Student conference on global warming: a collaborative network-supported ecologically hierarchic geosciences curriculum

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STUDENT CONFERENCE ON GLOBAL WARMING: A COLLABORATIVE NETWORK-SUPPORTED ECOLOGICALLY HIERARCHIC GEOSCIENCES CURRICULUM

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1. INTRODUCTION

A five week global warming curriculum for pre-college students has been designed as part of the Learning through Collaborative Visualization Project (Pea, 1993). A collaborative version of the curriculum will be enacted in January, 1996, within twenty classrooms located primarily in Illinois, Michigan, and New Jersey. The primary goals for this curriculum are:

A. Forge links between students and the scientific community around a topic of common interest.

B. Engage students in scientific investigation using current data sets, analysis tools, and computer-communication tools.

C. Lead students to consider the earth as an interdependent ecological system that can be analyzed in terms of cycles (especially radiative, hydrological, and carbon) and their interactions at multiple ecological hierarchic levels (e.g., different spatiotemporal resolutions; see below).

2. WHY GLOBAL WARMING?

The controversy around global warming has been growing over the past few decades. Currently, there is an enormous amount of scientific and policy work occurring in this area. This explosion of adult interest leads to the following advantages to studying global warming:

A. There are numerous scientific, economic, and political consequences attached to global warming. Thus, there is a large community of practitioners that can serve as mentors for students. Further, global change data sets are widely available on the Internet.

B. Global warming provides an example of a cross disciplinary investigation that studies the earth as an integrated system. This is consistent with an increasing focus within the sciences to choose systems or environments as the unit of investigation and with developments within geosciences, in particular, to study the earth as an integrated whole. Studying the earth as a whole provides students with an explanatory framework in which they can organize their disparate observations and understandings.

Moreover, students have been found to be interested in global warming because it is a controversial environmental issue:

A. Hearing both sides of the controversy often challenges students existing beliefs motivating them to analyze the evidence so as to decide their own position.

B. Students have a natural self-interest in environmental decisions because they will bear the brunt of environmental decisions made by their elders.

3. STRUCTURE OF GLOBAL WARMING CURRICULUM

The five week curriculum is divided into three stages: staging activities (two weeks), student project (two weeks), and synthesis through presentations and critique (one week). The purposes of these stages are as follows:

A. Staging activities are designed to introduce students to a new area of inquiry.
The first imperative is to build student interest in the topic. After motivating student interest, a series of structured activities are presented that are organized around "natural" beginning questions. The activities are designed to answer student questions through analyzing influential data sets, examining "what-if scenarios" through spreadsheet modeling, and performing laboratory experiments. These activities provides familiarity with basic principles (e.g., an energy balance must be maintained) and techniques (e.g., graphing data) while also modeling scientific inquiry.

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B. Projects encourage students to take on more of the executive functions of scientific inquiry, such as, choosing a topic, finding or creating data sets, and drawing conclusions and detailing limitations on the extent of those conclusions.

Student projects are the heart of the enterprise. In projects students are encouraged to bring together the concerns of the scientific community with their own interests, leading to student involvement in scientific inquiry. Projects are conducted in groups of two to four in order to promote students learning from one another, learning to share tasks, and to accomplish more ambitious tasks than a single student could reasonably complete.

C. Synthesis is accomplished through students presenting their work to one another and then coming to a classwide consensus on a related issue.

Student presentations provide a culmination to project work as well as the impetus to crystallize their findings into a form that permits succinct communication to their peers. Through presentations students find out what their peers have accomplished and learn from them. The need to come to a classwide consensus provides a context where students must develop a common language in which they can negotiate their opinions, beliefs, and knowledge.

The activities designed to achieve these purposes are now described.

4. STAGING ACTIVITIES

The purposes of the staging activities are to motivate student interest, illustrate scientific principles and techniques through "natural" questions, and model student inquiry.

Motivation Controversy can be an excellent motivation for students. The controversy surrounding global warming is presented through videotapes where experts make conflicting predictions on the likelihood of global warming and its probable impact on human life. In particular, disagreements between Stephen H. Schneider and Richard S. Lindzen are often shown to summarize the conflicting viewpoints and to show the disagreement is occurring between leading scientists in the field.

