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Integrating Online GIS into the K–12 Curricula: Lessons from the Development of a Collaborative GIS in Michigan

Paul Henry and Hugh Semple

ABSTRACT
GIS has shown promise in Project Based Learning (PBL) environments, but many obstacles exist in its integration into school curriculums. This article discusses the development and utilization of an online GIS tool that was created to illustrate that the perceptual gap between relevance and ease of use of GIS software can be bridged at the K–12 level. This online GIS tool, referred to as the H2OMapper, is a watershed data management system designed to directly support teachers and students in middle school earth science. It features a student observation database, preprocessed contextual datasets, and an easy-to-use interface to reduce the time it takes to learn operations. Teacher experimentation with the software indicates that negative perceptions about GIS technology can be reversed if the adoption process is carefully planned.

Key Words: geographic information systems, geographic education, instructional technology

INTRODUCTION
Constructivist learning environments employing inquiry-based, student-led investigations, open-ended questions, and real world experiences are increasingly seen as a key to educational reform (Jonassen 1999; Markham, Larner, and Ravitz 2003). There are many technologies available to teachers to help implement these modes of learning. One technology that seems particularly suited to constructivist classroom environments is a geographical information system (GIS) (Bednarz 1995; Drennon 2005). GIS is recognized as an interdisciplinary technology that supports high-level thinking and spatial reasoning. It is deemed well suited to inquiry science and open-ended investigations, has direct correlation to real world experience, allows students to visualize complex real world problems, and supports multiple modes of learning (Donaldson 2001; Bodzin and Anastasio 2006; National Research Council 2006). Yet, GIS remains largely unused at the K–12 level. In 1999 only 2 percent of American high schools were reported to have adopted GIS technology (Kerski 1999). Since then, data has been sparse on the national rate of adoption of GIS in K–12 schools, but the general tone of papers written on GIS adoption in these schools in the U.S. suggests that rates of adoption have not dramatically accelerated (Patterson, Reeve, and Page 2003; Kerski 2003; Bednarz and Van der Schee 2006; Baker, Palmer, and Kerski 2009). The slow rate of adoption of this technology at the K–12 level has been attributed to a number of reasons including the lack of preservice teacher training in GIS, a paucity of appropriate curriculum material, lack of accessible and relevant data, and the fact that GIS software is often perceived as too complex to master and too expensive to acquire (Audet and Paris 1997; Bednarz and Audet 1999; Kerski 2003).

In light of the gulf between the potential educational value of GIS technology and the difficulties of using this technology for classroom instruction, there is a recognized need for better approaches to the adoption of GIS at the K–12 level of education. In this article, we support the view that if the underlying rationale for promoting GIS at the K–12 level is its utility in fostering development of spatial reasoning skills, then an appropriate implementation model is one in which spatial thinking is greatly emphasized in lesson planning while at the same time the details of the technology are minimized (Schacht et al. 2005; Shin 2006; Marsh, Golledge, and Battersby 2007). This model may also be appropriate for introductory GIS classes in social science departments at colleges and universities where GIS is a new subject for many students and where the focus is also on developing spatial reasoning skills rather than on the details of GIS technology, as is typically the case with GIS degree programs.

In recent years, the rise in popularity of online virtual globes such as Google Earth, NASA’s World Wind, and ESRI’s ArcGIS Explorer Online, plus other programmable world maps such as Google Maps, Yahoo Maps, and Bing Maps, point to a willingness by people to engage in spatial thinking if the perceived value of the technology to the user is not outweighed by a steep learning curve required for its use (Schultz, Kerski, and Patterson 2008). In other words, if the number of operations required to complete tasks is minimized, the time it takes to learn how to use the software is reduced and gives users more time to focus on applying spatial concepts to solve everyday problems. Therefore, a central research question regarding GIS adoption at the K–12 level is how best to minimize the learning curve of this technology in the classroom, while at the same time highlighting the
analytical power of the technology. This article outlines an approach to adopting GIS technology at grades 7–9 that involves the use of a Web-based GIS designed to directly reduce the learning curve needed to use GIS. The focus of lessons built around this Web-based GIS is more on the higher-level spatial analytical benefits of the GIS rather than on the mechanics of the GIS itself. This approach has been labeled a “minimal GIS approach” by Marsh, Golledge, and Battersby (2007).

