Looking at Student-collected Global Warming data using ArcIMS

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ESRI Paper Number

587 – 2003 ESRI User Conference

Abstract

It was Alfred Wallace who first identified the geographic distribution of species as a lynch-pin to understanding evolutionary succession. Today, students' must apply the same fundamental concepts to the collection, analysis, and interpretation of biodiversity and geological data. Using Web-based data entry forms and ArcIMS mapping software, students involved in PathFinder Science research (http://pathfinderscience.net) are able to explore their data with real-time visualizations of our changing planet to better understand global warming.

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A distributed network of students, scientists, teachers, and citizen-scientists participating in collaborative work is not new concepts. The advent and proliferation of public school and residential computers with Internet access have fostered substantial growth in these networks. With the capabilities of networked technologies these collaborations have been working on the collection, display, and analysis of scientific data in real-time. These new technologies support collaborations between classrooms, citizen-scientists and expert-researchers across city, state, and national boundaries. Projects such as PathFinder Science (http://pathfinderscience.net), and others, have been developing collaborations between thousands of students, teachers, and mentors in dozens of countries. These projects use the Internet and advanced telecommunications as a communication medium for the exchange of issues and data embedded within a Project-Based Learning environment. In most cases, the geographic spread of the classrooms participating in the network is an advantage to the research or problem the students are investigating. Bridging great distances is therefore not a luxury of the technology, but a demand of the inquiry. This work allows students and citizens to participate in understanding the natural world in new and powerful ways. An example of this work emerges from a simple laboratory technique allows students to explore a bioindicator, leaf stomata, for the impact of a variety of environmental changes. This simple laboratory work creates a rich context of understanding for essential content of biology and from which students can develop a wide array of scientific research into climate change.

Classrooms teachers ask a simple and powerful question about new instructional methods and materials; what will help their students learn the process and content of science**?** This very practical question comes from a deep commitment to see their students successfully reach their learning goals. It is also driven by a high stakes testing environment in which classroom teachers know that student achievement will be reflected in the assessment of their teaching. Teaching within these boundaries, the adoption reform based curriculum or materials can feel risky. Since the publication of the National Science Education Standards in 1995, science education reform efforts have stressed that developing students' understanding of the process of science is an objective of all high quality science instruction. The National Science Education Standards state that, "Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities" (NRC, 1995, p. 105). This emphasis requires a significant and unproven change in classroom instruction.

Using Project Based Learning, PBL with integrated collaborative Geographic Information System data visualizations has been a successful curriculum model to develop scientific inquiry. Using an integrated science process model to organize a collaborative research network has supported changes in instructional behavior and resulted in improvement of student performance and is one way to organize the Standard's vision within a science classroom. .

The National Science Education Standards

The Standards not only brought scientific inquiry into its' own content area but they also distinguish scientific inquiry from inquiry instruction. The standard give vision to scientific inquiry by stating, "Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments." (NRC, 1995, p. 105) As a classroom teacher I felt that the inquiry standard gave direction to the most important outcomes that I looked for in my students; critical thinking and problem solving. Because I had to face students the next day, I also realized that I did not have a clue of how I would implement the inquiry standard within my instructional program. Project based learning has established a foundation to implement the inquiry standard.

The National Geography Standards

The *National Geography Standards* (GESP, 1994) call for the education of geographically informed students, able to ask and answer authentic questions with geographic components. Geographic inquiry is intended to be the primary method for developing students who are able to proceed through the five stages of asking and answering geographic questions. Asking geographic questions, followed by acquiring, organizing, and analyzing the information, allows a student to answer the geographic inquiry, usually resulting in a new set of questions and subsequent inquiries (GESP, 1994). Information technologies, more specifically Geographic Information Systems, are mentioned in one appendix of the standards. While the discussion is minimal, “the standards were written with geographic information systems in mind but not in sight” (p.257). The standards note the expense and gradual adoption of GIS technology in schools.

National Educational Technology Standards for Students

The *National Educational Technology Standards for Students* (NETS) provides a general description of linkages between curriculum and technology for K-12 education (ISTE, 2000). NETS profiles what a technology literate student is able to accomplish at particular grade ranges and includes performance indicators and curriculum examples in English, math, science, and social studies. NETS articulates a vision where classroom technology is used to augment traditional teaching models while simultaneously supporting new student-centered, authentic learning environments, rich in multi-sensory collaborative Problem Based Learning experiences.

