HANDS-ON THUNDERSTORMS

Activities to help students and teachers understand thunderstorms and severe weather.

By Mark H. Palmer

THUNDERSTORMS ARE ONE of the most powerful and spectacular natural forces on Earth. A bellowing tower of cumulonimbus clouds can rise at speeds over 160 km per hour and reach altitudes of more than 15,240 m. Once mature, these giants may produce torrential rainfall, lightning, hail, and tornadoes.

Have you ever wondered how thunderstorms actually form? Students and teachers from around the country regularly ask this question at the Center for Analysis and Prediction of Storms Education and Outreach Program. Offering an age-appropriate explanation can be quite challenging because thunderstorms are very complicated atmospheric phenomena. Even experienced meteorologists are unsure about some elements of severe storms. However, by using a little creativity and a few household items to serve as concrete examples, students can conduct experiments that help them understand the various stages of thunderstorm development.

Teachers who are unfamiliar with the science of thunderstorms should review the content material found in three National Oceanic and Atmospheric Administration (NOAA) public information booklets. The publications are free and can be found at your local National Weather Service office or on the Web.

- *Thunderstorms* at http://www.nws.noaa.gov/om/trw.htm
- *Tornadoes* at http://www.nws.noaa.gov/om/tornado.htm
- *Floods* at http://www.nws.noaa.gov/om/ffbro.htm

Each demonstration and hands-on activity used in this article can enhance individual classroom units on storms, clouds, severe weather, and the water cycle. Furthermore, teachers can use these activities to explain the physical properties of a thunderstorm, such as convection, barometric pressure, condensation, static electricity, hail formation, and tornadic rotation.

Properties of a Thunderstorm

Perhaps the easiest way to explain the physical properties of a thunderstorm is through a simple analogy: Thunderstorm development is similar to making a cake. A cake needs certain ingredients to make it rise, such as flour, sugar, milk, eggs, baking soda or baking powder, and a heat source. The basic ingredients for a thunderstorm are

- warm-moist air (the most important ingredient; it is fuel for the storm);
- a lifting mechanism such as a cold front, sea breeze, or mountains (the vehicle used to transport the fuel);
- and an unstable atmosphere (cold air overriding warm ignites the fuel).

Suddenly, the warm-moist bubble of air accelerates upward at incredible speeds. It condenses like a glass of iced tea sweating on a hot summer day, producing a thunderstorm.

Cloud Formation

The first step in thunderstorm development is cloud formation. Clouds develop when a warm-moist parcel of air ascends from the ground into the atmosphere. These parcels of air are lifted by the sun's heat energy, frontal boundaries, mountainous topography, or sea breezes. Cold air is dense and tends to sink toward the ground. Meteorologists refer to this rising and falling air as *convection*. A simple convection model can be replicated in the classroom using both hot and cold water.

To conduct this activity, you will need

- a medium-size plastic aquarium (15 cm × 24 cm × 13 cm),
- a 170g (6 oz) baby food jar,
- red food coloring,
- a hotplate,
- scissors,
- a pair of tongs,
- and 1 L water.

First, fill the aquarium three-quarters full with cold water. **The teacher** boils 100 mL water on the hotplate and pours the hot water into the baby food jar until it is filled. (Be sure to wear protective gloves when handling the hot jar.) Next, four or five drops red food coloring are added to the hot water. Using the end of a pair of scissors, punch several holes in the lid of the jar and secure tightly. Using tongs, submerge the baby food jar into

Students observe the very distinct striation between the red and colorless water.

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the tub of cold water. The hot, red-colored water emerges from the jar and rises to the top of the aquarium. After a minute or so, students see a distinct striation between the hot and cold water, demonstrating convection.

Students are amazed by the very distinct striation between the red and colorless water. Let the experiment sit for several minutes. Eventually, the red-colored water will cool, causing red "streamers" to descend to the bottom of the aquarium, giving the illusion of rain falling from a red cloud. Students are very excited by this phenomenon. They will offer explanations of why the red-colored water descends over time.

Cloud formation also requires plenty of moisture, a change in atmospheric pressure, and raindrop nuclei, such as dust or smoke particles—the heart of every raindrop. Students can think of the nuclei as a peach seed and the raindrop as the fruity flesh. A simple experiment that students enjoy is creating bubbles using condensation nuclei and a saturated environment. Each student needs

- a container of iodized table salt,
- one 296 mL (10 oz) clear plastic cup,
- and 296 mL clear carbonated soda.

First, the students fill their cups with the soda. Next, they sprinkle salt

Squeezing the rubber bulb creates "high" pressure inside the apparatus. Releasing the bulb will create "low" pressure inside the apparatus, thus creating a cloud.

into the soda and observe the formation of bubbles around the salt crystals. The salt crystals act as nuclei that allow bubbles to form.

As warm air rises into the atmosphere, it cools, condenses, and forms a cloud. An excellent instrument for investigating the science behind cloud development is a cloud-forming apparatus (see photographs above), which is made using

- a 500 mL glass flask with side tubulation (filtering flask);
- a rubber tube, approximately 1 cm in diameter and 7 cm long;
- a rubber hose clamp;
- 100 mL water;
- and a rubber bulb.

