DESIGNING GIS SOFTWARE FOR EDUCATION:

A Workshop Report for the GIS Community

This report documents a workshop that investigated
the challenges to designing GIS software for the education community.
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The Geographic Data in Education Initiative
at Northwestern University

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Background

For more than a decade, educators and educational researchers have recognized the promise of Geographic Information Systems (GIS)[2] for supporting inquiry-based learning in middle and high school science and geography (Baker 2002, p.; Keiper 1999, p.; Kerski 2001, p.; Lloyd 2001, p.; TERC 1995, p.). Texas's state standards now call for the use of GIS by name. Advocates have cited numerous motivational, cognitive, social, and policy reasons that visualization and analysis of geospatial data should be an integral part of K-12 education. Three of these are particularly compelling. First, spatial data analysis can provide students with new ways to understand and learn about phenomena through interaction with dynamic visual representations. Second, it can bring authentic inquiry activities into the classroom, as called for by national standards (AAAS 1994, p.; NRC 1996, p.). Finally, it can provide students with the opportunity to develop fluency with visual representations of data, quantitative data analysis, and database techniques.

Research on the use of GIS in grades 5-12 has shown that GIS tools can enable students to successfully engage in sophisticated spatial data interpretation and analysis (Baker 2002, p.; Kaplan 2003, p.; Kaplan and Black 2003, p.; Keiper 1999, p.; Kerski 2001, p.). Research has also documented important benefits of using GIS beyond the acquisition of spatial analysis skills, including motivation (Keiper 1999, p.; McWilliams and Rooney 1997, p.), self-efficacy and attitudes toward technology (Baker 2002, p.), and geographic content knowledge (Kerski 2001, p.).

Overall, however, GIS has made only limited inroads into schools. In a survey of more than 1500 high school teachers who had purchased GIS software, Kerski found that

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[1] The GEODE Initiative is dedicated to the improvement of Earth and environmental science education through the use of data visualization and analysis tools, including GIS, to support inquiry-based pedagogy. The GEODE Initiative is engaged in several curriculum development projects as well.

[2] A GIS is a software environment that allows a user to display and analyze data that are associated with specific geographic locations. The popular conception of a GIS is as a tool for interactive mapping. However, a GIS is much more. It combines data visualization capabilities with a database environment that, enables users to analyze data using conventional database relationships and spatial relationships. Thus, for example, an urban forester might query a GIS to find all the trees over a certain age (conventional query) and all the trees that are within a certain distance of each other (geospatial query).

45% of them had not used GIS and another 15% had no plans to use it. Of those who did report they had used GIS, only 30% had used it in more than lesson (Kerski 2001, p.). This research identified the following obstacles to GIS implementation: complexity and cost of software, technology infrastructure including technical support, availability of curriculum materials, and teacher training.

Most efforts to bring GIS into K-12 classrooms have focused on teacher professional development and on curriculum development. The curriculum development efforts have produced compelling examples of authentic and inquiry-based learning activities. The professional development efforts have engaged large numbers of teachers. Examples drawn from the classrooms where these projects have been successful offer impressive evidence for the ability of GIS to enhance teaching and learning. Nevertheless, the implementation rate is low even among teachers who participate in training and professional development.

The GEODE Initiative at Northwestern University is pursuing the hypothesis that this low rate is due, in part, to a mismatch between currently available GIS software and the needs and resources of students teachers, and schools. The GEODE Initiative's NSF-funded My World GIS Project is exploring the premise that designing GIS software to be more appropriate for use by students and teachers in educational settings can increase both the implementation rate and learning outcomes over existing GIS software that was designed for professionals.

Even GIS proponents acknowledge that the learning curve for current GIS software is both steep and long for novices like teachers and students. Some examples:

- "More teachers would like and more schools would participate in the [project] if you could make the GIS software easier to get started." (State curriculum officer to PI of NSF-funded professional development project).
- Seventy-six percent of teachers surveyed report that "GIS software is complicated" (Audet and Ludwig 2000, p. p. 8).
- "Even supposedly user-friendly GIS software such as ESRI's ArcView GIS relied on a user interface whose complexity worked against the goal of having students spend their time learning geography rather than learning GIS" (Lloyd 2001, p. 159).

In fact, when the National Research Council (NRC) convened a study on how to incorporate spatial analysis tools into the K-12 curriculum, one of the two central questions for their study was, "how can cognitive developmental and educational theory be used to develop new versions of GIS that are *age-appropriate in their design?*" National Research council, 2006 (National Research Council 2006, p. 4) Further, the report advocates tools that are designed to address that particular needs of educational settings:

> GIS should be redesigned to accommodate the full range of learners and school contexts, to be more developmentally and educationally appropriate, to be easier

> to teach and to learn, and to accommodate the current levels of computing equipment (National Research Council 2006, p. 8).

The intimidating learning curve of GIS tools should not be surprising. First, GIS tools are powerful, and therefore complex. More to the point, however, existing GIS software was developed for professionals, who generally receive extensive training in the use of the tools. Therefore, the developers of GIS tools have been more concerned with providing experts with functionality than with lowering the learning curve for novices.

The My World GIS Project is investigating three categories of challenge presented by GIS for students and teachers:

> **Conceptual challenges**. Conceptual challenges are the obstacles to successful use that result from the fact that software is complex and therefore difficult to understand and use at a conceptual level.
>
> **Usability challenges**. Usability challenges are obstacles to use that result from the difficulty of understanding and using the user-interface to achieve one's goals.
>
> **Infrastructure compatibility challenges**. Infrastructure compatibility challenges result from a mismatch between the requirements of an application and the resources available in the setting in which the software is to be used.

To help investigate how GIS tools could be re-designed to support geoscience and geography education, the GEODE Initiative organized a workshop of 19 prominent researchers, curriculum developers, software developers, and teacher trainers who specialize in the use of GIS in education. The goal of the workshop, held in October 2004, was to identify the critical challenges that students and teachers face in using GIS in classrooms and consider strategies for addressing these challenges through the re-design of GIS tools.

Our focus on the design of GIS software does not mitigate the importance of dealing with challenges such as teacher preparedness and curriculum design, areas in which the workshop participants have much expertise. Rather, the goal of this effort is to eliminate the software obstacle in order to make the efforts of people working on the other issues more effective.

