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ABSTRACT
         This paper describes the development of a prototypic,
Web-accessible GIS solution for K-12 science education and citizen-based
watershed monitoring. The server side consists of ArcView IMS running on an
NT workstation. The client is built around MapCafe. The client interface,
which runs through a standard Web browser, supports standard MapCafe calls to
the server and also the uploading and viewing of "shape" or georeferenced
spreadsheet data. Preliminary supporting tutorials and classroom materials
are in development. The key features of the tool, the approach to design and
prototyping, plans for further development of MAP-IT! and its integration
into the middle and high school science curriculum are discussed.
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Map-IT! A Web-Based GIS Tool for Watershed Science Education

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Map-IT! A Web-based GIS Tool for Watershed Science Education
(Paper # 449)

Abstract

We have developed a prototypic, web-accessible GIS solution for K-12 science education and citizen-based watershed monitoring. The server side consists of ArcView and ArcView IMS running on an NT workstation. The client is built around MapCafe. The client interface, which runs through a standard web browser, supports standard MapCafe calls to the server, and also uploading and viewing of "shape" or georeferenced spreadsheet data. Preliminary supporting tutorials and classroom materials are in development. In this paper we will present the tool's key features, describe our approach to design and prototyping, and outline plans for further development of Map-IT! and its integration into the middle and high school science curriculum.

Introduction

In the technology-intensive society of the next century, K-12 science educators will be charged not only with preparing tomorrow's scientists and technologists; they will also be expected to foster an educated citizenry that is capable of weighing the potential benefits and limitations of new technologies and discoveries, and making informed decisions about their lives and communities (1). In support of this broader vision, evolving standards (2,3,4,5) for K-12 science and mathematics education have emphasized student-centered, engaged learning and problem-solving, as distinct from more traditional, teacher-centered approaches to instruction and learning (6,7).

A number of research studies suggest that GIS has considerable potential to promote K-12, inquiry-driven, interdisciplinary, project-based learning (8, 9) spanning local to global issues, particularly those focused on understanding and conserving the environment (10). However, other studies have identified several barriers to widespread adoption of GIS at the K-12 level. These include: 1) a shortage of exemplary curriculum incorporating GIS (11); 2) insufficient resources for pre-service training and professional development (8,9); 3) cognitive challenges, such as linking electronic map representations to the real world, or progressing from simple mapping to spatial analysis (12); 4) technical hurdles of learning the software; 5) access to data that can be readily viewed and analyzed or added to without the need for prior processing) (13); and 6) institutional forces that can limit (or promote) the adoption of GIS technology (22).

With regard to 4), some researchers have contended that neither interface problems nor technical difficulty should necessarily impede GIS diffusion in K-12 education (11). Others, though, have argued that it is desirable, even necessary, to simplify the interface and constrain the range of functions available to learners, while also maintaining the power of the software to support open-ended inquiry (13). With respect to 5), though federal, state and local agencies are making spatial data readily available via the Internet (14), such data is often not accessible to novice learners.

Such spatial data is available but in varying formats and map projections that complicate viewing, overlaying and analysis. Map creation, viewing and analysis requires installing and running GIS software such as ArcView or ArcExplorer on every user's machine and/or local area network server.

Emerging, web-based, GIS-related technologies have the potential to overcome barriers 4 and 5 (15). These client/server applications can be customized to support a variety of functions appropriate to learners, including spatial data access and entry, map generation, simple query and data sharing through easy-to-use interfaces and without the need to install and run GIS software on every desktop. This paper reports on Map-IT!, a proof-of-concept, web-based GIS application (16). Map-IT!, which is based on GIS and Internet server software created and marketed by Environmental Systems Research Institute, Inc.(ESRI), was developed primarily with and for local area middle and high school learners and educators. Below we describe and discuss our overall design methodology, salient features of an initial prototype, preliminary usability data, and plans for further development.

Design Methodology and Objectives

In prototyping Map-IT!, our overall goal was to design and develop a user-friendly, prototype, web-based GIS viewer to support watershed science education and natural resource planning and management. Our intended audiences included middle and high school educators and students and local or regional resource managers. From the inception of the project in August 1997, through the completion of a working prototype, we sought to establish a consultative design process with target users. To this end, we established a small, local area testbed. Participants were recruited not only from local area teachers (Champaign, Urbana, Mahomet, and Villa Grove school districts) but also from among local resource management offices (USDA/National Resources Conservation Service; Champaign Soil and Water Conservation and Forest Preserve Districts).