**WEB-BASED GIS**

Given the problems associated with implementing desktop GIS at the K–12 level, Web-based GIS is being increasingly advocated as holding the key to faster GIS implementation in schools (Baker 2005; Bodzin and Anastasio 2006; Schultz, Kerski, and Patterson 2008). The ease of use of these applications, their relatively flat learning curves, reduced software cost, and capacity to support constructivist-learning techniques are the principal benefits of Web-based GIS. Furthermore, in the light of declining educational budgets and increasing demands on teachers’ time, Web-based GIS provides a cheaper, more accessible, and less time-consuming platform upon which geospatial technologies can be integrated into the classroom. Support for Web-based GIS does not imply doing away altogether with traditional desktop GIS systems. While Web-based GIS can be the foundation or main software used for school-based GIS lessons, desktop GIS software can still be used to perform certain advanced analytical or geoprocessing functions not present in the Web-based applications being used by the school.

Web-based GIS in K–12 education is not without its challenges. These include slower data processing due to data being streamed over the Internet rather than processed on the desktop, limited Internet bandwidth at some schools, lack of access to high-speed Internet, and server-side conflicts originating from concurrent, high-volume access, and user interactions.

**THE COMPARING AND CONTRASTING WATERSHEDS IN MICHIGAN (CCWIM) PROJECT**

The Web-based GIS tool presented in this article was developed as part of a two-year teacher training project in Michigan that focused on comparing and contrasting the physical aspects and human use of watersheds in the state (CCWIM). The CCWIM project started in June 2008 and was a collaborative effort between the Wayne County Regional Educational Service Agency (Wayne RESA), the Marquette/Alger Regional Educational Service Agency (MARESA), and the Wayne County Math Science Center. The project was designed to promote improved teaching and learning of watershed science through project-based learning, curriculum aligned unit design, and collaboration between urban and rural schools. The project was aimed at grade levels seven through nine where most of the curricula units on watersheds in Michigan exist.

In order to promote new educational technologies in the classroom, teachers were trained in the use of a variety of instructional technologies such as field data collection probes and sensors, cameras, USB microscopes, GIS, GPS, scientific calculators, software for data processing, and online social networking tools. Teachers were also trained in various project-based learning (PBL) techniques including how to act as facilitators and advisors to students as they collect and analyze information, make their own discoveries, and write reports. They were also exposed to Global Learning and Observations to Benefit the Environment (GLOBE) protocols in order to standardize data collection and reporting. The GLOBE Program is a worldwide program that provides opportunities for primary and secondary school students to learn science by being involved in practical, hands-on projects (http://globe.gov/). Students take scientifically valid environmental measurements and report them to a publicly available database. Since the data collected by GLOBE schools are reported to a worldwide science community, protocols and instruments must meet rigorous specifications to ensure the highest quality standards for data collection. Teachers were required to become members of GLOBE and were asked to supervise the submission of relevant student-collected data to the program.

**Teacher Training in Support of the H₂O Mapper Application**

As part of CCWIM, teachers received training in the Michigan Environmental Education Curriculum Support program (MEECS). This was important to their subsequent H₂O Mapper training and their understanding of how to implement this technology in the classroom. The MEECS program itself was developed by the Michigan Department of Environmental Quality (DEQ) to help schools integrate Michigan-specific economic and environmental materials into their science and social studies curriculum (MEECS 2001). The units are aligned to Michigan’s state curriculum content expectations and are aimed at grades 4–9 classrooms. The curriculum consists of five foundation environmental education concepts: ecosystems and biodiversity, land use, water quality, energy resources, and air quality.

Teacher training for the CCWIM project included a four-day summer institute in each of the two years. Participating sites were connected via live videoconference for the duration of the institutes, and with the exception of actual field work all training was jointly done. Additional professional development took place throughout the year. Teachers were paired with the Marquette/Alger and the Wayne RESA groups and encouraged to collaborate over the course of the program. The significance of two groups is that each represented teachers from one of the two peninsulas that comprise Michigan, the Upper Peninsula in the north and the Lower Peninsula in the south.

Since part of the CCWIM project involved introducing teachers to GIS and GPS technologies, the project represented an ideal situation to explore ideas about bringing
a geospatial perspective to K–12 education, but without burdening students with too many technical details about the technology. In studying about watersheds, teachers used geospatial technology to help understand the geomorphology of watersheds, their biophysical and hydrological functions, and how human land use decisions impact watersheds and their health over large geographic areas. Course participants were required to visit a site in their local watershed, collect field data, and assess the relative health and quality of a stream. They were also required to draw conclusions about the nature of upstream subsheds.