This report on the workshop provides an overview of this conference and is intended to further the discussion of these issues within a growing community that is interested in expanding the use of GIS in education. The report is addressed specifically to GIS software developers. The GEODE Initiative is using the results of this workshop to set the development priorities for My World GIS, a geographic information system that we are creating to meet the needs of students and teachers in classrooms from middle school through college. We are also committed to bringing the findings of the workshop to the attention of the major GIS vendors, two of whom were represented at the workshop.

Part 1 of this report describes the workshop, its aims and agenda. Part 2 discusses the outcomes of the workshop discussions and post-workshop surveys and describes some implications for the re-design of GIS tools.

Part 1. Workshop Overview

1.1 Workshop Goals

We had two specific objectives for this workshop. The first goal was to document challenges to GIS use in schools in at least three categories: (1) conceptual challenges presented by GIS for non-expert users; (2) software usability issues; (3) administrative and technical challenges of GIS tools for schools. The second goal was to identify the features and functions that are critical for a GIS tool to be useful for middle school through college geography and geoscience courses.[3]

1.2 Workshop Outcomes

The chief outcomes of this conference included: (1) creating this report for software developers outlining the critical challenges to using GIS in educational settings and the software features deemed most useful for accomplishing educational goals; (2) helping to build and sustain the community of GIS Educators; and (3) obtaining formative feedback for the My World software.

1.3 Workshop Format

The workshop was organized as a series of large-group discussions and small-group breakout sessions. In addition, we set aside additional time for informal networking as well as a "share fair" in which attendees could share their work with each other. Prior to the workshop, we submitted our plan to a select group of invitees for feedback and incorporated their comments into the planning.

The first day of the workshop was devoted to identifying the challenges to using GIS in educational settings. The question that was posed to participants was, *What are the biggest challenges to effective use of GIS in classrooms.* We began with a large-group

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[3] We note that our focus is the use of GIS to enhance learning in courses where the primary learning objectives are science or social science, not technology. We are specifically interested in fostering conceptual understanding through investigations of data and in having students develop data analysis skills for the purposes of understanding the practices of scientists. We are not particularly concerned with teaching GIS skills for career preparation. In other words, we are interested in students' learning *with* GIS, rather than *about* GIS. We expect that the goal of teaching GIS for other purposes would lead to different conclusions.

brainstorm of challenges, followed by two small group sessions to enlarge and elaborate on the list of challenges, followed by a group discussion to prioritize challenges raised in small group sessions.

The second day of the workshop was devoted to identifying the most important features for educational GIS software—including both commonly used features and "wish list" items that do not yet exist. The question that was posed to participants was, *Which features of GIS are most valuable for use in educational contexts?* The format was similar to the first day.

Part 2. Results from the Workshop: Challenges to GIS use in schools and important features for GIS in education

The first goal of this workshop was to document challenges to GIS use in schools in at least three categories: (1) conceptual challenges presented by GIS for non-expert users; (2) software usability issues; (3) administrative, technical, and infrastructural challenges of GIS tools for schools. The second goal was to identify the features and functions that are critical for a GIS tool to be useful for middle school through college geography and geoscience courses.

The lists of challenges and features were generated during the workshop by participants working collaboratively through breakout groups and whole-group discussion. The participants were also surveyed at the end of the workshop to refine the ranking of individual items relative to the list as a whole. After some processing of the results, the items were again refined into a more concise list and given to participants as an online survey that participants completed in the weeks following the workshop[4] (see Appendix 3). In the following pages, we present the results of that survey. .

2.1 Challenges to GIS use in Schools

On the follow-up survey, workshop participants were asked to rank challenges to GIS use in school by picking the 15 most important challenges from the list generated at the workshop (see Appendix 3). For that list of 15, they were then asked to rate each challenge as critical (3 points), major (2), minor (1). Items that did not receive a vote were given a score of zero (0) when calculating the averages. Results were sorted by average vote, number of votes per item, and a weighted average[5]. Table 1 shows the top 15 items (see Appendix 4 for the full results).

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[4] Fifteen of the 18 workshop participants completed the surveys.

[5] The weighted average gives us a way to measure both the number of people who voted for the item as well as the score they gave. To get the weighted average, we multiplied the average score by the number of votes. So for Multiple Platforms, 12 people x 2.0 average score = 24 weighted average. The rankings are intended to provide a

(footnote continued on next page)

Table 1. The Top 15 challenges to GIS use identified by workshop participants.

Challenge	Description	Average (of all; no vote=0)	# Votes (out of 15)	Weighted Average
Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware	GIS software needs to be able to run on the wide range of equipment found in schools.	2	12	24
Navigating through file system and across networks to load data or projects.	Loading a project or a data file in a GIS project typically involves navigating through a computer's hard disk or through a network file server to retrieve files. Users have a lot of trouble locating such files, especially on school machines and networks containing a high levels of security.	1.67	9	15
Aligning different projections (i.e., bringing aerial photos into an existing dataset)	GIS data can be represented in a wide range of projections that must be aligned in order to view multiple datasets simultaneously. Typically, users need to know a lot about projections in order to align different types of data. This sort of expertise in uncommon in school settings.	1.27	9	11.4
Installation for tech staff and teachers	Installation and setup up GIS software can require working with multiple plug-ins and extensions, downloading required third-party software, and obtaining administrative privileges to school machines. Installing GIS is very time consuming and intimidating for many school technology staff and teachers.	1.2	8	9.6
Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want	Using GIS requires a wide range of technical, analytical and procedural knowledge and skill. Supporting GIS users requires knowing these requirements and finding ways to support learners as they develop the necessary competencies.	1.33	7	9.33

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general sense of each item's popularity; no analysis was conducted to measure the statistical significance of differences of ratings..

