GIS in K–12 Education

An ESRI White Paper—March 1998

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An ESRI White Paper

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Executive Summary

Geographic information systems (GISs) consist of robust hardware, powerful software, spatial data, and a thinking explorer. Together, the technology elements are powerful tools for automated cartography and extensive analysis of information about places. Recent improvements in computer hardware and software allow the powers of GIS to move effectively and affordably into the precollege arena. Schools can take advantage of this "new geography" in many ways, in a variety of grade levels. With less than $2,000 investment (spring 1998), schools can have a brand-new, full-featured, high-powered computer ready for classroom needs plus a school site license for a powerful starter package of GIS software and basic data.

GIS can be incorporated into current curricula in all grades and subjects, supporting and enhancing existing activities instead of requiring an isolated, dedicated place within the curricula. These powerful tools permit teachers and students to explore and analyze information in new ways, focusing students' activities on the higher order thinking skills of observation and exploration—questioning, speculation, analysis, and evaluation. But more important even than the robust technology, GIS requires an educational paradigm emphasizing individual exploration, a style that is unfamiliar to many teachers—so there are some major hurdles to effective use of GIS in the K–12 classroom. Still, early examples point to powerful results.

Part I—Basics

A. The Vision: Dream Versus Potential

In the dreams of educators, administrators, and parents alike, school is a magical place. Students go to school and are engaged in stimulating, challenging, energizing activities through which they learn about the world of today, how it came to be as it is, and how to make it better in the future. They learn to think both independently and critically, taking advantage of information from others, yet testing the ideas and casting them in new configurations. They learn about a multitude of topics, yet integrate the important ideas and information across disciplines. They develop skills and attitudes in one subject that transfer to all others—skills of thinking, questioning, finding information, expressing ideas, listening to others and valuing their contributions, and developing a disposition to learn. Such skills are critical for their present and future lives and for the lives of all people around them.

In such a scenario, school is not without conflict or contest. Indeed, wrestling with ideas and coming to grips with different information, skills, and values brings a steady stream of issues to explore. But, in this dreamland, the focus of the participants might be toward exploration, integration, and collaboration instead of segmentation, stratification, and conquest.

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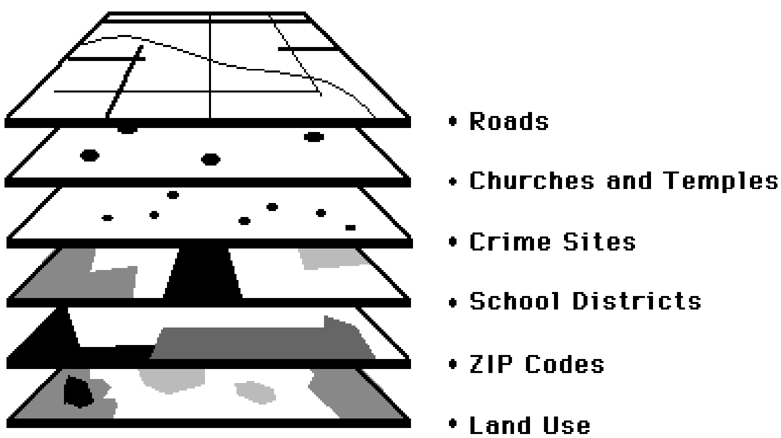
Such a scenario is not so far away. A tool is available that has the potential to help schools move much closer to this dream. The tool is a geographic information system, or GIS.

B. Definition: What Is a GIS?

A geographic information system is a combination of elements designed to store, retrieve, manipulate, and display geographic data—information about places. It is a package consisting of four basic parts: robust hardware, powerful software, special data, and a thinking explorer.

The hardware is a peppy computer. The software is a powerful set of instructions and procedures that can be applied. The geographic data are computerized bits of information about places, in a variety of formats. The thinking explorer is the operator, who does not know all the answers, and may not even know all the questions, but who wants to learn about places and knows how to use tools creatively to look for patterns.

Like any system, a GIS works best (perhaps only) when all parts are operating in concert. Again, like any system, the whole is far greater than the sum of its parts. And, again like any system, it may be hard for the novice to see the full picture at first glance. To help explain what a GIS is and does, consider this analogy:



Imagine an overhead projector, with a series of transparencies laid upon it. Each transparency is about your town, drawn to the same scale, and can therefore be integrated with the others. But each transparency deals with a different topic: rivers, roads, railroads, elevation, vegetation, zoning, land use, buildings, population characteristics, crime sites, churches and temples, school attendance boundaries, ZIP Codes, utility lines, newspaper boxes, and so on. Standing before the overhead, you mix and match the layers at will, magically changing classification schemes and modifying symbols, colors, patterns, and combinations. You can zoom in and out, seeing all the information available or only the data you specify, comparing this layer with that feature, exploring the data in every way imaginable. As you play with these layers of information, relationships appear.

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This is sort of what GIS is like. Through the power of a computer and software, using a wide range of electronic data, and with an eye toward patterns and relationships, GIS users explore information about places. Through creative questioning, careful analysis, and even random exploration, GIS users learn the patterns of people, objects, and features of one site, how they interact, and how one region influences another. In short, GIS is a tool for learning about the world and all that is in it.

As a tool, GIS by itself does not provide answers. What it provides to users is the opportunity to exercise creative vision, to integrate information, and to evaluate endless alternatives. Its value is enhanced when the user collaborates with others, and the technology itself facilitates such sharing of resources, understandings, and interpretations.

C. Hardware: The Visible Tools of the Engine

The remarkable explosion of power in personal computers has meant enormous opportunity for the public. GIS used to be available only to those with access to the huge mainframes and powerful workstations necessary to churn large amounts of data. The recent skyrocketing of computer power, coupled with a steady decline in price, has made space-age tools affordable for schools, even for those facing tight budgets. While configurations of hardware can vary widely, typical stand-alone stations for using GIS in the classroom share some minimum pieces:

- Windows = 486DX or higher PC (preferably Pentium or higher) running Windows 3.1 or higher (preferably Windows 95 or Windows NT)
- Macintosh = PowerMacintosh running Mac OS 7.1 or higher
- 16+ MB physical RAM (preferably 32+)
- 100+ MB hard drive space dedicated to GIS (preferably more)
- CD–ROM drive (preferably fast)
- 256+ color monitor (preferably large)
- Mouse
- Color printer

Going below these levels for a single-station setting in a classroom is not practical because of the time required to accomplish tasks on less powerful machines. In an environment where ten seconds of delay can mean a significant drop in excitement, attention, and productivity, speed is a critical element. (For a more detailed discussion of options, see **Appendix A.**)

D. Software: The Critical Interface for the Engine

There are two parts to the engine of a GIS: the physical tools and the instruction set that tells the hardware to accomplish tasks. That instruction set is the software.

Powerful software can use the rising capabilities of new hardware to its fullest extent. Good software can accomplish many tasks and is adaptable to many purposes. The GIS software called ArcView® GIS, by Environmental Systems Research Institute, Inc. (ESRI), is akin to a combination of several packages: a page layout program for desktop publishing, a database program for managing tables, a spreadsheet program for processing numbers, and a programming language, all tied together with a powerful geographic exploration engine.

It can take a long time to learn to use these tools to their fullest extent. One big challenge, of course, is that people can do many things with good GIS software. Fortunately, however, the vast majority of tasks that schools wish to accomplish can be handled with a reasonable number of basic operations. Students and teachers generally need just the basic features of the software and should not be concerned with learning immediately "all there is." (For a summary of the basic tasks that ArcView GIS users should concentrate on in schools, see **Appendix B.**)

E. Data: The Fuel

A car engine needs fuel to run. Without fuel, there is little point in having a car. Same, too, with a GIS. It needs fuel, in the form of geographic data, or information about places. Fortunately, unlike the fuel for automobiles, there is no shortage of data for a GIS. Indeed, such data sets are exploding in volume. These data come in several basic formats.

First is the geographic data that represent physical places: points, lines, and areas. (These three kinds of features are referred to as vector data.) These data sets form the outlines and locations of places and features on a map. On a world map of earthquakes, for instance, one might expect to find a line layer for latitude and longitude, an area (or polygon) layer for the continents, and a point layer for the sites of quake centers. The map might also have another polygon layer for countries, another line layer showing rivers, and another point layer designating cities over one million in population. These geographic data sets (examples below) show where something is on the planet and provide each feature a unique name or an identifying number.

