# What's the Next Step?

*How to keep students engaged and on track when teaching inquiry skills during an experiment*

***By John Zenchak and Mary Jean Lynch***

You stand before your students holding a balloon in one hand and a sharp nail in the other. "If I poke this balloon with the nail, what will happen?" A number of hands eagerly wave in the air and one little boy shouts, "It will pop!" You move the nail toward the balloon and the students start squirming and covering their ears with their hands. Slowly, you push the nail into the balloon. . . but nothing happens! The balloon does not pop. The children begin asking questions.

The demonstration was a success—you captured your students' attention and now they are excited to learn. But what's the next step to keep the students engaged and effectively promote development of inquiry skills?

We have developed a series of inquiry-based activities called "demonstration-experiments" that begin with the demonstration of a discrepant event: what the students expect to happen does not match what they observe. The mismatch between the students' expectations and the outcome gives the discrepant event the potential to be a powerful teaching method because students ask questions and want to try the activity themselves. Sometimes, though, some students—especially young ones—may not have had enough prior experience with the materials or the topic to even have an expectation, and the discrepant event loses its power.

Our approach uses a demonstration with two similar setups that provide students with both the prior experience to form an expectation and the discrepancy to grab their attention. We follow the demonstration with a structured exploration format that gives students a method for experimenting to find the one built-in difference (i.e., the variable) that caused the different results between the two setups. Because the demonstration-experiment approach can be applied to various science content areas, inquiry is not the focus of just a single unit, but is used to teach content throughout the school year. Students repeatedly practice and refine their inquiry skills—asking questions, creating hypotheses, designing and conducting experiments, making predictions, interpreting results, and presenting their investigations to others.

One activity we designed deals with the concepts of density and convection currents and is called "Chill Out." Although Chill Out and our other demonstration-experiments can be adapted for particular grade levels, we describe it here for the third- to fifth-grade level.

**Figure 1.**

Teacher demonstration materials

- 2 tall clear plastic containers
- 1 teaspoon
- Water (room temperature)
- 1 straw
- Salt (NaCl)
- 2 ice cubes (same size)

CAUTION Although this is a teacher demonstration using salt water, chemical-splash goggles should be worn to demonstrate good safety practices.

## Demonstration: What the Teacher Does

To generate curiosity, give your students an opportunity to view the materials (Figure 1). Set the containers on different sides of your work area. Next to one container, place the teaspoon, salt, and straw. Between the two containers, place the water and ice cubes.

As the students watch, fill the containers about 90% with room-temperature water. Put one rounded teaspoon of salt (NaCl) into the first container and stir until the salt is dissolved. Slowly blow three long breaths ($CO_2$) through a straw into the first container (Figure 2a) and then remove the straw. Add one ice cube to each container, and ask, "What do you see happening?" (Figure 2b).

Students observe that the ice cube in plain water melts more quickly than the ice cube in the container of water with NaCl and $CO_2$. Many will be surprised and someone may say, "But I thought salt is used in winter to melt ice!" If no one does, ask "What is used to melt ice on streets and sidewalks in winter?"

## Experiment: What the Students Do

Ask each student to draw the two setups, describe in writing what was done with the materials, and record the results of each setup. Students usually do not need assistance in recording their observations beyond a reminder to include everything they saw. Figure 3, p. 52, shows the first page of a worksheet we designed to guide students through the experiment process. The worksheet page was completed by a fifth-grade student.

Next, each student lists the differences (variables) between the two setups and the similarities (constants) (Figure 4, p. 52). To be sure all students have correctly identified the variables (carbon dioxide, salt), ask the class "What things were different about the two setups?" Then ask about the constants (water temperature, size of ice cubes)—"What was the same about the two setups?"

## Form a Hypothesis

Working in small groups, students develop a hypothesis for each variable. They learn that a hypothesis describes the potential relationship between the variable that changes (independent variable) and the outcome (dependent variable). As recommended in the National Science Education Standards (NRC 1996), hypotheses are written in an "if. . .then" format. Providing students with a template guides them in developing hypotheses: "If ______ is the important variable, then changing ______ will affect ______." Students fill in the blanks to develop a hypothesis for each variable (e.g., "If carbon dioxide is the important variable, then changing whether carbon dioxide is used will affect how quickly the ice cube melts"). With each new demonstration-experiment, even young students quickly learn to formulate hypotheses.

## Design an Experiment

For each hypothesis, students design an experiment with two setups. For a fair test, students change only the variable being tested. The original constants remain the same, and the other variables are made into constants. In

**Figure 2a.**

Setting up the variables for the demonstration.

