of learning cycles as an inductive approach to concept formation.

Student exploration changes misconceptions, promotes interest, motivates learners, and alters attitudes (Bruner 1960; Dewey 1967; Martin et al. 2005; Piaget 1970; Turkmen and Usta 2007). The *Next Generation Science Standards (NGSS)* and *A Framework for K–12*

Science Education, upon which the *NGSS* is based, agree. No matter how instruction is administered, the result should be that students "generate and interpret evidence and develop explanations of the natural world through sustained investigations" (NRC 2012, p. 255). Additionally, reading lab procedures and writing lab reports are promoted by the *Common Core State Standards* (NGAC and CCSSO 2010; see Connections to the Standards sidebar).

The activities described in this article allow students to apply their understanding of air pressure to a gadget we use daily.

What are learning cycles?

"Grounded in the constructivist approach to education" (Martin 2012, p. 23), learning cycles allow students to explore independently and construct a concept rather than having it told to them. Although there are different variations of learning cycles, I utilize a four-stage model. In the elicitation phase, students share prior knowledge, and then I use a discrepant event to "hook" them into the topic being taught. In the exploration phase, students engage in several activities that form a pattern. They develop a generalization in the invention phase and construct the concept. In the application phase, students use new knowledge to solve a problem that is similar but more complex.

Groundwork for the Straw Mini–Learning Cycle

Over two centuries ago, scientists Daniel Bernoulli, Jacques Charles, and Robert Boyle investigated how speed, temperature, volume, and air pressure are related. In Appendix H, the *NGSS* specifically argue for the use of examples from science history in the form of scientist case studies, which help develop students' understanding of how science works. To help my students view science as a human endeavor, I constructed biographies of these brilliant people. (Find the biographies and a list of references used to compose them at *www.nsta.org/middleschool/connections.aspx*.)

To help my seventh graders build an understanding of the discoveries of Bernoulli, Charles, and Boyle, I created a unit on the laws of fluids that consists of four mini–learning cycles. Students' objective is to discover conditions that affect air pressure. Examples of group activities from Cycles 1, 2, and 3 are as follows;

- To observe Bernoulli's principle, which states that an increase in the speed of a gas or liquid causes a decrease in pressure, students arrange two books 4 cm apart, place a sheet of paper over the gap between the books, blow air through the opening, and watch the paper dip into the gap.
- To examine Boyle's law, which explains the relationship between pressure and the volume of a gas, students pour water into a funnel attached to a clay-sealed bottle and an unsealed bottle, then note that the water remains in the funnel of the sealed bottle.
- The teacher inserts a deflated balloon into an Erlenmeyer flask, stretches the neck of the balloon over the opening of the flask, and places the flask into beakers of hot and cold water. To observe Charles's law, which states that the volume of a gas increases as the temperature increases, students inspect the balloon expanding and contracting.

The Straw Mini–Learning Cycle

The exploration phase

After students complete the cycles above, the groundwork has been laid to close the unit by carrying out the Straw Mini–Learning Cycle. My seventh graders apply their newly constructed knowledge by investigating something they have all experienced: drinking through a straw. Their objective is to explain how a straw really works. After demonstrating the procedures for the Straw Mini–Learning Cycle: Part 1, Part 2, and Part 3 (see Figure 1), I turn the exploration over to my students and become the facilitator.

For health reasons, all students are given their own plastic cup and clear straw. Chemical splash goggles should be worn. Students fill their plastic cups about halfway with water. As groups of four students sit at their tables, I add food coloring to make it easier to observe the water level. In the Straw: Part 1, students do what they have all done while waiting to be served in a restaurant: They place their straw in the cup of water, put their finger over the opening at the top of the straw, and remove the straw from the cup. Students are not excited or surprised by what they observe. As expected, the water remains in the straw. They record their observations in their science notebooks. Their challenge is to explain why the water stays in the straw and to draw models that illustrate their thinking. In their groups, students discuss possible reasons for their observations. All explanations are considered, and usually a consensus is reached after a few minutes. Discourse is encouraged as a procedural step in each activity through a requirement that group members compare their inferences. I also document group participation using a checklist of expectations.