Project Based Learning

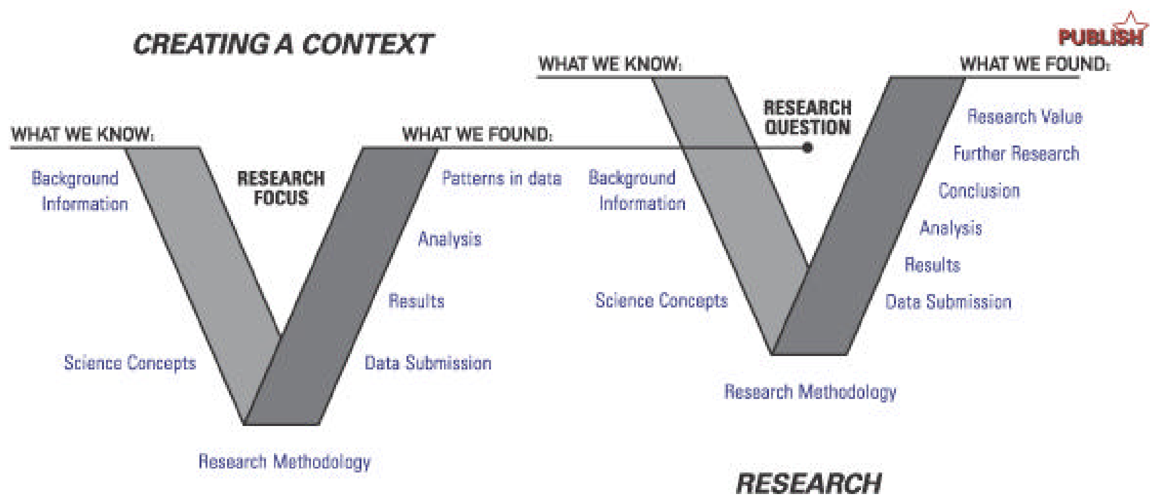
Project based learning is instruction organized around a number of activities that lead to the production of a product. The September 1918 Teacher College Record published an article called, “The Project Method”, in which William Kilpatrick develops a definition for project based learning. Even then he states, “the concept is not in fact newly born.” Kilpatrick, through his advocacy of the project method, launched one of the most successful implementation efforts of PBL by starting curriculum development with student interests, then bringing in subject matter incrementally as it was relevant to pursing those interests. For Kilpatrick (1918), “purposing, the expression of the child’s own interest in pursuing some activity, remained the essential first step in the curriculum-making process.” Even with this fairly long history as an instructional technique it has never been widely implemented.

Recent research in cognitive psychology and learning tend to support Kilpatrick’s opinion about the efficacy of this teaching technique. The National Research Council book, “How People Learn” is a synthesis of cognitive science research indicates that “These investigations will provide fertile ground where their students can transfer their learning to multiple contexts. Learning that only occurs in a single context will become inert except within that context.” (NRC, 1999) The Northwest Regional Lab (1997) embraces this notion of constructivist learning theory by stating that “Project-based learning engages students in complex, real-world issues and asks them to acquire and apply skills and knowledge in a variety of contexts." The National Research Council reinforces this connection to constructivism stating, "Problem-centered learning allows many experiences and prior knowledge to come into play as students develop new constructs." (NRC, 1999)

Unfortunately a simple definition for PBL has lead to the criticism that it is unclear what exactly constitutes a project and how specifically instruction should proceed. In order to engage students in the linkage between project based learning and standards based scientific inquiry, students and teachers need an organizational framework. This framework must offer highly specific support and guidance, a roadmap of sorts, through the process of scientific inquiry. This process structure creates the scaffolding necessary for learning and an organizing framework for communication, reflection and discussion of the process.

A Model to Support Scientific Inquiry

Pathfinder Science (http://pathfinderscience.net) is an Internet research community that involves over 1200 schools and over 4000 citizen scientists from twenty-nine countries in authentic, meaningful, scientific inquiry. The research process model that has emerged from Pathfinder Science is a modified Vee-diagram (Novak and Gowin, 1984).



