Global Warming – Should We Worry?

A Problem-based, Simulation, and Teamwork Approach
To Teaching Integrated Math & Science

by

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Introduction

Three major issues in science education are the use of educational technology, problem-based learning, and the teaching of science in an integrated format. While the use of technology in the classroom has been growing rapidly and recognition of the effectiveness of active, problem-based formats is spreading, implementation at most campuses is still piecemeal. The third issue of employing an integrated format is gaining momentum and has received national attention from professional organizations and funding agencies for the past several years. Change, however, is difficult due to the entrenched structure of single discipline-based instruction.

California State University, Chico, is considered as a leader in the 23 campus California State University system in the implementation of educational technology. What we are in the process of doing now, with the assistance of a National Science Foundation grant through the Institutional Reform of Undergraduate Education program, is enhancing the entire basic core science curriculum with educational technology using a problem-solving, computer simulation, and integrated science approach. It is our aim that early in their education students will have the opportunity to see that the sciences have many commonalties - such as, the scientific method, a need for quantifiable and verifiable data, and the use of statistics and probability. Most importantly, all the sciences require a healthy skepticism tied to the process of critical thinking. Our goal is to have student teams investigate and model complex problems involving current scientific controversies of national importance chosen specifically to require knowledge and skills drawn from many different scientific fields.

Presently, a student, whether a science major or not, receives an introduction to college-level science by taking a basic science course in one discipline, be it chemistry, biology, physics, or geoscience. It is perhaps only after several courses and years that students begin to be able to integrate knowledge across the sciences and see a more authentic process of doing science. If they only take a couple of courses, they may never see the big picture. An integrated approach to science is needed and the best way to accomplish that is for faculty from different disciplines to work in teams. It is our hope that by paving the way with a substantial development of resources and through faculty training, we can invite more faculty to jump on board, promote a cross-discipline, team teaching approach and, thereby, revitalize the core science curriculum with the latest in educational technology and pedagogy.

A Problem-based, Integrated Science Curriculum

For the past year, a team of six faculty from the College of Natural Sciences have been working on the NSF-funded development of integrated science materials employing a problem-based approach and infusing computer modeling and simulation with traditional laboratory experimentation. One of our long-term goals is to develop a library of curricular "Modules" centered on interdisciplinary scientific issues, which could be packaged into semester and yearlong integrated general education science and critical thinking courses. The NSF grant, also, has helped to fund the remodeling of a classroom into a modern and effectively designed combination class/computer laboratory. In addition, we were able to purchase and construct science equipment, which will effectively promote our underlying teamwork and hands-on approach. This semester, we are conducting faculty workshops to highlight our accomplishments and train faculty in the use of our materials and the use of equipment in the newly remodeled room.

Currently, we have completed course materials for a one-semester course based on the theme: *Global Warming – Should We Worry?* Global warming is an ideal "big" issue with plenty of national attention, relevant to the lives of our students, contains heavy doses of math and science drawn from numerous disciplines, and is steeped in debate over political and social side issues. Other topics under consideration and in various stages of development are origins & evolution, watersheds, wetlands, and pollution.

In the section below, we briefly discuss some of the pedagogy and student activities comprising our course on global warming.

Global Warming – Should We Worry?

In an attempt to incorporate the latest educational pedagogy and provide for effective student and program assessment, we have researched the literature on program development and course design. A brief overview of our course, including course objectives, course outline by topics, student assessment, and course evaluation, based on the work of Wiggins and McTighe in "Understanding by Design", is given below.

First, we identified our course objectives. Then, we addressed how we would know if students have met these objectives, which formed the basis for developing a series of rubrics as assessment tools. With these two important foundations in place, we began the process of developing the student activities.

Course Objectives

In switching from a content driven to a problem-based course, considerable thought went into identifying our goals and expectations. The following three objectives illustrate our emphasis on the process of doing science more than developing a storehouse of scientific facts.

1) Students can critically discuss contemporary scientific issues.

2) Students demonstrate proper use of scientific method.

3) Students can make informed decisions involving science and society.

Course Outline

I. Global Warming – What's The Big Deal?
An introduction to global warming with web-based research using a web site we created containing numerous links to interesting pro/con debates and various climate change organizations.

II. Modeling
An introduction to computer modeling and simulation using the software program Stella. Students will learn how to create their own models using conceptually simpler problems, such as, population growth and draining sinks.

III. Modeling Global Warming – The Experimental Connection
This is a series of components where students will begin creating a model for the global mean temperature of the surface of the earth. Their model will evolve as understanding of various science issues grows. There are numerous ties to traditional laboratory experimentation in the sub-components: Energy & Temperature, Energy Flow- Absorption and Reflection, Respiration and Photosynthesis, CO_2 Solubility, and Using Satellite Data.

IV. Science & Society
The course will culminate with a mock-Kyoto accord meeting where student teams will represent various nations or regions of the world in coming to a consensus on identifying the dangerous issues of global warming and what to do about them. Students will then be responsible for writing a news article debriefing VIP's of the accord and defending their stance.

Student Assessment

We have created a series of rubrics to address how we would know if students have met our course objectives. The general format involves a matrix with descriptions related to categories, such as, Explanation, Interpretation, Application, etc. as they pertain to the various components and key activities. The components call for a mix of individual and team papers, team oral reports, designing experiments, team reports on creating, testing, and evaluating models, some traditional quizzes, and a portfolio.

Course Evaluation

This is an area still under development but the following are some ideas we have that directly relate to our course objectives.

> Critical discussion on scientific issues: We will make an initial versus final paper comparison. At the beginning of the course, a writing assignment/questionnaire, designed to assess the student's initial understanding of basic issues involved in global warming, will be given. This will be compared with a final summary report going into each student's portfolio to assess growth in their ability to discuss the issues involved in global warming.

Proper use of the scientific method: We will use a pre-post test comparison along with a beginning versus final design of experiment comparison.

Making informed decisions on science and society: We will use a video tape of the Kyoto-type meeting and group paper to assess the decision making processes students incorporated in reaching their consensus.

