Melting Ice: Designing an Experiment

Suggested Grade Level(s): 8-12
Estimated class time: one 45-minute class period

Summary

This lesson uses a discrepant event to help students realize that a carefully designed experiment may yield unexpected results, due to unseen events, even though the experiment is precisely planned and executed. The addition of a new technology may clarify factors in the experiment which were previously unknown.

Objectives

- Students will design an experiment to determine whether ice melts faster in pure water or salt water
- Students will understand that the design of an experiment can affect the outcome
- Students will understand that new technology can reveal processes that were previously unseen

National Science Standards

- NS.5-8.1 SCIENCE AS INQUIRY
  As a result of activities in grades 5-8, all students should develop--
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.5-8.2 PHYSICAL SCIENCE
  As a result of their activities in grades 5-8, all students should develop an understanding
  - Properties and changes of properties in matter
  - Transfer of energy
- NS.9-12.1 SCIENCE AS INQUIRY
  As a result of activities in grades 9-12, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.4 EARTH AND SPACE SCIENCE
  As a result of their activities in grades 9-12, all students should develop understanding of
  - Origin and evolution of the earth system
  - Origin and evolution of the universe
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE
  As a result of activities in grades 9-12, all students should develop understanding of
  - Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

Knowledge Prerequisite

It is helpful if students have had experience with winter conditions of snow and ice on pavement and the use of de-icing agents such as salt to remove the ice.

Materials

- Clear plastic party cups with smooth sides (best for observation)
- Ice cubes of uniform size
- Bucket of fresh tap water at room temperature
- Bucket of very salty water at room temperature
- Graduated cylinders at least 100 ml
- Clock
- Thermometer

Preparation

The day before the experiment prepare one large bucket of plain tap water and another bucket of warm tap water with **as much salt dissolved in it as possible**. Lab grade salt is nice, but expensive and not really necessary. Un-iodized salt from the grocery is fine, but the water will be a little cloudy due to non-clumping additive. If the students ask why one container is not clear, explain the additive and that it is not likely to have an effect on the outcome. **Allow both buckets to sit in the classroom overnight so that they are the same temperature and at equilibrium with the air.** Check the temperature of the buckets before you begin the experiment.

Use ice cubes from a refrigerator icemaker if possible because they are very uniform. If you make them in ice cube trays, each cube should be only about ½ to ¾ of the compartment. Use a syringe to fill them if necessary to make them uniform. (Cubes made from a full tray will not be melted in a class period and the students will need to make a judgment about which is melting faster. Using smaller cubes will result in one cube being totally gone before the other and the results won't be as fuzzy. A cube containing about 15ml of water is about right. They do not need to be "cubes" but they should be as uniform as possible, whatever the actual shape.)

Students will work in teams of two. Each team has two ice cubes and two cups, one cup with **100ml** of fresh water and one with **100ml** of salt water. Ask them to watch very closely and make careful observations of the start time as they begin melting the ice.

Procedure:

As scientists search deeper into the origin of the universe and the secrets of galaxies in deep space they become more and more dependent on remote technology to collect data. The outcome of the experiment is dependent on the ability of the experimental design to answer the actual question it is asking. Sometimes the design itself can influence the result, even when the experimenter makes every effort to remain unbiased.

The precision and accuracy of the sensors themselves can determine the result of an experiment. The original detection of the cosmic microwave background seemed extremely uniform throughout the universe. The addition of NASA's COBE satellite, launched in 1989, showed that there were slight variations, or tiny lumps, in this earliest remnant of the Big Bang.

I. Engagement

Have your students imagine that it is a snowy winter day and the highway department is working hard to clear the roads. There have been few "snow days" this year and they find themselves wishing the highway guys were not quite so efficient. Sensing that the class is less than enthusiastic for school today, you decide to begin with an easy question: *Will an ice cube melt faster in fresh water or in salt water?*

(**Teacher note**: Most students who have experienced icy winter pavements will expect the salty water to melt the ice faster because salt is used on sidewalks to melt ice. Pouring fresh water on an icy pavement would just make it even icier.)

II. Exploration

(**Teacher note**: This activity has more "punch" if it is introduced without the summary and objectives listed above. It is also good to do this activity during the winter when snow removal and icy pavements are fresh in everyone's mind.)

The students should be told something like this "The best science experiments are carefully designed to be a fair test. We try to be sure that we do not bias the outcome by doing something which gives one side or the other an edge. Today we are going to design an experiment and we will ask a question which most of you can probably answer already, "*Will an ice cube melt faster in fresh water or in salt water?"*

Ask each student to write the question on her paper and then to write a hypothesis that explains what she thinks will happen and why.

Begin a list on the board of the things that will be necessary to ensure that the experiment is designed as a "Fair test". Students will suggest using the same size containers, same shape and volume of ice cube, same temperature and volume of melting water, same environmental conditions in the room etc. When they have volunteered as many factors as they can, ask if they should stir the melting cubes or not? Mention that stirring would be hard to make exactly the same in both containers and wait for them to tell you that neither container should be stirred. It **is very important that neither container be stirred during the experiment!**

It will become obvious very shortly that the cube in fresh water is melting much faster than the expected one in salt water. If one of the cubes rolls over, don't disturb it, but continue making observations. Most students do not watch very closely, but at least remind them several times. Very careful observation indicates the motion of density currents in the fresh water container, but if they don't see them, don't mention it yet.