To produce a cloud in the apparatus, smoke particles from an extinguished match and water must be added to the flask. *There must be adult supervision when conducting this experiment.* Students release the clamp from the end of the rubber tube and pour 100 mL water into a small bowl. They then squeeze the rubber bulb on the end of the apparatus, put the open end of the rubber tube into the bowl of water, and release the rubber bulb; the water will be sucked into the apparatus.

Next, one student holds the cloud-making apparatus and squeezes the bulb. Another student lights a match and lets it burn for a couple of seconds. The student holds the lighted match close to the end of the rubber tube and blows out the match. The student holding the apparatus releases pressure on the rubber bulb and watches as the smoke from the extinguished match is sucked into the apparatus. By clamping off the rubber tube and squeezing the rubber bulb, the students control the air pressure inside the apparatus. Squeezing the rubber bulb creates "high" pressure inside the apparatus. Releasing the bulb creates "low" pressure inside the apparatus: The moisture condenses with the smoke particles acting as condensation nuclei, and a cloud is produced.

This demonstration is a favorite with students and shows how changing physical conditions leads to cloud formation. Students usually pass the cloud-forming apparatus around class so everyone can participate.

Often, cumulus clouds will start to build and then dissipate. Cumulus clouds can be seen on summer days as warm currents of air rise into the atmosphere. However, when specific atmospheric elements are present, these clouds continue to build upward into huge cumulonimbus clouds. At this point a thunderstorm is produced.

Cycle of a Thunderstorm

Storms have a cycle that includes a developmental stage, a mature stage, and a dissipation stage. Rising currents of air or *updrafts* appear as towering cumulus clouds during the developmental stage. Updrafts fuel the growth and development of storms. Very little rain is associated with this stage. To learn about updrafts, each student inflates a medium-sized balloon. The teacher explains that students' breath represents warm-moist air and the balloon is a developing thunderstorm cloud.

A fast-moving layer of air called the *jet stream* can also influence the formation of thunderstorms. The jet stream is a horizontally moving layer of air approximately 7.5 km–10.5 km (25,000–35,000 ft) above the ground. The jet stream of air decreases the air pressure aloft. Thus, the air pressure below the jet stream is greater and tends to rise. In other words, air under greater pressure is seeking a more comfortable low-pressure region.

A great experiment showing this principle can be conducted using a single piece of notebook paper and a textbook. Students insert one end of the notebook paper into the top of the textbook. The teacher asks students what will happen if they blow air across the top of the paper. The usual answer is that the force of their breath will force the paper down. Actually, by blowing across the paper, the students are decreasing the pressure on top. As a result, the paper will lift upward.

The experiment always gets a "Wow!"

Torrential rainfall, hail, lightning, strong winds, and tornadoes can occur during the second stage, the mature stage, of a thunderstorm. A mature storm takes in warm-moist air through the updraft and grows to tremendous heights. Soon, precipitation forms within the storm. Rain cools the surrounding air, which becomes heavy and descends to the ground. This descending air is called a *downdraft*. We often refer back to the hot-and-cold-water experiment as evidence that cold air sinks. Slowly, the thunderstorm weakens as cooled air and precipitation fall through the updraft. This process cuts off the warm-moist air feeding the storm.

Within a half hour, the thunderstorm begins its third stage—dissipation. Rainfall within the thunderstorm starts to decrease in intensity, though lightning can be present, even as the storm begins to collapse. This can be the most dangerous and damaging stage of the thunderstorm. Without an updraft holding the thunderstorm up, it collapses and transports heavy air to the surface. This rapid descent of air is known as a *downburst*.

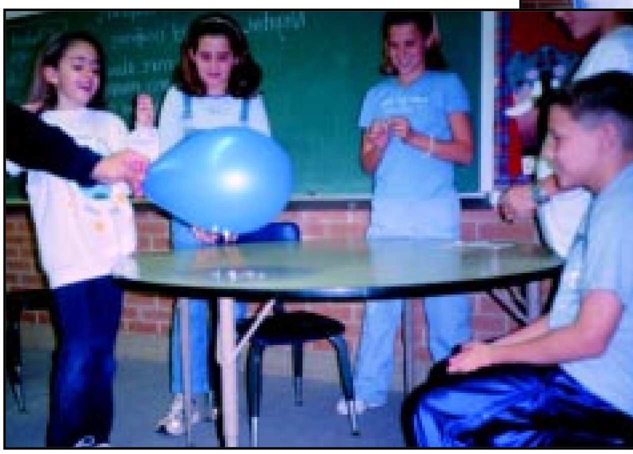
Collapsing thunderstorms are like deflating balloons. Students can simulate a downburst by inflating their balloons, holding them vertically, and releasing the air. To enhance this effect, students cut 10 small pieces of paper (less than 1 cm) and place them under the balloon as they release the air. The disturbed paper will fan out in all directions.

