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 was itself inspired by “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. 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 ancient life. Climate change is real: without it we would not be here. Students may have heard about 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.

The Science of the Greenhouse Effect
Air, clouds, soils, plants, rocks and lake and ocean waters all reflect, absorb, and re-emit the radiant energy that arrives from the Sun. 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\textsubscript{2}O) and carbon dioxide (CO\textsubscript{2}), are very effective at both absorbing this energy and re-emitting some of it down toward the Earth's surface, 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 (0 degrees F).

Objectives
• Students will model and observe a simplified “Greenhouse Effect.”

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

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 in the bottle cap 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 need to 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 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
Each team will need two bottles:
1. Remove the bottle labels by soaking in warm water.
2. Cut several elongated slits (1 x 4 inches, 3 x 10 cm) in the sides of one of the bottles. (“vented” bottle.) Do not cut slits in the second bottle. (“Intact” bottle.)

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

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) Ask students what factors influence our daily temperatures. (Amount of sunlight, cloud coverage, closeness to a body of water.)

Explore/Explain
Distribute Student Worksheet 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.

Students should record their hypotheses, raw data and analyses in their journals, together with any additional observations they make during the Activity. Discuss results as a class. Why were there variations in results? Also guide students to see how this Activity models some, but not all, aspects of Earth’s actual GHE.

A Note on Soda Bottles and the Greenhouse Effect
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 useful in helping students understand the principles underlying the actual greenhouse effect.

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

NOAA OAR web page for students on the greenhouse effect and ozone: good background information, activities and links to additional resources.

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

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