The Vee is flexible enough to span a wide variety of projects and allow for the representation research process in different science disciplines. It offers guidance without being overly prescriptive. The design helps teachers facilitate student work by providing a specific process structure, the road map, which facilitates the integration of GIS as a data analysis tool.

Creating a Context for scientific Inquiry

The Creating the Context Vee diagram, the left of the two V-diagrams, reflects the view that good research questions emerges from a rich context of understanding. It is difficult for students to ask good research questions: questions that go to the heart of what they want to know. The activities and experiences organized around that the Creating the Context V-diagram are a set of experiences that bring a much deeper level of understanding to the student. Science knowledge is contextualized within a larger understanding of the physical world. The activities of Creating the Context include engaging background information, standardized methods of measurement, active experience in gathering and analyzing data and discussion about what is known and not known on a specific research area. The intent of these activities is to develop the rich context of understanding from which research questions emerge. Geographic relationships and searching for patterns is an important aspect of "Creating the Context" for research. Geographic representations dramatically enhance students' ability to observe relationships in data, which stimulates them to begin to ask questions about causality (i.e. what is cause of the pattern I am looking at?)

Asking a good research questions drives scientific research in this process model. The V-diagram on the right, the Research Vee, represents the process driven by a very specific research question that emerged from the activities of Creating the Context. Most students, and frankly many teachers, have not engaged in scientific research. The task of creating a good research project seems too large and quite daunting. Online, a Guided Research Area is provided for additional support to an authentic, meaningful research project. This allows students to engage in ongoing research without the need to develop the entire process on their own.

Extending project based learning with GIS

Geographic Information Systems offer the potential to support classroom learning in student driven inquiries in many aspects of the natural and social domains. A GIS allows for the collection, storage, analysis, and display of location-based data (Burrough, 1986; Burrough & McDonnell 1998). The typical display of a GIS is a map-based image where layers represent distinct attributes or types of information. These layers can be added in any sequence the user prefers, allowing for student exploration or analyses.

The use of inquiry or Project Based Learning in the classroom requires a rich suite of tools for fostering and driving understanding and assimilation. These tools include media and technical applications for information access, analysis, and reporting. Researchers have concluded that technical tools, when used appropriately as instructional supports, have the potential to enhance student achievement and teacher learning (Cognition and Technology Group at Vanderbuilt, 1996; Dede, 1998). Furthermore, GIS has been shown to extend student self-efficacy in science, technology attitudes, and achievement in science (Baker, 2002). GIS holds the potential to assist with many of the necessary elements for supporting classroom scientific inquiry and PBL, encouraging the collection and display of dispersed environmental data. After data are mapped, classroom scientific inquiries could consider areas of further research from the data presented during pattern seeking and analysis activities. In this way, GIS can facilitate question formation and hypothesis refinement for further scientific inquiries for students.

PathFinder Science uses GIS technologies to aid in three distinct components of the research process, varying greatly depending on the exact project in question. As a wealth of free, readily attainable GIS data already exists, many teachers and students opt to use Internet-based GIS maps in the exploration of background research. Maps provide a great interface for rapidly introducing students to large, complex, or interactive data sets. By using Internet-based maps, students immediately engage in the content and avoid the complexities of traditional desktop GIS applications.

As GIS technologies have rapidly expanded over the past decade, many new and exciting features are becoming available to GIS users. Desktop GIS can be a powerful ally in the collection of data on several PathFinder Science projects. Image analysis tools are no longer strictly reserved for the examination of aerial or satellite data, such GIS tools are also well suited for the mapping and analysis of leaf stomata and lichen growth.

Most notably, GIS is used to examine and analyze data collected by students involved in a collaborative project. As PathFinder Science schools provide a unique geographic distribution, mapping student-collected data is critical to the basic understanding of the data. Using both Internet-based and desktop GIS, students suing GIS are able to compare and contrast their findings within the context of other collaborative data. Students are able to begin and extend fundamental pattern seeking processes and as time and expertise allow, students may begin to spatially analysis data, create new data from multiple pre-existing layers, and construct three dimension maps, time-sensitive map animations, or other visualizations.