We are currently consulting with in-house faculty whose area of expertise involves student and program assessment to add to and refine the components outlined above. We are currently in the process of learning more about the effective use of portfolios and designing an attitudes survey as another tool for course evaluation.

There are two major directions for our future work. One is to complete modules centered on other topics to help make our program more flexible and portable. Another direction is to develop a one-semester general education mathematics course aimed at non-math and non-science majors that would dovetail with our integrated science course. The primary objective of the mathematics course would be to extract and more fully cultivate the substantial mathematical threads connecting all of the components of the science course, while the science course provides the context – the "big" interdisciplinary picture. This context is what would drive the course and motivate the need for the various mathematical components, such as, making measurements, estimating error, converting units, the use of experimental data and associated understanding of some probability and statistics, and the understanding of mathematical relations involved in input-output responses from computer simulations.

Given below are some URL's for our global warming web site, providing a link to download some of our finished Stella models, and where to download a demo version of the Stella program to run theses models.

1) **Our CSU, Chico website on Global Warming**

   http://www.csuchico.edu/~jbell/GlobalWarming/

2) **Information on Stella and free run-time versions**

   Stella Home page

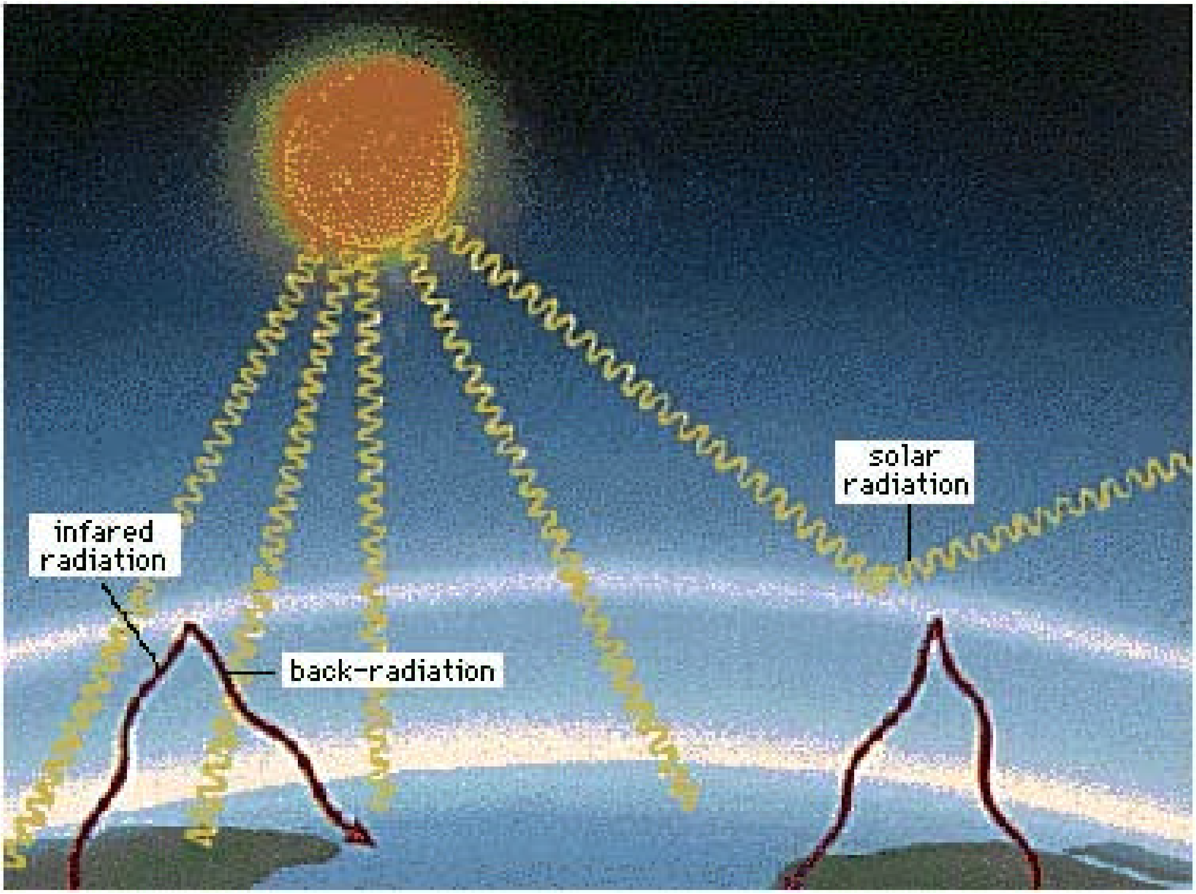
   http://www.hps-inc.com

   Free run-time versions

   http://www.hps-inc.com/products/stella/free_runtime/runtime.html

The paper will conclude with a series of "snapshots" illustrating some of the computer modeling activities and ties to hands-on experimentation. The experiments developed for the course involve measuring the solar constant, planetary albedo, specific heat and the conversion from energy to temperature, blackbody radiation and the Stefan-Boltzmann law, atmospheric absorption and greenhouse gases, and photosynthesis and respiration.

The Experimental Connection



Questions – Solar to Earth

- What's the "solar constant" – the intensity of solar radiation incident to the earth?

- What fraction of the solar radiation is reflected by the surface?

- How do the properties of the Earth's surface materials influence the surface temperature?

Questions – Surface to Space

- How much energy absorbed by the surface of the Earth is re-emitted to space?