Questions In order to lead students into the topic common questions are used as the basis for the initial activities. The following questions and activities comprise the bulk of the staging activities.

A. *Is global warming just natural variation?*

1. An example of natural variation is provided by studying seasonal change. The seasons are investigated by examining monthly mean visualizations of insolation (i.e., sunlight) and surface temperature for different seasons of the year using the Greenhouse Effect Visualizer[1] (Gordin et. al., 1995).

2. An example of "unnatural" variation is provided by graphing increasing levels of atmospheric carbon-dioxide as measured at Mauna Loa (Keeling and Whorf, 1994) over the past thirty-five years. In this context, "unnatural" means an anthropogenic forcing (i.e., a human impact on the environment).

3. Finally, the unknown case in point is examined: Is the rise in average global temperature over the past century the result of natural or "unnatural" variation (Jones et. al., 1994).

B. *Why is a 3°C change in average global temperature important?*

1. To provide a context for students to evaluate this change the average global temperature for the past 165,000 years are provided on 100 year intervals (Jouzel et.al., 1994). Using this record students can see the how little variability has occurred and that a 5°C drop signifies the onset of an ice age.

2. Using a *Blackbody model* to convert between temperature and energy the amount of additional energy that a 1°C change would cause to flow through the earth-atmosphere system can be calculated (using a base temperature of 288°K the answer is over 2000 Terra Watts). A spreadsheet calculator is provided for students to calculate energy increases of this sort. Students are then asked to speculate on what effects this additional energy flow might have by consulting a chart on the energy consumption of various phenomena (e.g., annual human energy production amounts to 10 TW, annual life processes consume 92 TW, and evaporation uses 44,000 TW; Taube, 1985).

C. *How is the global temperature maintained?*

1. A "greenhouse effect in a bottle" activity was adopted from the GEMs global

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[1]The Greenhouse Effect Visualizer can be accessed over the World Wide Web (see http://www.covis.nwu.edu/gev.html).

warming curriculum (Hocking et. al., 1990). This activity has students expose two plastic bottles partially filled with dirt to a light bulb. One of the bottles is covered with plastic wrap, while the other is open at the top. Thermometers are placed in both and readings made once a minute for ten minutes. This experiment demonstrates a temperature rise in both bottles which then stabilize as their dynamic equilibriums are reached. This experiment provides an example of how systems reach a temperature equilibrium and how the equilibrium point can be raised by inhibiting the release of energy from the system.

2. The impact of the biosphere on climate is illustrated by a microworld simulation of Daisyworld (Simon and Poole, 1992), the model developed by Lovelock to illustrate the Gaia hypothesis (Lovelock, 1988).

D. *What scientific and policy work is going on in the area of global warming?*

Using the World Wide Web (WWW) and other information resources students search for scientific and political investigations on global warming. The WWW is rich in such resources, for example, the International Institute for Applied Systems Analysis has made available visualizations of model predictions of world temperature if a doubling occurred in carbon-dioxide levels (see http://www.iiasa.ac.at/) and the United Nations Environment Programme has published the resolutions of the Earth Summits where international regulations on the emissions of greenhouse gas were negotiated (http://www.unep.ch/).

Modeling A model of what student investigations should look like is provided by the above structured activities as well as providing examples of prior student reports. Excellent examples of student reports can be found from the ESSC project (http://www.circles.org/ESSC/).

5. STUDENT PROJECTS

Projects provide an opportunity for students to intermix their individual concerns with the issues of global warming. The projects are conducted by groups of students and fall into one of two categories: a *country* project or a *global issue* project. In order to facilitate these projects relevant data sets will be organized and provided to the students (e.g., greenhouse gas emissions by country, model based predictions of temperature, and Paleolithic data sets based on proxies such as oxygen isotopes and tree rings).

Country projects Countries are a useful unit of analysis because greenhouse gas emissions vary based on a countries energy usage and choice of energy production. Further, policy measures are implemented in terms of countries. Focusing on a country can also provide students a way to approach the project, since students often have interests in specific countries (e.g., due to place of birth, location of family members, or vacation site). Students choice of which country they want to represent (i.e., investigate) is facilitated by providing a list of several dozen countries organized into the following categories: major carbon-dioxide emitters, countries in danger of flooding, countries that experience monsoons, developing countries, and mega-biodiverse countries. Projects that a *country* group might choose are:

A. Analyze a countries past greenhouse gas emissions and predict future levels. Discuss these levels in context of international policy initiatives and global emission levels.