The basic question that this research sought to answer was what characteristics should a GIS possess in order to be successfully utilized in middle and high school classrooms. Based on a literature review of attempts to introduce GIS modules at the grade four level through to preservice teacher education courses (Gatrell 2004; Schacht et al. 2005; Shin 2006; Bodzin and Anastasio 2006), the following criteria were deemed necessary for such a GIS:

1. The GIS software should not appear intimidating.
2. A teacher should be able to learn the basic features of the tool in one to two hours.
3. Learning to operate the GIS software should not get in the way of using it for instructional purposes. (i.e., the purpose of a GIS lesson should not be perceived as learning how to operate a GIS software. Rather it should be seen as way to help students learn their science content.)
4. The geospatial data needed to use the GIS (vector and raster layers) should be preprocessed and included as part of the GIS.
5. Technical and administrative support should be available as teachers begin to explore using GIS for classroom instructions.

The H2O Mapper

Generic, off-the-shelf desktop GIS software with their myriad functions typically exceed the needs and capabilities of most K–12 teachers and students. Although this type of software is widely available, the intention of this project was not simply to place an off-the-shelf GIS into the hands of teachers and hope they master it. Rather, the intention was to develop a customized Web-based GIS application that had only a few key, desired functions. This would make the software less intimidating, more user-friendly, and reduce software-learning time. Additionally, developing a custom application that ran on the Internet meant that the purchase of expensive GIS software was not a requirement to access the tool. Students could access the software twenty-four hours a day and could utilize their spare time to learn additional details about the software.

The Web-based GIS application that was developed under the CCWIM project was named the H2OMapper. Its main goal was to provide an online map-based environment for storing data on water quality, terrain, and land use for different watersheds in Michigan. By recording the locations where water quality samples were taken and then storing the attributes of water quality associated with those point locations, a profile of water quality in the watershed can be created over space and time. The terrain, land use, and other data provide contextual information and allow students to relate the water quality findings to the natural and human use of the watersheds. The application intentionally does not contain statistical modules for analyzing water quality data or to relate the water quality data to terrain and land use patterns. This is due to the fact that the emphasis, at this stage, is on using GIS technology for data collection, data visualization, and for encouraging spatial thinking by generating hypothesis about the relationship between water quality, geomorphology, and land use within watersheds. Specifically, students at varying grade levels could do the following with the Web application:

Grade 7.

- Create point features (markers) on the map to record the locations of observations
- Input text and numeric attribute data about the observations into the application’s database
- Upload images and video about the observations into the database
- Query the GIS layers to answer basic geomorphology and land use/land cover questions about their watershed

Grade 8.

- Perform all of the skills required for grade 7
- Examine temporal changes in land use and cover in their watershed
- Develop hypotheses and questions regarding the relationship between water quality findings and the information gleaned from the GIS layers
- View observations from other watersheds, compare findings, and generate questions based on those comparisons

Grade 9.

- Perform all the skills required for grades 7 and 8
- Compare observations from multiple locations in the same watercourse
- Compare observations from multiple years
- Export observation data, maps, and images for reports and presentations
- Successfully navigate and use online GIS and database, helping to meet requirements that exist in the state curriculum

Application Development

The Institute of Geospatial Research in Education (IGRE) at Eastern Michigan University was contracted to develop the Web application. After carefully evaluating various
options, a decision was made to develop the application using open-source software. The main factor driving this decision was cost. Whereas the upfront cost of development was higher using open-source tools, the long-term costs were lower because proprietary licensing fees required by commercial GIS server packages were avoided. Due to the scale of their project, educators involved with the CCWIM project elected to hire professional GIS programmers to develop their custom GIS. However, it should be noted that for teachers interested in developing a GIS with much smaller scope, hiring professional developers is not a requirement for successful GIS implementation. For small-scale projects that have simple data visualization and spatial analytical requirements, teachers can freely download and use available Web-based GIS software such as ESRI’s ArcGIS Explorer Online. This software does not have licensing requirements for educational users and can be used without programming skills for developing high-quality GIS lesson plans.