Software requires high-end hardware. Schools have older machines (5-year replacement cycle)	GIS technology typically requires large amounts of memory and fast processor speeds. School machines often do not meet the latest requirements of GIS, and if they do, slow replacement cycles mean that future GIS technologies will advance beyond their capacity in a very short time.	1.13	8	9.07
Dealing with importing data in different data formats	Importing data into GIS requires knowing a lot about how the data is formatted and techniques for reconciling data that is in different formats. This requires specialized knowledge and is frequently beyond the expertise of many educational users.	1.13	8	9.07
Creating new fields in existing datasets, or bringing in new complete datasets	Manipulating and adding to GIS datasets requires a high degree of data literacy that many educational users lack.	1	9	9
Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)	GIS software must meet the needs of a range of users at different skill levels. Novices, who engage in basic GIS tasks, require a simple interface and limited feature set. Expert users require more functionality and thus a more sophisticated interface. It is a challenge to meet the needs of a wide audience.	1	8	8
Project transportability (portability)	GIS tasks often require users to save and share their work across time and locations. Yet, GIS projects frequently use large datasets that are not easily transported from machine to machine. Portability refers to the need to support easy sharing and transfer of projects for use in other settings.	0.93	8	7.47
Understanding connection between tables and maps	GIS data is usually based upon an underlying tabular database. Understanding the relationship between these tables and their corresponding spatial (map) representations is difficult for novices.	1.07	7	7.47
How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials	It is possible to identify a core set of basic skills and common sequences that support a range of GIS tasks. Novices tend to lack these skills and need support in developing them. Even more experienced users can benefit from GIS support than makes common steps more streamlined. These issues must be considered both at the micro level (i.e., using specific GIS tools) and the macro level (i.e., engaging in common GIS task sequences).	1	7	7
Understanding where data came from (accuracy, resolution, source)	Data literacy is a key challenge to GIS use. Often times a GIS representation alone is not enough to understand a dataset's full implications. Also important is knowledge about the dataset's source, how it was collected, its resolution, important caveats, etc. This information can have important implications for how users interpret and use GIS representations.	0.93	7	6.53
Challenges of working with or around security software	In addition to the challenges that security software poses for the installation of GIS are the challenges that security software poses for the ongoing use of GIS. Even once GIS software has been successfully installed, security software used by many schools often prohibits students from saving their work on local hard disks. In such settings, users must	1.07	6	6.4

	have access to removable media or to networked servers in order to save their work.			
Hard to get data into appropriate format	GIS data is widely available, though it is seldom in a consistent format. In order to even begin the process of importing raw data into GIS (discussed separately), it is often necessary to reformat it in a manner that consistent with the requirements of GIS software.	0.93	6	5.6

As discussed earlier, we are interested in challenges in three distinct categories: conceptual challenges presented by GIS for non-expert users; (2) software usability issues; (3) administrative and technical challenges of GIS tools for schools. The rankings of the top 15 challenges reflect a distribution across these categories, with 3 conceptual challenges, 7 software usability challenges, and 5 infrastructure challenges. We attribute the predominance of usability and compatibility challenges has to do with their immediacy and status as gatekeepers. If these challenges become obstacles for teachers and students, then they will never get to the point of confronting conceptual challenges. Below, the top 15 challenges are organized into these categories.

(1) Conceptual challenges presented by GIS for non-expert users

	Ave	# Votes	Weighted Ave
Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want	1.3	7	9.33
Understanding connection between tables and maps	1.1	7	7.47
Understanding where data came from (accuracy, resolution, source)	0.9	7	6.53
Average/Sum/Average	**1.1**	**45**	**8.22**

Interestingly, the top conceptual challenge is a challenge for teachers regarding how to help students understand and learn to use GIS. The other two are challenges for students that are focused on data and representations, rather than analysis.

(2) Software usability challenges

Navigating through file system and across networks to load data or projects.	1.7	9	15
Aligning different projections (i.e., bringing aerial photos into an existing dataset)	1.3	9	11.4
Dealing with importing data in different data formats	1.1	8	9.07
Creating new fields in existing datasets, or bringing in new complete datasets	1	9	9
Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)	1	8	8

How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials.	1	7	7
Hard to get data into appropriate format	0.9	6	5.6
Average/Sum/Average	**1.2**	**32**	**9.77**

Four of the seven usability challenges are about getting data into a form that it can be used in a GIS (navigating file systems to load data, aligning projections, importing data in different formats, creating new fields and importing new data, and re-formatting data). This reflects the fact that getting data into a GIS in a usable form is a gatekeeper to the successful use of GIS. The other two are very general, but both describe the challenges to usability posed by powerful and complex software. They describe the challenges posed by a complex user interface and the supporting students through extended, multi-step tasks.

(3) Infrastructure, Administrative and Technical challenges of GIS tools for schools

Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware	2	12	24
Installation for tech staff and teachers	1.2	8	9.6
Software requires high-end hardware. Schools have older machines (5-year replacement cycle)	1.1	8	9.07
Project transportability (portability)	0.9	8	7.47
Challenges of working with or around security software	1.1	6	6.4
Average/Sum/Average	**1.3**	**42**	**11.3**

The five infrastructure challenges reflect important realities of school computing environments that professional GIS tools were not designed for. *Multiple platforms and configurations* reflects the fact that the distribution of operating systems in schools is different from professional workplaces. Specifically, the Mac OS is much more common in schools. *Installation* reflects the fact that schools often have limited staff time available for installation and limited expertise for performing installations that require special configurations or for troubleshooting installation problems. *Software requirements* reflect the fact that school computing infrastructures are often well behind professional environments. *Project transportability* reflects a specific characteristic of current GIS environments that often make it difficult to move a project containing large quantities of data from one computer to another in a way that will enable all the links and data to be preserved. *Challenges of security software* reflect the fact that computers in educational environments have to be secured against either malicious or accidental tampering with settings, which means that most software applications and users have only limited permissions on the machines. This can be a major challenge for software that was designed with the assumption that the user has administration privileges on his or her computer.

Taken together, the list of challenges demonstrates that real challenges to the use of GIS software in schools exist, and that a diverse group of experienced professional developers and curriculum designers have encountered the same ones.

2.2 *Features Critical to GIS use in Education*

On the follow-up survey, workshop participants were also asked to identify the ten most useful and important features of GIS for use in content area (geosciences and geography) courses from the list generated at the workshop. Once they had identified these features, they were asked to rank them from 1 (most important) to 10 (least important). Results were sorted by average vote, number of votes per item, and a weighted average (average vote multiplied by number of votes).[6] Table 2 contains the top ten features ranked by weighted average (see Appendix 4 for the full results).