During the project year, participants were invited to four focus groups to help guide the development of a working prototype and its subsequent refinements. Attendance varied from six to more than a dozen participants, mostly teachers. At an initial focus group we demonstrated what GIS is and what it can do, using ArcView. (Two participating resource managers were quite familiar with GIS basics. Not so for most of the teachers.) In tandem with these demonstrations, informal input was solicited as to the baseline GIS software functionality desirable for effective integration into the classroom. Early on it became clear that in order to develop a useful prototype, we would need to customize both functionality and interface to meet the needs of a more tightly defined audience. Based on an initial, "front-end" needs assessment, we chose to target our prototyping effort toward middle and high school educators and their students rather than resource planners and managers. The project's driving questions were as follows. What is the optimum number of functions required in a web-based GIS tool to facilitate adoption of GIS in the classroom? How and to what extent could such an application facilitate effective use of GIS in the classroom? What activities would constitute effective use?

In verbal and written feedback during the initial focus sessions, the participating teachers indicated a desire for the following features: dynamic map generation, viewing and simple query; printing and export of map views to disk for further image editing or processing; uploading and viewing of pre-existing datasets (in shapefile format), as well as of point data from field investigations; and remote user account and project set up capabilities.

Once we had an initial grasp of which functions to include in Map-IT!, programming commenced. Subsequent focus groups led to further refinements of the tool. Map-IT! was developed around the following elements. On the client side, ESRI's MapCafe Java applet provided the foundation around which "wrapper code" was scripted in Java for user and project administration. On the server side, ArcView 3.0, Avenue scripts were written to control how the ArcView Internet Map Server 1.0 mediates calls from the web client to the application, specifically to enable dynamic loading of map views from saved project files. Additional software was scripted in Java to handle requests from the "wrapper" code, such as saving projects or creating directories. Also developed was a script to automatically convert delimited text files (generated by field studies containing latitude and longitude readings) into POINT shape files for use in student projects. Key features of the most recent version of Map-IT! are described next.
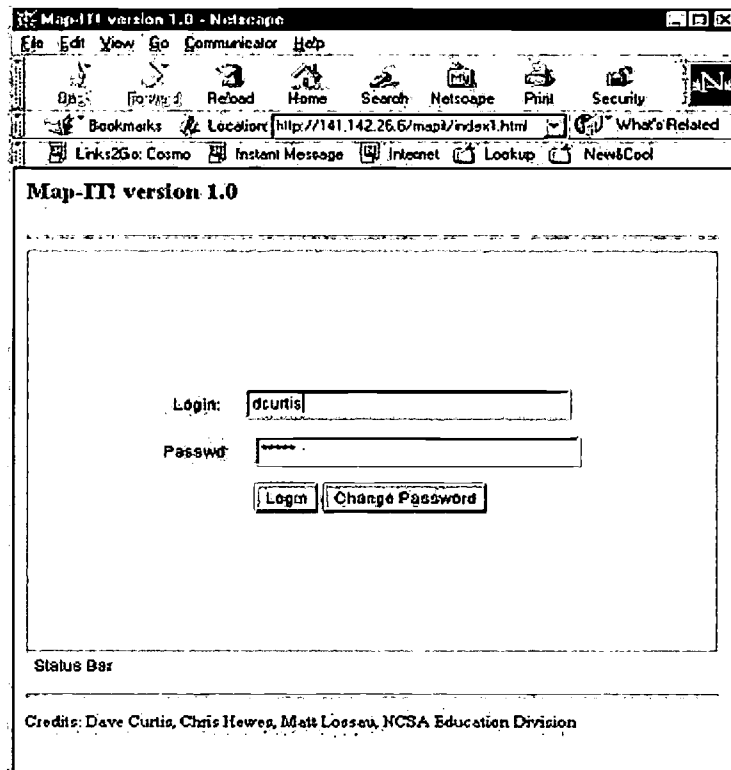
Products