IGRE recommended a PostgreSQL/PostGIS spatial database solution with MapServer being used for geovisualization and spatial analysis. PostgreSQL is an open-source, robust, object-relational database management system (http://www.postgresql.org/). It uses PostGIS (http://postgis.refractions.net/), an extension to PostgreSQL to add spatial data handling capability to the database software. MapServer (http://mapserver.org/) is an open-source Web-mapping server that publishes spatial data in the form of interactive maps. IGRE worked closely with Wayne RESA for several months to develop the prototype program. During application development, a close working relationship was maintained between IGRE technicians and educators from Wayne RESA and this proved to be the single most crucial element for successful application development. Educators from Wayne RESA provided the initial interface design as well as constant feedback about the usability of the GIS tools throughout application development. These interactions were particularly helpful to the IGRE programmers as they provided for early identification and resolution to a range of unanticipated problems. The result of these efforts was the H₂OMapper (http://h2omapper.resa.net/pmapper/map.phtml) (Fig. 1). H₂OMapper runs within standard Web browsers such as Internet Explorer, Mozilla Firefox, and Safari. The application allows students and teachers to post water-related data and explore their watersheds through a simple set of GIS tools.

The main interface of the H₂OMapper consists of a collection of panels. These numbered panels, shown in Figure 1, are described below:

**Figure 1.** User interface of the H₂OMapper.
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Figure 2. Data entry form for physical and chemical measurements.

1. Log On window—Users with accounts can log into the system to create observation records and edit their data.
2. Title Bar / Watershed Selector—Users can jump directly to the extent of a watershed by selecting it from this drop down list.
3. Map window—This is the area where users can interact with geospatial data layers. A set of tools to the right side of this window allows users to manipulate and query the map layers.
4. Map Layers panel—Often referred to as the Table of Contents, this is where users can control the visibility of map layers.
5. Map Locator—Displays an overview of the map and the current visible extent (view).
6. Footer bar / X,Y Coordinates—Displays longitude and latitude of the cursor.
7. Observation panel—Student-generated content is entered and viewed here.
   a. Data entry / Selection—Generate and view new observation records. This area allows users to enter new records, or use the filter tool to select existing observation records for viewing.
   b. Multimedia window—Students can view and upload images and videos collected during their in situ observations.

The core of the H2OMapper is its database module and its data visualization module. Each of these modules is described below.

The Database Module

The database module is used to store observation data collected by students during field visits to their study sites. The module contains four sections and separate data entry forms are used to enter data into each section. Data stored in the database can be retrieved using Structured Query Language (SQL). The four sections are:

(i) The Physical/Chemical Measurements section, which stores data from stream sampling such as dissolved oxygen, total phosphates, nitrites, total dissolved solids, etc. (Fig. 2). The physical and chemical attributes listed above were drawn from the MEECS water quality program, while data input was guided by GLOBE protocols.

(ii) The Physical Characteristics of Stream section, which stores data about students’ observations of stream morphology. Observations can be supported with photographs and video in the multimedia area. An illustration of the data entry form is shown in Figure 3. The physical characteristics, classes, and ratings were based on the MEECS water quality guidelines.

(iii) The Macroinvertebrate Counts section, which provides three weighted groupings for species, with two ratings per group:
   1. Pollution Sensitive: Rare (<11) = 5.0, Common (≥ 11) = 5.3
   2. Somewhat Pollution Sensitive: Rare (<11) = 3.0, Common (≥ 11) = 3.2
   3. Pollution Tolerant: Rare (<11) = 1.0, Common (≥ 11) = 1.1

   When the counts are entered, the application tallies the scores and issues an overall biological assessment score. The groupings and ratings used in this section were based on the MEECS benthic macro invertebrate field sampling worksheets (Fig. 4).

(iv) The General Questions section. This section stores students’ observations about the basic physical characteristics of the hydrological unit (e.g., total area, contributing subsheds, soil types, and stream characteristics), as well as land use and land cover characteristics, through examining the geospatial map layers. Students must query the map layers and provide answers to existing questions (Fig. 5). The questions were...
generated from concepts presented throughout the MEECS water quality unit.