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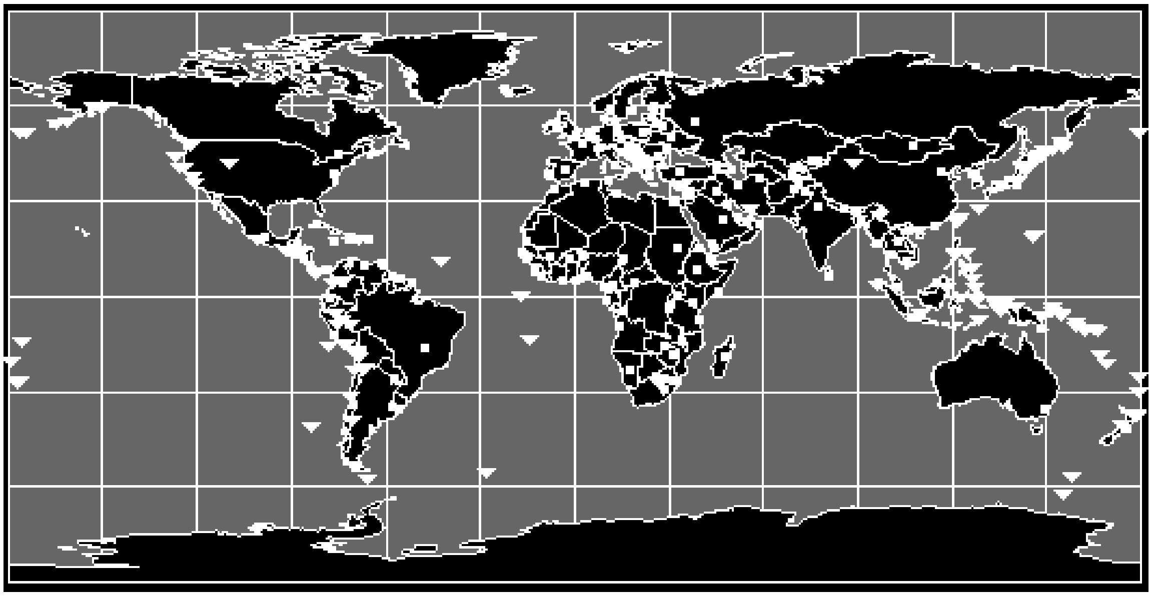
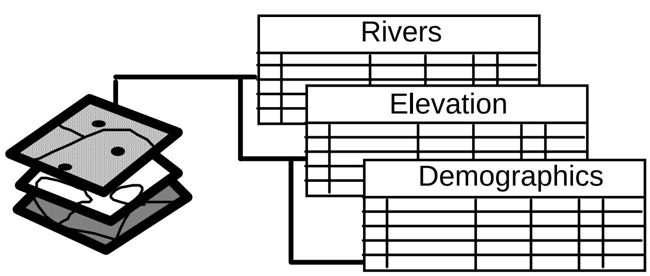


Brazil	147294000	2.01	2.29	34.33
Bhutan	1403000	2.16	2.17	31.94
Bulgaria	9001001	0.17	0.41	405.88

Next is the set of attribute data, or characteristics of features. These data sets are tables, made up of rows (or records) and columns (or fields) of information. In a countries data table, for instance, each country would be one record, and each piece of information about that country would go in its own field. Very quickly, one could have many pieces of information about many countries. There can even be many tables of country information. Matching each unique name in a table with the corresponding name in the geographic data converts dull tables into visually powerful displays. Countries are no longer uniformly colored but instead shaded according to, say, population growth rate. Rivers are no longer single blue lines but graduated to show water volume or the amount of barge traffic upon them. Cities are no longer identical dots but sized and shaped and colored to demonstrate one attribute or another.



Geographic features and tables of data form the warp and weft of a GIS. Matching data tables to their counterparts in feature layers, GIS users in schools can map an endless array of information. But there are other important types of data to consider, as well.

Vast quantities of cell-based data (raster data as opposed to vector data) exist such as elevation models, aerial photos, or satellite images. Each file contains cells of uniform size holding some information about the nature of region portrayed. These cells may document tiny parts of the landscape, as in a photograph, or swatches over a mile on a side. And their attributes can be analyzed in powerful ways.

Text documents abound and deserve attention. It is easy to set up ArcView GIS so that the click of a button brings up precrafted text files about geographic features such as an essay about the Good Friday Earthquake of 1964. Similarly, scanned documents, digital pictures, and videos can be identified and tied to a map, so that clicking a feature tells the computer to display a particular file. Even audio or video files can be integrated and attached to geographic features. In short, any information that can be captured and represented in a digital format can be tagged for presentation at particular sites.

Returning to the overhead projector analogy, with layers of information about a city, we could arrange the GIS to show many things: the different parts of the city, patterns of how the city grew, where the airport is, how the airport runways line up, which way the jets fly, what it sounds like in different places when a jet flies overhead, how much noise spreads out how far, how the hotels and shopping areas near the airport fare compared to those farther out, and so on. We could use the GIS to display any kind of data that vary from one place to another.

(For further details about data for use with GIS, look at **Appendix C.**)

F. Operator: The Driver

Vastly more important than all the technological elements of this toolkit, however, is the operator. A thinking user with a disposition for exploration and a capacity to think geographically, to search for relationships, and to see spatial patterns is far and away the most crucial element of the entire system. There are so many possible combinations for so many data items that the system needs careful guidance. Someone needs to find the most appropriate data. Someone needs to decide if—and why—one representation is better than another. Someone needs to identify the impact of seeing the data one way instead of another. Because a given set of data can be shown in many different ways, someone needs to determine what is accurate, appropriate, and complete; why the data are important; and what message is transmitted by a particular configuration.

During this exploration, important gaps in the data may be discovered. It may turn out that an existing data set has a hole or a flaw that needs to be fixed. Or the need for a certain set of additional information may become apparent only after significant tinkering has already occurred. Using GIS is an evolutionary process, involving exploration of what exists, wondering and hypothesizing, evaluating results based on available data, identifying what other data are needed, and presenting interpretations based on the data used and the judgments made.

It is this last piece that points so clearly at schools. To be a positive force in society—to make well-considered decisions, to be a resource with the potential to improve the quality of life—people need to be comfortable with exploring and integrating information, seeking relationships, thinking critically, acknowledging differences, and finding common ground. Using a GIS, these essential skills can be developed in schools, in all subject matters, by students young and old, and with all degrees of innate ability. They are indeed the very heart of GIS. And the most delightful part about all of this is that using a GIS is fun.

(For details about professional GIS users and schools collaborating, see **Appendix D.**)

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Part II—Incorporating GIS in Schools

A. Exploring Common Ground: The Educational Promise of GIS

(This outline was first published by ESRI as a stand-alone four-page document that identified the range of opportunities presented by GIS. Its outline format is designed to help education professionals match the opportunities to their own particular needs.)

Effective use of geographic information systems involves more than just clicking buttons to create a map. In a school setting it means engaging in active learning, with significant thinking required. GIS can mean more to education than just having a source of maps. GIS can affect the whole educational experience for students, teachers, and the community. This outline describes some of the broader requirements, possibilities, and implications.

1. GIS can play a role in educational reform.

A. GIS can be an effective tool to promote change and growth for students, teachers, skill development, classroom organization, instructional methodology, curricular content, and community participation, all at the same time.

B. The software and the data do not contain or present "the" answer. People define answers according to the questions they ask and the parameters they establish. GIS provides methods to explore alternative responses for specific problems and situations. Users still need to define what constitutes a satisfactory answer to their question. Critical thinking plays a primary role in using GIS effectively. Explorations thus involve profound challenge for learners.

C. Students and teachers can both be active learners at the same time. By developing new skills and exploring new understandings of a variety of topics, teachers can model for students the process and value of lifelong learning.

D. Because the computer is a powerful tool for exploring similar content through divergent paths, students engaged in GIS can progress in varied ways in a style and at a pace appropriate for their individual interests, strengths, and needs. Active exploration with GIS can more easily match the multiple modes of information access that different students need, while still affording each the chance to contribute to group activities and providing each a powerful opportunity for constructing individual visions of the world.

E. Assessment of student progress, achievement, or development can be accomplished in multiple fashions in ways that are appropriate to the students' interests, the school curriculum, and the community needs.

F. Using GIS can help students and teachers become more involved as local community participants and global citizens. Partnering with other GIS users from the community enacts the "community as classroom" concept. Students, schools, and the community all benefit as each pays closer attention to the needs of the others.

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2. GIS is a vocational tool.

A. GIS helps develop basic computer literacy.

B. Effective use of GIS provides integrated training in the process of research including data gathering and preparation, storage, analysis, and presentation.

C. Long-term partnering including student internships may be available through GIS using operations in the local community.