Table 2. The 10 most useful features of GIS for geoscience and geography courses as identified and ranked by workshop participants.

Feature	Description	Average (of all; no vote=0)	# of Votes	Weighted Ave
Query construction	Real language, form-based, or formula-based queries to select subsets of data based on either variable values or spatial relationships.	6.7	13	87.5
Spatial analyses	Simple methods for selecting records based on spatial relationships in datasets-- including buffer, slope aspect, raster overlay operations, models, spatial operations (union, clip, etc.), conversion between vector and raster formats including point interpolation and iso-contours.	6.5	12	78.4

[6] For the purposes of scoring, votes were inverted from the responded surveys so that most important items were scored as 10 and least important items as 1. These results were then sorted by average vote (where no votes = 0), number of votes per item, and weighted average (average vote multiplied by number of votes). The list shown here is sorted by "weighted average", which measures both the number of people who voted for the item as well as the score they gave. To get the weighted average, we multiplied the average score by the number of votes.

Classification	Represent the data within a particular field of a given dataset (e.g., Surface Temperatures for January; or Female Populations of each Country) by equal interval, quantile, natural breaks, standard deviation, normalization, custom.	5.3	14	74.7
Summary tables	Provide brief statistical summaries of the fields within a given dataset's table (i.e., number of values, min, max, sum, mean, median, mode).	3.5	10	34.7
On the fly Projections	The software automatically handles re-projection of the display with re-projection of individual layers handled on the fly, saving users from having to set the appropriate projection for each dataset and reconcile datasets that use different projections.	3.3	9	29.4
Generating graphs/charts from data	Provide a supportive way for users to generate customized charts from datasets, such as scatter plots, histograms, pie-charts, and graph intersect.	2.9	10	29.3
Import from data-servers over the web	Provide a seamless mechanism for direct import of data to GIS from web data servers (including IMS servers) of both real-time (current) and archival data for a pre-selected set of relevant websites. Automatically handle projections and format conversions. Automatic update when new data is available.	3.5	8	28.3
Importing Wizard	Provide a scaffolded process for importing new data into a GIS that assists users with common import challenges. Step the user through the process of importing from existing data files (describing current data projection, determining which columns are visible, specifying units, etc.) possibly doing some automatic parsing of metadata.	2.7	8	21.9
Interface to GPS	Provide a seamless mechanism for importing data from GPS devices into a GIS. Upload files or one-click synchronization directly with GPS device.	2.3	7	16.3

An analysis of this list reveals the values of this group, as far as benefits of GIS for education. Five of the elements on this list are analysis operations (all appearing in the top 6 spots on the list): query construction (#1), spatial analysis (#2), classification (#3), summary tables, (#4), generating graphs/charts from data (#6). Any GIS user would recognize these as the core analysis operations of GIS, and the workshop participants provided a clear message that analysis is where the value of GIS for learning lies. This stands in contrast to the strategy of making geographic data accessible to novices by providing viewers that support visualization but not analysis. These are not simple operations for students to understand and use

They present real conceptual and usability challenges for software designers, curriculum developers, and teachers. Nevertheless, the workshop participants put a high value on them.

The other items on the list are all concerned with importing data into a GIS, either from existing libraries of data or from a GPS. The message here appears to be that the participants place a value on enabling students and teachers to locate data themselves to serve their specific needs and interests.

Some of the features specifically address challenges raised in the prior section. For instance, "on the fly projections" addresses the usability challenge of aligning different projections, "importing wizard" addresses the conceptual and usability challenges related to finding and importing new data.

Other features in this list correspond challenges that were identified by the group but which did not make the top 15 ranking for challenges. These include: "query construction", which refers to the conceptual difficulties of using formulas to construct queries, and "interface to GPS," which refers to the usability challenge of importing data from GPS.

This is not to say that the remaining features do not explicitly address important challenges to the educational use of GPS. Since challenges and features were discussed separately at the workshop, there was no intended correspondence between the two lists.

2.3 Comments from Participants

In addition to the surveys of challenges and features, the Center for Children and Technology (CCT), the external evaluators for the My World GIS Project, administered a survey asking for open-ended responses to questions about the usability and conceptual challenges of using GIS software in different classroom settings.[7] Below is a brief discussion of this survey's findings.

Consistent with the approach that has been taken in prior efforts to foster the use of GIS in educational settings, participants stated that the two most significant challenges facing teachers and students in their use of GIS software in their school computing environments were (1) access to the appropriate hardware and software technologies and (2) integration of GIS into the curriculum. Participants believed that most schools' technology infrastructures are not usually able to support high-powered, networked applications such as GIS. Specifically, schools lacked access to the adequate hardware (e.g., network reliability, adequate memory, security systems and administration access policies, number of computers) and software (e.g., limited number of programs designed for school use, limited capacity to write files on existing systems) needed to run GIS applications. Furthermore, schools lacked technical and

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[7] There were 18 participants in this workshop, 7 females and 11 males. All but one responded to the survey. CCT researchers conducted descriptive analysis on the collected data using SPS-X.

administrative support for the software. These usability issues often led to quick frustration with using the tool for teaching and learning.

The main conceptual issues raised by participants were tied to integrating GIS into the curriculum and defining specific educational goals— getting teachers and students to think spatially by knowing what spatial questions to ask and what they need to do to achieve their educational and learning goals; framing inquiries in terms of data needed and relationships to explore; and getting teachers to incorporate GIS in instruction through inclusion in state education standards and standardized tests. For example, as one participant explained, "Students need to understand how what they see on the computer screen applies to real-life projects. How does a certain section of a computer map relate to the "real world"? Furthermore, most participants pointed out that the following posed integration issues: the procedures and navigation of software, use of common operating systems, data management and conversion into useful information for teachers and students, and complexity of software and spatial analysis.

Participants also stated that professional development is needed to help teachers understand how to teach with GIS, connect it to their curriculum and align GIS activities with state and local curriculum standards.