**DATA ENTRY**

Once a user establishes an account, the user can create and edit observation records following metadata standards provided by GLOBE protocols. When an observation is created, either through adding an observation point on the map or through the data entry fields, an observation ID number is generated. A user may enter field and lab data into the observation record, use the mapping tool to study their watershed further, or add notes, images, and video related to the observation. All of the data entered for an observation remains linked to the observation ID, which, in turn, is linked to the user who created the record. To preserve data integrity, only the creator of an observation record has rights to edit that record. When the data is posted it becomes public for viewing purposes. Students can compare the results in their watershed to other watersheds in geographically distant areas. Teachers can also upload content to the database.

Individual responsible for observation data, imagery, video, and notes posted by their students. The system administrator is responsible for reviewing all multimedia files for inappropriate content prior to final posting. This provides a layer of scrutiny to all posted materials. After the system has been in operation for six months to a year we will review the procedure. Only registered users can create or edit observation data, and only the teacher or student that created an observation record can edit that observation. We defined five levels of users:

1. Administrators—full rights to manage accounts and data.
2. Teachers—create student and team accounts, create and edit observations, upload media.
3. Students—create and edit observations.
4. Teams—create and edit observations.
5. Public—read only observations.

(All users would be able to access the mapping tool and perform queries.)

**Datasets**

The primary dataset required for the application was water quality data. Since the Michigan Environmental Education Curriculum Support (MEECS) Water Quality Unit for grades 6–8 was selected as one of the core training modules for the CCWIM project, the schools are field data requirements for these units were used for the application. By using the MEECS dataset, the utility of the Web GIS application was extended to schools that did not participate in the program but still wanted to utilize the application for their own watershed units. Also, by employing GLOBE protocols to guide data collection, students are
able to create and share data that can be used by others in the worldwide GLOBE community, by their CCWIM peers, and by others using the H2OMapper in the future. The Physical/Chemical measurements dataset in particular relied heavily on GLOBE protocols for sampling and testing. Point location data were also collected using Garmin consumer grade GPS units. GLOBE GPS protocol was used in collecting location data.

In addition to the water quality data, map layers were also required to provide context for the various watersheds. These datasets included:

- County lines
- Human features (e.g., roads, railroads, cities)
- Hydrological features (e.g., lakes, rivers and streams; base flow; wetlands; aquifers; watershed boundaries)
- Landscape features (e.g., soils, land systems)
- Land use/land cover (multiple years)
- Digital Elevation Model (for a background hill shade)

The datasets were obtained from the Michigan Geographic Data Library (MGDL) at the Michigan Center for Geographic Information. The map layers were downloaded and geoprocessed outside of the Web application. This was done deliberately so that users did not have to be burdened at this stage with knowing the details of geoprocessing spatial data, which is a time consuming and very technical task.

**The Data Visualization Module**

This module contains an area for viewing map layers associated with the various watersheds (Fig. 6). These layers include county boundaries, roads, cities, lakes, rivers and streams, wetlands, and land use, among others. The locations where sampling of watershed parameters was conducted are also displayed as a separate layer. An inset map at the bottom left of the screen helps the user to know where in Michigan the larger map is currently focused. Windows for viewing output from spatial and attribute queries, tabular data, and multimedia content are also available.

**Using the H2OMapper**

Initial training on the H2OMapper occurred in June 2009 during the four-day summer institute that marked the beginning of the second year of the CCWIM project. As with the first year, training occurred at Wayne RESA for southern Michigan teachers, and at Marquette/Alger RESA for teachers in the Upper Peninsula of Michigan. The two sites were linked together via video-conferencing for the entire four days. Teachers came together to share experiences, review what they had learned during the training, and prepare for their first data collection, which began in July 2009.

![Figure 6. The data visualization module.](image-url)
first year, and develop additional pedagogy and technical skills.

During the course of the institute, teachers received training in GIS concepts and on GPS usage and protocols. The H₂O Mapper was introduced on the fourth day. Teachers benefitted from demonstrations of the user interface and features, user account and observation record creation, observation dataset population, and working with the map layers and tools. After the demonstration period, teachers went into the field and collected sample data using the scientific instruments and techniques on which they had been trained. GPS data points were collected as part of this effort. The group from the Marquette/Alger region collected their data from a local stream, and the group from Wayne County collected their data from a pond on the Wayne RESA campus. Teachers returned to the training centers and practiced creating a new observation record, entering observation data into the database, and using the map layers to try to answer the location based questions in the database. A sample lesson for using the H₂O Mapper is presented in Appendix 1.