D. GIS activities provide actual training for many careers. GIS is a tool for the twenty-first century.

3. GIS engages and exercises multiple capacities and intelligences.

A. Critical thinking (ability to analyze, synthesize, and evaluate)

B. Logical-mathematical intelligence

1. Numeracy (ability to interpret and use numbers and numeric skills)

2. Technological capacity (ability to understand and use tools that facilitate acquisition, processing, and transferal of information)

C. Linguistic intelligence

1. Literacy (ability to interpret and present information in word form)
2. Graphic recognition (ability to read and use visible symbols)

D. Spatial intelligence

1. Map literacy (ability to transform real life into a mental or visual picture, or vice versa, at multiple scales)

E. Interpersonal intelligence

1. Communication (ability to transfer effectively to others through multiple modes of representation the information and knowledge gleaned through the investigative process)

4. GIS relies on and fosters a mindset of exploration.

A. Effective users have a disposition for discovery learning.

B. Effective users look for new possibilities.

C. Effective users explore multiple views of a single issue or set of information.

D. Effective users recognize that there is rarely a "right answer" to a given question or problem.

E. Effective users make mental leaps, involving both direct iterations (multiple slight variations on a single theme) and "inspired explorations" (divergent, creative thinking).

F. In effective situations, the teacher is a facilitator who models lifelong learning, rather than simply being a deliverer of information. Students and teachers can collaborate in their explorations.

5. GIS relies on and promotes finding information and knowing what to do with it.

A. Effective users are able to identify appropriate types and sources of information needed to solve a problem.

B. Effective users integrate information from multiple sources and of multiple types.

C. Effective users recognize that appropriate use of any given data includes understanding the nature and quality of the data.

D. Effective users can identify factors that affect the quality of data and know how to match data and task appropriately.

6. GIS relies on and promotes spatial awareness.

A. Effective users see patterns in actual landscapes and symbolic representations.

B. Effective users ask iterative questions to describe and explain spatial patterns.

C. Effective users explore patterns identifiable across a range of data sources and different types of representations.

D. Effective users integrate data at multiple scales and identify patterns and processes at and across a range from macro to micro.

7. GIS relies on and promotes computer literacy.

A. File management (critical skill)
B. Database manipulation (critical skill)
C. Spreadsheet operation
D. Graphics tool use
E. Using remotely sensed data such as satellite imagery and aerial photos
F. Accessing the Internet for data
G. Using presentation software
H. Producing multimedia projects
I. Integrating additional technologies such as global positioning systems

8. Using GIS effectively requires knowing how to make the GIS software perform particular tasks.

A. Effective users learn, over time, how to make the software do what they want.

B. Effective users take advantage of different levels of software capacity. Some needs and tasks are more complex than others; some tools are more broadly applicable than others. Effective users learn to employ fundamental tools early and add to their tool-using skills over time.

Summary

What this all means is that GIS can be a powerful ally in the effort to enhance education. Students and teachers can work together to build a coherent framework for information about the world. The community can share in the process of providing educational experiences and can gain from intelligence provided by the students. The focus on collaboration between students, teachers, school, and community can provide significant long-term benefit for all.

Individually, students can benefit from increased attention to their strengths and weaknesses. The potential to relate schoolwork with explorations from everyday life can add powerful connections for students constructing their own views of the world. Engaging GIS in multiple grade levels and disciplines can yield an uncommon synergy in a setting too often fractured.

This is the vision and expectation built from early explorations of GIS in the K–12 classrooms. Because of the speed with which this technology has burst on the scene, these descriptions are not supported by exhaustive studies. Similarly, because of the complexity involved, it has not been proven beyond all doubt that students and teachers who engage GIS develop the desirable traits noted above where such traits did not exist before. Rather, this is the view of individuals who have gained sufficient background with both the technology and the challenges of elementary and secondary education. As with much of education, the results may not be clear for years. But, given the current anecdotal evidence, there is strong reason to believe these positive statements are true for all students.

Finally, as technology brings us all ever closer to each other, it seems only too obvious that there is a need to understand more fully the changing relationships between people and places around the planet. We share many parts of our existence, and we need to explore our common ground.

B. The Implementation Challenge

Given the many enticing descriptions about what can be achieved (and has been), it is a powerful temptation for people to think, "Yes, let's put this into our schools, so we can be like that too." It would be wonderful if, with the wave of a wand and the introduction of a new tool, all this educational promise were suddenly achieved. Unfortunately, this does not happen quite so magically.

Administrators may be tempted to say that their teachers can adapt to this new tool quickly and incorporate it efficiently. They may see the long range impact coming in short order, as soon as the tools are made available.

Teachers may see the technology and think, "I need only know the proper sequence for working the tool, and powerful things will happen." The "magic" may be perceived as happening simply through their mastery of a single procedure or by going through one of a legion of carefully scripted lessons.

Parents may be using the tool at their daily work and think, "This is powerful vocational training, which can be matched with any amount of content. Of course it will work. People will want to do it instantly and will be able to use it effectively in short order." Parents know how quickly students pick up on computer-based activities, and they may extrapolate that into the classroom.

Students may even get to see the tool and think, "If only we had the computers in school so that we'd have the chance to play with these things…"

The potential for GIS is tremendous. The potential for people to expect too much too soon without proper support being in place is also high. Teachers, administrators, GIS users, parents, and students are often guilty of over-zealous expectations.

The challenge is to understand what and where the barriers are and learn what strategies exist for dealing with these hurdles. The typical barriers people identify are these:

- Insufficient hardware available at school
- Insufficient access in the classroom to existing hardware
- Lack of GIS software for use on available computers
- Lack of usable data about the desired focus topic
- Insufficient basic computer expertise on the part of teachers
- Insufficient GIS skills on the part of teachers
- The time it takes to "learn GIS"
- Lack of a specific, relevant curriculum engaging GIS
- Insufficient time to engage in unscripted explorations with only vaguely defined goals or highly variable results
- Pedagogical style not conducive to using GIS, especially as an exploratory tool

These complaints and variants of them are the most commonly listed impediments to engaging GIS in schools. The most substantial challenge of these is the last one. All the others can be met with a relatively reasonable and predictable expenditure of energy, dollars, or attention. But using GIS effectively in the classroom involves an instructional style, indeed a whole paradigm, that is different (often radically) from that of many currently practicing educators.

The challenge for teachers is to bring a powerful tool into the classroom setting and allow the students to use it. Experience has shown that many teachers are uneasy thinking about using a tool with which the teachers themselves do not have total comfort.

Geography is a diverse discipline, covering a vast range of information. The computer in general is a tool that facilitates divergent paths. Thus, GIS may be considered "divergence squared." Opportunities are ripe for students to explore in unpredictable paths, engaging both standard and unimagined modifications and coming up with analyses and conclusions ranging from commonplace to ones that couldn't possibly be foretold. They may step off the beaten path in their studies, and a teacher may have some difficulty identifying exactly what has occurred to bring students to a given spot in their investigation. When using GIS, users follow this process:

- Think about a topic or a place.
- Make a map.
- See the patterns that result.
- Modify the data used or analyses performed.
- Create a new map.
- Repeat.

This is the educational frontier for teachers. The power of the tool lies in its ability to support critical thinking and to be used with infinite variation. Teachers need to create an environment that will permit the students to take advantage of this variability yet still accomplish the educational objectives the teacher has in mind.

Different strategies are being employed with varying levels of predictability and success. They can be broken down into two main camps: teaching about GIS and teaching with GIS. In teaching about GIS, teachers focus on the tool and seek to help students acquire a full range of skills for meeting particular tasks. In teaching with GIS, teachers strive to teach particular subject matter by taking advantage of the power of GIS.

Teaching about GIS can be effective in a setting where students are learning vocational skills, and GIS is presented as a more or less generic tool, similar to CAD or multimedia or programming. These students need to know the meaning of buttons and tools and menu items, and the procedures for accomplishing operations. But this is not the most effective approach for most teachers, who are oriented toward more traditional views of content—information and skills for processing it. Teaching with GIS means teaching one's standard subject matter using this new tool. That is, the concepts of regions or plate tectonics, or the skills of comparing and contrasting data, can be addressed using the tool of GIS.

Teachers need to be comfortable giving their students the opportunity to explore, and they must be prepared to face some unanticipated paths and results. This does not mean teachers should present GIS with a laissez-faire attitude. Teachers can and should help students steer their usage. But, even with this channeling, students will end up bringing in new data, finding unexpected correlations, or extending the limits of what can be done with a given set of data. Seldom will results be limited to just what a teacher is able to predict. Therein lies the challenge.