Participants provided the following explanations as the reasons for the lack of successful implementation and difficulty in integrating of GIS software in education:

- Teachers are not provided enough time in school settings to master GIS software and adapt it into their curriculum activities. So "when frustration with technical or software issues interferes with learning, the technology is often abandoned."
- "Teachers lack an understanding of basic science practice and cannot formulate good classroom activity."
- Teachers have limited access to a library of lessons and easy-to-use spatial data.
- Students and teachers often do not have experience with GIS outside of school settings.
- Most students have little geographic awareness beyond their local community.
- Teachers do not value inquiry-based learning in the context of increasing standardized test requirements, especially when they do not have access to rigorous assessment tools for inquiry-based learning. "Spatial thinking has little value in today's curriculum."
- Teachers often do not have access to GIS assessment tools to use in their classrooms.

Other challenges mentioned include education leaders focusing too much on standardized testing and not focusing enough on the importance of fostering spatial thinking in students.

Next Steps

The My World GIS Project at Northwestern convened the October 2005 workshop on the design of GIS Software for Education with the dual aims of informing the project's own software development aims and of disseminating the findings of the workshop to the larger community of GIS software developers. This report represents a step toward the latter goal.

The findings contained in this report have also been used to shape the software research and development of the My World GIS Project in the year since the workshop. The aim of this NSF-funded Instructional Materials Development project is to develop a geographic information system that is appropriate for use in middle school through college level geosciences and geography courses. My World GIS™, which is commercially distributed by PASCO Scientific, is the product of that effort. My World provides the functionality of a professional GIS through an interface designed for use by students and teachers. Its goal is to provide the most important features of GIS for these educational settings while addressing the conceptual, usability, and infrastructure compatibility challenges that GIS presents for educational settings.

As of the time of the workshop, My World offered five of the top ten features identified by participants of the workshop as being important for educational use of GIS. Based on the consensus about the remaining 10 features from the workshop participants, the project has implemented the remaining 5 of those features, in addition to many others. Similarly, as of the workshop My World incorporated strategies for addressing eight of the challenges in the top fifteen identified by workshop participants. In fact, the project was engaged in classroom user studies of GIS software during the 2004-5 school year, which independently identified many of the same challenges that were identified by participants. In the intervening year, the project has identified and implemented strategies for addressing the remaining seven. The effectiveness of these strategies at addressing the challenges still needs to be empirically evaluated, and the project is engaged in classroom studies to assess their effectiveness during the 2005-6 school year. However, the project anticipates that additional cycles of software development and evaluation are likely to be necessary to overcome all of the substantial challenges to GIS use in classrooms. Nevertheless, preliminary results from the ongoing indicate that My World GIS has succeeded in reducing the obstacles to classroom use of GIS by a measurable amount.

Conclusions

The workshop discussions as well as the findings from the follow-up surveys reveal a broad consensus among participants on key challenges to using GIS in educational settings and important GIS features to support educational use. Challenges raised by participants were distributed across the categories of infrastructural, conceptual and usability and provide a roadmap for developers of GIS tools as we continue to improve their usefulness and utility in classrooms. The recommended features provide an important starting point toward this end, though much additional work—both in the design lab and in classrooms— is needed to understand the needs and entailments of such solutions.

GIS technology has reached a state of maturity and accessibility that makes the prospects for its use in classrooms more promising than ever. However, as reported by the participants at the workshop, current GIS tools do present challenges for teachers and students in school environments. It is the hope of the My World GIS Project at Northwestern that documenting the these challenges in this report will lay the groundwork for further research and development that can move GIS toward achieving the promise that it holds for classrooms.

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Participant Background

Most of the workshop participants had a graduate level education: 10 PhDs, 4 Master's degrees, and 4 Bachelor's degrees.

The average year of expertise in their field for most participants was 13 with a range between 5 and 35 years and a standard deviation of 7. Most of the participants had considerable experience conducting professional development (average years 10, range 0 – 30, SD=8) and curriculum development in different education settings (average years 12, range 0 – 35, SD=9), and had a range of expertise and rich experiences with GIS such as teaching its use to graduate students and teachers as well as designing GIS-related curriculum materials and field-testing software.

Most of this expertise was focused on ways to introduce GIS in education settings. The curriculum materials developed by workshop participants focused on the following disciplines and activities: social studies, science, image processing, oceanography and marine biology, environmental education, GIS programming, and community-based projects. For instance, two workshop participants noted:

> *"I have taught K-12 workshops for teachers and students and college courses on GIS. I am "fluent" in ArcView 3.x and ArcGIS, and I'm working on developing activities to support spatial thinking among late elementary/early middle school students. I have also developed curricular activities for using GIS in K-12 and college classrooms."*
>
> *"I used ArcView GIS 3.x technologies in my classroom with my students as a vocational as well as a cross-curricular tool. I have been providing professional development for teachers to integrate ArcView 3.x and 8/9.x GIS across their curricula and designing and providing one to two GIS week summer institutes for teachers."*

Some of the participants had used GIS in research projects and engaged in GIS programming for education. Some of the participants were introduced to GIS in graduate school in the 1980s and early 1990s.

> *"I have been involved with GIS since the first annual conference on GIS in education. For two years I … explored GIS and curriculum in middle school. Then I was project director for a GIS software development project …."*

Participants reported being involved in more than 50 GIS projects between them. In those projects, most workshop participants were training teachers to use various aspects of GIS technologies in the classroom, developing curriculum and online courses, helping teachers learn new tools and develop implementation strategies for their classrooms, developing GIS lessons for community-based projects, designing online collaborative environment for science and social studies teachers, field-testing GIS software, analyzing data about the use of GIS in education, disseminating support materials in the use of GIS in education, and conducting community outreach about environmental issues using GIS.

More than half of the participants taught GIS to students and teachers in the fields of geography, oceanography, environmental studies, and science. Specifically, they taught geosystems incorporating geospatial technologies, college-level classes around the use of GIS in environmental applications, undergraduate and graduate GIS courses; they conducted a combination of field study in Earth Science and GIS; and they helped science and geography teachers integrate GIS in their teaching at the k-12 level. Four of the participants indicated that they use GIS in their geoscience and geography curriculum activities and classroom settings.