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1. The Application

The client applet can be run within a standard web browser (Netscape 3.0 or Internet Explorer 3.02 or higher). The client interface has three components: Users, Files, Viewer.
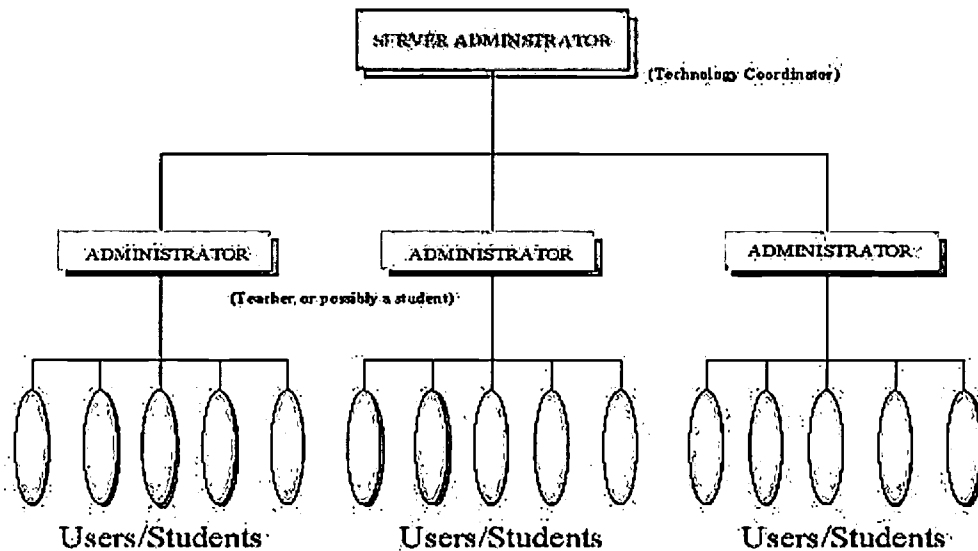
a) Users

First, the student-user is invited to login with a user ID and password.

Fig 1 User Login

The present prototype incorporates a hierarchical structure for remote session management.

Fig .2 Session Management Hierarchy

Only server administrators can create directories, whereas teacher-administrators can upload data to these directories, once they are set up. In contrast, users (typically students, but possibly teachers) are limited to manipulating pointers (aliases or shortcuts) to the data within their own "projects"; they

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cannot alter or add actual data on the server. A teacher-administrator sets up user accounts and passwords in coordination with the server administrator (a technology coordinator, for instance).

Once logged in (see Fig. 4), users can create, modify and delete their own Map-IT! projects (which correspond to ArcView projects) but not those of other users. The teacher can create, modify and delete student projects, set up user accounts, and upload or delete data to and from the project directories. However, the teacher-administrator cannot create or alter the Public Data directories – those containing a default set of datasets gathered from third party sources (e.g., state boundaries, national highways, wetlands, streams, floodzones, contours, etc.), against which students can overlay datasets when viewing their individual projects (see c below). Only the server-administrator can set up and alter the Public Data directories, as well as perform all the functions available to the teacher-administrator and student-user. Fig. 3 shows the corresponding hierarchy of directories on the server side. Fig. 4 shows how user "accounts" are created or removed on the client side.