Without any class discussion, the groups move to Part 2. They poke a hole through their straw about 2 cm from one end and place the straw in the water with the hole above the waterline. With their finger over the top of the straw, they remove it from the water. This time, they observe that very little—if any—water remains in the straw. Observations are recorded, and the groups discuss possible explanations. Again, the procedure is easy, but the explanation is challenging. Students consider what causes the difference in the water's behavior.

In Part 3, the groups turn their straws upside-down and place them in the cup of water with the hole made in Part 2 below the waterline. Students then put their finger over the straw's mouth and lift the straw out of the water. This time the water remains. Again, students record observations in their notebooks, make inferences, and draw models to explain the water's behavior. Straws and cups are discarded at the end of class, and new equipment is provided for the next class meeting (see Figure 1). Students compare observations and discuss possible reasons for what occurred in the activities in the invention phase.

The invention phase

In the class period that follows, I bring students together to share observations, models, and explanations gathered during the exploration phase. Each group member selects a numbered index card among ones that have been placed facedown on their table so that group roles can be randomly assigned. Today number 1 is reporter, who is called on to offer the group's find-

Connections to the standards

Next Generation Science Standards (NGSS Lead States 2013)

Disciplinary core idea

MS-PS1. Matter and its interactions: Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.

- MS-PS1-4. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.

Science and engineering practices

- Asking questions (for science) and defining problems (for engineering)
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence

Crosscutting concept

Cause and effect

Connections to nature of science

- Scientific knowledge is based on empirical evidence.
- Science models, laws, mechanisms, and theories explain natural phenomena.

Common Core State Standards, ELA (NGAC and CCSSO 2010)

Reading and writing standards for literacy in science and technical subjects

- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

FIGURE 1 The Straw: Parts 1, 2, and 3: The exploration phase

Materials for all parts (per student)

- Indirectly vented chemical splash goggles
- 1 straw (clear if accessible)
- 1 plastic cup
- Water
- 1 straight pin or pushpin
- Food coloring (administered by the teacher)

Be sure to tell students to wear indirectly vented chemical splash goggles while working on all parts of the activity.

Procedure

Part 1

1. Fill your cup about halfway with water and place your straw in the cup. Food coloring will be added by the teacher.
2. Predict what will happen when you place your finger over the top of the straw and lift the straw out of the water. Explain why you think this will happen. Compare your prediction with others' in your group.
3. With you finger covering the top of the straw, lift the straw out of the water. Do this several times.
4. Observe, record, and explain your observations. Draw a model to explain the behavior of the water and the air.

Part 2

1. Now, poke a hole in the straw about 2 cm from one end of the straw.
2. Place the straw in the cup of water, with the hole you poked above the water.
3. Predict what will happen when you place your finger over the top of the straw and lift the straw out of the water as before. Explain why you think this will happen. Compare your prediction with others' in your group.
4. With you finger covering the top of the straw, lift the straw out of the water. Do this several times.
5. Observe, record, and explain your observations. Draw a model to explain the behavior of the water and the air.

Part 3

1. Turn the straw upsidedown. Place the straw in the plastic cup with the hole you poked under the water.
2. Predict what will happen when you place your finger over the top of the straw and lift the straw out of the water. Explain why you think this will happen. Compare your prediction with others' in your group.
3. With your finger covering the top of the straw, lift the straw out of the water. Do this several times.
4. Observe, record, and explain your observations. Draw a model to explain the behavior of the water and the air.

Be prepared to discuss your findings for the three activities with the class.

ings to the class. Without judgment, all explanations are recorded on the whiteboard for consideration and then discussion ensues. Based on their findings from the Straw: Part 1, the groups explain that by placing their finger over the top of the straw, they block air from entering it. They reason that perhaps a difference in air pressure below the straw is holding the water in place. Based on the results of Part 2, the groups surmise that when the hole is above water level, air enters through the hole and the water falls out of the straw. Students conclude that when air can enter the straw, the pressure is no different in the straw than in the room. Air pressure in the room is now unable to support the water in the straw. In Part 3, the hole is below the water's surface, and after much collective thinking, students explain that air cannot enter the straw because it is plugged by both the water and their finger, so the water remains in the straw. Air pressure in the room can now support the water. They recognize the pattern across all three activities.