Appendix 3: Follow-up Surveys

Below are the two follow-up surveys that were sent to participants following the workshop in order to seek further clarifications of their views on most important challenges to using GIS software in education settings and most important features for GIS software in education settings.

Follow-up Survey: Most important challenges to using GIS software

Choose the 15 challenges most important to you.

Then, rate each of your 15 challenges using the following scale:

- Minor challenge (1)
- Major challenge (2)
- Critical challenge (3)

Note: Do not group challenges together. Do not rate whole categories. If a challenge is not on your list, leave its rating blank.

RATING	CATEGORY	CHALLENGE
	File Management	
		Project transportability (portability)
		Internet access: Limitations on networking, accessing data, accessing web-mapping, etc.
		Navigating through file system and across networks to load data or projects.
		Finding/defaulting to,working directory
	Challenges of GIS operations for novices	
		Creating new fields in existing datasets, or bringing in new complete datasets
		Difficult to build queries with formulas
		Difficulty of linking/joining data with features
		Difficult to generate a new theme by querying multiple themes and combining
		How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials.
		Difficulty of supporting map construction
		Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)

RATING	CATEGORY	CHALLENGE
		Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want
		Keeping track of what's displayed when you have lots of variables displayed.
		Working across multiple screens / worksheets
		Recognizing need to make theme active before performing action on it.
		Reliance of GIS tools on accurate typing
	Supporting and Documenting Student Process	
		Documenting inquiry process (providing audit trail). How do you retrace steps? Pick up thread of previous thought process?
		Support for planning, logging, tracking, unwinding/changing paths
		Providing support for meta-data and for describing the process you went through to get where you are (meta-history)
	Compatibility with School contexts	
		Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware
		Software requires high-end hardware. Schools have older machines (5-year replacement cycle).
		Long processing time of computationally-intensive operations on slower school computers
		Challenges of working with or around security software.
		Ways of picking up an investigation where you left off.
		Data Integrity-- everyone using the same dataset, vs. mutations. As students create their own maps, representations may change, operations on the maps, make errors, accidental changes non-copy-protected data.
		Installation for tech staff and teachers
		Software and data updates
		Repairing/installing/turning on extensions
		Dealing with trends toward (a) terminals (b) laptops
	Data issues	
		Dealing with importing data in different data formats
		Hard to find data (esp local)

RATING	CATEGORY	CHALLENGE
		Hard to get data into appropriate format
		Hard to import from GPS
		Batch processing of compressed files & archives (hiding decompression, importing, file management, etc. Zips within zips. Peek inside of zipped archives)
		Simple way to register images
		Compatibility with other GIS tools.
		Aligning different projections (i.e., bringing aerial photos into an existing dataset)
	Basic GIS Concepts	
		Raster vs. Vector data (Understanding how functionalities / tools change with different types of data. E.g., legends with vectors are there, legends of rasters have to be manually called)
		Understanding connection between tables and maps
		Understanding where data came from (accuracy, resolution, source)
		Vocabulary for GIS concepts and operations that new users can understand

Follow-up Survey: Most important features for GIS software

Please list your TEN most important features for GIS software from 1 to 10.

1 = most important

...

10= least important

Note: Assign each rank to <u>one feature only</u>. Do not group features together. Do not rank categories.

RANK	CATEGORY	FEATURE	DESCRIPTION
	Data Import/Export		
		Importing Wizard	Steps a user through the process of importing from existing data files (describing current data projection, determining which columns are visible, specifying units, etc.) possibly doing some automatic parsing of metadata.
		Interface to GPS	Easy import from standard GPS. Upload files or one-click synchronization directly with GPS device.
		Import from data-servers over the web	Direct import from web data servers (including IMS servers) of both real-time (current) and archival data for a pre-selected set of relevant websites. Automatically handles projections and format conversions. Automatic updates when new data is available.
		Multi-site data sharing	Simple interface for uploading locally created data to shared project space on server, server-side aggregation of data from multiple sites, and simple interface for download.
		Joining data tables	Interface for joining non-georeferenced data tables with existing data.
	Data Creation/ Modification		
		Drawing Data	Generating new features by drawing on a map
		Hand digitizing	Simple interface for digitizing from existing maps
		Dynamic data	Time-varying (real-time) data, columns computed from others by formula that updated automatically.
	Inquiry Support		
		Planning tool	A tool for planning out a project including steps in the annotation
		Record-keeping tool	A tool that tracks activities and creates a historical record of actions taken
	Data Views		
		Generating graphs/charts from data	Scatter plots, histograms, pie-charts, graph transect…
		Summary tables	Tables with summary statistics for the fields in a layer
		3-d maps	Maps in 3-d perspective with z-axis representing a variable and others painted on the 3d surface
		Classification	Classifying data by equal interval, quantile, natural breaks, standard deviation, normalization, custom
		Annotations	Simple interface for labeling features on maps based

			on fields in the record or user-entered text annotations.
		Output for sharing	Output of nicely produced map for reports or posters with legends, titles, labels, scale, compass rose, etc.
		Export to interactive map server	Interface for exporting maps to a web-based, interactive map server
		Hotlinks	Provide embedded links to non-GIS sources (photos, websites, etc.)
	Analyses		
		Query construction	Real language, form-based, or formula-based queries to select subsets of data based on either variable values or spatial relationships.
		Direct-manipulation query construction	Specify selection by dragging out a region or clicking on a legend.
		Image Processing Functionality	Smoothing, filtering, edge-finding, etc.
		On the fly Projections	Re-projection of the display with re-projection of individual layers handled on the fly.
		Spatial analyses	Including buffer, slope aspect, raster overlay operations, models, spatial operations (union, clip, etc.), conversion between vector and raster formats including point interpolation and iso-contours
	Data comparisons		
		Map comparison	Side-by-side, animation, tiled display of multiple small maps.
		Explicit support for comparing across time	A way to specify that certain columns represent the same variable in an ordered sequence of time intervals. Function for selecting specific time interval to display. Animation function.
	Interface customization		
		User-specific views	Customizable configurations for different levels of users.