- What is the role of the atmosphere in the surface to space flow of energy? (Greenhouse gases)

Measuring the Earth's Albedo

An in house constructed "Light Box"

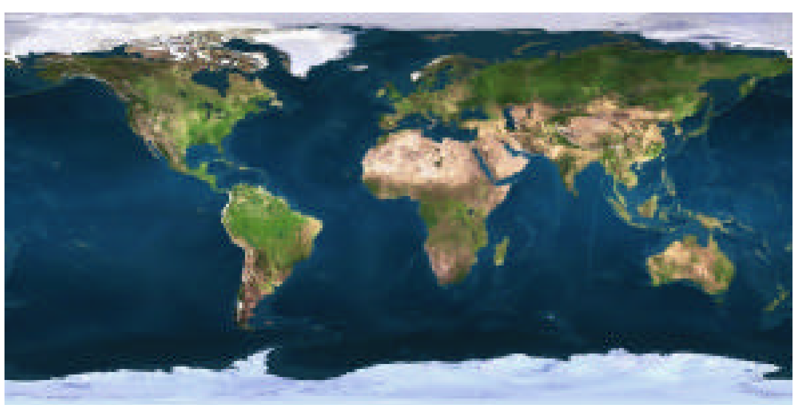
Initial Instructor-led Calibration Experiment

- Measure the light intensity reflected off a "black" tray
- Measure the light intensity off a mirror

  - This calibrates the maximum and minimum intensities allowing us to assign a reflectivity % to other materials

Student-designed Experiment

- Choose and collect materials to put in the tray and measure light intensities
- Estimate % of surface area coverage and use to compute a weighted average of intensities to get a planetary albedo

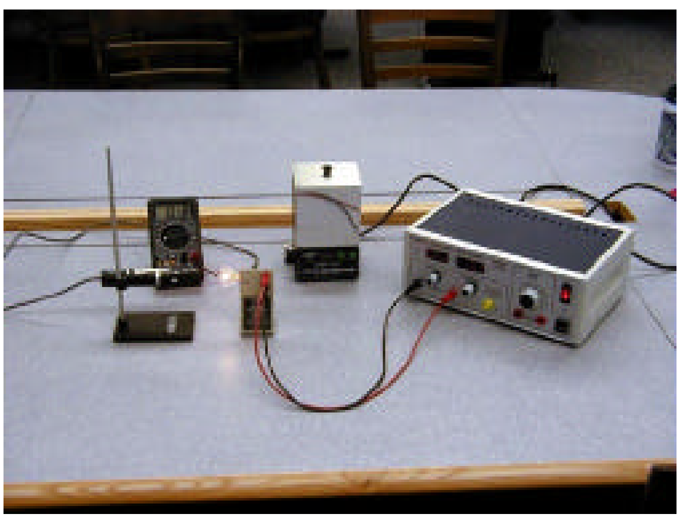


Density and Heat Capacity

This involves a common laboratory experiment in traditional science courses but now it is supplied with a context – results are needed in the student's computer model and then for follow-up simulation evaluations.

ΔQ = *mass* x *specific heat* x ΔT

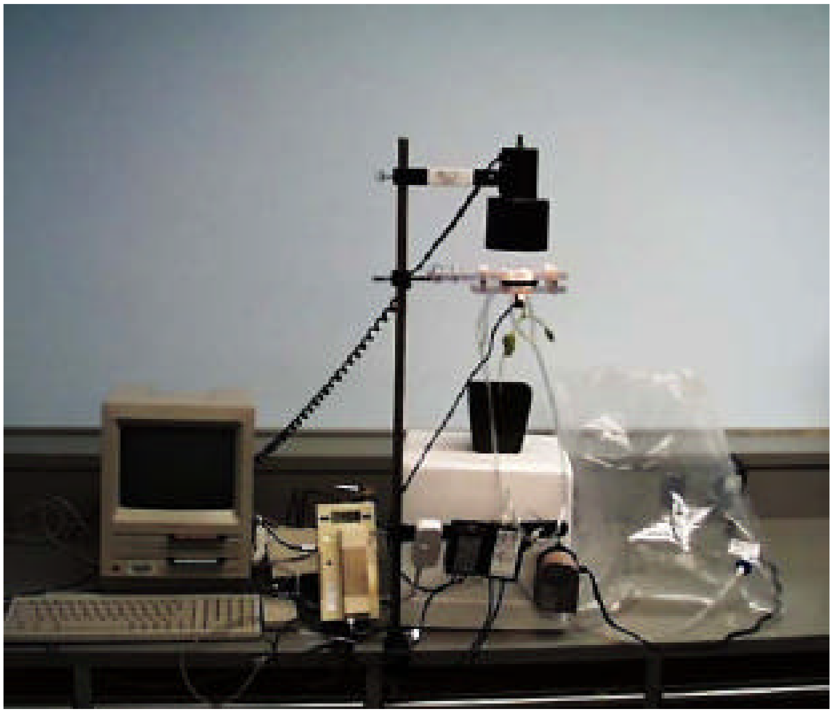
Blackbody Radiation



(Radiancy) $R = \sigma T^4$

Radiation sensor and equipment used to measure the solar constant also can be used to discover the Stefan-Boltzmann law.