The most plausible justification agreed upon for the water's behavior is that when air is blocked from entering the straw, the amount of air trapped is extremely small, so air pressure is greater on the outside and can support the water. When air is allowed to flow freely in and out of the straw, there is no difference in pressure, so the air in the room cannot support the water column. Students realize that air pressure is at work in all three activities. The simple straw is now added to a list of everyday gadgets and inventions that the class compiled while investigating Bernoulli, Boyle, and Charles's discoveries. All of the inventions on this list work because of air pressure.

The application phase

I again become the facilitator as students begin the final group activity (see Figure 2). Expanding students' understanding of how a straw works is my primary purpose for conducting the preceding explorations. I am excited now, anticipating that the usual description of "sucking" or "pulling" the water up into the straw will be replaced with an accurate explanation. For health reasons, all students fill their own plastic cup with water and sip through their own straw. Obviously the water moves up the straw. Then they poke a hole in the straw about 2 cm from one end, place it in the cup so that the hole is above the waterline, predict the outcome, support their predictions, and sip the water. The groups observe that the straw does not work. A great amount of inhaling is required to get any water to move up the straw. Some students keep trying until they finally give up. Explanations are recorded or drawn. Now students place their straw in the water with the hole submerged, predict, justify their predictions, and sip. The straw works! Why? Time to explain and illustrate.

After students complete these activities, I lead the class in discussion. Students comment that when the hole poked in the straw is above the waterline, it allows air to move into and out of the straw, making it hard to sip any water. They recognize that there is no difference in air pressure inside and outside of the straw. Students suggest that when the hole is below the waterline, air cannot enter the straw because the water and their mouth act as plugs. This creates less air pressure inside the straw.

The big moment comes: How does a straw really work? My students know air pressure is pushing on something—but what? It is rewarding when the class agrees that a straw works because air pressure is greater in the room than in the straw. Pressure pushes on the surface of the water in the plastic cup, forcing it up into the straw. The water is not being pulled into the straw; it is being pushed. As students describe this phenomenon, I energetically sketch on the whiteboard, using arrows to illustrate their explanation. I can see the look of satisfaction on my students' faces. They really understand!

FIGURE 2 **The Straw: The application phase**

Materials (per student)

- Indirectly vented chemical splash goggles
- 1 straw
- 1 plastic cup
- Water
- 1 straight pin or pushpin

