Activity 4.4 Modeling the Greenhouse Effect

PTK wishes to thank Carol McLaren, et al., and UCAR (the University Corporation for Atmospheric Research) for permission to adapt the Greenhouse Effect activity originally developed for "Project LEARN", supported by NSF grant ESI-9153756. This activity itself draws upon "Global Climates Past, Present and Future: Activities for Integrated Science Education" EPA/600/R-93/126, pp. 39-46.)

Teacher Background

We humans and all other living things on Earth have always experienced a "greenhouse effect." Without it our world would have been too cold for life to have colonized the surface of our planet. Over the millennia, our Sun and Earth have established a distinct and critical energy balance that has allowed life to develop and evolve. Life itself has "terraformed" the planet. Without photosynthetic organisms operating over hundreds of thousands of years, Earth would not have the oxygen we need to survive. Our life today is the product of changes in Earth's atmosphere caused by archaic life. Climate change is real: without it we would not be here. What students may have heard about is the current debate about "global warming" and its causes. This Activity demonstrates how the Greenhouse Effect works, some of the factors which drive or mitigate changes in temperature, and prepares them for some of the Wrap Up activities in which they are invited to research and report on some of the social dimensions of climate change.

The Science of the Greenhouse Effect

Air, clouds, soils, plants, rocks, lake and ocean waters all reflect, absorb, and re-emit the radiant energy that arrives from the Sun. Electromagnetic radiation includes energies from the entire solar spectrum. (See Activity 2.6, "Making Rainbows.") On average, around 30 percent of the Sun's incoming energy is reflected back to space by clouds, the atmosphere and Earth's surface, and the remaining 70 percent increases the temperature of solids, liquids, and gases which absorb it.

Some of the energy absorbed by these various substances is then re-radiated to space. This re-radiated energy is in the *infrared* portion of the electromagnetic spectrum. Certain gases in our atmosphere, such as water vapor (H_20) and carbon dioxide (CO_2), are very effective at both absorbing this energy and re-emitting some of it down toward the Earth's surface again, thus trapping and keeping a greater portion of the Sun's energy within the Earth's atmosphere and surface. This delicate balance is "just right" (as Goldilocks would have said) for maintaining Earth's average surface temperature at about 14 degrees C (57 degrees F). Without these infrared-absorbing gases, the average temperature would be about -18 degrees C (O degrees F).

A note on soda bottles and the Greenhouse Effect

Clear physical barriers such as plastic bottles can be used to *model* the greenhouse effect because they allow visible light energy to enter but block the escape of heat energy. The analogy between soda bottles and the atmosphere is not perfect. But it does serve as a crude model of actual atmospheric processes and is therefore of some use in helping students understand the principles underlying the actual greenhouse effect. Just as in Section 2, the Student Worksheets include the key steps. We suggest you have them beside you as you read through this part of the Guide.

Objectives
Students will model and observe a simplified "Greenhouse Effect."

Vocabulary
Greenhouse Effect (GHE)
electromagnetic spectrum
infrared
trace gases
re-radiate
re-emit

Materials (for each student team)
2 two-liter plastic soda bottle "greenhouses" (one vented, the other intact)
2 thermometers
150-watt floodlight bulb
clamp-on, portable reflector lamp
stand for lamp set-up
graph paper
Student Worksheet 4.4

LFSTORM Standards Correlation sheet for teacher reference

TEACHER TIP:
Teacher Tip on preparing the model greenhouses
The "Experimental Chambers" are easy to make if you have laboratory thermometers, or thermometers without the metal backing. Make a hole the same size as the thermometer in the bottle cap. The thermometer needs to fit easily through this opening, but do not make the opening so large that there is a gap. For standard laboratory thermometers a 19/64 drill opening works well.

If you use thermometers with a metal backing you will need to cut an opening in the bottle to place the thermometer inside. The best way to do this is to cut an opening in the seam of the bottle (the ridge where the halves are joined together) large enough to maneuver the thermometer inside the bottle. Tape the thermometer to the side of the bottle with the thermometer side out, i.e. so that you can read the index through the bottle wall. Tape up the opening, using *clear* packaging tape both to place the thermometer and to close up the bottle.

Preparation for Activity 4.4
Each student team will need two bottles. 2-liter clear plastic bottles are ideal.
1. Remove the bottle labels by soaking in warm water.
2. Cut several elongated vents (1 x 4 inches, 3 x 10 cm) in the sides of one of the bottles. (Referred to as the "vented" bottle.) Do not cut slits in the second bottle. ("Intact" bottle.)

Engage
"It's a hot summer day. You've decided to go outside and walk barefoot. Where will it be cool enough to walk?" (On grass, light colored surfaces, puddles.) "What causes some surfaces to be hotter than others?" (Darker surfaces absorb heat while light surfaces reflect heat, see Activity 1.2.) Ask students what factors influence our daily temperatures. (Amount of sunlight, cloud cover, closeness to a body of water, urban vs. rural climate.)

Distribute Student Worksheet 4.4 and review procedures with students. Have student teams implement the Activity, circulating among the groups to ensure the procedures are being carefully followed, answering questions and generally encouraging them as the fabled "guide on the side."

Students should record their hypotheses, raw data and analyses in their WEATHERlogs, together with any additional observations they make during the Activity. Bring the whole class together to discuss results. Guide discussion to see why there were variations in results. Also guide students to see how this Activity models some, but not all, aspects of Earth's actual GHE.

Expand/Adapt/Connect
Go online to the LIVE FROM THE STORM website to learn more about the Greenhouse Effect. A fully described extension to this Activity, "What Factors Influence the Greenhouse Effect?", can be found online. Students will be able to see how the amount of solar radiation absorbed by the atmosphere and the surface of the Earth is influenced by 3 factors: clouds, surface albedo and ocean water and experiment with different conditions which influence the Greenhouse Effect. Research what causes the creation of greenhouse gases in the atmosphere and ways to stop or at least reduce the production of these gases and the various international Protocols (Rio, Montreal and Kyoto) regulating the emission of chloroflurocarbons, CO_2, and other greenhouse gases. Students might research and design their own plan to reduce the creation of greenhouse gases. (See also Wrap-Up Activities.)

Suggested URLs
http://www.coe.usouthal.edu/oar/html/atmosphere.html
NOAA OAR web page for students on the greenhouse effect and ozone: good background, activities and links.

http://www.learner.org/exhibits/weather/atmosphere.html
The Annenberg/CPB Project: information about the greenhouse effect and ozone depletion.

http://whyfiles.news.wisc.edu/069renew_energy/1.html
"The WhyFiles" considers whether a record number of high temperature days signifies global warming.

http://www.enviroweb.org/edf/ishappening/ishappening_frameset.html
"Global Warming is Happening" simple explanation with pictures