Connecting classrooms to real-world GIS-based watershed investigations

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Abstract

Incorporating authentic science investigations and data into school curriculum can be challenging. GIS technology provides a way for teachers and students to examine relevant real-world issues with data and tools regularly used by science professionals. We will explore a multi-week supplementary curriculum that has students mapping watersheds, analyzing land use impacts on stream ecosystems, and applying their new knowledge and skills to develop watershed management plans. We will discuss how these GIS-based environmental investigations can enhance student learning and support science standards.

Introduction

There is a growing disconnect between the science world and the pre-college science classroom. Few students work with tools regularly used by scientists or pursue authentic inquiries using current scientific data and information. Instead, science in the schoolroom is often "…an exercise in memorizing technical terms and getting through the textbook…[h]eavy on vocabulary and light on actual science…" (Fratt 2002). Teachers themselves often lack experience with scientific inquiries (NRC 2000). To make this connection and to promote science and computer literacy, students need first-hand experience with scientific tools in ways that parallel professional uses. To guide students through authentic inquiries, teachers need to experience these tools in a similar way (Loucks-Horsley et al. 1998) with support of resources designed for the classroom (Edelson et al. 1999).

Environmental investigations using geographic information system (GIS) provide an ideal way to meet these needs for K-12 teachers and students. Visualization and modeling tools like GIS can increase students' ability to transfer new knowledge to novel situations (Bransford et al. 1999) and can help students understand complex science concepts and phenomena (Gordin & Pea 1995). Coupling GIS with environmental science topics and scientific datasets opens the door to local and regional investigations, which can improve student performance (Lieberman and Hoody 1998) and help them connect new concepts with prior knowledge (Carlsen 2001). However, GIS-based activities also present significant challenges for the classroom. Designed for professionals, geospatial software is complex and has a steep learning curve, especially for teachers with limited computer experience. Advanced skills are often necessary to acquire and import geospatial datasets and convert them into a format and size appropriate for classroom. Even with data in hand, many teachers lack time to construct from scratch high-quality GIS-based curriculum using real-world data and aligned with state science content and skill standards.

To meet these needs and challenges, we developed a three-year GIS education project—*Inquiring with GIS (iGIS)*—that helps science teachers guide students through GIS-based environmental investigations that examine regionally-relevant issues in ways that parallel professional inquiries but with tools tailored for the classroom. We target high school environmental science, general science and biology teachers in the Central Appalachian region (western Maryland, western Pennsylvania, and West Virginia). The project team is made up of education specialists, GIS technicians, scientists, teachers and evaluators from the University of Maryland Center for Environmental Science, Northwestern University, Canaan Valley Institute, The Learning Partnership, and local schools.

Our Approach

We have incorporated four strategies to meet the needs and challenges of classroom-based GIS investigations. First, we developed and refined a comprehensive supplementary curriculum for the iGIS Project. In seven lessons (24 classroom periods), students use newly-acquired GIS skills to delineate watersheds, examine regional land cover impacts on stream health, and propose watershed management solutions. With a focus on content, both curricula center on the following two enduring understandings:

- Streams can be organized into watersheds based on topography, making watersheds important natural resource management units; and
- Some human land use choices can diminish stream health by increasing stormwater runoff, introducing pollutants to streams, and removing riparian buffers. Protecting and restoring forested and wetland areas can help maintain healthy streams.

We organized the curricula around state high school standards in environmental science, general science and biology. These include the following:

- *Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices, and explain how human practices affect the quality of the water and soil* (Pennsylvania 10th grade science);
- *The student will evaluate the interrelationship between humans and land resources…including considering land use planning* (Maryland high school Environmental Science); and
- *Use topographic maps and Geographic Information Systems (GIS) to investigate biological systems and patterns (e.g., land use)* (West Virginia 11th and 12th grade Biology Technical Conceptual).