Leaf Stomata as Bioindicators: stimulating student research

Stomata are the pores on leaves through which carbon dioxide, oxygen, and water vapor are exchanged with the atmosphere. Several researchers have found that leaf stomatal densities change in response to several environmental variables (light, temperature, humidity), including atmospheric levels of carbon dioxide, a greenhouse gas (Van Der Burgh, Visscher, Dilcher, Kurschner, 1993). A simple laboratory technique allows students to explore leaf stomata as a bioindicator for environmental changes. This work creates a rich context from which students can develop interesting research, while teaching the essential content of biology. Biologic knowledge related to work with stomata includes structure and function of leaves, structure and function of stomata, photosynthesis, the stomata's role in gas, stomata's role in water release (transpiration) and the environmental balance that plants must have between water loss and carbon dioxide uptake. This work also requires that students learn microscope skills and proper data handling skills in the context of the project.

Leaves are the primary photosynthetic organs of most plants. Leaf surfaces are equipped with small openings or pores, stomata, which allows carbon dioxide to enter the leaf and oxygen to escape, facilitating photosynthesis. The cost to the plant for this exchange is water loss. It is estimated that ninety-nine percent of the water absorbed by the roots of the plant, is lost by the leaves in transpiration. The number of stomata on leaf surfaces varies widely among different species of plants. Generally, the lower epidermis of the leaf tends to have a higher total number of stomata than the upper surface although this does not always hold true. One plant only has stomatal opening on the upper surface of the leaf. Botanists have made stomatal counts for many species and the data indicates that the number of stomata may vary from zero on the upper epidermis of an apple leaf to as high as 58,140 per square centimeter on the lower epidermis of black oak leaves.

Leaves from two species of trees and/or a bush will be collected, and the number of stomata on the leaf will be determined using clear fingernail polish, clear tape, a glass slide and a microscope. The number of stomata and epidermal cells in a high power (400 X) field of view are counted. From these counts, a Stomatal Index of the upper and lower epidermis of each leaf is determined. The Stomatal Index (I) =[S / (E+S)] * 100, is calculated where S is the number of stomata per field of view area and E is the number of epidermal cells per same field of view area. Using the stomatal index controls for several variables including different optics between microscopes and variation in epidural cell sizes. Data should be shared and aggregated by the class. In this way, no one student is required to complete large numbers of tedious counts. Data collected can be shared through the nationwide project at http://pathfinderscience.net/stomata. All data from this site is shared to create a large geographically dispersed data set. The use of this type of Distributed Human Networks (DHN) (Baker & Case, 2002) for data collection and GIS visualization is a powerful concept, one which finds increasing support in educational research and case study literature. To support the DHN study of Global Warming, the

PathFinder Science network utilizes web-based data entry and retrieval forms as well as GIS and modeling analysis tools.

The technology used in the project resides on three different servers at various geographic locations. The first Windows 2000 (with IIS) web server contains the Macromedia ColdFusion Application Server 5.0. This server handled static and dynamic web forms and acts as the central and controlling machine. The server handles all web forms, including uploading and downloading data. The second Windows 2000 server contains Microsoft's SQL Server and is responsible for all database content, services, and operations. This machine serves as a dedicated database and maintains constant connections with multiple web servers and the map server. The third Windows 2000 server contains ESRI's Internet Map Server 4.0, Macromedia JRun 3, and ColdFusion 5.0 with ArcIMS ColdFusion connectors. The map applications residing on this server are created especially for PathFinder Science projects. Because we have not restricted data posts in any PathFinder Science project, data posted by students appears immediately, available on the map and text-file downloads. This degree of connectivity is essential for classrooms engaged in collaborative research and for students who need instantaneous feedback.

Student Research

Based on this data collection and the geographic visualization of data, students should be lead in a discussion of environmental factors that may cause the observed variation in Stomatal Index. The class discussion is directed toward helping students generate research ideas including approaching the data from a geographic perspective. We can focus on a broad view of patterns in data by using the general elements of geographic relations from Module Two:

- Where are things? - Searches are conducted for a specific point or points meeting identified parameters.

- High-Averages-Lows (HAL) - This element denotes the need for maximums, minimums, determining averages, and potentially mapping bivariate color schemes.
- Density is Represented - The frequency of samples (and resulting map representations) is considered.
- Assessing Inside/Outside Elements - This element could include determining boundaries or regions in which data express commonalties.
- Assessing proximities - This element includes measures between a point or points and other nature features.