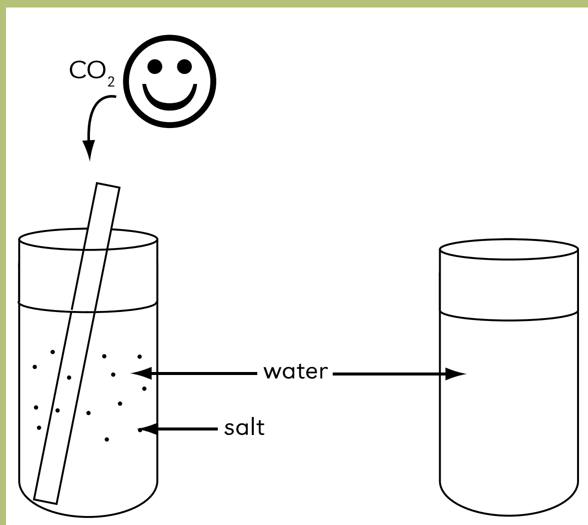
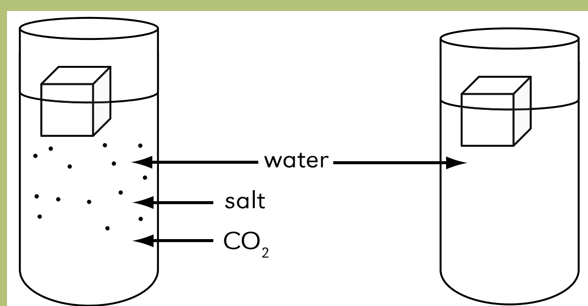
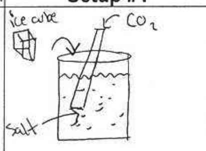
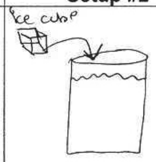



**Figure 2b.**

Adding the ice cubes.



## Figure 3.
Student draws setup.

| Name: Erika | | Date: |
|---|---|---|
| Experiment: Chill Out | | |
| **OBSERVATIONS** | **Setup #1** | **Setup #2** |
| **Draw Setup** |  |  |
| **Action** (What did the teacher do?) | fill jar with H2O | fill jar with H2O |
| | add 1 tsp. salt | |
| | blow in CO2 through straw; 3 breaths | |
| | put in one ice cube; observe | put in one ice cube; observe |
| **Results** (What happened?) | ice melted slowly | ice melted faster |

## Figure 4.
Student lists variables.

| **VARIABLES** (Different) | **Setup #1** | **Setup #2** |
|---|---|---|
| $CO_2$ | yes | no |
| Salt | yes | no |
| | | |

| **CONSTANTS** (Same) | |
|---|---|
| | size of jar |
| | temp. of water |
| | ice cube size |
| | amount of water in jar |

other words, only the variable named in the hypothesis is the one changing; therefore the other variables cannot affect the outcome.

Students in some groups may comment that others are doing a different experiment and ask "Which one is correct?" Remind the students, "Even though your experiments may look different, you are both correct because you are testing the same variable." For example, one group may design an experiment to test the $CO_2$ hypothesis using salt in both setups (Figure 5a), but another group may design an alternative $CO_2$ experiment in which salt is not used in either setup (Figure 5b). The two experiments appear to be different, but they are both fair tests of the $CO_2$ hypothesis because $CO_2$ is the only independent variable changing; there are no other variables that can account for different outcomes between the setups if they occur. Figures 6a and 6b show an experiment to test the salt hypothesis and the alternative salt experiment.

Before students do the experiments, they make a prediction about what will happen in each experiment, based on your original demonstration. They focus only on the variable they are testing because the other variables are now constants and constants cannot cause different results. The students will know when they have identified the important variable (the one responsible for the different outcomes in the original demonstration) when the results from their experiment match the outcomes of the teacher demonstration.

## Do the Experiment

After designing their experiments, students are ready to do the testing. Follow standard laboratory safety procedures, such as wearing chemical-splash safety goggles. Because the experiments for each variable may require different materials samples of student work and blank worksheets are available online (see NSTA Connection). Each group must decide which materials they need gather them. Once the group completes the experiment as designed, they write down the results for each setup and compare the results to the predictions they previously made based on the initial teacher demonstration. If their experiment results do not match both demonstration setup outcomes, students did not identify the important variable yet. Students are excited when the experiment results match both demonstration setup outcomes because it means they found the important variable. Even if by chance the students identify the important variable in their first experiment, they should do the experiments for all the variables to support their conclusions.