Fig. 3 Map-IT! Directory Tree
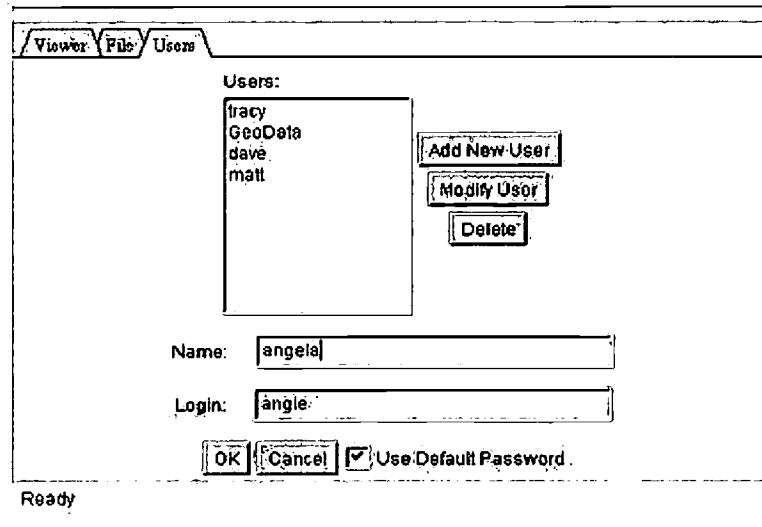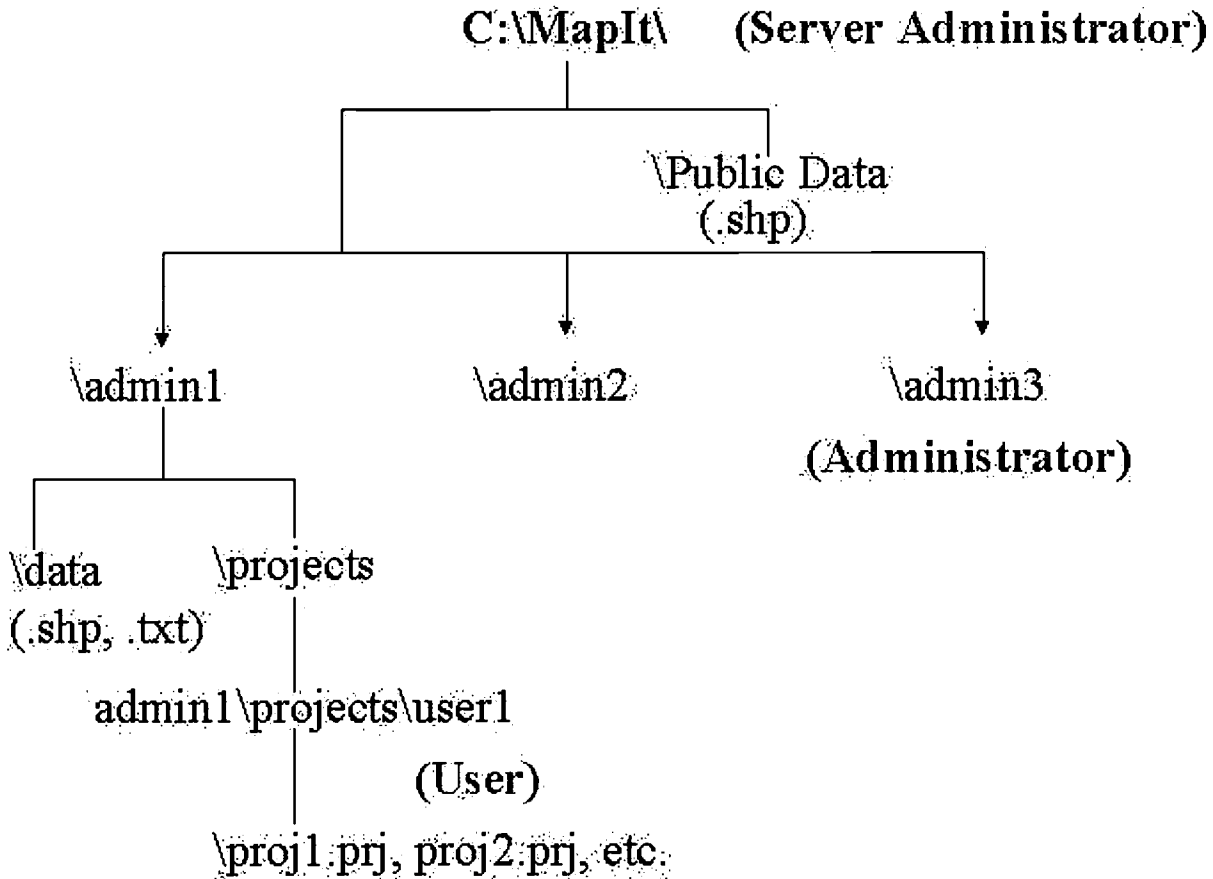
b) Files