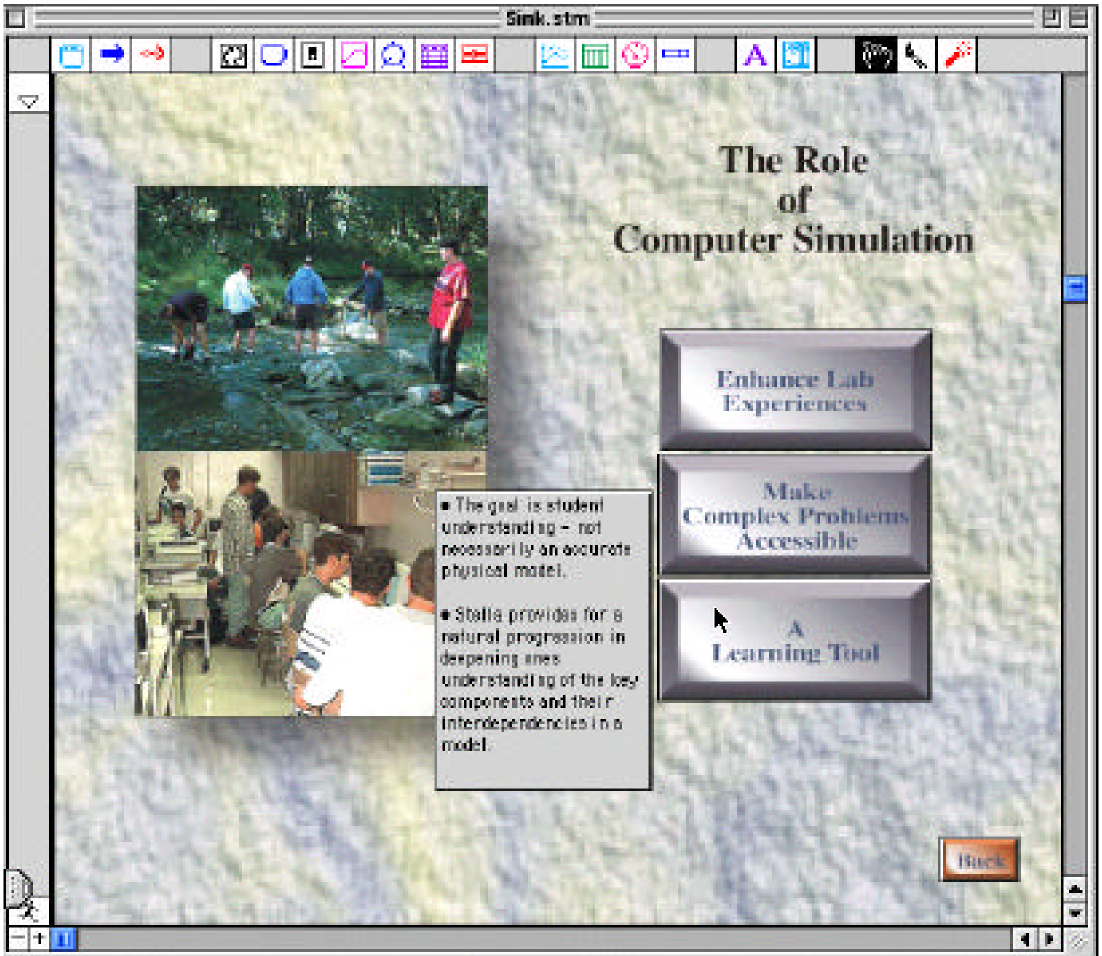
Photosynthesis and CO_2



How do greenhouse gases affect the radiation absorbed, transmitted and re-emitted by the atmosphere?

This provides a rich source of experimentation. Near the end of the course, students will be more proficient with the scientific method and proper design of experiments to handle the sophisticated equipment and processes for this component of the course.

An Introduction to Computer Modeling With *Stella*



• Supplements, not replaces, traditional hands-on experimentation and data collection activities, which can be tied to key parameters in the models

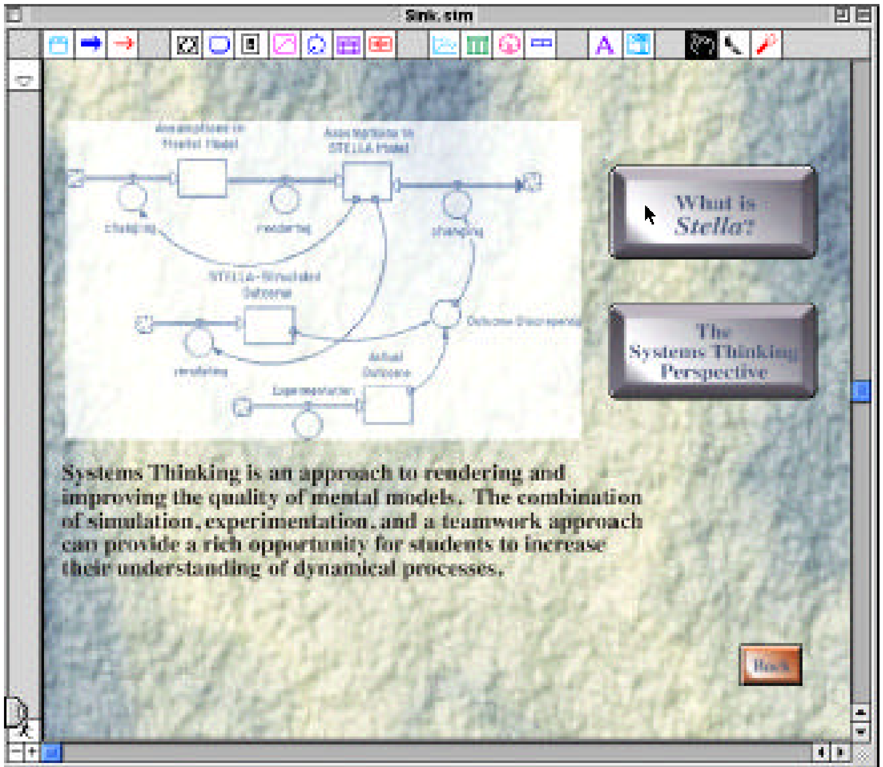
• Helps students discover that real problems are open to interpretation and may support many different solutions

• Helps make a problem-based approach involving complex dynamical systems accessible

• The goal is student understanding, not necessarily accurate physical models

• The process of "mapping" out a model provides an effective learning environment for students to gain understanding of physical systems

Stella and The Systems Thinking Perspective



What is Stella?

Stella was specifically designed to support the building of understanding, developing the capacity to build understanding, and developing the capacity to share understanding.

Stella provides a simple interface for "mapping" out conceptual models and a variety of perspectives for looking more deeply into these models.