Teachers need to be skilled at turning new possibilities into powerful educational experiences. They need to be comfortable with students developing skills more than acquiring raw content. Students develop skills in finding data, processing it into information, and combining bits of information from various sources into knowledge. It can be a challenge for teachers to predict what will be accomplished and how to measure the learning that has taken place using traditional methods. Projects, portfolios, and peer reviews can play an extremely powerful role in helping teachers who use GIS identify and verify learning.

These teacher skills, plus those of simply working in effective ways with computers, can take time to develop and do not appear simply as a result of bringing in GIS. Fortunately, there are any number of professional growth activities that teachers can engage in that will help them develop the computer skills and pedagogical vision described above.

C. GIS in Different Levels

Teachers can use GIS tools successfully in all levels of school. However, it is important that teachers carefully match the task or opportunity with the developmental level of the students. A mismatch between student, educational tool, learning objectives, and instructional method can render even the most powerful tool ineffective. No tool, by itself, can match the direction and customization that a tuned-in teacher can give. Even powerful tools only reach their potential when focused; indiscriminate introduction of a tool in a classroom is as unwise as in a hospital operating room. Tools are only as good as the users make them be. With GIS, while activities may vary widely from grade to grade, the skills and principles endure. In each setting, exploration and discovery are key, with critical thinking skills to be fostered throughout.

1. Elementary School

In early grades, teachers can introduce students to maps as models and to geography as a discipline. Important concepts of absolute and relative location, place, region, scale, symbolization, and generalization can be brought in. Students can begin to explore significant features of human and physical geography (mountains, cities, deltas, farmland, etc.) through satellite imagery. Or they can use local area maps of relevance (neighborhoods, local watersheds, forests, etc.) produced by local GIS users.

Kids love seeing familiar places on a map. Some of the most powerful explorations can be done with nothing more elaborate than a set of local streets on which they can plot their own addresses, the neighborhood playground, the church, and the store.

Even in the earliest years, kids can learn to zoom in and out, turn layers on and off, shuffle the display of layers, and ask, "What's that thing?" These basic skills will serve them in all future explorations.

Students should see (1) computers are tools with capacity for displaying information effectively, and (2) maps are dynamic and representational (thus distortable) displays rather than static and "correct" portraits. Perhaps above all, students in the early grades need to have fun exploring information on the computer; for this aspect, multimedia linkages can be very powerful.

2. Middle School

In middle school, students can begin examination of special topics and regions. They can study a given phenomenon over space, seeing how it relates to others. They can survey the characteristics and relationships of geographically varied traits (population, economic makeup, physical features, etc.). They can examine a region and its features and begin to understand the complex traits that identify and unite or separate areas, at scales local to global. Middle school is also the best opportunity for engaging in cross-disciplinary studies.

Students in grades 5–8 have built up life experiences that can be used to advantage. Their existing computer skills make it easy to involve them in producing geographic data about the local area. They can map trees in the neighborhood, parks and recreation centers, empty houses, safe bicycle routes, potholes in the roads, and so on. By creating data that the community can actually use, students learn the importance of accuracy in measurement, documentation, and representation.

3. High School

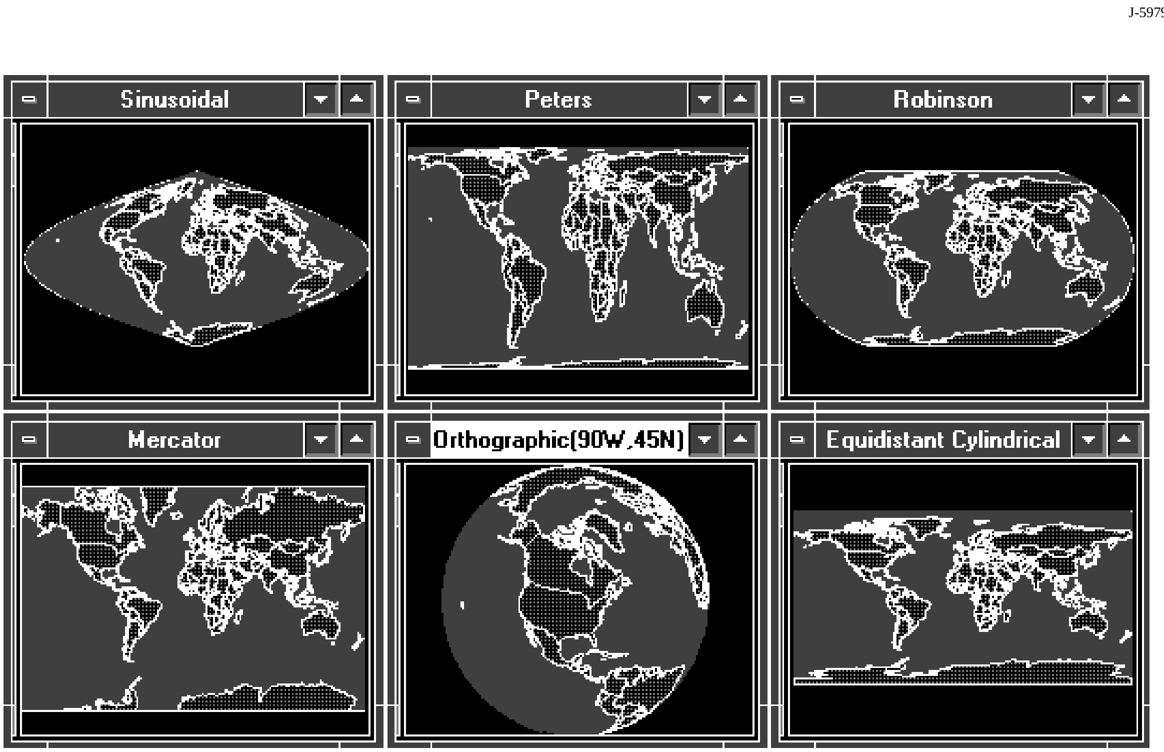
High school students can expand the study of topics and regions and explore geography-related job markets. Earlier regional and topical studies can be carried deeper or integrated with other studies. Students can focus on interrelationships between features and factors in other places. They can survey vocations that rely on ability to gather, process, analyze, and report spatially varied data. Guidance counselors and teachers can explore the jobs that rely on spatial data (urban planners, marketers, environmental engineers, energy and utility companies, etc.) and how these workers gather, use, and display their data.

In each grade range, Avenue™ software, the scripting language that can be used to customize ArcView GIS software's look and operation, can play an important role. Setting the software to have only one or two visible functions available can be powerful at all grade levels, and developing preconfigured tasks can facilitate explorations and analyses. However, the interface of a GIS should not be thought of as intimidating to students. Experience has shown that even very young students adapt quickly to a standard "designed-for-adults" interface and are able to be productive with an "adult tool," as long as they are provided some basic direction about menus, buttons, tools, and the task at hand.

D. GIS in Different Subjects

Teachers of geography are not the only ones to benefit from a GIS. Just as the tool can have powerful application in varied grade levels, so too can teachers in different subjects explore a universe of topics. Once again, exploration and discovery are key, with critical thinking skills to be fostered throughout.

In math classes, students can explore various map projections. They can investigate the process of locating objects with reference to relative and absolute markers. Or they can use the rich spreadsheet functions and database graphing and charting capacities to study the mathematical relationships between factors found at various places.



Science classes can expand analyses of environmental relationships by displaying the micro and macro systems as they occur over space. Local environmental analyses can be enriched by seeking similar patterns in other places, whether studying frog health, water quality, air temperature, or soil fertility. Students can explore the impact on visible patterns by altering the electromagnetic radiation received in satellite imagery. They can overlay these images with ground mapping to examine how people and the environment influence each other.

In language arts classes, students can enrich reading exercises by exploring the nature of a place using maps. Conversely, geographical exercises can be supplemented by describing in writing the nature of a place or the analysis of relationships.

Art classes can be an especially important venue for GIS. Since the same data can be presented in many different ways, and since a crucial aspect of mapping is how the untrained viewer interprets colors, symbols, and patterns, the impact of various schemes needs exploration. And because GIS can be a powerful multimedia tool—integrating still picture, evolving scene, actual movie, sound file, text file, and external program with infinite variety—art students can explore the richness of human expression.

Social studies classes, of course, can practically live in GIS, exploring decisions made in the past and how those decisions were shaped by differences in characteristics from place to place. With data as fresh as the daily news, students can explore current events, conditions, issues, and conflicts, and see how their contributing factors are influenced by changes over space. All users can ponder the impact on societies caused by fundamental changes in technology and the types and amounts of information available.

