educational courseware

A Tool to Learn about Equilibrium and

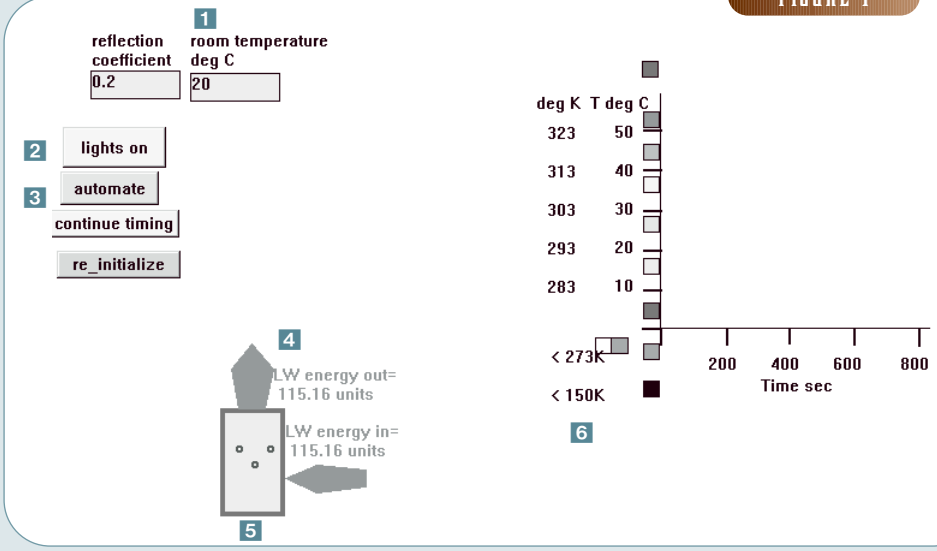
SAMUEL BORENSTEIN

Among the most important science concepts needed to understand our climate and appreciate public discourse about century-long global warming trends is the notion of how Earth balances energy received from the sun to produce a habitable temperature. A question of particular interest is: *How sensitive is the balance between total incoming energy and total energy leaving to factors that govern the Earth's equilibrium temperature?* For students, the relevance of this scientific question to their lives is revealed when they consider how the presence of humans on our planet or forces of nature influence three of the factors, or variables, that determine this equilibrium: distance between Earth and the Sun, reflectivity of Earth's surface and its atmosphere (planet's albedo), and absorption characteristics of atmospheric gases, particularly greenhouse gases.

In general, equilibrium is an important, albeit abstract concept for students to grasp. In science courses, lab experiments are often designed for students to collect observations and study the influence of forced disturbances on a system. A main objective of their inquiry is to understand whether a system remains in equilibrium or do conditions change to such a degree as to produce another state of equilibrium *(AAAS, 1993)*. For example, to study equilibrium temperature as a function of distance from an energy source as well as the albedo and Greenhouse Effect, one can use a "box model" that consists of a shoebox-sized container, colored gravel, water, plants and other materials. For an explanation of box model experiments, please see the article on the Earth Climate Course on page 16 in this issue of *Research Education*.

We have designed computer modeling courseware to make concepts such as equilibrium less abstract by enabling students to visualize them and conduct repeated experiments under varying conditions. In the upcoming school year, we plan to evaluate whether the courseware used in conjunction with labs where students collect their own observations, and class lectures gives them a more in-depth understanding of equilibrium and planetary energy balance.

FIGURE 1



Features of the Courseware

1. The user can enter room temperature and albedo.
2. Time starts when the "lights on" button is clicked.
3. The "automate" button sets the three dots, representing molecules, in the box into motion.
4. The box is surrounded by a selectable albedo. Before the light is switched on, the box is at room temperature. Its equilibrium state is indicated by equal amounts of incoming and outgoing long wave radiation.
5. Molecular speed is governed by the box's temperature, which acts as a measure of average molecular energy. The user can vary temperature and see how the molecules' speed changes.
6. The graph framework for plotting temperature as a function of time.

SAMUEL BORENSTEIN is Professor of Physics at York College, and faculty fellow at the GISS Institute on Climate and Planets.

Planetary Energy Balance

Computer-based Experiment: Planetary Energy Balance Modeling Courseware

A computer-based version of the box experiment is available on ICP website at http://icp.giss.nasa.gov/education/courseware/radabal4.tbk. It can be introduced via guided discussion of models and their use in studying systems. Just as students design box model experiments, they do so for computer model simulations. In class discussion, students should identify how variables in the computer model are represented in comparison to their box model Earth and the capabilities of both methodologies to study planetary energy balance.

Suggestions for Classroom Implementation

This computer-based tool can simulate a box model experiment, allowing a student to vary room temperature, albedo and distance between the light source and a box. Potential uses of this module in the classroom are suggested below:

1. An instructor can use the computer animations to illustrate energy concepts in conjunction with a lecture.
2. A student can experiment with the module by setting different parameters, and ask and answer self-initiated questions (inquiry-based), and produce a lab research report.
3. A student can conduct a series of controlled experiments, defining independent and dependent variables. For example, to study the dependency of equilibrium temperature on distance from the light source, keep all variables constant but set the distance to several determined values.

System Requirements for Using this Courseware

1. A Windows 95/98/NT PC
2. A graphical web browser
3. Plug-in *Neuron*: download from http://www.asymetrix.com/products/toolbook2/neuron
4. The module at http://icp.giss.nasa.gov/education/courseware/radabal4.tbk

CONTRIBUTOR:
GEORGE TSELIOUDIS, Columbia University.

REFERENCES
American Association for the Advancement of Science. 1993. Project 2061: *Benchmarks for Science Literacy.* Oxford University Press, New York.

Features of the Courseware

1. With the "lights on," the larger arrow represents incoming short wave radiation and the smaller arrow represents its reflected amount.
2. Initially the total energy (long + short wave) coming in is greater than the energy leaving, and the box loses equilibrium, as it heats up. This is illustrated by a color coded curved line graph.
3. As time passes, the box emits more long wave radiation until it reaches a new equilibrium temperature when incoming energy equals outgoing energy.
4. The student can drag the box away from the light source to study the effect of distance on equilibrium temperature.

FIGURE 2