B. Discuss the impact on a countries agriculture, severe weather, or threat from flooding using an established global warming scenario (e.g., doubling of carbon-dioxide levels within 100 years).

Global Issue projects A global or earth systems perspective is the primary way global warming has been analyzed. In particular, an ecological analysis focusing on cycles and dynamic equilibrium are prevalent modes of analysis within global change studies, in general, and global warming, in particular. The primary cycles of interest with respect to global warming are energy, hydrological, and carbon cycles. It is also important for students to choose the appropriate time dimension along which they will study. Some students will look at Paleolithic data sets, while others will look at model-based predictions. Projects that a *global issues* group might choose are:

A. Examine the correlation between average global temperature and carbon-dioxide levels as measured from ice cores. Assuming carbon-dioxide is a forcing agent on temperature what temperatures would be predicted by these data if carbon-dioxide levels doubled. A similar analysis could be performed using insolation levels and temperature data. These two investigations encapsulate the ongoing argument whether temperature variations are determined by internal or external forcing functions (i.e., by varying composition of atmospheric gases or varying levels of solar input).

B. Using existing "fast plants curricula" from University of Wisconsin (see http://fastplants.cals.wisc.edu/) students could compute increases in plant growth rate due to increased carbon levels. This data can then be used to provide a rough prediction of how rising carbon levels would impact forest growth and the global carbon cycle.

6. SYNTHESIS THROUGH PRESENTATIONS AND CRITIQUE

It is in the culminating week that the curriculum best earns its title of a "Student Conference on Global Warming". First, students give brief presentations of their work to one another. Second, students critique the key piece of global warming international legislation to date, namely, First World and Eastern European countries (i.e., the former USSR and its satellites) should reduce their greenhouse gas emissions to 1990 levels by the year 2000. It is not intended that comprehensive critiques be made nor need a revised policy be suggested. Instead, specific issues and examples should be explored. For example, one class might critique the proposal by detailing what cutbacks would be necessitated locally. Another class could evaluate whether the policy reaches its objectives, even if the agreement is followed to the letter, and if not by how much it falls short. Another class could consider what policies might be applicable for developing countries, and so on. The primary goal is for classwide conversation and debate to occur and for that discussion to draw on the students' earlier investigations including both *country* and *global issue* projects.

7. USE OF COMPUTER NETWORKS AND COLLABORATION AT A DISTANCE

The extensive reliance on analyzing data sets requires students obtain digital forms of the data. The WWW is used to provide students access to the data by providing an on-line version of the curriculum along with spreadsheet files that can be downloaded. The spreadsheet files are provided in the industry standard SYLK format. If a suitable "helper application" is configured for the WWW browser the spreadsheet application is executed and the appropriate file loaded. In this way, the WWW becomes a shell or top-level interface to the curriculum and the analysis tools. Similarly, visualizations to be analyzed are directly available through the WWW. Advantages of providing the curriculum as networked resource include the ease and speed with which it can be updated, the ability to couple the curriculum to heterogeneous computational tools (e.g., for data analysis or model simulation), and as a ubiquitous delivery system.

The curriculum as described till now could be implemented stand-alone in an individual classroom. However, there are opportunities for collaborative involvement between classrooms and involving scientists and policy specialists. This opportunity for collaboration should provide unique opportunities for teachers and students to build on each other's diverse skills and knowledge. These collaborative activities will take place when the curriculum is jointly conducted in some twenty classrooms in early 1996 under the auspices of the Learning through Collaborative Visualization Project. The opportunities for collaboration are as follows:

A. Threads of conversation can be conducted between students and teachers in different classrooms using a multi-user writing facility called the Collaboratory Notebook (Edelson and O'Neill, 1994). This facility should be particularly useful when students are engaged in their projects, since students in other classrooms will likely be working along similar lines. For example, all students researching greenhouse gas emissions in Eastern European countries might share a thread of conversation on why those countries predominately use coal and what possibilities might exist for changing to a different means of energy production.