CAUTION

## Making Sense of the Results

Review the results of all the experiments conducted by the students to make sure that everyone identified the important variable. For "Chill Out" the important variable is the salt; salt keeps the ice cube from melting quickly. The $CO_2$ blown into the water has no effect on melting rate.

As the ice cube in the plain water melts, the cold water around it becomes heavier (denser) than the rest of the water in the container. The cold water sinks and pushes up warmer water from the bottom, which melts the ice cube more and continues the cycle. This circular movement of water is called *convection current* (Read more about convection in "Science 101" on p. 60). Adding salt makes water even denser than cold water. As the ice cube in the salt water begins to melt, the denser salt water keeps the cold water around the ice cube from sinking. The ice cube melts at a much slower rate because no convection current is set in motion to bring warmer water up from the bottom.

Some weather events, such as lake effects and sea breezes, are based on convection currents. Ask your students, "Has anyone been to the beach lately? Do you remember anything about the wind at the beach?" Students sometimes respond with "It was cooler by the water" or "The

**Figure 5a.**
Test of $CO_2$ hypothesis.

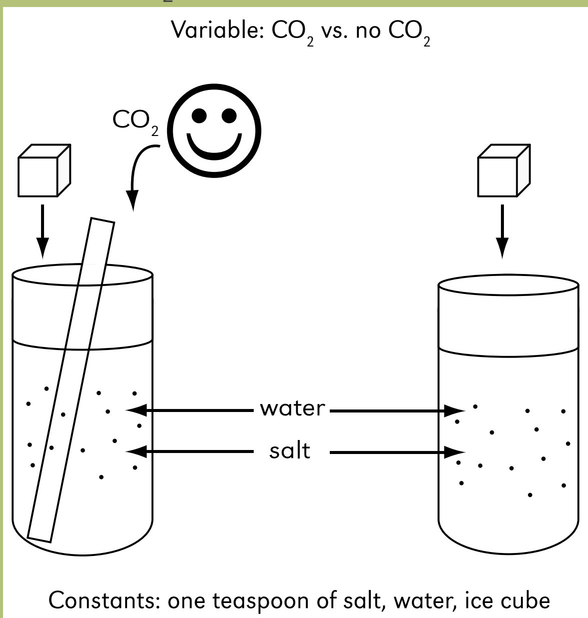



**Figure 5b.**
Alternative test of $CO_2$ hypothesis.

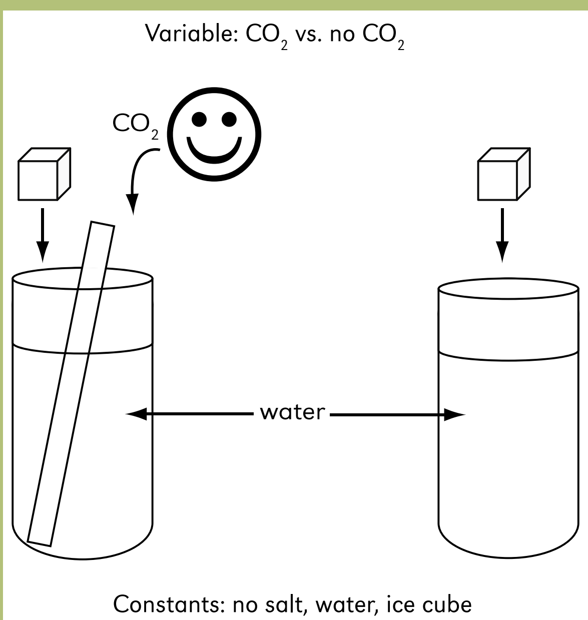



**Figure 6a.**
Test of salt hypothesis.

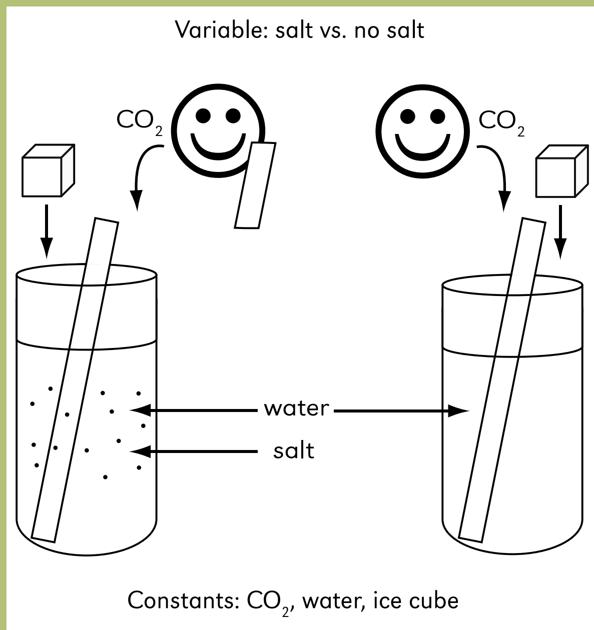
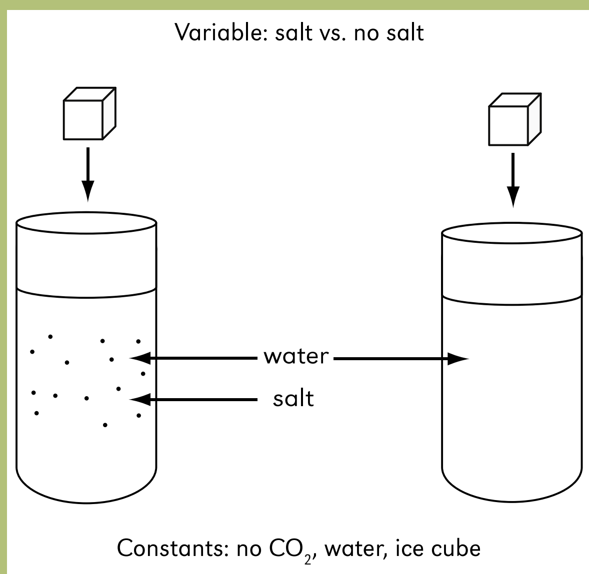



**Figure 6b.**
Alternative test of salt hypothesis.



wind came from the water."

During the day, the land warms faster than the water because water changes temperature slowly. Air above the land warms more quickly, becomes less dense, and rises. The rising air is replaced by cooler air that was above the water. Convection current is created and a breeze comes off the water toward the shore. At night the opposite happens. The land cools more quickly than the water. Air above the water is now less dense than the air above the land, so it rises. The rising air is replaced by the cooler air that was above the land. A reversed convection current is set up and the breeze moves off the land toward the water.

To show the actual convection current or lack of current, create colored ice cubes in advance using enough food coloring in the water to make the water nearly opaque. Re-create the original setups, substituting the colored ice cubes for the original clear ones. The convection currents in the container with plain water will become clearly visible as the colored ice cube melts and the denser, cold, colored water sinks to the bottom. In the container with salt water, the melting ice cube will form a layer of cold, colored water that stays on the surface. No convection currents are formed because the salt water is denser than the cold, colored water.

