Using GIS in the Development of Science Standards Supporting Curriculum

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Abstract: This paper describes the development and implementation of a field based project that uses GIS to study the history, geography, oceanography and biology of The Bolsa Chica Wetlands in Huntington Beach, California. The Lakewood High School Science Department has been participating in the Ocean Explorers project of the Center for Image Processing in Education, an NSF funded initiative aimed at increasing knowledge and interest about information technologies among teachers and students in California. The Lakewood High School project can serve as a model for teachers who wish to use GIS, but are struggling with overcoming the challenges of implementing the technology in their classrooms. In particular, the Lakewood project highlights how GIS can be employed as a tool for inquiry-based learning that supports mastery of state educational standards.

Introduction

Thirteen educators from the Science Department at Lakewood High School in California have been participating in the Ocean Explorers project of the Center for Image Processing in Education. Ocean Explorers is a National Science Foundation (NSF) funded initiative aimed at increasing knowledge and interest about information technology among California teachers and students. Ocean Explorers is a professional development and materials development project funded by the Information Technology Experiences for Students and Teachers (ITEST) program at NSF. The project is being conducted by CIPE in collaboration with the Channel Islands National Marine Sanctuary (CINMS), a federal reserve located off the coast of Santa Barbara, California. The project was created to assist teachers in overcoming barriers to educational implementation of informational technologies (IT) such as geographic information systems (GIS) identified during previous outreach efforts by CIPE and CINMS, and to help teachers create IT-based instructional activities that support achievement of the *Content standards for California public schools* (California Department of Education 2002). The obstacles K-12 educators face in implementing new technologies are numerous. Many school systems provide only limited access to computers and costly technology and training essential for integration of software and novel teaching methods. Bureaucratic systems within schools can prevent experimentation and implementation of software and instructional approaches. There also exist circumstances where the educational atmosphere isolates teachers within a community of skeptics opposed to new technologies and instructional approaches and political administrative regimes that favor rote memorization over exploratory learning. These pressures in turn prompt time

pressured educators to use cost benefit calculations when selecting classroom resources and teaching methods: teachers often choose not to use GIS in their classrooms because of the time intensive nature of learning GIS software and concepts, the time and expertise required to acquire data and construct GIS based activities, and the lack of computers and technical support sufficient to maintain a GIS platform in a school setting.

Ocean Explorers is providing support and resources to overcome these obstacles. During a three-year professional development training program, 71 educators from California and Arizona are endeavoring to learn GIS, digital image processing analysis (IPA), and ocean science as ways of engaging students and incorporating information technologies (IT) into science and mathematics education. The participants have formed 20 teams of three to five teachers that are learning, utilizing and exploring GIS and IPA as tools for learning. Teachers participating in the project are receiving mentoring, software, equipment, funding, field experiences and training that will foster the development of curricula that support achievement of targeted science standards. The inquiry-based activities in development by the Ocean Explorers teams in collaboration with CIPE are being designed to support achievement of California state and national science, technology, engineering, and mathematics Standards (STEM). Each team is conducting field based or web supported community atlas projects (Environmental Systems Research Institute {ESRI} 2005). The development process is being guided by the Understanding by Design method of Wiggins and McTighe (1998) and other templates such as the geographic inquiry process (English and Feaster, 2003). The understanding by design method encourages teachers to work backwards from targeted standards to create assessments and activities that support student achievement. The geographic inquiry process encourages learners to ask geographic questions, acquire geographic resources, explore geographic data, analyze geographic information and act on geographic knowledge.

Project Description

Lakewood High School, a part of the Long Beach Unified School District in southern California, is a large urban institution with a diverse student population. Thirteen teachers from the science department are participating in the Ocean Explorers project. They are organized into three teams. The teams are conducting GIS based field research within the Bolsa Chica Wetlands in Huntington Beach, California. The teams are using aerial photographs, water quality sampling data, watershed and conservation databases and historical data on archaeological sites to study the history, geography, oceanography, biology and ecology of the wetlands. Four separate but interconnected inquiry based sets of GIS lessons on geology, water quality, ecology and human interactions are being created that will cover the earth science, biology/life science and investigation & experimentation subject Areas of the California Science Content Standards (California Department of Education 2002).