Students thinking within these geographic bounds can help us observe and articulate patterns (relationships) in their data set and can add additional richness to the questions the students will generate. Theses questions have spanned a wide range of interesting areas includeding; what is the normal variation in the Stomatal Index found on a species? How much does the Stomatal Index vary between species? Is the age of the tree related to the number of stomata found on the leaf? Does the cardinal direction the leaf comes from on the tree influence the Stomatal Index? (In North America, the south side of a tree will receive more light and be exposed to more wind.) Does the direction the terrain slopes (where the tree is) make a difference tree on the number of stomata found on the leaves? Is there a difference in stomatal index on leaves grown in a carbon dioxide enriched environment to those grown under normal atmospheric conditions? Is there a variation in the stomatal index along a rainfall gradient? What is the variation in numbers of stomata that occur between plants growing in similar habitats but using different photosynthetic pathways, C3, C4, and CAM?

As the class discussion proceeds the students should be thinking of ways to measure, test, and/or simulate these environmental variables. The discussion creates a teachable moment where instructors can introduce the plant structure and function, so that the questions are asked in the context of known information.

Does it work?

It is absolutely necessary to answer the very practical question that classroom teachers ask. In a dissertation study exploring what factors support changes in teacher's instructional behavior, the impact that a science and technology network, Pathfinder Science, had on the teaching behaviors of the elementary (K-8) science teachers who had participated in the network for two years was significant. The findings regarding change in science teaching behaviors, as well as implications for future science teacher professional development are substantial. (Carroll, 2001) In this study, teachers reported changes in instructional behavior as a result of the support offered were verified through classroom observation.

In our work we have found that in order to engage students in meaningful and authentic scientific inquiry, they must have an organizational structure that offers both guidance to process and scaffolding to learning. It is important to ask if participation in this inquiry model provides compelling evidence of an increase in student achievement. More important, does the ability to apply these skills transfers to novel situations? In a recent study of student learning in the Kansas City Kansas Public Schools, a fairly typical, somewhat small urban school district, the use of the research model was explored. A wealth of student data was available from the district-wide systemic reform effort. Since longitudinal measures of student attitudes are generally difficult to obtain, this study tapped into this wealth of attitude measures of ongoing district work. Using the statistical technique of Structural Equation Modeling, multiple learning variables were combined with participation in the research model. This study created and tested a model of science classroom variables related to scores on a science performance assessment. Models were run separately for samples of middle school students (grades 6-8) and high school students (grades 9-12). The middle school model indicates that participation in the Pathfinder

Science research model is an independent, positive, direct, and meaningful predictor of science performance (Case, 2001). In a five-year study, researchers at SRI International found that technology using students in Challenge 2000 Multimedia Project classrooms outperformed non-technology-using students in communication skills, teamwork, and problem solving (SRI, 2000). A three-year 1997 study of two British secondary schools, one that used open-ended projects and one that used more traditional, direct instruction, found striking differences in understanding and standardized achievement data in mathematics. (Boaler, 1999) Another study by the Cognition and Technology Group (1992) at Vanderbilt University examined student competence in basic math, word problems, planning capabilities, attitudes, and teacher feedback. Students who had experience in the project work performed better in all categories. An additional report, "Authentic Intellectual Work and Standardized Tests: Conflict or Coexistence?" by the Consortium on Chicago School Research (2001), states that students whose routinely engaged in "authentic intellectual assignments" increased their scores on the Iowa Test of Basic Skills by 20 percent more than the average increase in scores nationally.

Baker (2002) found that when a collaborative science learning unit with GIS support was introduced to 7th graders, modest improvements in students' science self-efficacy, attitudes toward technology, and integrated science process skills occurred, especially data analysis (geographic and mathematical) activities. He further notes that the speed and accuracy with which collaborative GIS can represent large datasets makes it a very valuable tool for classrooms working within a network of schools focused on a common question or issue. "The use of collaborative GIS contains great potential to move students quickly beyond the practice of mapping where things occur and immediately launches them into determining why things occur" (p. 155).

In answer to the question, yes it is possible. Given a supporting environment, teacher instructional behavior will focus around scientific inquiry as the organizer of student activity. Students engage in this research process, teaching content in the context of process, will show an increased understanding of science and an increased ability to transfer inquiry skills to new situations.

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