Fig. 5 Public Data and Projects
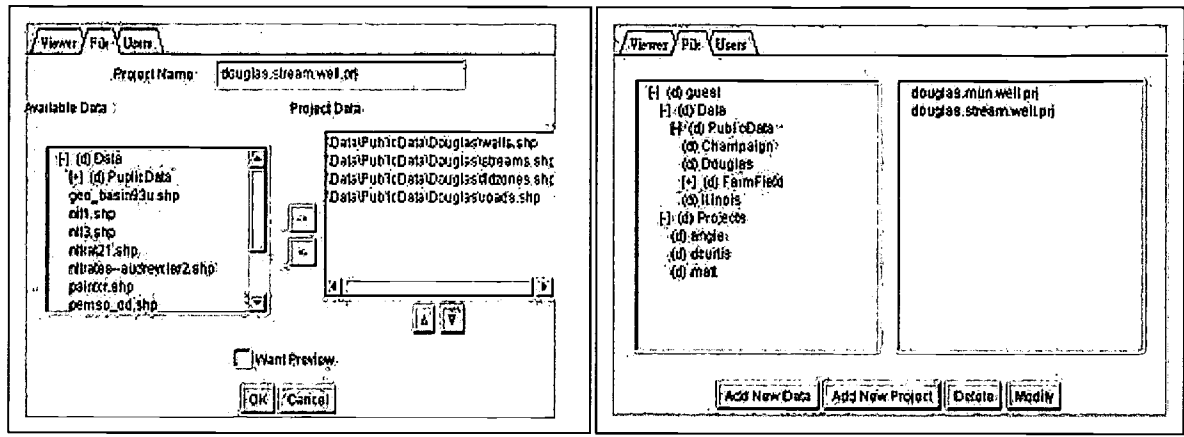
There are two types of directories. One, Public Data, consists of directories on the server that house various datasets acquired by the teacher and installed by the server administrator to support specific student activities. The other, Projects, are created or modified by student-users. Students can select and import data "layers" or "themes" from the Public Data directories, then manipulate the order to emphasize various spatial relationships when overlaid in the viewer. Just as in ArcView, projects only index the underlying data files rather than incorporate them directly. Student-users cannot inadvertently delete the Public Data. In addition, users (teachers or students) can upload their own data, which can either take the form of acquired shape files or spreadsheets saved as comma delimited text files. Such spreadsheets, which would typically be generated from data gathering activities in the field, would include a list of attributes, for instance environmental variables such as soil acidity, water quality indicators, species type or frequency, and longitude and latitude for those attributes. Data assembly is discussed in more detail below.
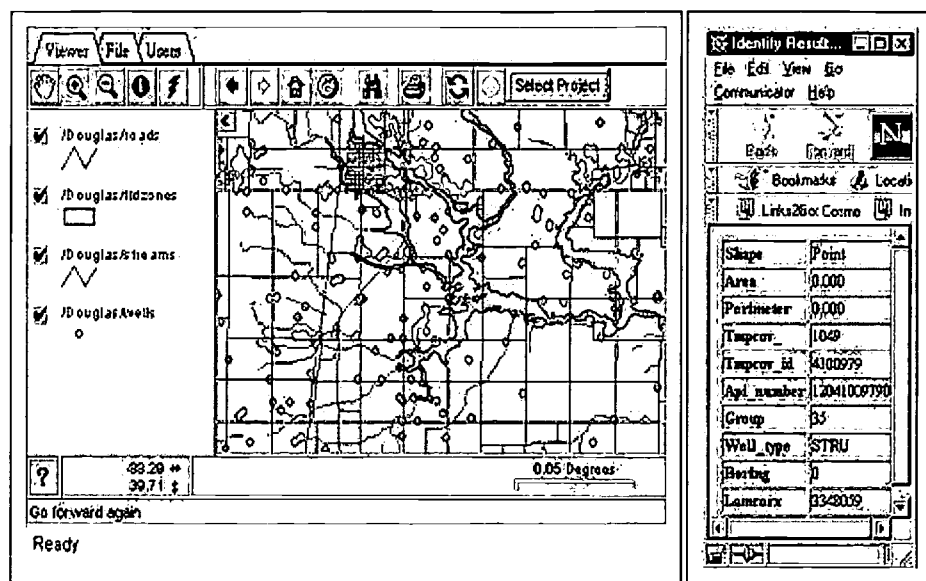
Fig. 6 Uploading Data
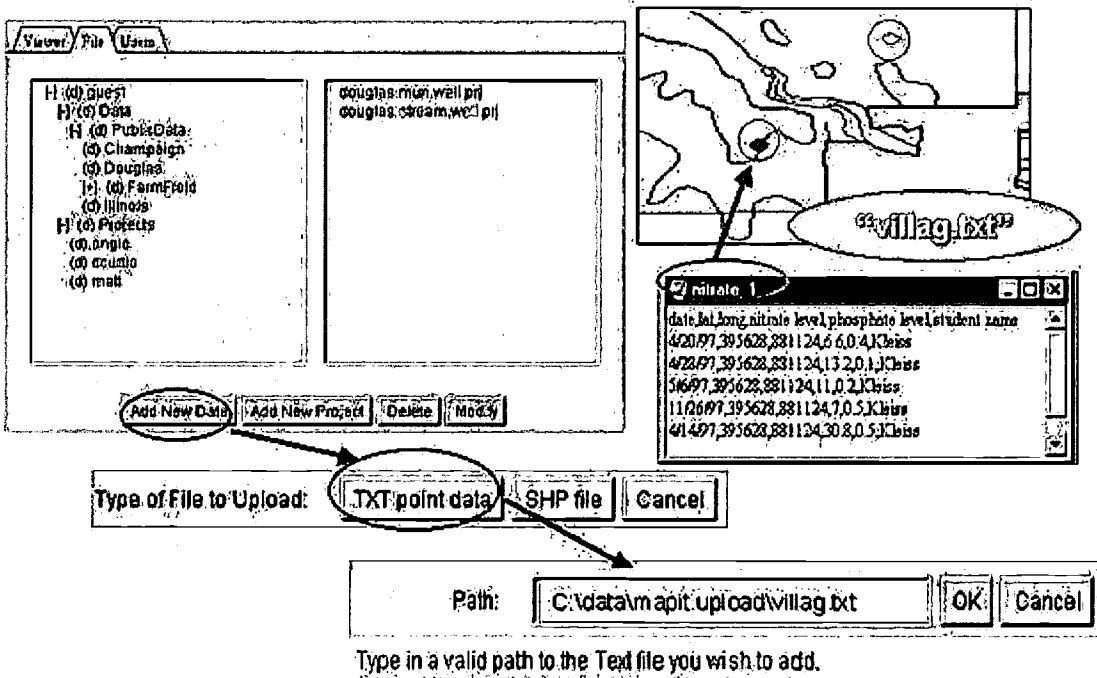
Once the filepath (to the directory on the client computer) is entered, the data can be uploaded, whereupon it is converted automatically at the server side into a point .shp file. It can then be added to a project for viewing with other data files.