Appendix 4: Results of Survey Analysis

Challenges to GIS use in Schools

Workshop participants were asked to rank challenges to GIS use in school by picking the 15 most important challenges from the list below and then rating those challenges as critical (3 points), major (2), minor (1). Items that did not receive a vote were given an score of zero (0). The tables below provide complete rankings as sorted by average vote, number of votes, and weighted average (average vote multiplied by number of votes).

Sorted by Average Vote
Items that did not receive votes scored as "0"

Challenge	Challenge Code	Average (of all; no vote=0)
Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware	C20	2.0
Navigating through file system and across networks to load data or projects.	C03	1.7
Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want	C12	1.3
Aligning different projections (i.e., bringing aerial photos into an existing dataset)	C37	1.3
Installation for tech staff and teachers	C26	1.2
Software requires high-end hardware. Schools have older machines (5-year replacement cycle).	C21	1.1
Dealing with importing data in different data formats	C30	1.1

Sorted by # Votes
Total number of votes received by each item

Challenge	Challenge Code	# Votes
Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware	C20	12
Navigating through file system and across networks to load data or projects.	C03	9
Creating new fields in existing datasets, or bringing in new complete datasets	C05	9
Aligning different projections (i.e., bringing aerial photos into an existing dataset)	C37	9
Project transportability (portability)	C01	8
Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)	C11	8
Software requires high-end hardware. Schools have older machines (5-year	C21	8

Weighted Average
*Average Vote * # Votes*

Challenge	Challenge Code	Weighted Average
Multiple Platforms & Configurations: Software has to support diversity of Operating Systems and hardware	C20	24
Navigating through file system and across networks to load data or projects.	C03	15
Aligning different projections (i.e., bringing aerial photos into an existing dataset)	C37	11.4
Installation for tech staff and teachers	C26	9.6
Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want	C12	9.33
Software requires high-end hardware. Schools have older machines (5-year replacement cycle).	C21	9.07
Dealing with importing data in different data formats	C30	9.07

			replacement cycle).					
Challenges of working with or around security software.	C23	1.1	Installation for tech staff and teachers	C26	8	Creating new fields in existing datasets, or bringing in new complete datasets	C05	9
Understanding connection between tables and maps	C39	1.1	Dealing with importing data in different data formats	C30	8	Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)	C11	8
Creating new fields in existing datasets, or bringing in new complete datasets	C05	1.0	How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials.	C09	7	Project transportability (portability)	C01	7.47
How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials.	C09	1.0	Understanding different kinds of learning patterns for users, and understanding what needs to be done to accomplish what they want	C12	7	Understanding connection between tables and maps	C39	7.47
Providing appropriate level of interface complexity for the task/ audience (when to show / hide complexity)	C11	1.0	Simple way to register images	C35	7	How to support common sequences / procedures -- at the level of larger activities and smaller skill tutorials.	C09	7
Project transportability (portability)	C01	0.9	Understanding connection between tables and maps	C39	7	Understanding where data came from (accuracy, resolution, source)	C40	6.53
Hard to get data into appropriate format	C32	0.9	Understanding where data came from (accuracy, resolution, source)	C40	7	Challenges of working with or around security software.	C23	6.4
Understanding where data came from (accuracy, resolution, source)	C40	0.9	Difficult to build queries with formulas	C06	6	Hard to get data into appropriate format	C32	5.6
Difficult to build queries with formulas	C06	0.8	Difficulty of linking/joining data with features	C07	6	Simple way to register images	C35	5.6
Difficulty of linking/joining data with features	C07	0.8	Difficult to generate a new theme by querying multiple themes and combining	C08	6	Difficult to build queries with formulas	C06	4.8
Difficult to generate a new theme by querying multiple themes and combining	C08	0.8	Documenting inquiry process (providing audit trail). How do you retrace steps? Pick up thread of previous thought process?	C17	6	Difficulty of linking/joining data with features	C07	4.8
Simple way to register images	C35	0.8	Providing support for meta-data and for describing the process you went through to get where you are (meta-history)	C19	6	Difficult to generate a new theme by querying multiple themes and combining	C08	4.8
Raster vs. Vector data (Understanding how functionalities / tools change with different types of data. E.g., legends with vectors are there, legends of rasters have to be manually called)	C38	0.8	Challenges of working with or around security software.	C23	6	Ways of picking up an investigation where you left off.	C24	3.86
Hard to find data (esp local)	C31	0.7	Ways of picking up an investigation where you left off.	C24	6	Hard to find data (esp local)	C31	3.67

Internet access: Limitations on networking, accessing data, accessing web-mapping, etc.	C02	0.7	Hard to get data into appropriate format	C32	6	Providing support for meta-data and for describing the process you went through to get where you are (meta-history)	C19	3.6
Data Integrity-- everyone using the same dataset, vs. mutations. As students create their own maps, representations may change, operations on the maps, make errors, accidental changes non-copy-protected data.	C25	0.7	Recognizing need to make theme active before performing action on it.	C15	5	Data Integrity-- everyone using the same dataset, vs. mutations. As students create their own maps, representations may change, operations on the maps, make errors, accidental changes non-copy-protected data.	C25	3.33
Ways of picking up an investigation where you left off.	C24	0.6	Data Integrity-- everyone using the same dataset, vs. mutations. As students create their own maps, representations may change, operations on the maps, make errors, accidental changes non-copy-protected data.	C25	5	Raster vs. Vector data (Understanding how functionalities / tools change with different types of data. E.g., legends with vectors are there, legends of rasters have to be manually called)	C38	3.2
Providing support for meta-data and for describing the process you went through to get where you are (meta-history)	C19	0.6	Hard to find data (esp local)	C31	5	Recognizing need to make theme active before performing action on it.	C15	2.86
Recognizing need to make theme active before performing action on it.	C15	0.6	Internet access: Limitations on networking, accessing data, accessing web-mapping, etc.	C02	4	Internet access: Limitations on networking, accessing data, accessing web-mapping, etc.	C02	2.67
Vocabulary for GIS concepts and operations that new users can understand	C41	0.5	Difficulty of supporting map construction	C10	4	Documenting inquiry process (providing audit trail). How do you retrace steps? Pick up thread of previous thought process?	C17	2.4
Finding/defaulting to,working directory	C04	0.5	Keeping track of what's displayed when you have lots of variables displayed.	C13	4	Vocabulary for GIS concepts and operations that new users can understand	C41	2.13
Working across multiple screens / worksheets	C14	0.5	Working across multiple screens / worksheets	C14	4	Working across multiple screens / worksheets	C14	1.87
Documenting inquiry process (providing audit trail). How do you retrace steps? Pick up thread of previous thought process?	C17	0.4	Long processing time of computationally-intensive operations on slower school computers	C22	4	Long processing time of computationally-intensive operations on slower school computers	C22	1.6
Long processing time of computationally-intensive operations on slower school computers	C22	0.4	Software and data updates	C27	4	Software and data updates	C27	1.6
Software and data updates	C27	0.4	Raster vs. Vector data (Understanding how functionalities / tools change with different types of data. E.g., legends with vectors are there, legends of rasters have to be manually called)	C38	4	Difficulty of supporting map construction	C10	1.43