Astute teachers will see the capacity for GIS as an integrative tool. Interdisciplinary studies are enhanced mightily when the same tool, skill, or concept finds a home in multiple settings. Because it is so all-encompassing, GIS actually has the potential to revise the nature of education in profound ways. With GIS, students can learn how the many diverse facets of the world are integrated. They can learn the value of exploration, wondering, and questioning. They can see a single set of information being portrayed in many ways. They can develop their analytical skills, exercise integrative thinking, and practice expressing their ideas effectively to others. And they can learn about the magical richness of the world and all that is in it. In short, GIS is a tool that promotes lifelong integrated learning.

A caveat: Given the flexibility and power described for multiple ages and subjects, some may be tempted to focus school resources solely on GIS, to the exclusion of other tools. But GIS is meant to supplement educational tools, not replace them. Unless a school has 36-inch wide printers and a computer at every desk, plus a bevy of professionally trained geography teachers, there is no substitute for wall maps, atlases, and globes. Just as one would not stop buying literature simply because one has a dictionary and an encyclopedia, nor stop using math books simply because one has a calculator, nor eliminate teachers just because one has a VCR, GIS is not a panacea. It is a powerful tool in the hands of thinking explorers, but it is not the only tool necessary. Wall maps permit a level of "instruction by osmosis" that is hard to replicate with other media, especially ephemeral images. Atlases provide a vast universe of information in a handy, portable, searchable medium. Globes provide a level of three-dimensional vision and means to understand scale that is difficult to match with any two-dimensional resources. Together, globes, wall maps, atlases, and GIS can provide today's students with a powerful grasp of the real world.

E. Methodologies for Using GIS

The challenges for bringing GIS into the classroom invariably focus on "How do we do this?" As happens with most new technologies, many potential users seek single, definite, concrete answers when, in fact, the options are extremely varied. Still, there are some alternatives that teachers can consider—guidelines for thinking about the use of GIS in the classroom. In each case, the expectations need to match the possibilities.

1. One-Computer Classroom

Having only a single full-power GIS station for a class of twenty to thirty-five students can be a manageable setting that still takes advantage of the capacities of GIS. There are two basic options.

- Use different display devices such as an overhead projector panel or large monitor to engage a full class at once with the display on a single screen. (See **Appendix A, Section 2.**) In this setting, activities would be led by the teacher with all students working on a similar task. Focus in this setting can be as much on the technology as on the information. Students could, for instance, learn the basic operation of the software through a live group demonstration or see modeled the explore–question–analyze–evaluate process of geographic inquiry. Similarly, they can be led through a careful exploration of relationships between features. It just depends on the teacher's style.

- Use a single full-power station to prepare a series of electronic or hard-copy output files. (See **Appendix A, Sections 1** and **4.)** In this mode, students could work individually, in groups, or as a whole class. Here, the focus is weighted more heavily on working with the information, rather than on the technology.

2. Working in Groups

Putting two or more students to a computer can increase learning, as long as the methodology and tasks are sound. Students of all ages seem to pick up most about the chosen subject when there are two pupils per computer. (This qualitative observation is based on several years of introducing GIS to students and adults and deserves special research, but none is available at this point.) More than two per computer dramatically reduces the amount of time each person has for hands-on interaction, which limits students' total focus.

Group projects involving GIS could be organized to engage students with the technology, perhaps on a rotating basis. After some introductory training, and with a carefully designed set of activities, students can incorporate GIS activities with tasks at other stations around the learning center. For instance, in an examination of the school neighborhood, different stations around the room might involve scrutinizing photographs, studying historic documents, comparing data tables, and translating mental maps to hard copy, along with working on the GIS.

3. Working Solo

Individual work on GIS can be extremely powerful. Students can explore in depth in their own fashion and develop their own view of the situation. This can also result in widely different projects, "study directions," results, and timetables. Because of this, teachers should be extra careful to have realistic expectations. With extended training beforehand and appropriate coaching during the process, students can stay on a fairly consistent and very productive course.

For this reason, teachers working with more than a dozen students at a time should view such solo efforts as projects for later in the school year, after developing requisite concepts and skills. When engaged in solo projects, students will have widely varied interests, approaches, and results, even when working with consistent data, so it is extremely important to allow the opportunity to share projects with each other.

4. Network Settings

Working with a computer network poses a special set of challenges and opportunities. Teachers in a school with a powerful local area network are in an excellent position to take advantage of GIS. However, computer network technology is somewhat tricky and requires special technical skills not common among subject- or age-focused teachers. Therefore, working with GIS on a network should be explored carefully, well in advance of the anticipated event. GIS demands extensive computing power and often relies on large data sets, so the school's network traffic may be much higher in GIS projects than for other network-based activities. The opportunities to engage in wide-ranging group projects, however, make networks an extremely attractive option.

F. ArcView GIS and ArcVoyager

When first encountering GIS and the variety of data sets available, many people are overwhelmed by the range of items to consider: software interface containing a myriad of menus, buttons, and tools; procedures that are appropriate at one level but not another;

scale, quality, and content of data all affecting what it makes sense to do; and thinking geographically about a topic with important social or physical contexts. Additional options, in the form of extensions to basic ArcView GIS software, exist for people dealing with Windows 95/NT platforms, leading to even more chance for confusion. The volume of considerations to understand has kept many a good teacher from jumping in and using the tools in a productive way in short order.

With that in mind, ESRI created a special suite of data, ArcView GIS projects, and lessons designed to give the GIS novice an easier entry into the world of interactive mapping. The package was designed so that, with little technical expertise, teachers could complete the installation and be productive in minutes, rather than hours or days. The package is named ArcVoyager™ software, and it is available on Macintosh and Windows platforms at no cost for any licensed user of ArcView GIS.

ArcVoyager presents GIS in a tiered fashion that will allow people to move quickly into the level appropriate for them. It permits and encourages wandering between the four levels, as the user becomes more and more comfortable with the tool of GIS.

Level One is called **Exploring Key Concepts: Teach Me.** This level consists of only a help file, constructed in hyperlink fashion. In this level, students and teachers have only text and pictures and links, not live GIS capability. The text and pictures will help teachers and students understand some of the critical issues they will face later: scale, projection, data, classification, and so on. Because this section contains powerful information about the nature of map construction, it is recommended that students and teachers refer to this section regularly, even when they are working in a different level of ArcVoyager.

Level Two is called **Viewing World Snapshots: Show Me.** This level actually engages live ArcView GIS, but in a highly constrained environment. Simpler even than bicycle and training wheels, this is more like bumper cars, where the user can do whatever they want in a tightly controlled universe. Here, users can learn about working with layers of information, zooming in and out, and using an Identify tool. With twenty-five layers of information to integrate, there is actually a lot of work that can be accomplished at a global or continental scale. Live tests have demonstrated that students even as young as early elementary school can work with this tool and be productive, solving puzzles and finding information. But there are still enough data available at this level to make high school activities appropriate as well.

Level Three is called **Designing Global Adventures: Point Me.** At this level, there are more of ArcView GIS software's traditional menus, buttons, and tools (plus some special new ones); a greater variety of data sets in place; and the opportunity to add elements from outside of ArcVoyager. But there is still simplicity in design, as projects open with a raft of data already prepared, just waiting for exploration. Social studies teachers, math teachers, and science teachers will find a wide selection of study options here. Since this level uses an open architecture, new data sets can be brought in on the fly. And because projects can be modified and saved, explorations can easily carry over from one day to the next or be precreated with special focus items in place.

Level Four is called **Creating New Worlds: Turn Me Loose.** In this level, the interface from Level Three remains the same, but there are no prepackaged data sets in place. The user has full power to bring in data sets and save projects. This allows users to focus on the data of choice, yet still retain the ease of use enhancements included in the ArcVoyager interface.

When ArcVoyager has been mastered, users are ready to work with full-fledged, unmodified ArcView GIS. But even before this mastery has been achieved, there is so much in ArcVoyager already available for detailed study that students and teachers alike may spend the entire school year accomplishing quite powerful explorations without ever leaving the ArcVoyager environment.

G. Geotech Tools

(This section is excerpted from the separately available document "GEOTECHing: Mapping and Other Cool Tools for the Classroom," by ESRI.)

Interest in bringing mapping, GIS technology, and active spatial inquiry into the classroom can lead to an interest in adding other tools and capacities as well.

Educators and students wishing to engage in personal geographic explorations are also finding that they want to

- Create and add their own data to existing map displays.
- Capture photographic images and embed them into projects.
- Use mapping tools as cartographic clip art engines.
- Produce electronic publications and multimedia presentations incorporating personal maps and charts.
- Retrieve and use data sets from the Web that are in compressed, text, and other formats.
- Share data and images as well as projects with teachers and students in other locations.

What are some other tools I should have hanging from my technology tool belt?