Teacher responses during the training were generally positive. Many expressed enthusiasm at the prospect of having the tool available for the coming year. The GIS solution for storing the students’ data so that the dataset could be used in future classes received many positive responses, as did the mapping tool. Actual use in the classrooms did not begin until fall 2009. During the interim period a user guide for the H₂O Mapper was written and made available through the Help menu. Individual school districts have scheduled their watershed units for different times of the year, with many waiting until spring to do their data collection. The teachers who posted data in the fall were very helpful in providing feedback, and several improvements were made to the application including interface changes, layer optimization for performance, bug fixes, database field modifications, and the development of a user guide. Future modifications will include:

- A new orthoimagery base layer to provide an enhanced sense of place, and for additional visual interpretation. The abstract nature of the vector layers and classified raster layers did not provide enough information for the students to establish the relationship between land use and their water quality observations. Imagery provided the context to make the vector-based layers more meaningful.
- New land use and land cover layers from 1996 to 2006.
- Additional tools for creating buffers and selections.
- Implementation of tiling for large datasets to increase performance.
- Metadata links to the layers in the table of contents.
- Enhanced reporting functions.
- Changes in user rights to allow teachers to directly modify the multimedia postings and add an interface for them to create new groups.
- Embedded links to short instructional video clips in the various utilities that comprise the H₂O Mapper.

**DISCUSSION**

The H₂O Mapper was received positively in the training sessions during the 2009 CCWIM summer institute. Teachers were able to easily interact with the tool and perform the basic functions necessary to use it in the classroom. Several expressed a need for additional practice and support when the time to implement the tool in their classrooms grew closer. It remains to be seen how utilization will play out as students complete their watershed studies. However, judging from utilization practices among the teachers themselves, the goal of incorporating GIS into the curriculum with a small learning curve was achieved.

The decision to utilize a custom GIS contributed significantly to the success of the project because only desired functionalities were included in the final application. This meant that teachers were not intimidated by the presence of a wide range of GIS functionalities, most of which are not used at the K–12 level (Fitzpatrick and McGuire 2001), and were able to focus only on desired tools. Undoubtedly, the use of custom GIS flattened the learning curve considerably and made working with the GIS an easy task. We suggest that attempts to incorporate GIS technology into the K–12 curricula should pay serious attention to creating and using a custom GIS. Customization makes geographic information systems user-friendly. Grade K–12 appropriate GIS tasks can then be carried out at the basic level through to intermediate and advanced levels with no need for programming or advanced geospatial analysis skills. For basic customization, many GIS applications allow for the removal of unneeded functionalities without even writing a single line of code. This means that lessons can be developed around existing functionalities within the GIS; unneeded buttons, menus, and tools that complicate the GIS interface can be removed for the purpose of the lesson.

For advanced customization, such as those in the H₂O Mapper, a group of teachers can collaborate to seek grants to finance the programming of custom modules, which can then be made available to schools throughout a county, a state, or even at the national level, either for free or at minimal cost. In situations where resources do not exist to sponsor the development of a custom Web GIS application, teachers could consider developing lessons using ArcGIS Explorer Online. This lightweight Web GIS software has an uncomplicated interface, a relatively flat learning curve, and allows access to ready-to-use GIS base maps and layers. Moreover, users can easily use their own data with this software or they can use the large quantity of preprocessed datasets that ESRI has made available for use online.

We derived many benefits from developing a customized Web-based GIS. First, we avoided the need to ask local school districts to install GIS software on their computers, which is often a key stumbling block in classroom technology initiatives. Classroom computers are often...
out-of-date and cannot run current versions of GIS software. Second, because the Web GIS application is browser-based, teachers took advantage of their knowledge of browsers and quickly mastered the GIS functionalities. The GIS learning curve was thus flattened considerably. Third, the Internet made it possible to easily share GIS data over broad geographic areas, and allowed teachers to work in a collaborative manner. Fourth, the Web GIS application turned out to be a relatively inexpensive way to put customized GIS software into the hands of a large number of users from different school districts. For this project, the single Web application could potentially serve all school districts in Michigan, limited only by the size of database storage capacity.