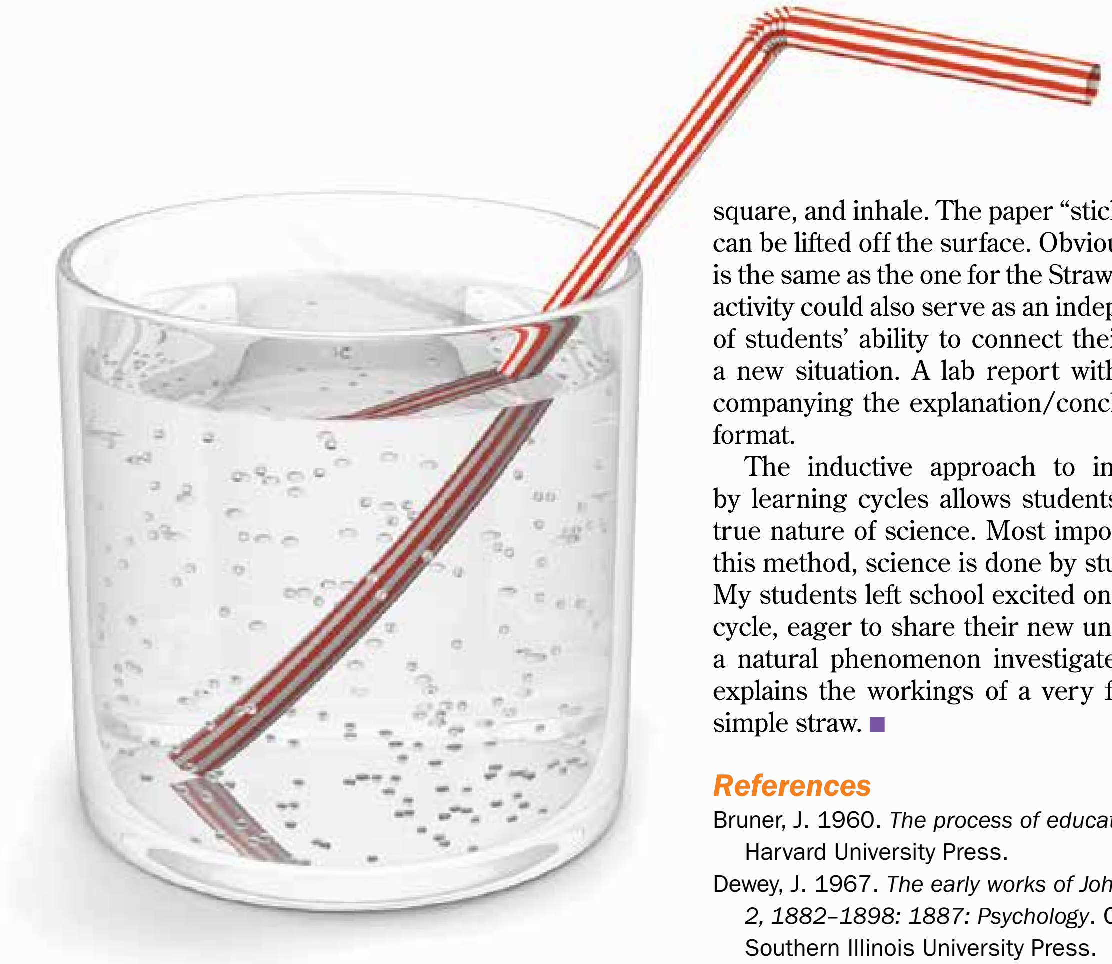
Be sure to tell students to wear indirectly vented chemical splash goggles while working on all parts of the activity.

Procedure A

1. Fill your cup about halfway with water.
2. Place the straw in the cup and sip. Observe and record what happens.
3. Remove the straw.
4. Poke a hole in the straw about 2 cm from one end and place the straw in the cup with the hole you poked above the water.
5. Predict what will happen when you sip through the straw.
6. Observe, record, and explain what happens. Draw a model of your explanation.

Procedure B

1. Turn the straw upsidedown so that the hole you poked is in the water.
2. Predict what will happen when you sip through the straw.
3. Observe, record, and explain what happens.
4. Using these observations and what you know about air pressure, explain how a straw works. Draw a model of your explanation.



Reflections

The Straw Mini–Learning Cycle fits logically into a unit introducing air pressure. However, my rationale for placing it at the end of the unit on the laws is to reemphasize that the science students do in the classroom is relevant to their lives. Closing the unit with the straw activities serves to anchor lofty scientific discoveries in a simple, everyday experience. The cycle could be completed independently, but from my experience, cooperative learning leads to individual understanding.

I sometimes add a fourth activity to the exploration phase. In this activity, students place a small square of paper on a flat surface, bring the straw close to the square, and inhale. The paper "sticks" to the straw and can be lifted off the surface. Obviously the explanation is the same as the one for the Straw: Parts 1 and 3. This activity could also serve as an independent assessment of students' ability to connect their understanding to a new situation. A lab report with an illustration accompanying the explanation/conclusion could be the format.

The inductive approach to instruction provided by learning cycles allows students to experience the true nature of science. Most importantly, when using this method, science is done by students, not to them. My students left school excited on the final day of the cycle, eager to share their new understanding of how a natural phenomenon investigated centuries before explains the workings of a very familiar gadget: the simple straw. ■

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