The geology component of the community atlas project will support achievement of Earth science content standards such as the following:

- Plate tectonics operating over geological time has changed the patterns of land, sea, and mountains on Earth's surface (Standards 3 a, b, d, and e).

- The geology of California underlies the state's wealth of natural resources as well as its natural hazards (Standards 9 a, b, c, and d).

In the geology component, students and teachers will use global positioning system (GPS) units to georeference data collected in the field, display the data on aerial photographs of the wetlands using ArcView 3.3, and integrate the data with GIS layers such as topography, earthquake faults, soil dynamics, hydrology, watershed boundaries and earthquake location, frequencies and magnitudes. Specific activities covered in this aspect of the community atlas project will include collecting latitude and longitude data with handheld GPS units, capturing digital images of the wetlands, creating ArcView projects with maps of the data layers, using georectified aerial photographs, and incorporating hotlinks of locations with digital images.

The water quality component of the community atlas project will provide an opportunity for students to master concepts related to the following Earth science and life science standards:

- Energy enters the Earth system primarily as solar radiation and eventually escapes as heat (Standards 4 a and b).

- Heating of Earth's surface and atmosphere by the sun dries convection within the atmosphere and oceans producing winds and ocean currents (Standards 5 a, b, e, f, and g).

- Climate is the long-term average of a region's weather and depends on many factors (Standards 6 band d).

- Changes in an ecosystem result from changes in climate, human activity, introduction of non-native species or changes in population size due to relative rates of birth, immigration, emigration and death (Standards 6 b and c).

- Ecosystem balance is influenced by the water, carbon and nitrogen cycling between abiotic and organic matter in the ecosystem and oxygen cycles in the processes of photosynthesis and respiration (Standard 6 d).

In the water quality component of the project, students will conduct their own field based research, testing water quality in different parts of the wetland and comparing their results to existing data from ecological monitoring studies of the Bolsa Chica Wetlands (Bolsa Chica Conservancy website, http://www.bolsachica.org/WaterQualityData.html). Students will further propose and test hypotheses to explain the difference in water quality at different locations in the wetlands. Students will correlate the water quality

data gathered in the field with stream flow data and precipitation records to develop a predictive model of how rainfall affects water quality indicators such as temperature, dissolved oxygen, nitrates, phosphates, dissolved solids and pH. These activities will lead into an analysis of how normal tidal fluctuations and El Nino events affect water quality in a wetland watershed system.

The ecology component of the community atlas project will focus on the following standards:

- Biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats. (Standard 6 a).

- Changes in an ecosystem result from changes in climate, human activity, introduction of non-native species or changes in population size due to relative rates of birth, immigration, emigration and death (Standards 6 b and c).

- Ecosystem balance is influenced by the water, carbon and nitrogen cycling between abiotic and organic matter in the ecosystem and oxygen cycles in the processes of photosynthesis and respiration (Standard 6 d).

- Evolution is the result of genetic changes that occur in constantly changing environments and speciation is affected by reproductive or geographic isolation (Standard 8d).

To address these standards in the ecology section of the project, students will create ArcView maps on the migratory patterns and nesting sites of birds in the Bolsa Chica Wetlands. Data collected during field experiences will ground truth the exploration of larger data sets of migratory birds and research on habitat usage patterns of birds within the wetlands. GPS data and digital images will be used to construct hotlinked themes showing nesting sites and different bird species within the various areas of the wetlands. Students will research the natural history of the bird species and propose hypotheses about what factors that might explain how different bird species select habitats within the wetland. These predictions will then be correlated with the bird sightings data. To explore the importance of wetland communities to our environment, students will propose a plan for development of a residential community and theme park adjacent to the wetlands, using ArcView to explore changes in the geography and ecology of the wetlands correlated to various planning scenarios. Students will manipulate various factors such as road placement and size of land development parcels within an ArcView project to visualize the possible changes on the wetland.