Following are a number of software applications and electronic devices that will support interests in undertaking these activities.

Category	**Purpose**	**Low-Cost Suggestion**
Personal Mapping	Design and present user-defined maps, charts, and graphs. Develop simple spatial queries and searches. Geographically code personal databases.	*Business*MAP™ PRO (Windows), ArcExplorer™ (Windows 95/NT), both with MAPables data product

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Category	Purpose	Low-Cost Suggestion
GIS	Design and present user-defined maps, charts, and graphs. Create new geographic data. Develop spatial queries and searches. Analyze spatial patterns and relationships. Create multimedia geographic presentations.	ArcView GIS (Windows, Macintosh) with ArcVoyager data product
Database or Spreadsheet	Create and edit geographic data sets.	Microsoft Works (Windows, Macintosh) or Claris Works (Windows, Macintosh), word processors
Screen Capture	Create personal clip art image files for print and electronic documents and presentations.	Computer's PRINTSCREEN function (Windows, Macintosh), JASC Professional Capture System (Windows), BSG ScreenShot (Macintosh)
Illustration —Paint	Create, retouch, and crop pixel-based images. Convert image files from one format to another.	Paint (Windows), MacPaint (Macintosh); JASC PaintShop Pro (Windows); GIF Converter (Macintosh)
Illustration —Draw	Create and edit images based on points, lines, and polygons.	Claris Draw, CorelDraw, Freehand (Windows, Macintosh)
Presentation —Design and Edit	Create, edit, and display "slide-based" presentations.	Astound, Hyperstudio, PowerPoint (Windows, Macintosh)
Presentation —Display	Organize and display prepared images.	Above, plus JASC Media Commander (Windows); GraphicConverter, GIF Converter (Macintosh); AfterDark (Windows, Macintosh)
Electronic Publishing	Create, view, print, and search electronic documents.	Adobe Acrobat (Windows, Macintosh), HTML browsers
Images—Royalty Free	Use existing digital photos and clip art in print and electronic presentations and documents.	Photo CDs (check license) and numerous Web sites (e.g., NASA, NOAA)
Images—Personal Photos	Create and use personal digital photographic images in print and electronic presentations and documents.	Photo CD from local photo finisher or Seattle Filmworks (Windows, Macintosh)
Computer Video Capture and Viewing	Create, edit, and view computerized movies with or without sound. Useful in video reports or demonstrating the steps of a process.	Lotus ScreenCam (Windows), Apple QuickTime (Windows, Macintosh), computer's media player
File Compression	Reduce file sizes for easier transfer from machine to machine and across the Internet.	Nico-Mak WinZip (Windows), Aladdin Systems StuffIt (Macintosh)

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Category	Purpose	Low-Cost Suggestion
File Transfer	Move file from machine to machine.	LapLink, FastMove (Windows), AppleTalk (Macintosh)
Internet, FTP, and E-mail Access	Access geographic data, research and reference information and ideas, retrieve and deposit files and mail.	Local Internet Service Provider (ISP), America Online, Microsoft Network, Prodigy
GPS (global positioning system)	Determine geographic position by x, y, z coordinates (longitude, latitude, elevation), and navigate using these.	Garmin, Magellan, and Trimble have personal devices ranging from $150 up.
Digital Camera	Compose and view personal photographs "instantaneously."	Various sources have digital cameras with varied features, from $200 up.
35mm Camera	Compose personal photographs for later photo finishing.	Single-use fixed lens cameras.
Scanner	Capture images and text files.	Various sources have scanners with widely differing capacity and price.
Printer or Plotter	Print documents and images in black and white or color.	Hewlett–Packard, Epson, Canon, and Lexmark have color printers under $300.
Projection Device	Present computer display on large screen.	Various sources from $3,000 up.
Video Camera	Create and edit digital video images.	Many sources from $100 up.

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Appendix A—Hardware Enhancement Options

1. Support Stations

Not all computers in a classroom need to be full power stations. In a situation where one or two full power stations exist, lower powered computers can be used very easily and profitably as support terminals. These computers can even be of different platforms, since key file formats cross platforms very easily.

Depending on the capacity of these stations, students could use them to prepare data tables for importing into the GIS, craft text documents that will be called by the GIS or that incorporate and summarize the findings from the GIS, display and modify electronic screenshots generated on the GIS station, or even produce hard-copy output from files first produced on the GIS station. For instance, early Macintoshes can prepare text documents that summarize a project created when databases were constructed on AppleIIs and image files were modified on low-powered PCs, and everything was brought together on a high-end GIS station (Macintosh or PC). The resulting images and documents could be read in a Web browser on either platform.

Because a GIS is designed for exploration and integration, there is a significant role to be played by these supplemental stations. Careful planning and an adequate number of support machines can mean that schools with only one or two full powered GIS stations but a number of lesser machines can easily accommodate classes of thirty-six students.

2. Display Options

In a classroom setting where there may be a few dozen students eager to see the computer display, a typical fourteen-inch monitor is just too small. There are several options for dealing with these situations. Each has its merits and disadvantages.

- Use a large monitor on the basic station. A seventeen-inch computer display is large enough and crisp enough for most people to see the main patterns, even from twenty feet away. Large monitors, however, can be quite expensive, though some current reasonably priced computer packages include a thirty-six-inch monitor that provides only 640 x 480 or 800 x 600 resolution.

- Use a connector device to duplicate and translate the signal for display on a large screen TV monitor such as is used for VCR display. TV monitors do not have the same resolution and frequency as computer terminals, however, so resulting displays may not be sharp enough for text information. For larger patterns, they may be satisfactory.

- Use a video signal splitter and connect to two computer monitors. Splitting the signal can cause degraded displays and the gain may be minimal if the monitors are too small, so it is important to test this.

- Use a color liquid crystal display (LCD) projection panel with an overhead projector. This has the standard difficulties of overhead projection (the keystone effect, where the top of the image is wider than the bottom), and also demands a darkened room and a modern overhead projector (which is intense enough to project a bright image yet cool enough so that the panel won't overheat and cause fading of the image). Despite the cost and difficulties, this is a commonly used solution because of its portability and flexibility.

- Use a color projection device. These devices are exploding in usage, and they have the advantages of higher number of colors, sharper contrast, higher pixel resolution, and greater brightness. They are expensive, but they are extremely powerful in classroom setting.

- Use slides prepared by photographing the monitor on the GIS station. This method requires the greatest advance planning, but it can be extremely effective for large-room presentations or transporting to sites distant from the GIS stations. Using a tripod, slow film, basic single lens reflex camera, and cable release brings good results.

- Use the color printer to create transparencies of special displays. This can be a very effective procedure, but it does rely on having sufficient time and materials beforehand, and it sacrifices the capacity for shifting settings on the fly.

- Change the classroom operation so students cycle in front of the GIS station. This is the tried-and-true shifting stations approach teachers have relied on for decades. It is useful, but requires careful planning in order to avoid inefficiency or chaos.

3. Data Storage Options

Although modern multimedia-oriented computers carry ever larger hard drives with faster CD–ROM drives, not all GIS stations in schools will have hundreds of megabytes of disk space onboard to allocate for GIS data. Again, there are options.

- Use a buildingwide local area network for data storage. Networks with dedicated file servers have their own sets of issues that need attention and care, but using a schoolwide network for storage of data can be extremely powerful and efficient.

- Use a work group network for data storage. There are issues to be resolved in work group situations also, where only a handful of computers are linked together, but this may be a more manageable option for a classroom setting.

- Use small data sets. Very often, data can be trimmed down, with extraneous information cast aside, as long as the original source data are still available if necessary. Sometimes, geographic data (such as boundary files) of a low resolution can be substituted for high-resolution data, saving additional space and also increasing drawing speed.

- Acquire supplemental removable storage media such as Iomega Zip or Jaz drives. These can be cost-effective ways to add storage space, particularly if the devices can be shared from station to station.

4. Output Options

The configuration described above calls for a color printer. Prices for reasonable ink-jet color printers are below $300 (spring 1998), so these are typically available. Still, many classrooms do not have such a printer on hand. Here, the options are fewer.

- Use black-and-white printouts from an ink-jet or laser printer. While all ink-jet printers and black-and-white laser printers have dropped significantly in price, color laser printers are still out of reach of most schools. Laser printers and even ink-jet printers can produce some stunning graphics in black and white, but the richness of GIS relies heavily on color representation of objects and places; there may not be enough shades or symbols to communicate the necessary information when restricted to black, white, and gray.

- Use screenshots, saved as GIF images, to present the information desired. These screenshots can be combined into quite powerful presentations using standard presentation software, or even using screensavers with a slideshow component.