Remind the students that it is very important to label and document all samples, to measure carefully and follow all of the steps for a "fair test." They will assure you that they have done everything correctly and it is still not coming out "right." Now is a good time to be very dramatic about precise and careful procedure. When the cube in fresh water has completely melted, the one in the salt water should still be fairly large. Adjust the size of your ice cubes to fit your class period. Have them clean up and put away materials, but do not discuss the results until later. Ask them to write if they will be accepting or rejecting their original hypothesis and to explain why.

III. Explanation

Have the students repeat the experiment just as they did before, but this time add five drops of food coloring to the top of each melting ice cube. Ask them write down any new observations that are different from those they have already recorded.

(**Teacher notes**: The next class period, set up two new containers that are large enough for the students to see from their seats. Place a thermometer in each container and record the temperature. Do not remove the thermometer. Add the ice cubes as before.)

Explain that sometimes the same experiment done with the addition of a new technology reveals something happening which was not apparent before. Scientists do the best they can to collect data with the tools and abilities they bring to the problem, but are always looking for additional ways to find out what is really going on. After a few minutes, record the temperature of the thermometers. The bulbs of the thermometers are sitting on the bottoms of the containers and there is beginning to be a difference between them. The thermometer in the fresh water shows a decreasing temperature, but the one in salt water remains about the same.

Have students carefully add 5 drops of food coloring to the top of each melting ice cube without disturbing the container. The food coloring will remain with the melt-water as it flows off of the ice cube. Cold fresh water is denser than the fresh water in the cup, but it is less dense than the salty brine in the other cup. The melt water in the fresh water cup is sinking to the bottom of the container. The cube in the fresh water is always bathed in the warmer water of the cup while the cold water from the melting cube sinks away from it. The cube in salt water is surrounded by its own very cold melt water, which is still less dense than the very salty brine. The cold melt water insulates the cube from the room temperature water around it. The cube in the coldest water melts slower! A band of colored melt water will form at the bottom of the fresh water cup and at the top of the salt-water cup. The food coloring "technology" showed that the cubes were not actually in the same environment. The temperatures on the thermometers confirm it. Originally we thought that stirring the containers would lead to an unfair test because it would be hard to do it uniformly. Now the students will ask what would have happened it they were stirred. This is a good place to remind the students that the results of one experiment are frequently the beginning of a new question and encourage them to find out for themselves.

IV. Extension

Next, have the students design a new experiment to answer additional questions they may have. Remind them to be sure to control the variables so that they conduct a Fair Test.

(**Teacher note**: Students can repeat the experiment trying to incorporate some type of uniform stirring. If the cups of water were at the same temperature originally and the ice cubes were the same size and temperature, the ice should melt at about the same rate in both cups as they are stirred.)

Given the unexpected outcome of this experiment, someone will ask why we use salt to melt ice on sidewalks. Depending on the time available you can discuss that solutions have lower freezing points than pure water and that salt is only applied to ice if the temperature is fairly close to the freezing point of water or slightly above it. The salt dissolves in the liquid, which makes it more difficult to freeze. At temperatures close to freezing the pressure of traffic rolling over the pavement raises the surface temperature just enough to melt the ice and the salt dissolving into it keeps it from refreezing. The ice skater's blade concentrates the pressure of his body weight so that he glides on a thin layer of liquid water. If the temperature is already very cold, the highway department spreads cinders or sand to improve traction. Salt is not very effective at low temperatures.

V. Evaluation

Finally, ask the students to write down their answers to the following questions:

1. What did you learn from doing this experiment?
2. Are you accepting or rejecting your hypothesis? and why?
3. This experiment is about melting ice. Why has your teacher asked you to do it now as part of an exploration of galaxies and deep space?

(**Teacher note**: Each new development in technology may explain a past conclusion in a totally different light. This lesson uses a "new" technology (in the form of food coloring) to help show us what's going on in a physical process. In doing so, we are able to discard old hypotheses and understand the phenomenon better. Likewise, the answers to our questions are right in front of us, but we need an open mind and new tools to see them.)

The cosmic microwave background was predicted by the Big Bang Theory to be an extremely uniform radiation emitted from the Big Bang. It would be the remains of radiation from the original Big Bang. The wavelengths would have lengthened as space expanded, so that today we can detect the remnants of that expansion as microwaves. The discovery of actual CMB was a great boost to the Big Bang Theory. The CMB was initially found to be very smooth. The question arose as to where the galaxies then come from. There needed to be some irregularities in the background from which galaxies could form. The data discovered by the new technology on the COBE satellite showed that the CMB, although generally smooth, actually did contain the slightest universal non-uniformities. Those very slight “lumps” are what gravity pulled together to form the galaxies we see today.