Students today are growing up with ozone alert days, water restrictions, traffic tangles, and West Nile warnings. While the specific problems may differ community to community, an exploration and discussion of such environmental issues provides fertile opportunity for meaningful learning. Well-mediated instruction on such issues also promotes students' ability to build their science knowledge in the relevant context of science-technology-society interactions.

While environmental issues are naturally engaging, we have found that students are more motivated to engage in thoughtful discussion when led into these topics with a model, simulation, or demonstration. Such modeling can also serve to illustrate complex concepts, making them more accessible. However, modeling and demonstrations should be conducted in an interactive manner that promotes discussion in cooperative learning groups that provide an opportunity for students to interpret phenomena and develop understanding of environmental issues. Thus, students work in a manner that parallels the inquiry process utilized by scientists (NRC 1996).

The purpose of this article is to, first, present two engaging environmental modeling activities and a related online exercise, and second, to explain proven teaching methods that make demonstrations less teacher-centered and more engaging for groups of collaborating students.
Biosphere bubbles

Biosphere bubbles can be generated by collecting the CO₂ produced when dry ice is placed in water. The gas collects in the bottle, then passes up through a PVC pipe and down its curved end. By wrapping a paper towel that has been soaked in soap solution around the pipe opening, “biosphere bubbles” will form as the gas exits the tube. Since CO₂ is more dense than the surrounding air, the bubbles that form fall rapidly downward. Most students find these bubbles fascinating.

Materials
- Two, clear plastic 2-L bottles
- One, 70 cm long piece PVC pipe, 2 cm diameter
- Two 90 degree elbow pieces of PVC pipe, 2 cm diameter
- Two, PVC couplings, 2 cm diameter
- Paper towels
- Rubber bands
- Plastic cup
- Soap solution (dish soap diluted to 20 parts water/1 part soap)
- Masking, duct, or electrical tape
- Several chunks of dry ice, 50–150 grams each
- Water

Safety alert
The teacher is the only one who should be working with the dry ice in this activity and the bubbles are not dangerous, so gloves are not necessary for students. However, using eye protection is a good idea, as the dish soap may be an eye irritant.

Procedure
1. Carefully cut the top off of one of the bottles about 3 cm below the bottom of the cap. Keep the bottom portion.
2. Carefully cut the second bottle about 5 cm farther down where the bottle reaches its widest point. Keep the top of this bottle.
3. Connect the three pipes and two elbow joints to construct the CO₂ cane (should look like a “shepherd’s hook” or an upside-down “J”).
4. Tape the top of the second bottle to the bottom of the CO₂ cane and secure it tightly.
5. Fold up the paper towel into 2-3 cm wide strip and wrap it around the mouth of the pipe. Trim off the extra towel and secure it with a rubber band.
6. Fill the other bottle about half full of warm or room temperature water, and then drop in a few pieces of dry ice.
7. Place the bottom of the CO₂ cane over the top of the bottle so a seal is formed between the bottles.
8. Place the cup of diluted soap solution up to the mouth of the cane and wet the paper towel to establish a soap film across the opening. Repeat this as needed.
9. Observe as the unusual white bubbles fall quickly from the cane. If you cover your hands with a little bubble solution, you can try to catch the bubbles or bounce them off the table.
10. As the production of bubbles slows down, you can replace the water and add more dry ice.

Guiding questions
1. How are these bubbles different from the ones we normally see?
2. Why do you think the bubbles fall instead of floating?
3. If the average American produces three million, 1-L bubbles per year, how many is that per day/hour/minute?
4. Why do you think Americans produce more CO₂ than anyone else in the world?
5. What kind of things can we do to reduce our production of carbon dioxide?

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Biosphere bubbles

The Earth’s atmosphere has been called “the precious envelope.” This relatively thin film of air, some 75 kilometers thick, swirls above our planet’s surface blocking cosmic rays and providing elements essential for the life on our planet. In some ways, our atmosphere is like a bubble. Both beautiful spheres are delicate and easily damaged. Just as the structure of a bubble depends on a precise balance of soap, water, and pressure, the well being of our biosphere depends on a delicate balance of soil, water, and air. A critical equilibrium is found in the atmosphere where a balance of gases is necessary to maintain a relatively constant temperature on the Earth. These gases, which include carbon dioxide, methane, nitrous oxides, and others, help keep the planet warm by trapping some of energy that would otherwise escape into space. Without this natural “greenhouse effect” the Earth would be much colder than it is today. The key to a healthy climate is to maintain a relative balance in the concentration of these gases.