5. Strategies for Acquiring Hardware

Perhaps the biggest challenge for schools today is ensuring they have the appropriate hardware for taking advantage of the great powers of GIS. While it is true that the most important component of the package is the user, it is clear that users cannot easily accomplish the most exciting tasks of GIS without proper hardware. Teachers across the country have used a variety of strategies to build effective GIS stations. Here are just a few:

- Make hardware requests part of the standard budgetary process, building up stations and components over the years.

- Combine dollars available for various grades and disciplines, since GIS can be used for a multitude of tasks and grades.

- Hold special fund-raising projects.

- Write grant proposals to national, regional, and local companies and foundations. Schools will have relatively less competition in seeking grants from local organizations than from national ones. Frequently, local branches of national organizations are willing to provide extra support for local schools.

- Write articles for the school or community newspapers describing clearly the specific hardware needed, local "street prices," and the potential uses. Since one quite serviceable GIS station can be bought for well under $2,000, it takes only a few modest donations to acquire the necessary funds. Be sure to mention a contact name at the school.

- Take out a loan for necessary hardware and pay it off with low-cost, low-effort adult classes in the evenings. This is one of the most creative strategies that has been shown to work. When teachers and schools demonstrate such a commitment to technology, it sends a powerful message to the students and the parents. Bringing the parents and others in the community into the lab during evenings to learn the basics of hardware plus word processing, databases, spreadsheets, telecommunications, graphics, or desktop publishing can generate substantial income. Even more important, it can facilitate later investment in the resource of the school by helping the adult community understand the importance of up-to-date hardware, software, and procedures.

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Appendix B—Basic ArcView GIS Skills

These are the basic practices in ArcView GIS that users in schools should focus on learning:

1. Mapping

- Identifying a geographic feature
- Zooming in and out
- Changing the classification scheme for a given set of data
- Creating standard choropleth ("area value") maps of graduated colors, or dot maps with graduated symbols
- Choosing the best symbols and colors when integrating multiple layers
- Selecting the best map projection for the chosen region and scale
- Subsetting a layer of data (e.g., "Instead of all states, let's make this layer contain only those along the Atlantic coast.")
- Exporting a subdivided layer of data to a shapefile and documenting its origin
- Querying a map by logical expression (e.g., "Please, computer, find all states with population less than 3,000,000.")
- Querying a map by geography (e.g., "Please, computer, find all cities within 50 miles of this long line.")

2. Manipulating Tables

- Sorting a table according to a value
- Querying a table
- Limiting the visible fields in a table
- Changing the visible names of fields
- Joining external tables to an existing map layer
- Exporting data from a "virtual table" to a physical file
- Creating a new field and typing in new data
- Populating an empty field with calculations based on existing fields

3. Working with Charts and Graphs

- Choosing the best chart type for a given data set
- Selecting appropriate numeric scales for axes in charts
- Modifying labels used in a chart

4. Layouts

- Combining the appropriate maps, tables, graphs, and text
- Incorporating helpful cartographic elements (scale, legend, north arrow, text, etc.)

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Appendix C—Data Sources: Cheap, Rich, and Plenty

1. Commercial Data Sources

There is a large cadre of organizations (companies or individuals) that can provide high-quality data, about all manner of subjects, for use with GIS. ESRI works with a growing community of data providers in the ArcData℠ Publishing Program. GIS users in schools can have access to a rich assortment of both geographic data and tabular information, often at quite reasonable prices. Companies participating in the ArcData program must adhere to certain protocols and standards, and the data tend to be quite carefully constructed and therefore are often very easy to integrate with other electronic data. The data cover a vast range of physical geography and human geography subjects: environmental boundaries, satellite imagery, elevation contours, climate information, pollution reports, transportation corridors, census data, marketing summaries, and so on. What users may legally do with these files may be constrained by copyright, license, or both, but there are many interesting analyses to engage in with these data.

2. Noncommercial Data Sources

As large as the supply of commercial data is, the noncommercial is even larger. Many companies and agencies involved in decision making on the basis of information they have gathered will share their data with schools. Researchers working on special projects in college collect or produce many megabytes of data. This wealth of electronic information covers an even wider array of subject matters than that from the commercial arena. In contrast with the ArcData program, these sources are less reliably consistent and may be less easily integrated; they can be just as high quality, or the creators may have been much less strict on certain issues.

Regardless, local GIS users may provide schools with a bounty of reasonable data at little or no cost. This is especially true where the school district is using GIS to conduct demographic studies, facilities management and planning, bus routing, and so forth; schools and students can be active participants in such an enterprise solution.

3. Public Domain

There is an additional universe of data that are free to the public and just waiting to be used in schools. Much of the vast mountain of information gathered and published by the federal government is free for use in the classroom. Perhaps most notable among this are data from the U.S. Census Bureau, whose regular works provide a rich resource for teachers. Whether the data are stored in electronic form or on printed pages, they are readily available in public libraries, university libraries, and increasingly via Internet. These data may need significant adjustment to move into a classroom-friendly form, but students can often be taught to conduct the work. When students find, enter, check, and cross-check the data on computers, they develop a significant stake in the data and are often especially excited about the project. Even low-powered machines can be very effectively used with this strategy.

4. Internet

The amount of data being carried online is growing by leaps and bounds. Much of it is extremely valuable; other parts are less so. Features, tables, text files, graphics, satellite images, movies, and sound files abound, and all can be integrated into GIS projects. New data tables can often be found here before they are publicly available in any other form. GIS users who will be providing projects to others should be careful to document the various data sources as completely as possible. An exciting data set may be rendered much less valuable if there is not supportive documentation indicating the source of the information. This documentation can be particularly easy to miss when using data gathered from Internet.

5. Newspapers and So Forth

One of the richest sources of data is the daily river of information coming from newspapers, radio, and television. Newspapers are especially powerful, since they generally provide a good summary of how data were gathered and/or processed. Again, the data may need to be transcribed by students in order to be integrated, but the timely nature of the information can bring special meaning to class activities.

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Appendix D— Adopt-a-School

1. What Is It?

In 1992, ESRI began promoting its Adopt-a-School program. This effort combines the resources of GIS-using professionals with their local schools. Business people, government agency researchers, and college students from around the country have collaborated to bring GIS and basic data into many classrooms.

GIS users have provided help for schools in different ways. Some have given an introduction, training, and data. Others have helped with the acquisition of software and hardware. Others have worked in close association to develop long-range research projects, design specialized curricula, or partner in training and internships.

The goal of the program is to enhance education as a whole. Students can learn about their world, from global to local, developing their knowledge base and thinking skills at the same time as they learn a powerful new tool. Bringing local data into the classroom brings the outside world closer, as well, by providing references and chance to compare and contrast.

The original bundle of materials included ArcView GIS for Windows software plus three data sets: ArcUSA™ 1:2M, ArcWorld™ 1:3M, and ArcScene™ USA Tour. With this package, teachers had access to basic but powerful packages of general information about the United States and world, plus a series of satellite images from significant sites around the United States. The contents of the kit expanded with the release of later versions of ArcView GIS and ever more data.

While national and international data can be intriguing, perhaps the most effective way to introduce the concepts and skills of GIS to new users (of any age) is through local data. When students can see on the monitor the features and attributes they know from daily life, exploration may prove more engaging, discovery more rapid, and relationships more readily apparent. Students can prepare their own analyses of local situations and add to that understanding as they go about everyday life.

In settings where water issues are an ongoing concern, or where the siting of an airport has become a hot issue, or where the distribution of social services to needy groups is a prominent news item, local data can be the ultimate hook to engage students in their schooling. When parents discuss the future of their jobs, neighborhoods, and environments, and students can gain from and even add to such deliberations, relevant school activities help make the classroom a vital and attractive setting.

2. Schools Seeking Users

Many schools are on the lookout for potential adopters who can help the school begin (or expand) the use of GIS. But users of ARC/INFO®, ArcCAD®, and ArcView GIS software are not always easy to identify in a community. There are some places to start looking and some effective strategies for seeking an adopter.

Put a short article in the school newspaper describing the desire for an adopter. Indicate the grade levels and subject areas in which the program would begin. Mention a specific contact teacher's name.

Describe GIS to the students in the class and ask if any student has a parent who works in a GIS-using industry or organization.

Prepare a special information flyer for parent conference days. Indicate the need for a sponsor. Note the special assistance sought: dollars, hardware, training, data, and expertise.