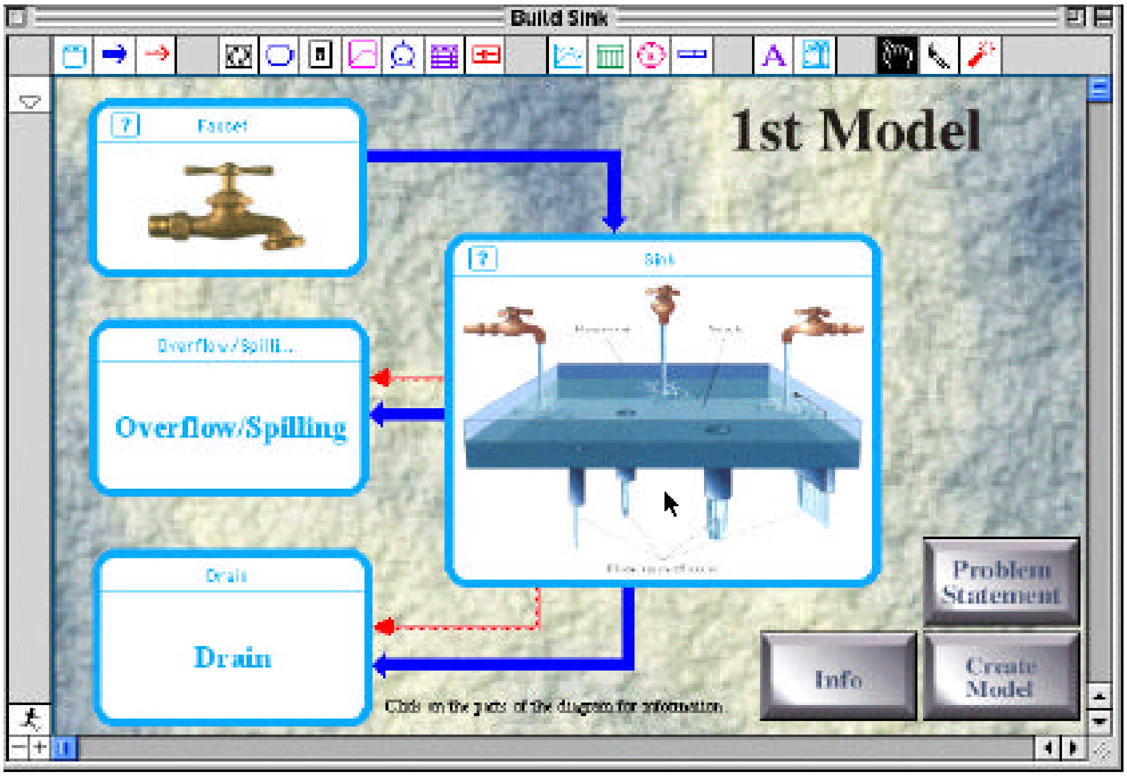
The Systems Thinking Perspective

Systems Thinking is a "process - oriented" approach to the modeling of dynamical systems as opposed to an analytic approach.

The key to this perspective is to identify the key players and then ask what's happening to them.

The 1st Modeling Activity

A Faucet-Sink-Drain System



Info

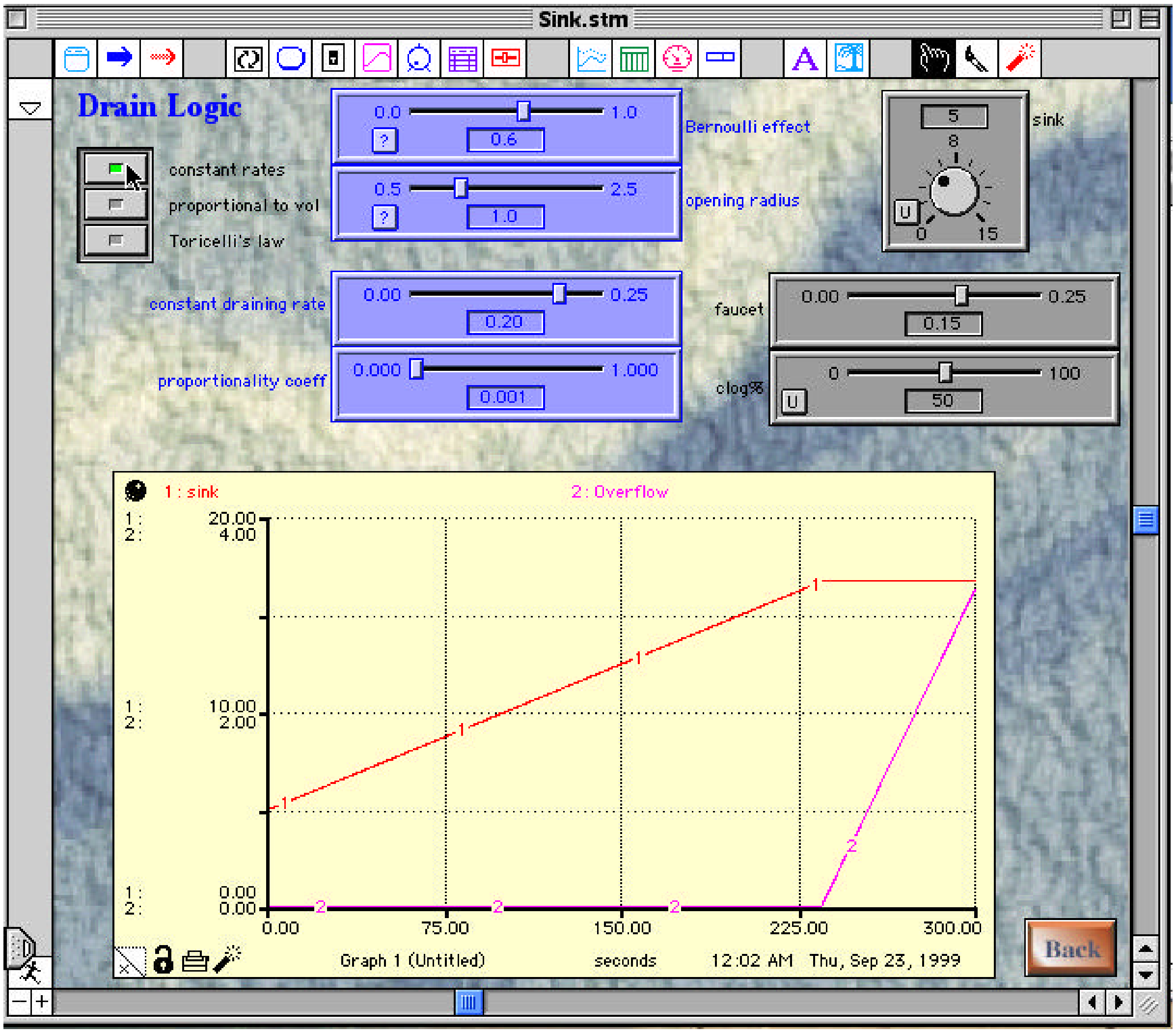
In this first activity, the main goal is to introduce you to the basic building blocks in STELLA: Stocks, Flows, Connectors, and Converters. Also, we want to illustrate two “looks” of a model supported by Stella - the "High-level Map" and a "Control Panel".