## Assessment

How do you assess understanding of the inquiry process? Use a demonstration-experiment! Students must apply their knowledge of the process to various parts of either the original or a new demonstration-experiment. In increasing order of complexity:

- Can students recognize components of scientific inquiry? Example: Show the same demonstration-experiment and ask students to identify one of the variables or constants.
- Can students transfer their understanding of scientific inquiry to different situations? Example: Show a different situation and ask students to identify the variables.
- Can students design an experiment to test a variable when given half of the experiment? The situation may either be similar to or different from one they have already seen.

## Practice Makes Perfect

The demonstration-experiment approach promotes students' communication, problem-solving, and reasoning skills. It dramatically increases understanding of scientific inquiry and improves understanding of content because the activities make the concepts concrete. The demonstration provides both prior experience and a discrepant event at the same time, giving students a more level playing field, regardless of their backgrounds. Teachers report that the structured format for inquiry gives them an appropriate way to follow an interesting demonstration, and the repeated practice of inquiry helps them and their students feel comfortable and competent doing science.

Perhaps the most important benefit of the demonstration-experiment approach is that it increases students' interest in science. During the activities, students are attentive, focused, cooperative, and enthusiastic. They are engaged by the experiments because they enjoy the challenge of figuring out how to get to the answer. Students have more ownership of what they are doing because they "write the recipe," instead of merely following a cookbooklike approach. After a number of demonstration-experiments, students feel empowered because they understand the science process of finding the reason for discrepancies they observe. Additionally, they start making connections between using this process and solving everyday problems. They enjoy science and eagerly look forward to doing science again. ■

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### NSTA Connection

Download blank worksheets and examples of student-completed worksheets at *www.nsta.org/SC1102*.

### Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

**Content Standards**

**Grades K–8**

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**Grades K–4**

Standard B: Physical Science

- Properties of objects and materials

**Grades 5–8**

**Standard B: Physical Science**

- Properties and changes of properties in matter

National Research Council (NRC). 1996. *National Science education standards.* Washington, DC: National Academies Press.