B. Following student presentations in the final week each class will select the two best projects as voted on by the students and selected by the teacher. Each of these student projects will be sent to scientists and policy specialists who will read them and write a brief critique. These reports and critiques will be published on the WWW.

C. The classwide critiques of international policy will be gathered together and submitted to a policy organization for comment. The critiques and comments will then be made available to teachers and students.

Through providing students with critique on their work from the scientific community a audience is provided that can provide insightful commentary on their work. Further, student work containing an inspirational approach or well thought out piece of analysis stands the chance of being picked up and used within the global warming debate.

8. UNDERSTANDING IN TERMS OF ECOLOGICAL HIERARCHIES

A fundamental means to organize systems and phenomena in the geosciences is along spatiotemporal dimensions (e.g., geological time or a logarithmic spatial scale). Hence, virtually any introductory text on geology, climate, oceanography, or astronomy early on presents a diagram presenting phenomena at different orders of magnitude. A more general form of this type of analysis is called ecological hierarchies (O'Neill et. al., 1986) where the level of analysis spans not only spatiotemporal resolution but also which entities are to be included in the analysis. For example, there are models of global climate which incorporate both the atmosphere and ocean while others rely on only one or the other -- the distinction here is not on spatiotemporal resolution but on which quantities are included in the model[2].

This ecologically hierarchic mode of analysis is crucial to understanding the issue of global warming. Much of the scientific research and debate can be explicated in these terms. For example, critiques of models often focus on inadequate spatial resolution or their failure to include certain phenomena such as the biosphere. Global warming research employs data in a wide variety of ecological hierarchies and much debate in the field centers on what ecological hierarchy is the best one with which to analyze data. This leads to the need for students to be sensitive to differing levels of ecological hierarchy and to be able to strategically employ the appropriate level for their investigation.

Several methods have been employed to familiarize students with this idea of ecological hierarchy in understanding global warming:

A. Data for certain quantities are provided at multiple temporal resolutions (e.g., average global temperature data provided yearly for a 100 years and every 100 years for 165,000 years.
B. Data are provided at multiple spatial resolutions (e.g., the Greenhouse Effect Visualizer provides a means to select at what resolution data is visualized by providing resolutions ranging from 2.5° square to an average global value).
C. Experiments are performed to model global phenomena (e.g., the "greenhouse effect in a bottle" experiment models the effect of the earth's atmosphere).
D. Student projects occur at two different spatial levels, that is, *country* projects and *global issue* projects. Further, for *global issue* projects several scales of data is provided ranging from Paleolithic data sets, to recent climatic statistics, to model based predictions of the near future.
E. Classwide critiques of international policy can focus on either global or local ramifications.

[2]The use of the term ecological hierarchies is not intended to highlight the role of living organisms per se nor to argue the Earth is alive ala Lovelock, but merely to focus on the importance of systems being understandable in terms of multiple spatiotemporal levels and in terms of selectively chosen sets of phenomena.

9. EMPIRICAL STUDIES ON CURRICULUM

A variety of data will be collected from the classrooms to aid in formative and summative evaluation. Each classroom will administer a pretest and posttest designed to evaluate student understanding global warming. In particular, questions are asked on the cause of the seasons, geological time, the greenhouse effect, the impact of changes in the average global temperature on human life, the atmosphere, carbon-dioxide emissions, and the role of sunlight in the Earth's radiative balance. In addition, teachers will categorize the activities that their classroom engaged in and enumerate which staging activities were used and how they were adapted. A sample of student reports and all the classwide critiques will be collected and analyzed. In addition, at least one class will be observed.

10. SUMMARY

A networked curriculum for global warming has been described that encourages collaboration between students, classrooms, and adult practitioners and that emphasizes using data from different ecologically hierarchic levels. The curriculum is divided into three stages, building from structured activities to project inquiry and culminating in presentations and critique which are designed as synthesis activities. The global warming curriculum should appeal to a broad range of students as it can be motivating on the following dimensions: it provides an opportunity to investigate a controversial environmental issue and to use advanced communication and computing environments, it provides ample opportunities to work with other students including group projects, and it provides incentives through the opportunity for project reports to be read and critiqued by adult practitioners and to be published on the WWW reaching a wide audience.

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