CYCLONE IN THE CLASSROOM: BRINGING THE ATMOSPHERIC SCIENCE COMMUNITY INTO THE HIGH SCHOOL

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1. INTRODUCTION

There has been much discussion about the failure of traditional science education to prepare students for careers in science (Halloun & Hestenes, 1985; Rutherford & Ahlgren, 1990). Students may become adept at solving textbook problems, but they fail to apply the theories that are learned in school to the actual phenomena that the theories attempt to explain (Tinker, 1992). This is in large part due to the fact that students don't often experience phenomena in the classroom. They spend most of their classroom time listening to lectures or engaging in cookbook labs (Ruopp et al, 1992). If students are to be prepared for a career in science or to become science literate citizens it is important that they be given the opportunity to engage in the practice of science.

The Learning through Collaborative Visualization (CoVis) Project at Northwestern University, in conjunction with the Department of Atmospheric Sciences at the University of Illinois, Urbana-Champaign and other academic and industry partners, will provide high school students with the opportunity to learn atmospheric science by engaging in the practices of the atmospheric science community. In the context of engaging in student-initiated science projects, CoVis students will use a high-performance computing and communications network (wide-band ISDN) funded by NSF to gain access to atmospheric science data which will enable them to further their understanding of atmospheric phenomena (Pea, 1993; Pea & Gomez, 1992). Through desktop video-conferencing, students can discuss their visualizations with members of the atmospheric science community.

2. TRADITIONAL SCIENCE EDUCATION

A very striking example of the failure of traditional science education comes from Halloun & Hestenes (1985). They developed a simple test to measure intuitive understanding of physical phenomena. The questions were designed to highlight the differences between a "common sense knowledge state" and a "Newtonian knowledge state" (Halloun & Hestenes, 1985, p. 1043). The problems were designed to measure a student's intuitive understanding, so they did not involve mathematical calculations. The test was administered to a group of 80 high school students and a group of 1500 college students across two levels of introductory college physics. They all took the test twice: before the semester and at the end of the semester.

The students performed very poorly on the pre-test. Students taking college physics averaged only 50% correct and the high school students scored only slightly better than chance on this multiple choice test. After a whole semester of clear and wonderfully presented lectures on mechanics, regardless of the kind of physics class, regardless of the teacher, regardless of the student population, there was no significant improvement from the pre-test to the post-test (Halloun & Hestenes, 1985). This kind of study has been replicated in other areas of science teaching as well (Tinker, 1992).

Halloun & Hestenes (1985) argue that the test is a stable measure of students' "beliefs and intuitions about physical phenomena" (Halloun & Hestenes, 1985, p. 1043). The failure of students to improve on the test demonstrates that even though students can recite theories of physics and solve textbook problems using these theories, they gain little understanding of the actual phenomena that the theories describe. It is our belief that students must be given more experiences investigating phenomena scientifically before their "beliefs and intuitions" will be influenced.

3. THE ATMOSPHERIC SCIENCE COMMUNITY

Before discussing how students can engage in the practices of the atmospheric science community, it is important to outline what it means to investigate atmospheric phenomena scientifically. Researchers from the CoVis Project interviewed seven members of the atmospheric science community in order to better understand what defines the practices of that science community (see D'Amico et al., in preparation for a complete description). The members of the community who were interviewed were chosen to represent a variety of viewpoints, including climatology, meteorology, and broadcast meteorology.

These atmospheric scientists all share a great interest and fascination with the atmosphere. Some are interested in applying their knowledge to the problems of weather forecasting. Some are fascinated with the intellectual puzzle that figuring out how the atmosphere works provides. Others use their knowledge of the atmosphere as one component in understanding a physical environment. The complexity of the atmosphere and the importance of the atmosphere to all facets of life allows for a great variety of investigations into its processes.

The atmosphere is a global system. Small changes in one part of the system can eventually affect other parts of the system that are thousands of miles away. Atmospheric scientists must take into account many interrelated variables in order to understand some of the basic processes. Forecasters who are interested in predicting the weather for a specific city, must take into account the weather trends that are taking shape in other parts of the world.