The diagram on this page is called a "High-level Map", which depicts the key components and their interconnections. Click on the various parts of the diagram for a brief explanation.

Problem

Even in this first introduction to modeling in Stella, the activity is problem-based. The Problem Statement button takes you to a discussion between two plumbers disputing why a clogged drain is behaving as it does.

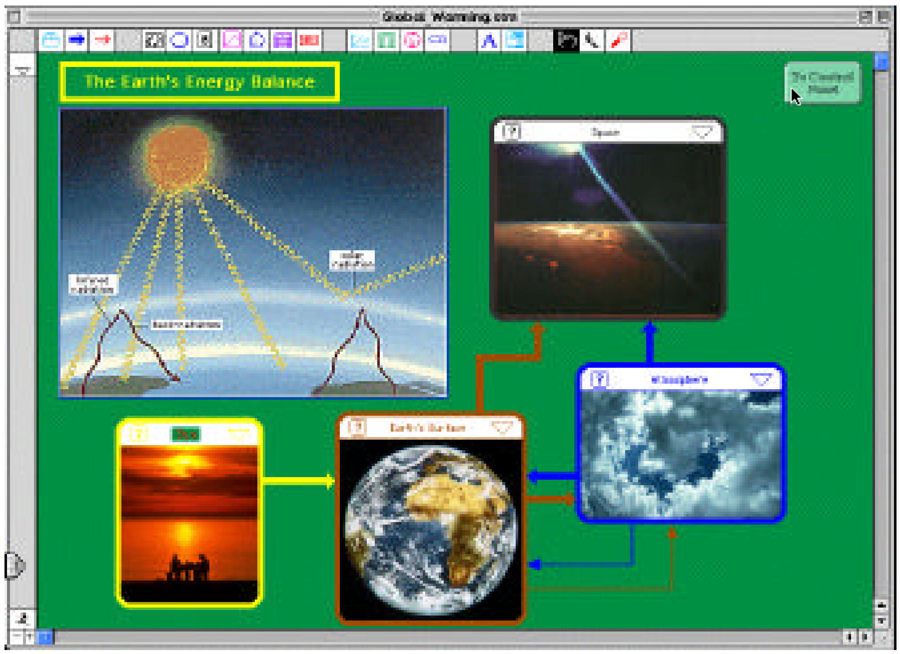
A Completed Draining Sink "Control Panel"

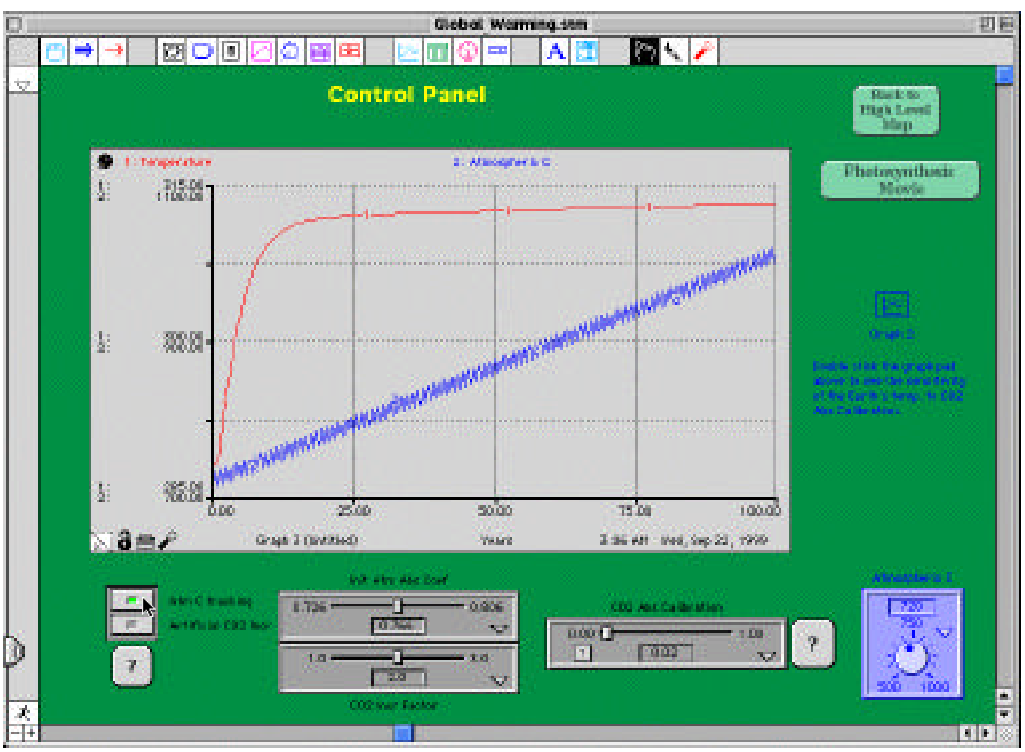


A control panel provides easy point & click access to input and output devices, making it efficient to run simulations and conduct "What if …" investigations.