The benefits of using a Web mapping application to circumvent some of the problems associated with GIS adoption at the K–12 level have been recognized and documented in the GIS education literature (Cheung and Brown 2001; Baker 2005; Bodzin and Anastasio; 2006). However, as Web mapping servers such as MapServer and Web mapping applications such as Google Map and Bing Map become more powerful, easier to program, and more accessible, it may be time to consider supporting Web-based GIS as one of the more important strategies for promoting GIS at the K–12 level. Web-based GIS applications can be developed not only for earth science-related topics but also for other areas of geography including historical, social, and economic geography. These applications can also be easily extended to other disciplines. For example, if there is a disease outbreak such as the H1N1 virus, social studies teachers can quickly show students how to use their Google accounts to gain access to a Google Map API key and then use already developed tutorials and easily accessible data to create markers to show locations where the disease occurred at national, state, or local levels. By studying the spatial patterns of the disease, students can develop their spatial thinking capacity by hypothesizing about the linkage between the disease pattern and geographical, environmental, or other features.

Another important lesson learned from this project was the need to work with preprocessed GIS data. Since GIS datasets are often difficult to work with, working with preprocessed data significantly reduced the time needed to complete lessons.

Due to the level of customization required for the Web application, H2OMapper, a professional GIS consulting company was hired to develop the application. For large Web mapping applications such as the H2OMapper, we suggest that application development be placed into the hands of professional GIS developers. We also suggest that GIS educators work closely with the application developers to provide guidance and feedback at every stage of the process.

Overall, the Web mapping application met our requirements for having utility and relevance to the user. For example, it supported a course of study the students were already engaged in; it had utility for the teacher in providing a way to manage student data; and the students could have the experience of interacting with spatial data in a way that is meaningful and relevant to their needs without having to understand the workings of a GIS software package.

**CONCLUSION**

The importance of spatial thinking and the potential of GIS to aid in its development continue to gain recognition. There are many approaches to incorporating geospatial tools into schools, and teachers and learners will respond to them according to their individual teaching and learning styles.

The H2OMapper is an attempt to introduce a minimalist Web-based GIS into classroom instruction as a way to address some of the problems associated with implementing GIS at the K–12 level. At this stage we are reasonably satisfied with the design and usage of the Web mapping application created. Some of the modifications mentioned earlier will improve its effectiveness and make H2OMapper more appealing to the teachers and students for whom it was designed. Also, the use of open-source solutions is an economical approach to application development especially in cost restricted environments. With more feedback and a willingness to modify the H2OMapper based upon this input, the application can serve as a model for GIS implementation at the K–12 level.

**NOTE**

1. CCWIM received funding and support from the DART Foundation, Marquette-Alger RESA, Michigan Department of Education, the REMC Association of Michigan, Seaborg Math and Science Center, Wayne County Math and Science Center, and Wayne RESA. The H2OMapper received additional funding from the Buck Institute for Education.

**APPENDIX: SAMPLE LESSON FOR GRADE 8**

**LESSON TITLE**

Land cover, land use and physical characteristics of a watershed, and local stream health: What’s the link?

**OVERVIEW**

Students will conduct an investigation into the health of their local watershed as part of a unit on water quality. Students will visit a local stream to make in situ observations and measurements of various indicators of stream health. They will also make assessments of land cover and land use characteristics of their watershed, soils, and other physical features of their watershed using an online GIS, the H2OMapper. Students will record their observations in an online database to share with other classrooms engaged in similar studies, and compare their observations with records from other classrooms. Students will assess the health of the local stream and generate hypotheses as to...
the relationship between the stream and land cover/land use characteristics.

CONNECTIONS TO MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM
The following Michigan Environmental Education Curriculum Support (MEECS) Water Quality Units are related to this lesson:

- Do You Know Your Watershed?
- How Do Land Uses Affect Water Quality?
- How Healthy Is This Stream?

CONNECTIONS TO MICHIGAN MIDDLE SCHOOL EARTH SCIENCE CONTENT EXPECTATION
- E.ES.M.8 Explain the water cycle—describe how water circulates through the four spheres of the Earth in what is known as the “water cycle”
- E.ES.07.82 Analyze the flow of water between the components of a watershed, including surface features (lakes, streams, rivers, wetlands) and groundwater.
- E.ES.07.41 Explain how human activities (surface mining, deforestation, overpopulation, construction and urban development, farming, dams, landfills, and restoring natural areas) change the surface of the Earth and affect the survival of organisms.