In addition to our target audience, our project has attracted as middle school science teachers, as well as high school teachers with computer science, chemistry and math course. We work with these participants to identify relevant content and skill standards for their courses and help them adapt the materials accordingly.

The iGIS curriculum was constructed with the Learning-for-Use (LfU) framework, which builds on cognitive science research and consists of three steps that foster engagement and promote useful knowledge that can be applied (Edelson 2001, Table 1).

Table 1: iGIS supplementary curriculum and Learning-for-Use framework

LfU Step	LfU description	iGIS curriculum
Motivation	Learning activities that create a need to learn specific skills and content and elicit curiosity by revealing limitations of current understanding.	Motivation occurs at several stages in the curriculum, as students apply prior knowledge to consider stream flow direction, components of healthy streams, and factors that affect stream health. They also read a series of memos that outline each activity, including the culminating activity.
Knowledge Construction	Learning activities that provide firsthand experiences and opportunities for communication to help students learn new knowledge and link it to prior understanding.	Students determine the impact of elevation on stream flow patterns, delineate watershed boundaries, describe and quantify stream health, and summarize land cover impacts on stream health.
Knowledge Refinement	Learning activities that allow students to apply their new understanding in meaningful ways and reflect on their knowledge and experiences.	Students apply their new knowledge in a preliminary management activity and then a culminating activity, in which they select a watershed for management; summarize its characteristics; identifies areas to consider for conservation and restoration; mark locations for sampling sites to study these areas more thoroughly; and justify their decision with maps in class presentations.

Within the curriculum, we provide scaffolding to support the concepts, GIS software functionality, and spatial analysis. Rather than working through a tutorial, students jump right into the first activity using the software. These initial explorations focus on basic functions and are supported with complete step-by-step instructions, as well as paper and pen activities (see Figure 1). For example, students first highlight stream networks and outline watershed boundaries on paper maps and then compare their results with an identical digital map using the GIS software. As students progress, the curriculum lessons become more challenging, incorporating advanced functions and providing less guidance. By the end of the multi-lesson unit, students apply their new skills (e.g., selecting, clipping and buffering layers; creating new layers; making map layouts) to select a watershed for management, identify areas for conservation and restoration, and mark associated sampling points. After each lesson, they reflect on their visual and spatial analysis and its results.

Figure 1: Examples of iGIS curriculum tasks with very guided basic steps on the left (hiding/showing layers; adding layers from the Data Library to the Layer List) and in center (delineating watersheds on paper maps and comparing predictions to GIS maps) to more advanced activities on the right (creating a 100-m buffer around a streams layer).

Second, to shorten the learning curve for the technology, we use a GIS software package designed specifically for the K-12 classroom. Built on Java, *My World* was developed by Northwestern University and incorporates portions of ESRI's MapObjects-Java Technology (e.g., ability to link to ArcIMS data sites). It runs on Macintosh OSX and Windows environments and contains a subset of professional functions including multiple geographic projections, map and table views of data, distance-measurement tools, buffering and query operations, and customizable map display and paper layout. *My World* can import ESRI shapefiles, tab- and comma-delimited text files, and GPS coordinators, and it provides a user-friendly option to access dynamic web images (e.g. Terraserver).

The *My World* software is structured to work effectively in the school environment, where local storage space is often restricted and Internet access is often unreliable. To support novice users, it is organized into four modes—*construct, visualize, analyze and edit*. In the construct mode, students add vector, grid and image data layers and GIS projects to their *mapview* from easily-accessible data libraries. They explore these data in the visualize mode with dynamic categorical and continuous legends and basic tools that include zoom, move map, open layer table and bar chart, identify layer features, create vertical profile, and select features with a lasso or marquee. The analyze mode offers basic and advanced data analysis options including selection by spatial relationship; clipping, intersecting, and buffering lines and polygons; and creating graphs—all supported with intuitive terms and clear instructions (e.g., if students do not label a new layer, *My World* offers a logical name). Finally, students can create and modify point, line and polygon layers in the edit mode. For the iGIS Project, we used many of these functions including creating a point layer with field data (GPS coordinators and stream attributes), clipping land cover to watershed boundaries, and creating 100-meter buffers around streams.