Contact various likely companies or government agencies to see if someone knows about the program, knows GIS, and would be willing to help the school. Here are some example sites:

- School bus company
- City planning departments
- Local foresters, geologists, agriculture experts, or water agencies
- Local conservation groups
- Departments of transportation
- Environmental engineering firms
- Market location analysts
- Energy or utility companies
- Real estate agencies
- College geography departments
- State geography alliance

3. Users Seeking Schools

Adult GIS users who are excited about the possibility of bringing GIS into local classrooms have discovered some effective strategies as well as blocks to the process. Here are some of the strategies that have proven helpful.

- Talk first with teachers you know—friends, neighbors, or teachers of a "special interest child."

- Talk with science teachers at school. Science is an area in which teachers and students are often more accustomed to exploration, speculation, and discovery through hands-on learning.

- Talk with library or media coordinators at school. Ask about other teachers who are especially interested in using computers.

- Talk with middle school teachers seeking an opportunity for an interdisciplinary or cross-curricular project.

- Write a brief note describing GIS and your willingness to provide some support. Send copies to the principal, superintendent, or head of the school board.

- Offer to give a demonstration at the school, showing how you use GIS in your current job. Alternatively, offer to be a field trip site, for teachers with or without students.

- Explore the current level of computer hardware available in the school, and identify recommended modifications. Be prepared to explain why GIS requires the greater powers of modern computers.

- Bring in a series of hard-copy maps from your work site, indicating how the maps were generated and how they were used.

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Appendix E—Standards in Education

The education community has spent much effort in the last six years developing standards for different topics or disciplines. Massive numbers of person-hours were spent developing each set of standards. The standards documents are important guideposts for teachers and parents everywhere.

GIS technology can be a powerful tool in the arsenal of schools and teachers everywhere. In and of itself, GIS may meet special needs for only the geography and technology standards. However, as a data manipulation tool that encourages and facilitates critical thinking, GIS can be just as helpful for teachers focusing on standards in history, math, science, and other areas.

Geography Standards

As an example of the standards being established in various disciplines, here is the "bare bones" wording of the Geography Standards, published by National Geographic Society in October 1994. The Standards describe the discipline of geography relative to three components: knowledge, skills, and perspectives.

Knowledge—Six Essential Elements and Their Geography Standards

I. The World in Spatial Terms

The geographically informed person knows and understands

1. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

2. How to use mental maps to organize information about people, places, and environments in a spatial context

3. How to analyze the spatial organization of people, places, and environments on the earth's surface

II. Places and Regions

The geographically informed person knows and understands

4. The physical and human characteristics of places

5. That people create regions to interpret the earth's complexity

6. How culture and experience influence people's perception of places and regions

III. Physical Systems

The geographically informed person knows and understands

7. The physical processes that shape patterns of the earth's surface
8. The characteristics and spatial distribution of ecosystems on the earth's surface

IV. Human Systems

The geographically informed person knows and understands

9. The characteristics, distribution, and migration of human population on the earth's surface

10. The characteristics, distribution, and complexity of the earth's cultural mosaics

11. The patterns and networks of economic interdependence on the earth's surface

12. The processes, patterns, and functions of human settlement

13. How the forces of cooperation and conflict among people influence the division and control of the earth's surface

V. Environment and Society

The geographically informed person knows and understands

14. How human actions modify the physical environment
15. How physical systems affect human systems
16. The changes that occur in the meaning, use, distribution, and importance of resources

VI. The Uses of Geography

The geographically informed person knows and understands

17. How to apply geography to interpret the past
18. How to apply geography to interpret the present and plan for the future

Skills

- Asking geographic questions
- Acquiring geographic information
- Organizing geographic information
- Analyzing geographic information
- Answering geographic questions

Perspectives

- The spatial perspective
- The ecological perspective

Clearly, there are major opportunities for GIS to play a powerful role in a core subject like geography. It can be applied in powerful ways in other disciplines as well. Rather than review each set of standards here, use the following list of references to help gather information about a specific field.

Below are addresses of organizations that can help schools, teachers, and parents learn more about the various disciplines.

Geography

National Council for Geographic Education
Indiana University of Pennsylvania
Leonard 16A
Indiana, Pennsylvania 15705-1087
www.ncge.org

J-5979

History

National Center for History in the Schools
University of California at Los Angeles 231 Moore Hall
405 Hilgard Avenue
Los Angeles, California 90024

Social Studies

National Council for the Social Studies
3501 Newark St. NW
Washington, D.C. 20016
www.ncss.org

Civics and Government

Center for Civic Education
5146 Douglas Fir Road
Calabasas, California 91302-1467

Foreign Languages

American Council on the Teaching of Foreign Languages
6 Executive Plaza
Yonkers, New York 10701-6801

English

National Council of Teachers of English
1111 Kenyon Rd.
Urbana, Illinois 61801-1096
www.ncte.org

Science

National Science Teachers Association
1840 Wilson Blvd.
Arlington, Virginia 22201-3000
www.nsta.org

Mathematics

National Council of Teachers of Mathematics
1906 Association Drive
Reston, Virginia 22091
www.nctm.org

Arts

Music Educators National Conference
1806 Robert Fulton Drive
Reston, Virginia 22091

Testing

National Center for Research in Mathematical Sciences Education
University of Wisconsin—Madison
Madison, Wisconsin 53706

National Center for Research on Evaluation, Standards, and Student
Testing (CRESST)/UCLA
145 Moore Hall
405 Hilgard Ave.
Los Angeles, California 90024-1522

National Center on Education and the Economy
Washington, D.C.
www.ncee.org

State Education Officers
Council of Chief State School Officers
1 Massachusetts Ave. NW, Suite 700
Washington, D.C. 20001-1431
www.ccsso.org

U.S. Department of Education
(For general information about content standards development)
Office of Educational Research and Improvement/FIRST Office
U.S. Department of Education
555 New Jersey Avenue NW
Washington, D.C. 20208-5524
www.ed.gov

GOALS 2000
U.S. Department of Education
400 Maryland Ave. SW
Washington, D.C. 20202

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(1-800-GIS-XPRT)

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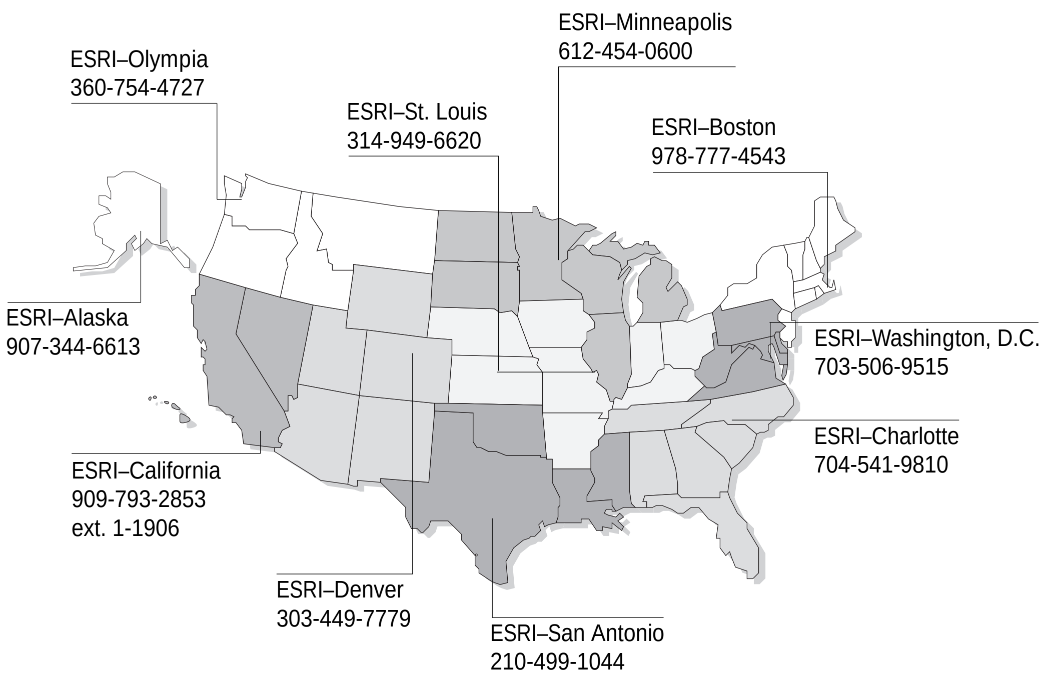

International

Australia 61-9-242-1005	India 91-11-620-3801	Sweden 46-23-84090
Canada 416-441-6035	Italy 39-6-406-96-1	Thailand 66-2-678-0707
France 33-1-46-23-6060	Poland 48-22-256-482	United Kingdom 44-1-923-210450
Germany 49-8166-677-0	South Asia 65-735-8755	Venezuela 58-2-953-0523
Hong Kong 852-2-730-6883	Spain 34-1-559-4345	

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