CONNECTIONS TO THE NATIONAL GEOGRAPHY STANDARDS
- Standard 7: The physical processes that shape the patterns of Earth’s surface.
- Standard 8: The characteristics and spatial distribution of ecosystems on Earth’s surface.
- Standard 14: How human actions modify the physical environment.
- Standard 15: How physical systems affect human systems.
- Standard 16: The changes that occur in the meaning, use, distribution, and importance of resources.

TIME
Three to four hours

MATERIALS NEEDED
- GPS receivers
- Water quality testing kit
- Access to computers connected to the Internet
- Create/Edit records privileges on the H2OMapper

OBJECTIVES
- Students will work in teams to produce an assessment of the health of their local watershed.
- Students will demonstrate understanding of basic scientific (GLOBE) protocols during collection and analysis of physical, chemical, and biological indicators of stream health both on-site and in the lab.
- Students will use an online GIS, the H2OMapper, to evaluate characteristics of their watershed and stream, and factors contributing to stream health such as land use and land cover, impervious surface, soil type, etc.
- Students will post their observation results to the H2OMapper, so that classrooms in remote watersheds may use them (or for future observations in the same watershed).
- Students will generate a hypothesis as to the relationship between land use, land cover (including soils and impervious surface), and the overall health of their stream as observed at their sample points.

GEOGRAPHIC SKILLS
Recording geographic data, visualizing geographic data, generating hypothesis

SUGGESTED PROCEDURE
Opening
The lessons “How Do Land Uses Affect Water Quality?” and “How Healthy is this Stream” in the MEECS Water Quality unit will serve as the primary introductory resource for this lesson. Teacher will review basic watershed concepts, including hydrology, physical and chemical characteristics of streams, benthic macro invertebrates and stream health, and land use and land cover impacts on overall stream health.

Teacher will also review GLOBE data collection protocols for the following areas: GPS, water transparency, water temperature, dissolved oxygen, electrical conductivity, salinity, pH levels, nitrates, and freshwater macroinvertebrates.

Development
Water Quality Data Recording. Students will visit a local stream to collect indicator data from at least one sample point using the GLOBE protocols listed above. Teamwork is emphasized, so students will be divided into teams for data collection.

Once teams have completed their data collection they will login to the H2OMapper and create a new observation record. (Instructions for this can be found in the H2OMapper User Guide, accessible from the Help menu).

Students will enter their observation data into the database in the first three sections Physical/Chemical Measurements, Physical Characteristics, and Macroinvertebrate Counts, following procedures outlined in the H2OMapper User Guide.

Water Quality Data Analysis. Students will compare their observed data values against water quality standards described in MEECS Water Quality unit to formulate views on the water quality of the streams they are investigating.
Map Queries. The fourth data entry section, General Questions, refers to information that may be obtained from manipulating the H2OMapper geospatial layers. Students have to query these map layers to answer the questions, below. Information for performing the map queries is contained in the H2OMapper User Guide. Students are also encouraged to generate their own questions based on the GIS layers.

- What is the total area of their watershed?
- What is the total area of the subsheds contributing to the stream at the sample point?
- What is the major land use type in the contributing subsheds?
- Approximately what percentage is developed? Agricultural land? Undeveloped/forest? Wetland?
- What is/are the predominant soil type(s) in the watershed? In the contributing subsheds?
- What is/are the predominant land cover type(s) in the watershed today? In the contributing subsheds?
- What was/were the predominant land cover type(s) in the watershed c.1978? In the contributing subsheds?
- What was/were the predominant land cover type(s) in the watershed c.1800? In the contributing subsheds?
- Describe the stream type at the sample point, (headwaters, major tributary, main channel).
- What is the base flow of the sampled stream segment?
- What is the direction of stream flow at the sample point?

Hypotheses Generation. Having explored the larger context of their watershed via the GIS query tools, students will generate hypotheses about the relationship between their in situ observations and human and natural characteristics of the greater watershed.

Closing
Have each group present its findings to the class.

Suggested Student Assessment
Students’ work will be assessed based on the level of completion and reliability of data entered in the database and the quality of their hypotheses.

Extending the Lesson
Students can conduct research into the history of their local watershed including land use and population changes, using materials gathered from the local library, local government agencies, or watershed councils, etc. to develop a more longitudinal knowledge of land use changes within the watershed. This will help them later on to generate better proposals for watershed management.

REFERENCES


Paul Henry and Hugh Semple