Given the size and complexity of the atmosphere, atmospheric scientists do not perform experiments on it. Although some might attempt to model a small portion of the atmosphere using physical models in a laboratory, most of the data that is used by atmospheric scientists is observational data. The collection of data is a community-wide effort. The projects aimed at building datasets attempt to collect the data so that it will be useful for a large audience of scientists. Each member of the community feels some responsibility to share not only data but also programs that will process and customize the data. Those members of the community of practice who build computer models of the atmosphere rely heavily on those who collect data. The models use the observational data to make the simulation more realistic.

In order to use atmospheric data effectively, atmospheric scientists need to understand how the data was collected. One major obstacle for the collection of data is location. Much of what is interesting about the atmosphere takes place in the upper atmosphere. The community uses two major sources of data about the upper atmosphere: (1) satellite images and (2) balloon launches that carry instruments to measure the atmosphere and transmit the results to the surface.

A second major obstacle for collecting data is time. People have not begun to seriously document the weather globally until the last few centuries. Climatologists do not have to go too far back before they hit a period of time where there is hardly any data available. So the atmospheric science community of practice has developed many techniques for inferring the world's weather during times when measurements were not taken. Even observational data from ancient peoples can be useful for verifying models that have been created.

The amount of data that the atmospheric science community is able to collect is minuscule compared to the size of the atmosphere. In order to understand atmospheric properties, scientists build mathematical models of the atmosphere that will allow them to predict atmospheric conditions that were not directly measured. Most of the models are built from a few simple fluid dynamics calculations that are repeated many times. It is possible to construct these complex models, because the millions and millions of necessary calculations are done using supercomputers. The models are very useful for "getting a picture" of the atmosphere. Often times the outputs from the models are used to generate simulated graphics of the atmosphere or they are used to generate abstract images of particular aspects. Each atmospheric scientist develops a particular approach to generating a mental picture.

However, members of the atmospheric science community of practice must be able to see through the models to understand what is actually happening in the atmosphere. Members of the atmospheric science community of practice use data, models, and visualizations to develop causal explanations of phenomena or to generate predictions for particular days. However, for those who rely on the models, it is important to understand which features each model takes into account and which it neglects. If a feature that is not accounted for becomes crucial in making a judgement about the atmosphere, scientists can adjust their understanding of the situation. There needs to be an awareness of the limitations of building models with computer technology, so that human intervention can compensate.

Students who wish to do science projects in atmospheric science must begin with an interest in explaining some atmospheric phenomena. They must understand that the atmosphere is a global system. They will probably want to use observational data and model output that was generated by the community. In order to analyze the data, it will most likely be displayed in a visualization. However, in order to maintain an understanding of how the data and models relate to atmospheric phenomena, it is essential that students understand how the data was collected. They need to understand the ways in which each model uses the scarcity of data to compensate for obstacles of time and location to generate new data. One way to accomplish this might be through student-collected data.

4. THE COVIS COMMUNITY

Given the pragmatic constraints of today's classrooms, it would be very difficult for students to engage in the practices of the atmospheric science community. Although students might become interested in investigating atmospheric phenomena, they lack any of the necessary resources that the atmospheric science community routinely uses to study the atmosphere. Students normally do not have access to atmospheric science data and models. When they do have access, it is often in a form that is difficult to interpret or manipulate (Gordin & Pea, submitted). Students do not have access to members of the atmospheric science community. Therefore in a traditional classroom, students do not have the opportunity to directly experience science nor do they receive indirect benefits by working with members of the community (Lave & Wenger, 1991).

The CoVis project will support students' efforts to engage in the atmospheric science community by providing access to the necessary resources. Through a high-performance computing and communications network (wide-band ISDN), CoVis will link teachers and students from two Chicago-suburban high schools in the suburbs of Chicago (Evanston Township High School and New Trier High School), learning science researchers from Northwestern University, and atmospheric science researchers from the University of Illinois, Urbana-Champaign. The network will provide connections to the Internet and high-bandwidth channels for desktop videoconferencing and shared computer applications (e.g. for sharing and interpreting visualizations) between members of the network. In the context of earth science and environmental science classes, students and teachers from both high schools will be working on projects centered around weather and the environment. CoVis students will gain access to necessary atmospheric data and mentors from the atmospheric science community.