c) The Viewer

Fig. 7 Viewer Functions

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Maps are viewed as images created dynamically by ArcView running on the server, and returning the resulting JPEG files to the client applet for display through the browser. In the present version, the viewer features the following standard MapCafe Java applet features: project selection, zoom, zoom to full extent, pan, previous/next map, refresh map, and turn layers on/off. Map-IT! also supports simple query capabilities included in the MapCafe API: a find feature capability, which queries the attribute data and displays the corresponding feature on the map; and an "identify" feature, which brings up the attribute data corresponding to the selected feature. In addition, once a project is created, it can be previewed directly in the viewer, thus facilitating experimentation with overlays to infer spatial relationships. Coordinates in decimal degrees appear below the viewer. A scale bar indicates distances, also in decimal degrees.

Using the print function within the client interface itself (as distinct from the browser), the map images can be saved to disk for further processing and incorporation into other documents, including web pages, or outputted to hard copy. Thus, Map-IT! enables students to add data, create their own maps and communicate the results of their investigations. Peers, teachers or parents can also assess these same products.

2. Datasets

During the course of the project, we assembled a wide variety of Public Data spanning national, statewide and local scales. We added some of this data in response to requests by the participating teachers themselves. Acquisition of exemplary datasets was essential to solicit their design input. Shape data incorporated on the server now includes: countrywide states, lakes, and rivers; Illinois counties, municipal boundaries, highways, roads, census tracts, quaternary geology, state forests and parks, wetlands, watershed boundaries, aquifers, wells, stream data, elevation, and soil type; and Ohio watershed and stream layers. With respect to point data, Map-IT! serves stream data gathered by citizen scientists in connection with the State of Illinois' EcoWatch program (20), as well as biological indicator data for Ohio streams, courtesy of the Ohio EPA. K-12 students are also contributing to the data, as part of the NSF-sponsored, PLAN-IT Earth science curriculum project linked to EcoWatch (21). This data is georeferenced, either by pre-assigned site ID, or through the use of portable Global Positioning System (GPS) units.

Though much spatial data in the public domain is readily accessible via CD-ROM or the web, inclusion on the Map-IT! Server of suitable third party data presented two challenges. First, Map-IT! works with shape files alone so data in any other format (Arc/Info coverage's, for instance) first had to be converted. Moreover, only vector data (points, lines, polygons) is accommodated in the present prototype, so satellite and aerial imagery was excluded. Second, much of the acquired data needed re-projection so that the data layers, when overlaid, aligned properly. The frequent need for such data processing, which is common to all K-12 GIS projects, whether employing web-based or standalone GIS tools, can result in considerable overhead for teachers and/or technical support staff, and must be factored into the real costs of implementing GIS in the classroom.

3. Web Support Materials

From the start of the project, we realized that for end-users to test and evaluate Map-IT! they would need to be provided with explanatory and support materials. Our current web pages feature an introduction to GIS and Map-IT!, a Quick Tour, information on technical requirements, detailed help pages on all the functions, including instructions for data uploads, and links to other GIS resources. These pages are being continually updated.

Usability Assessment

Four small focus groups were held in a PC training lab at the National Center for Supercomputing Applications during the first year of the project (August 1997- June 1998). An initial focus group in November 1997 provided a useful "front-end" assessment of interest in GIS, its potential uses in K-12 learning and instruction, and the level of functionality appropriate to those uses. Once a working prototype had been developed (by May 1998), three additional focus groups were organized. Participating local area teachers were instructed in the basic functions of Map-IT! and, after an extended period of experimentation alone or in pairs, were asked to provide informal and written feedback on the then current version of the tool.