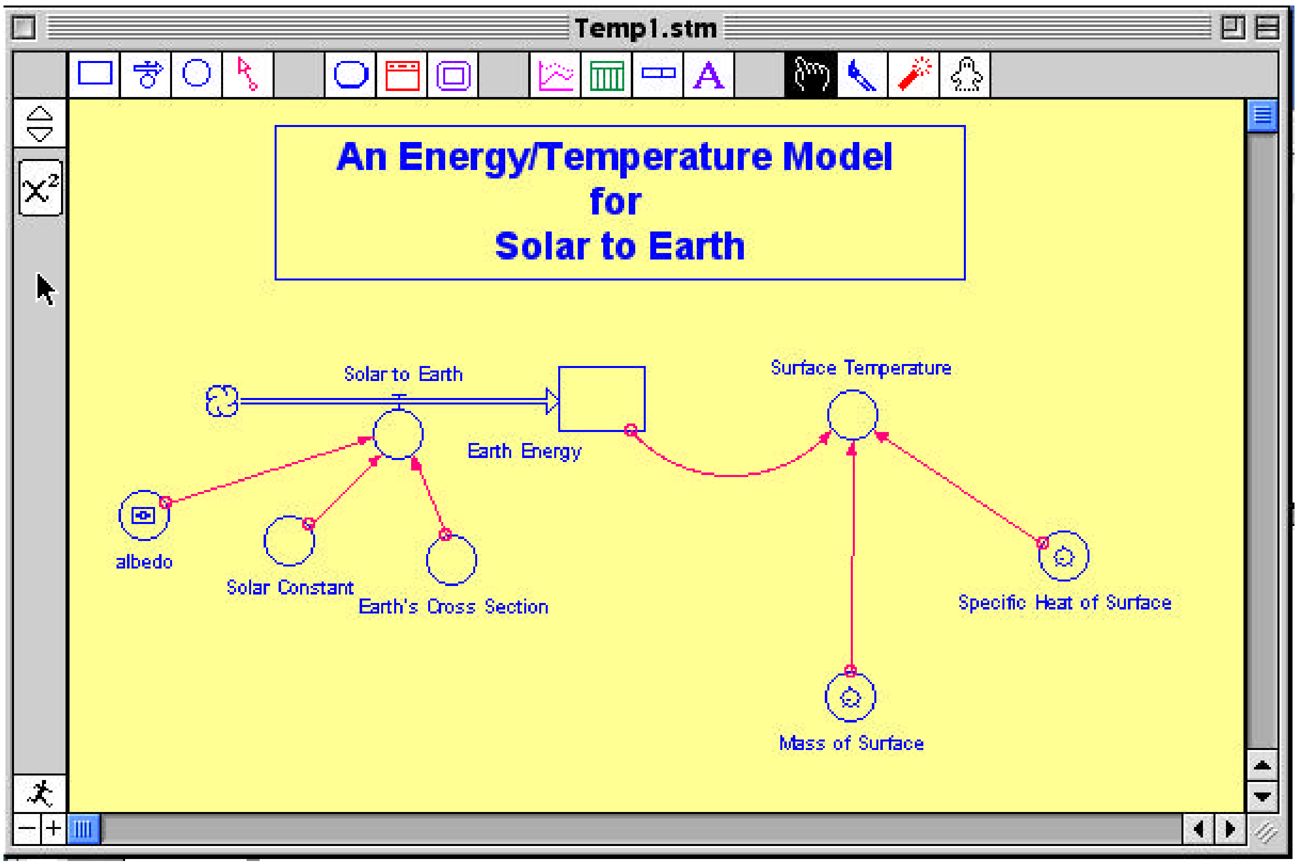
This look at a model allows the instructor to tailor the level of detail concerning a dynamical system to the audience, making explorations accessible to a diverse range of students.