Difficulty of supporting map construction	C10	0.4	Vocabulary for GIS concepts and operations that new users can understand	C41	4	Finding/defaulting to,working directory	C04	1.4
Keeping track of what's displayed when you have lots of variables displayed.	C13	0.3	Finding/defaulting to,working directory	C04	3	Keeping track of what's displayed when you have lots of variables displayed.	C13	1.33
Batch processing of compressed files & archives (hiding decompression, importing, file management, etc. Zips within zips. Peek inside of zipped archives)	C34	0.3	Hard to import from GPS	C33	3	Batch processing of compressed files & archives (hiding decompression, importing, file management, etc. Zips within zips. Peek inside of zipped archives)	C34	1
Hard to import from GPS	C33	0.3	Batch processing of compressed files & archives (hiding decompression, importing, file management, etc. Zips within zips. Peek inside of zipped archives)	C34	3	Hard to import from GPS	C33	0.8
Reliance of GIS tools on accurate typing	C16	0.2	Reliance of GIS tools on accurate typing	C16	2	Reliance of GIS tools on accurate typing	C16	0.4
Compatibility with other GIS tools.	C36	0.1	Compatibility with other GIS tools.	C36	2	Compatibility with other GIS tools.	C36	0.13
Support for planning, logging, tracking, unwinding/changing paths	C18	0.0	Support for planning, logging, tracking, unwinding/changing paths	C18	0	Support for planning, logging, tracking, unwinding/changing paths	C18	0
Repairing/installing/turning on extensions	C28	0.0	Repairing/installing/turning on extensions	C28	0	Repairing/installing/turning on extensions	C28	0
Dealing with trends toward (a) terminals (b) laptops	C29	0.0	Dealing with trends toward (a) terminals (b) laptops	C29	0	Dealing with trends toward (a) terminals (b) laptops	C29	0

Features Critical to GIS use in Education

Workshop participants were asked to identify the ten most useful and important features of GIS for use in content area (geosciences and geography) courses, and then rank them from 1 (most important) to 10 (least important). For the purposes of scoring, we inverted the scale so that 10 was most important and 1 least important. No votes were scored as zero. The tables below provide complete rankings as sorted by average vote, number of votes, and weighted average (average vote multiplied by number of votes).

Sorted by: Average Vote
Items that did not receive votes scored as "0"

Feature	Feature Code	Average (of all; no vote=0)
Query construction	F19	6.7
Spatial analyses	F23	6.5
Classification	F14	5.3
Import from data-servers over the web	F03	3.5
Summary tables	F12	3.5
On the fly Projections	F22	3.3
Generating graphs/charts from data	F11	2.9
Importing Wizard	F01	2.7
Interface to GPS	F02	2.3
Annotations	F15	2.3
Hotlinks	F18	2.3
Joining data tables	F05	1.9
Output for sharing	F16	1.9
Drawing Data	F06	1.7
Record-keeping tool	F10	1.7
Direct-manipulation query construction	F20	1.6
Multi-site data sharing	F04	1.5
Map comparison	F24	1.1
Dynamic data	F08	1.0
3-d maps	F13	0.7

Sorted by: # of Votes

Feature	Feature Code	# of Votes
Classification	F14	14
Query construction	F19	13
Spatial analyses	F23	12
Generating graphs/charts from data	F11	10
Summary tables	F12	10
On the fly Projections	F22	9
Importing Wizard	F01	8
Import from data-servers over the web	F03	8
Drawing Data	F06	8
Output for sharing	F16	8
Interface to GPS	F02	7
Joining data tables	F05	7
Annotations	F15	6
Hotlinks	F18	6
Record-keeping tool	F10	5
Multi-site data sharing	F04	4
Direct-manipulation query construction	F20	4
Dynamic data	F08	3
3-d maps	F13	3
Map comparison	F24	3

Weighted Average
Average / # Votes

Feature	Feature Code	Weighted Average
Query construction	F19	87.5
Spatial analyses	F23	78.4
Classification	F14	74.7
Summary tables	F12	34.7
On the fly Projections	F22	29.4
Generating graphs/charts from data	F11	29.3
Import from data-servers over the web	F03	28.3
Importing Wizard	F01	21.9
Interface to GPS	F02	16.3
Output for sharing	F16	14.9
Annotations	F15	14.0
Hotlinks	F18	14.0
Drawing Data	F06	13.9
Joining data tables	F05	13.5
Record-keeping tool	F10	8.3
Direct-manipulation query construction	F20	6.4
Multi-site data sharing	F04	6.1
Map comparison	F24	3.2
Dynamic data	F08	3.0
3-d maps	F13	2.2

Explicit support for comparing across time	F25	0.5
Hand digitizing	F07	0.1
Planning tool	F09	0.0
Export to interactive map server	F17	0.0
Image Processing Functionality	F21	0.0
User-specific views	F26	0.0

Explicit support for comparing across time	F25	2
Hand digitizing	F07	1
Planning tool	F09	0
Export to interactive map server	F17	0
Image Processing Functionality	F21	0
User-specific views	F26	0

Explicit support for comparing across time	F25	1.1
Hand digitizing	F07	0.1
Planning tool	F09	0.0
Export to interactive map server	F17	0.0
Image Processing Functionality	F21	0.0
User-specific views	F26	0.0