Unfortunately, this balance is being disrupted because human activities are altering the composition of the atmosphere through an increased production of greenhouse gases. According to the Environmental Protection Agency, carbon dioxide concentrations have increased more than 30 percent since the industrial revolution while methane concentrations have more than doubled (EPA 2002). These increases have enhanced the heat-trapping capabilities of our atmosphere. Of the greenhouse gases, carbon dioxide levels are thought to have the greatest impact on climate change. Though carbon dioxide is consumed through the process of photosynthesis, it is also a product of numerous chemical processes. The increase in carbon dioxide production can be attributed primarily to the burning of fossil fuels such as gasoline, coal, and natural gas. We are adding carbon dioxide into the atmosphere much faster than it can be recycled.

Students need to realize the fact that the United States is the world’s largest source of carbon dioxide emissions—only 4 percent of the Earth’s population resides in the U.S., yet we produce over 20 percent of its greenhouse gases. Recent accounts show that for the U.S., total CO₂ emissions since 1950 measure in at 186 billions of tons (Kluger 2001). This number is particularly telling when compared to the same measurements in the European Union (128), Russia (68), and China (58) over the same period. The burning of fossil fuels for energy production and transportation accounts for our high CO₂ emission levels.

The average U.S. citizen is responsible for six times as much carbon dioxide as the average Japanese citizen, and nearly 25 times as much as the average Australian. These data are humbling, even embarrassing, as we reflect on our global citizenship. To bring the concept of CO₂ emissions down to the level of the individual U.S. citizen, we’ve adapted a chemistry demonstration using the sublimation of dry ice (Flinn Scientific Foundation 2001). We call these “biosphere bubbles,” and find the demonstration to be an effective means of modeling the physical properties and significant problem of greenhouse gases. Individual CO₂ emissions equate to about 5,400 kg (12,000 lbs) of carbon dioxide per year, which in bubble terms is roughly equivalent to three million, 1-L bubbles per year or eight thousand bubbles per day. Directions for generating biosphere bubbles and discussion questions are provided in activity sheet 1 on page 25.

As you generate the biosphere bubbles, have your students observe the unusual properties and behavior of the gas. The “heaviness” of the CO₂ gas, and the fact that the bubbles fall instead of float, often leads to discussion about the blanket of greenhouse gases that surrounds our planet. We like to arrange students in cooperative learning groups of three or four as we do this demonstration, though the entire group watches the demonstrations at the same time.
By doing this we see more students engaged in interpreting the demonstration. We guide student thinking by writing the questions from the activity sheet on the board. Once the student groups have had adequate time to discuss their responses to the questions, we solicit responses from members of each group. In this way we avoid putting individual students on the spot, but instead allow them to collaborate and generate the best thoughts of the group.

**A “crystal ball” of population growth**

If a “fortune-teller” looked at the palm of the Earth, what do you think she would see? Would she predict a productive and healthy future, or would she groan and quietly look away? Though we would never promote superstition in the science classroom, we are not above using a metaphorical “crystal ball” that directs students to assess human impact on the environment. After completing the biosphere bubbles, we use the rest of the dry ice to make a few larger bubbles that look a bit like a crystal ball. The growing bubble stretches and quivers, surprising the students with its growth and resiliency. We use this as an object lesson for the way human population growth is stretching the Earth’s resources thin.

To do this activity, place a few pieces of dry ice into a bowl with water and then slide a wet and soapy paper towel over the top of the bowl. As the carbon dioxide gas builds up in the bowl, it pushes the soap film into a large bubble that looks like a crystal ball. We usually have three or four students producing these bubbles while we discuss related issues and ideas. The discussion begins in the groups and then is incorporated into a whole-class discussion. Directions and some of the questions used to facilitate discussion are provided in activity sheet 2 below.

Undoubtedly, we all stress that science relies on evidence. The superstitious stuff of fortune telling offends our empirical commitments. Scientific explanations must be supported by verifiable data. After making this distinction between superstition and science, it is a good time to di-

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**A “crystal ball” of population growth**

This slow-growing soap bubble filled with CO₂ gas is used to represent the expanding human population and the subsequent stresses that we place on the environment.

**Materials**
- bowl or can with a smooth, flat rim
- several chunks of dry ice (golf ball size chunks)
- soap solution (diluted 20 parts water/one part detergent) in a cup
- paper towels
- flashlight (optional)

**Safety alert**

The teacher is the only one who should be working with the dry ice in this activity and the bubbles are not dangerous, so gloves are not necessary for the students. However, using eye protection is a good idea, as the dish soap may be an eye irritant.