Modeling the Surface of the Earth's Global Mean Temperature



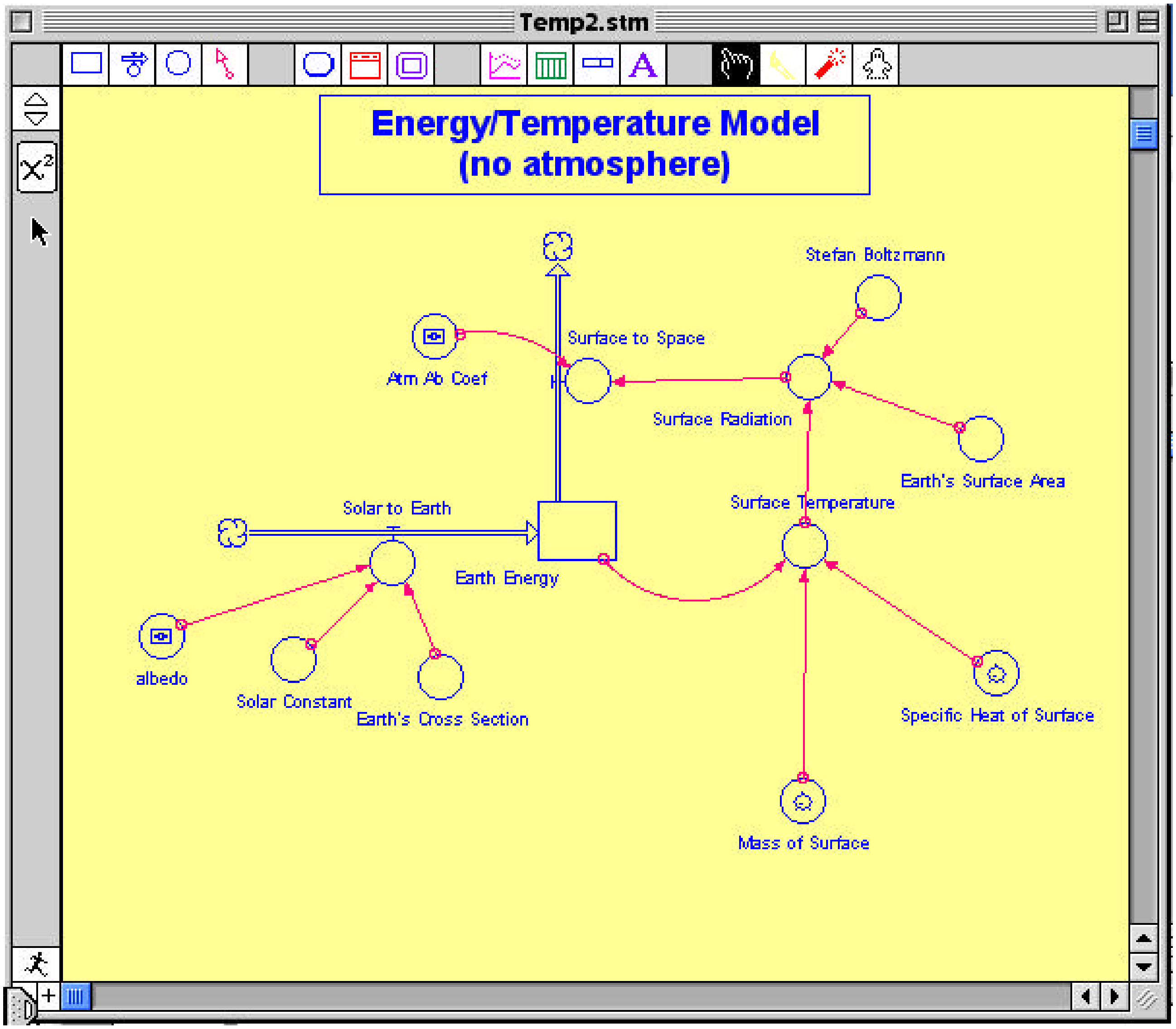


A Progression of Student Beginning Temperature Models



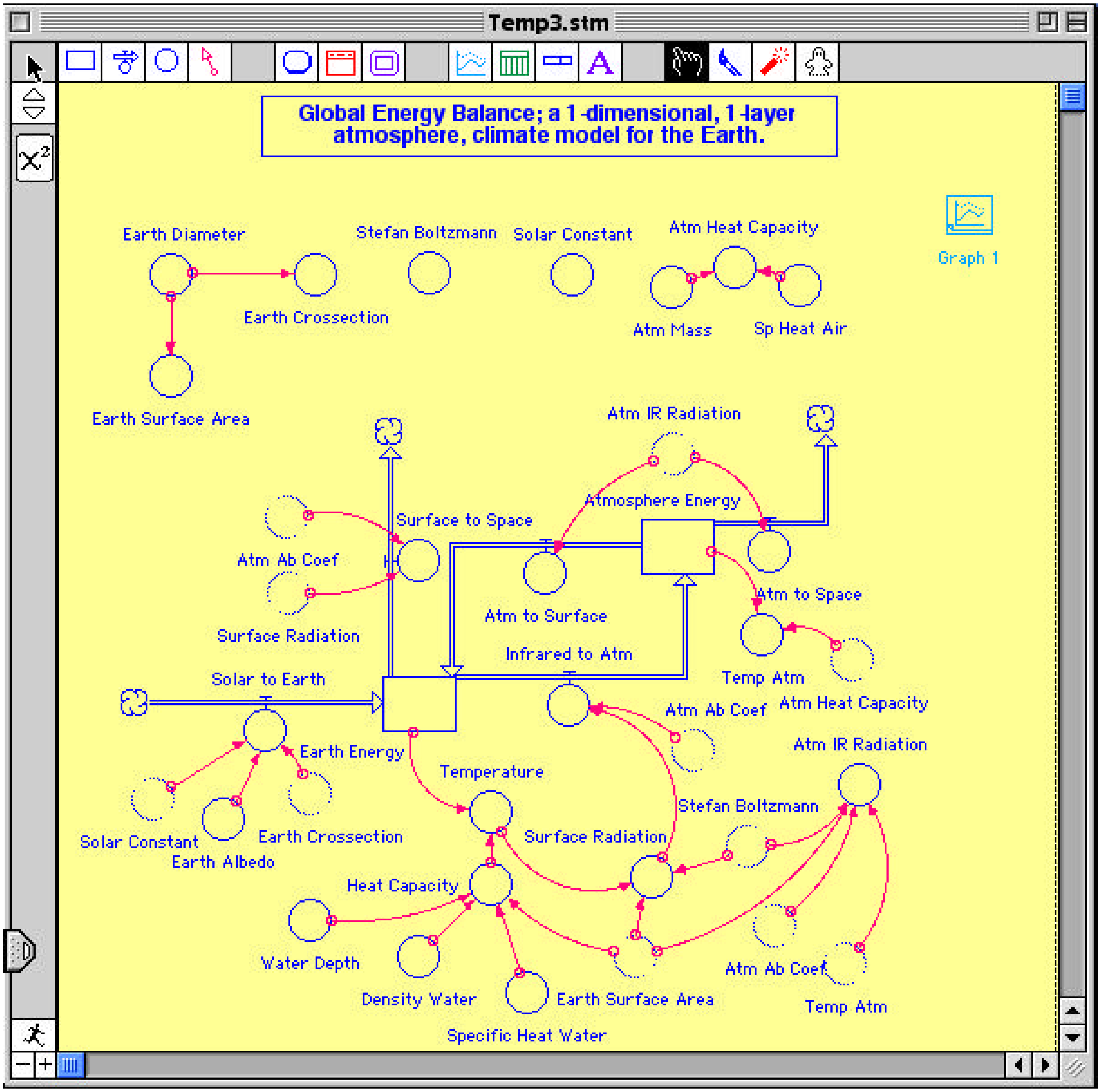
Every “flow”, in the model above it is Solar to Earth, requires students to deepen their scientific understanding so they can define the relationship for the flow – this is the natural connection to traditional experimentation.

The model above requires students to investigate the “solar constant”, planetary albedo, and the connection between specific heat of surface materials and temperature.



This model illustrates how students could use their Blackbody radiation experiments, in discovering or verifying the Stephan-Bolztmann law, to incorporate radiation emitted to space.

The effects of an atmosphere are essentially overlooked except to only allow a fixed percentage of radiation to escape to space. The next step is to consider the role of greenhouse gases in absorbing and re-emitting radiation.



Students would not necessarily be expected to arrive at a model this complex but it could be used for a completed global warming model to create a control panel interface for simulation activities.