Questionnaires were administered at each of the focus groups to solicit information such as:

- Institutional affiliation
- Subjects, grades taught
- School technology resources (hardware, software, connectivity, access)
- Prior exposure to GIS and GPS technology
- Assessment of Map-IT!: score rating (see below); what was liked least or most; what they would implement differently, and how, for the following items

- Overall capabilities
- Individual features: login, user administration and data management, discrete viewer functions
- If and how Map-IT! might be employed in the classroom, and for what types of activities.

Teachers attending the sessions represented secondary levels from middle to high school. Subject areas they covered included physics, physical science, chemistry, biology, geography, earth sciences, history, and social studies. School technology resources varied widely, from dedicated computer labs to one computer per classroom; connectivity ranged from a T1 link to 56 kbps dial up. Three teachers had had prior exposure to GIS via basic ArcView training. Two teachers had used Global Positioning Satellite (GPS) technology in student projects requiring data gathering in the field.

Averaging scores across the second, third and fourth focus groups, Map-IT! was rated as follows:

Table 1. Map-IT! Focus Group Ratings*

Feature	Score	N
Overall educational potential	3.8	18
Login	4.4	11
User administration	4.7	12
File management	4.1	7
Viewer (overall)	4.2	13
Mapview	4.4	13
Zoom	4.4	13
Turn layers on/off	4.6	12
Identify feature	3.6	12
Find feature	3.9	7

*0-5 score: 0= least favorable; 5=most favorable

Given the small number of participants in the focus groups, the qualitative feedback, both written and verbal, proved more informative in guiding our prototyping effort. On the positive side, this feedback indicated that:

- Teachers recognized and appreciated that Map-IT! provided a uniform, easy-to-use, web-integrated interface to access, visualize and compare large amounts of distinct types of spatial data from different locations. They appreciated the facility with which individual projects could be created and modified.
- In response to critical input at the second focus group, the user, file and project administration functions were organized into the present hierarchical access structure for multiple users. At subsequent focus groups, teachers appreciated such changes as protecting Public Data against deletion or modification, except by the server administrator. Teachers also expressed enthusiasm about the ability of students to remove and add layers, call up attribute data, and enter and view data procured from other sources, including field trips.
- Several teachers replied that they could envision incorporating Map-IT! in a large range of problem-solving, project-driven activities spanning disciplines from science to social studies. Most of these activities were concerned with the impacts of changes of land use and agricultural practices (e.g., no till conservation) on watersheds over time – stream channel depth and course, flooding, pollution, stream erosion, water quality (chemistry, indicator species), etc. A majority of the teachers in the first three focus groups said that they would consider developing lesson or unit plans along these lines.

To quote a high school chemistry teacher from Illinois Region 11 Villa Grove School District:

"This year, as students uploaded data from our school and were able to see the data in a map, which actually showed the dots where data had been taken, many questions started being asked. Students started remembering what they knew to be surrounding an area where readings seemed high and looked over our weather station data to consider what rainfall amounts might have been at or near that time. They became reasonably adept at turning various layers on and off in order to view different landforms, flood areas, and municipal boundaries. I am hoping that my students will be able to correspond with students in other schools downstream from Villa Grove and compare data both in raw form and on Map-It. Can other schools view our projects...? This would be an excellent way for students to see what other students are doing in other parts of the watershed or even between watersheds."

However, on the critical side...

- Concerns were expressed about the lack of consistency of colors assigned to different data layers, the absence of a distance scale in common units (miles, for instance), the small size of the map window, and the inability of the tool to support map symbolization. It was pointed out to participants that symbols could be added later by exporting the map images to image editors such as Photoshop or Paintshop Pro. Recently we addressed the problem of map size. Now, before downloading the Map-IT! applet, users can choose between 3 sizes: small, medium, and large.
- A few of the participants stated an interest in including a hotlinking capability, such that attribute data could be hyperlinked to other digital

objects such as movies or images.

- Teachers participating in the second focus group, in May 1998, suggested that we add a project previewing capability. Users could then quickly view their overlays, without having first to go to the viewer, then select their project. We added this function to Map-IT! soon afterwards.
- Some participants expressed disappointment that Map-IT! could support only vector data, and not raster data such as digital orthophotography or satellite images. In addition, there was disagreement among the participants as to whether students should be able to add data to their own projects, or if teacher-administrators should do this.
- The "Find Feature" function proved to be less useful to the teacher, in part because it seemed that one had to know something in advance about the feature one was looking for. Teachers also sometimes experienced difficulties in understanding the tabular data evoked by the "Identify" button. Most of the data is from third party sources, so the attributes are often coded; a key is required to "read" the data.
- There was disappointment among some of the teachers that the current version of Map-IT! works only on PC/Windows platform, and not with the Mac O/S (owing to delays by Apple to release a Java plug-in required to view the MapCafe applet through a standard browser).