**Procedure**

1. Fold the paper towel lengthwise into 3–4 cm wide strip. The strip should be 10–20 cm longer than the diameter of the bucket. If needed you can use two attached towels.
2. Soak the paper towel in the soap solution, remove it, and let the excess drip off.
3. Fill the bowl about half full with water and drop in a couple of pieces of dry ice. Observe as the fog spills over the rim and onto the table.
4. Slide the wet paper towel across the rim of the bowl and try to create a “lid” with the soap film. This may take several tries at first and it helps to wet down the rim at the start.
5. Observe as the crystal ball of carbon dioxide forms as the dry ice sublimates into the gaseous state.

**Guiding questions**

1. If a fortune-teller peered into her ball to see the future of the Earth, what do you think she would see? Would she predict a productive and healthy future, or would she groan quietly and look away?
2. The population on the Earth has doubled in the last 40 years, if the crystal ball represents this expanding population, how close do you think we are to “popping”? What evidence do you have to back up your prediction?
3. Some people see the Earth as a fragile bubble whose very survival is in danger. Others downplay the risk and assert economic prosperity should be our primary concern. What do you think?
rect student groups to reputable sources of current data on the causes, consequences, and possible solutions for the stresses humans have placed on the environment. We usually make this an online exploration and an excellent place to start is the global warming section of the Environmental Protection Agency’s website (see Resources). A students research global warming issues, they quickly find that the process of collecting and analyzing such data is open to multiple and often conflicting interpretations. We encourage our students to consider the sources of information, look for patterns that make sense to them, and see if there is a general agreement among scientists.

In this regard, recent scientific assessments of the Earth’s ecosystems indicate an unhealthy condition that is stressed to the limit. Specifically, a major United Nation analysis of our global ecosystems has concluded that the planet’s production capacity is beginning to decline to the point that it is threatening both our environmental and economic well being (WRI 2001). The report cites statistics that are truly alarming. For example, half of the world’s wetlands have been lost in the past century, 80 percent of our grasslands are suffering from soil degradation, and water scarcity will soon limit worldwide economic development. The source of these problems can be traced primarily to two recent developments. First, the human population has increased so much so that, just 40 years ago, there were less than half the people on the planet than are here today. Secondly, the natural resources on our planet are being depleted, primarily by a small percentage of the population that continues to consume resources at an unprecedented rate. Specifically, although Americans make up less than five percent of the world’s population, we use about 30 percent of our planet’s natural resources.

Tracking your ecological footprint
A fter we complete these demonstrations and discuss the ecological issues that are involved, we have our students go online to calculate their ecological footprints. (Although there are several footprint calculators available, we have our students use the one listed in the Resources section.) A fter calculating their footprints, students answer questions that are later used to foster class discussion. We want them to see firsthand how their lifestyles have an impact on our environment. If we take the amount of productive land on the planet and divide it by the world’s population, we find that the good Earth provides about 5.5 acres of bioproductive space for each person on the planet. Each acre represents about one football field worth of space—initially students think that this is more than enough to accommodate their needs. But when you ask them to consider everything that is necessary to support each facet of their lives—space for rest, shelter, growing food, feeding animals, depositing waste, and producing energy—things get crowded in a hurry. A fter briefly discussing these ideas, we have students predict the acreage of their footprints and go online to determine the actual size.

A fter completing their calculations, students then compare their results to other nations by going to another website (see Resources) which provides comparative information. Students are then asked to consider what implications this data has in regards to the long-term health and sustainability of our planet. Finally, they explore ways they can take action to reduce their ecological impacts.

In the middle grades, students have a distinct need to explore topics that offer them relevant, personal connections with who they are becoming in the world around them. A recent synthesis of recommendations for improving science education in the middle grades asserted that the “subject matter of the core program should be linked directly to young adolescents and how they fit into the world about them” (Hurd 2000).

The “world about” our students is fraught with a number of environmental predicaments that offer fruitful opportunities to engage students in meaningful thought, discussion, and action. In doing so, students have the opportunity to act constructively, to build their understanding, and to improve the world around them.

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Internet resources
EPA — www.epa.gov/globalwarming
World Resources Institute— www.dooleyonline.net/media_preview/millassessment.cfm
Ecological footprint calculator— webtech.kennesaw.edu/tbrown/ecofootprint.html

References