Additionally, the human interactions component of the project will address the following chronological and spatial thinking standards in the California Department of Education Historical and Social Science Analysis Skills for Grades 9-12 (2002):

- Students compare the present with the past, evaluating the consequences of past events and decisions and determining the lessons that were learned.

- Students analyze how change happens at different rates and at different times; understand that some aspects can change while others remain the same; and understand that change is complicated and affects not only technology and politics but also values and beliefs.

- Students use a variety of maps and documents to interpret human movement, including major patterns of domestic and international migration, changing environmental preferences and settlement patterns, the frictions that develop between population groups, and the diffusion of ideas, technological innovations and goods.

To illustrate the concept of change over time, students and teachers will investigate human impact on the wetlands from a historical perspective. Archaeological and historical records will be integrated into a GIS project to demonstrate how humans have interacted with the Bolsa Chica Welands in the past and what impacts they may have had on the ecosystem. Historical photographs, including aerial photographs from as early as the 1920's and digital ortho quarter photoquads from 2004 will be evaluated to uncover changes over time in the settlement, habitat and ecology of the region. Effects of human activity such as agriculture, housing development, military usage, road construction and oil production are evident in the photographs, giving students a rich visual historical record to work with. Using ArcView to measure the total area of wetlands in the images will give students an understanding of the rate of wetland disappearance that occurred along the California coast during the 20th and early 21st centuries. Understanding this concept will allow students to generalize the fate of wetlands worldwide.

Investigation & Experimentation

Overarching all of the content standards listed above is the practice of science. Because GIS excels as a platform for apprenticing students as self-guided researchers, the following standards will be addressed by the project:

- Select and use appropriate tools and technology to perform tests, collect data, analyze relationships and display data (Standard 1a).
- Formulate explanations using logic and evidence (Standard 1d).
- Read and interpret topographic and geological maps (Standard 1h).
- Analyze the locations, sequences, or time intervals that are characteristic on natural phenomena (Standard 1i).
- Analyze situations and solve problems that require combining and applying concepts from more than one area of science (Standard 1l).

Summary

The Lakewood High School Community Atlas Project is using GIS to teach concepts that directly support science, history, and social studies content standards in California. Ecosystem studies facilitated with GIS lend themselves well to the coverage of biology and life science standards. GIS allows students to integrate biological, geological, meterological and cultural data sets in a manner that allows them to pose interesting hypotheses about the alteration of habitats, natural fluctuations in a system, dynamic change and nutrient flow. Properly used, GIS is a scientific apprenticeship tool that helps students visualize connections among abiotic and biotic factors of an ecosystem. With GIS, teachers can provide students an opportunity and incentive to investigate more deeply, explore more concretely and think creatively.

GIS is a powerful, complex and interactive tool. It is an excellent tool for asking scientific questions, creating maps, exploring patterns, visualizing relationships in a data set and asking new questions. GIS allows for effective and comprehensive coverage of the traditional steps of scientific inquiry, framed within a geographic context that can be applied to a myriad of subject areas. In a broader sense, using GIS engages students in more critical thinking, integrates knowledge from multiple subject areas, connects a diverse range of global topics, emphasizes community-based investigations and allows for dynamic interaction via maps, charts, and other visual media. GIS in the classroom uses the same advanced technology now employed by business, government and science and prepares students for futures and careers dependent on increasingly greater levels of IT proficiency.

The challenge in using GIS as an integral component of curricular activity development is to create activities that help students master targeted skills and content. Unfortunately, the power and complexity of GIS can be its greatest handicap. Many teachers focus on the technological tricks of GIS and forget to create activities that focus students on mastering specific skills or learning specific content. Other teachers engage students in fascinating field studies that teach a great deal but may not be efficient techniques for teaching what is needed. The trick in creating GIS-based activities that support mastery of content standards is to keep the instructional goals clearly in mind when designing and implementing the activities. As noted in Wiggins and McTighe (1998), assessments are a particularly useful tool for keeping that focus. The Lakewood High School Ocean Explorers team, by implementing the Understanding By Design approach and other guiding frameworks in the design of their project, is charting a course for their students that will not only provide them with the richness of GIS-based study but also take them where they need to go.

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