Future Plans

a. The Tool

Feedback during the focus groups described above point to a need for the following improvements to Map-IT!

- Color control. Right now, ArcView on the server side assigns arbitrary colors to each layer or "theme." These colors can change each time a project is modified, then retrieved again for viewing. Upgrading to ArcView 3.1 (from 3.0) or installing an Avenue script might correct this. We are also examining the install options in ArcView IMS 1.0 and may need to upgrade to v.2.0. Our minimum objective is to enable users to assign a unique color to each theme from a menu up to 8 colors and shadings.
- Scale-bar. Choice of distance units (miles, km, yards, meters) through the client is needed so that users can determine approximate distances on their maps.
- Hotlinking of features in active themes to objects anywhere on the web. Such objects might, for instance, include movies and photographs generated in student projects.
- Cross-platform operability. During development of Map-IT!, it was not possible to run the client on Apple computers. However, Mac O/S 8 now contains the necessary Java components. We plan to conduct tests to establish that Map-IT! in fact can be run in conjunction with Mac O/S 8 and Internet Explorer.

- Accommodation of raster data, including aerial imagery.

Pending funding support, we plan to address the first three improvements – color control, scale-bar, hotlinking – within the programming framework provided by ArcView, Avenue, ArcView IMS and MapCafe. Further modification of Map-IT! will likely require a higher level of customization. Emerging GIS software such as ArcIMS [17] is highly flexible in that both the server and client sides can be readily customized to meet the differing needs of distinct audiences. We plan to explore the use of ArcIMS and develop other software not only to further elaborate on Map-IT! current capabilities, but also to study how and in what combinations different software functions, ranging from simple mapping to in-depth spatial analysis, might be optimized to support progressive cognitive levels.

a. Curriculum

Quite apart from assessing Map-IT!'s potential as a learning tool, further studies are needed to ascertain what types of classroom or field activities and learning are most readily enhanced by GIS, whether or not web-based [7,11,12,18]. Though preliminary usability studies of Map-IT! yielded several insights as to how the end-users viewed the initial prototype, the data we obtained was limited in that the tool was assessed out of the contexts of what students and teachers actually do and where they do it, individually, and in groups. This requires that Map-IT! be incorporated in well-defined learning activities that meet the needs of teachers and students, are integrated into the curriculum [8,11], and address national and state standards. A "situated" evaluation [19], one that assesses how a technology innovation such as Map-IT! is used across different contexts (e.g., classroom, lab, field, home), may also be indicated. In short, any future development of Map-IT! as a viable learning technology (along with GIS in general) needs to be more fully integrated with the learning process itself, as distinct from the narrower focus on tool usability described above.

To this end, we are beginning to forge partnerships with K-12 curriculum developers that stress inquiry-based, interdisciplinary learning focused on environmental research and conservation. An excellent example is the NSF-funded PLAN-IT project centered at Eastern Illinois University, which is developing field and classroom modules on forests, wetlands, streams, soils and urban settings [20]. As mentioned earlier, PLAN-IT allied to a statewide citizen science monitoring program, Illinois EcoWatch [21]. Similar programs exist in several other states. We will also be seeking opportunities to incorporate Map-IT! in tandem with other learning technologies into preservice training, which has been identified as providing "a key to the diffusion of GIS in K-12 classrooms [11]."

Conclusion

GIS is gaining importance as a business and learning tool. Its use could become commonplace in the 21st century classroom and workplace. Web-based GIS promises to transform the ways individuals, organizations and the public-at-large create, store, access and apply spatial data to define, investigate and solve problems of broad interest and concern. Web-based GIS tools for viewing, querying and publishing spatial data can further heighten the power of the web to serve as a medium for authentic, inquiry-based learning and facilitate the diffusion of GIS in the classroom. As a proof-of-concept, web-based GIS application customized for K-12 audiences, Map-IT! represents but a small step towards realizing this vision.

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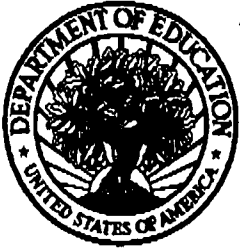
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