Third, the iGIS Project has an extensive teacher professional development component—120 contact hours. Teacher participants receive training during a two-day spring workshop, 24-

hour early summer online session, and five-day mid-summer workshop. With support from our staff, they then test out their new skills, knowledge and materials during one of two weeklong summer youth institutes. During the academic year, we provide follow-up support through monthly phone calls, regular email and web postings, at least one school visit by our staff, and two daylong workshops.

Finally, we strive to support both curriculum “adopters” and “adapters.” Our comprehensive curriculum lessons include objectives, instructions, assessment tasks, worksheets, and links to science standards, so that teachers can jump right into the materials with their students. But we also devote a significant portion of the professional development helping teachers make minor or major curriculum adaptations, and we give teachers the tools to make these changes (e.g., Microsoft Word versions of lesson documents, extra data layers, technology help documents). Our data library includes layers (e.g., land cover, streams, states, counties, roads) for the entire target area (Central Appalachian region), so that participants can explore both local and regional patterns. And we teach them how to import GPS coordinates and attributes into *My World* to expand their local dataset. During the summer workshop, each teacher prepares an implementation plan that describes how she/he intends to use the curriculum in their classroom, lists targeted county/district/state standards, outlines curriculum adaptations, and maps out when they will integrate lessons into their existing curriculum. As noted, we help teachers throughout the academic year, as they complete any curriculum adaptations and use the materials with classroom students.

Discussion

We are conducting pre- and post-project evaluations to assess the impact of these projects and have some preliminary results from the iGIS Project. All teacher participants in our first cohort (2005-2006) expressed satisfaction with our training, which included key features of effective professional development—sustained, collective participation, content focused, active learning, and coherence among professional development activities (Garet et al. 2001). However, some pointed to the need for more coherence. Overall, participants significantly increased their understanding of and skill with GIS and felt more confidence integrating GIS-based investigations into their existing curriculum. All implemented some portion of the iGIS supplementary curriculum (or an adaptation of the curriculum) in the 2005-2006 school year. However, some struggled with the curriculum’s complex content and use of technology, and many had difficulty getting the software loaded on school computers, which delayed their implementation.

We are addressing these issues by refining the professional development structure and project materials. We have clarified goals for and connections between each component of the professional development (coherence). We simplified software installation and now provide all project materials at the first (spring) workshop (software, data, lesson documents, and a software license letter for technology coordinators) and strongly encourage participants to install software as soon as possible. We will follow-up with email, phone calls and school visits as necessary to ensure the installation happens in a timely way. We refined the curriculum lessons, eliminating unnecessary complexity, providing more scaffolding for content and spatial analysis, and reducing overall length. We emphasis local connections, showing teachers how import aerial photos (in addition to GPS coordinators) and guiding them through possible local extension activities (e.g., mapping surface type and runoff in the schoolyard; sampling macroinvertebrates in local streams). As noted, we provide a fairly extensive data library but have had to degrade spatial resolution and limit spatial extent to keep data files to a manageable size (e.g., National Land Cover Dataset (30-meter-resolution raster data) was resampled to 270 meters and converted to vector format). The lower spatial resolution can make it difficult for teachers and students to examine local patterns. We are exploring other options that meet the desire for local links without adding too much complexity (e.g., providing higher resolution data layers organized into libraries on multiple CD-ROMs).

Over the next two years, we will continue to refine the iGIS Project, seeking a balance between comprehensive curriculum with prepackaged data and support for adaptations and local connections. Ultimately, we will distribute project materials and strategies to teachers and curriculum developers in the Central Appalachian region and throughout the U.S.

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