The Nature of Lightning

Even at the dissipation stage of thunderstorm development, the clouds are still electrified and can produce deadly lightning. Within the thunderstorm are millions of precipitation particles that collide with one another, split, and produce positive and negative charges. Large raindrops tend to have positive charges and smaller drops usually have negative charges. Electrical charges build up inside the cloud and on the ground. This energy buildup is released as lightning.

Lightning literally puts the thunder in thunderstorms. It can strike from cloud to ground, ground to cloud, and cloud to cloud. The rapid heating and cooling of air near the lightning channel causes a shock wave that results in thunder. Amazingly, the air surrounding a lightning strike can reach a temperature of 27,760°C—hotter than the surface of the sun!

Of course, classroom experiments can't replicate this hot temperature, but they can demonstrate the physical properties of electrical charges. One method uses static electricity. With a large balloon and a head of hair, you can produce a visually electrifying demonstration that students will love.



Students inflate a large balloon and charge it by rubbing it on a fellow student's head, which removes electrons. The balloon is then slowly moved up and down above the student's head; this causes his or her hair to react to the electrical charges on the balloon. Next, students tear some paper into small pieces and lay them flat on a table. Once the balloon is charged, the teacher describes it as a thunderstorm about to produce lightning. Students place the balloon approximately 2–4 cm from the paper pieces. Electrically charged balloons will pick up the pieces of paper like a big magnet. Next, students touch the balloon with their hands; this decreases the charge. They then place the balloon back over the paper pieces. The balloon will not pick up the pieces until it is recharged.

Lightning is certainly one of the most dangerous elements of a thunderstorm; however, one of the most damaging elements generated by strong storms is hail.

Ice in a Thunderstorm?

Many scientists believe that hailstones develop when ice particles rise and fall inside a thunderstorm updraft. The turbulent up-and-down motion within a thunderstorm causes the ice to melt and refreeze, which leads to hailstone growth. Eventually, the hailstones become too heavy for the updraft to support, and they fall to Earth.

Hailstones consist of a series of concentric rings. Using a half slice of onion or a cross-section of a small tree trunk helps students understand the concentric rings of ice that make up a hailstone.

Tornado Warning

On rare occasions, some thunderstorms produce tornadoes. Students are fascinated by tornado facts and

National Science Education Standards

This article addresses material related to the *National Science Education Standards*' (National Research Council, 1996) content standards (K–8 grades):

- **Physical Science**
  a. Light, heat, electricity, and magnetism (K–4)
  b. Properties and changes of properties in matter (5–8)
  c. Motions and forces (5–8)
  d. Transfer of energy (5–8)
- **Earth and Space Science**
  a. Changes in Earth and sky (K–4)
  b. Structure of the Earth system (5–8)
- **Science in Personal and Social Perspectives**
  a. Personal health (K–8)
  b. Natural hazards (5–8)
  c. Risks and benefits (5–8)

often have personal experiences to share with the class. Contrary to popular belief, scientists have yet to unlock all the mysteries associated with the formation of tornadoes. Some meteorologists hypothesize that tornadoes form when a rotating column of air near the surface of the ground is lifted to a vertical position by a severe thunderstorm's updraft. This vortex tube stretches vertically and contracts horizontally.

To demonstrate this concept, use a Slinky to represent a vortex tube. Two students hold each end of the Slinky and take 10 steps backward. The teacher asks them what happens to the diameter of the Slinky as they walk farther apart. (The diameter shrinks in size.) The same thing happens to a rotating thunderstorm updraft. As the rotation of the vortex tube tightens, it spins faster and produces a tornado. The same principle applies when an ice skater pulls her arms toward her body and spins faster. She rotates like a tornado on ice!

We like to end our presentations with a bang. Younger students make the reliable "tornado in a bottle." For this activity, students need

- two 1 L soft drink bottles,
- duct tape or plastic "tornado tube connector,"
- 1 L water,
- 30 mL dishwashing detergent,
- and some glitter.

To make the tornado, students fill one of the 1 L bottles with water, pour 30 mL dishwashing detergent into the water, and add a little colored glitter. Students use several layers of duct tape to attach the necks of the two 1 L bottles together, making sure that the bottle openings line up exactly. (Teachers can also buy plastic "tornado tube connectors" to use instead of duct tape.) They then hold the bottles vertically (with the water in the top bottle) and spin the apparatus in a counterclockwise direction to create a miniature vortex. Most tornadoes rotate in a counterclockwise direction. The glitter will rotate around the funnel, simulating flying debris. For third- through fifth-grade students, we end this presentation with several minutes of tornado video footage.

Bringing Weather into the Classroom

This program is guaranteed to capture the imagination of your students as they learn about interesting scientific concepts and participate in the activities. Be prepared for some good questions. Also, your students will probably want to relate a story or share an experience with the class. A creative writing exercise would be a great way for them to tell their stories. Best of all, you will be the new thunderstorm expert at your school!

Thunderstorms, lightning, and tornadoes are fascinating subjects for students to study. The awesome power of nature inspires and captures the imagination of children and adults alike. Further enjoyment comes from understanding the natural processes associated with the formation of clouds, the evolution of thunderstorms, and the mysterious phenomena that sometimes accompany them.

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Resources

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