4.1 *Access to Atmospheric Data*

The CoVis project will initially provide access to two sources of atmospheric data: the National Meteorological Center Grid Point Dataset Version II and National Weather Service current observations. Each of these datasets are designed to be flexibly used by scientists in a variety of settings for a variety of research agendas. It is up to each scientist to customize the data for their own purposes. This may involve writing custom computer programs to reprocess the data or developing specialized templates and color palettes for visualization software (D'Amico et al., in preparation). In order to develop these customizations, a scientist needs to understand how the data was collected and how it is stored. Often, key information is not provided within the data itself since it is commonly understood by the community (Gordin & Pea, submitted). This makes it quite difficult for students to use data from the atmospheric scientific community since they initially lack the skills to customize the data.

Working closely with atmospheric scientists from University of Illinois, Urbana-Champaign and from University of Chicago, the CoVis project has developed customizations of the NMC data and the NWS data that are specialized for the kinds of investigations that will be conducted in the CoVis classrooms. The Climate Visualizer provides a customized student-appropriate interface to the NMC data. It provides a graphical interface to temperature, winds, and height contours at several levels of the atmosphere in the northern hemisphere. The data can be accessed either as a daily reading or a monthly mean. It ranges from 1962-1989. The only other operation the Climate Visualizer currently supports is subtraction. Once a request is made, the Climate Visualizer displays the visualization of the data in a window along with the supporting information. It provides labels for the variables that were used, latitude and longitude, etc. Students can use the Climate Visualizer for a variety of investigations. For example, students can subtract months from different seasons to investigate seasonal differences or they could track historical severe weather outbreaks.

The Weather Visualizer provides access to the real-time satellite photos, weather maps, and station reports that University of Illinois, Urbana-Champaign generates from the NWS data. Most of the customization is accomplished at UIUC. The Weather Visualizer provides clear labeling of each image and Macintosh Balloon help explaining some of the weather symbols that are used. Students can use the Weather Visualizer to make weather predictions or to track weather conditions over time.

4.2 *Access to Mentors*

The Climate and Weather Visualizers can provide students with smooth access to scientific data free from the complications of customizing for a particular task. Students can concentrate on the task of interpreting the visualizations and generating evidence to support answers to their research questions. Graduate students in atmospheric science commonly learn how to interpret visualizations through their interactions with their professors (D'Amico et al., in preparation). Graduate students will generate interpretations and get feedback from their professors. They also have a chance to see how their professors would interpret similar visualizations. The day to day interactions between professors and students are a central mechanism by which students learn about the practices of the science community (Lave & Wenger, 1991).

Through desktop videoconferencing and shared computer applications, CoVis students will be able to get feedback from atmospheric scientists in a similar manner. A Resource Directory provides students with a mechanism to seek out and work with remote and local scientists as mentors. Students can draw from academic professors and graduate students from Northwestern University and University of Illinois, Urbana-Champaign. The mentors and students communicate using video conferencing, while sharing computer data in real time. Both mentor and student will simultaneously view and manipulate visualizations from the Climate and Weather Visualizers in order to collaboratively build interpretations. Scientists will be able to provide invaluable feedback and advice to high school students in a matter of minutes without leaving their desks.

6. CONCLUSION

By October of 1993, the CoVis ISDN computer network will be deployed between Evanston Township High School, New Trier High School, Northwestern University, and University of Illinois, Urbana-Champaign. This network will provide students with access to the atmospheric data that scientists use and it will provide access to mentors from the scientific community. In each of the CoVis classrooms, students will be engaging in science projects of their own design to investigate atmospheric phenomena. By having access to the atmospheric science community, students will not only learn about the content of science but they will also learn how to conduct science.

One of the main focuses of the CoVis project is on understanding the roles that next-generation communication and computing technologies can play in the adoption and support of a project-centered approach to instruction. Research on the CoVis project will focus on each of the science projects that is conducted in the CoVis classrooms. We will use project artifacts to provide a general picture of student behavior in project contexts. One aspect we will investigate is the ways in which the technology provides access to atmospheric science resources and mentors and how students take advantage of this access. We will also investigate the distinctive contributions of student backgrounds, interests, and software use to their learning outcomes in the distributed CoVis learning environment.

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