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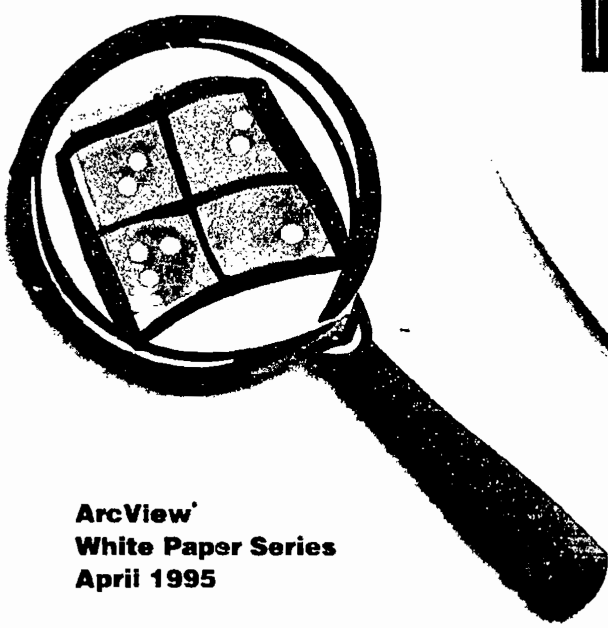
ABSTRACT

Geographic information systems (GIS) consist of robust hardware, software, data, and a thinking operator. Together, they provide 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 the "new geography" in many ways, in a variety of grade levels. This document is divided into three parts. Part 1 defines GIS and describes the components of the system. Part 2 discusses issues of incorporating GIS in education at the elementary, middle, and high school levels. The Adopt-a-School program, a collaborative effort to bring the ArcView GIS tool and basic data into the classroom, is also described. Part 3 focuses on the methodology for and challenges of bringing GIS into the classroom and discusses benefits of both individual and group learning. Appendices include: hardware enhancement options; basic ArcView skills; standards in education; data sources; and strategies for acquiring hardware. (AEF)

GIS by ESRI™

GIS in K-12 Education



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White Paper Series
April 1995

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE INC

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GIS in K–12 Education

An ESRI White Paper

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Environmental Systems Research Institute, Inc.
380 New York Street, Redlands, CA 92373
(909) 793-2853
Fax (909) 793-5953

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GIS in K–12 Education

Geographic information systems (GISs) consist of robust hardware, software, data, and a thinking operator. Together, they provide 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 $3,000 investment (March 1995), schools can have a new, full-featured, high-powered computer ready for classroom needs and a site license for a powerful starter package of software and basic data.

GIS can be incorporated easily into current curriculum in all grades and subjects, supporting and enhancing existing activities instead of requiring an isolated, dedicated place within the curriculum. The 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.

Environmental Systems Research Institute, Inc.
380 New York Street, Redlands, CA 92373

(909) 793-2853
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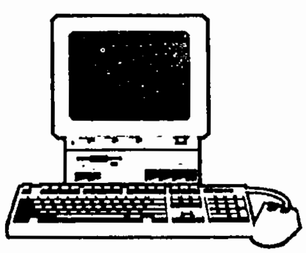
Part I—Basics

A. 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.

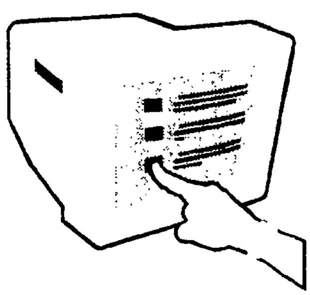
In such a scenario, school is not without conflict or contest. Indeed, wrestling with ideas and coming to grips with different information, skills, and values bring a steady stream of issues to explore. But, in this dreamland, the focus of the participants might be toward exploration, integration, and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



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

B. Definition: What Is a GIS?

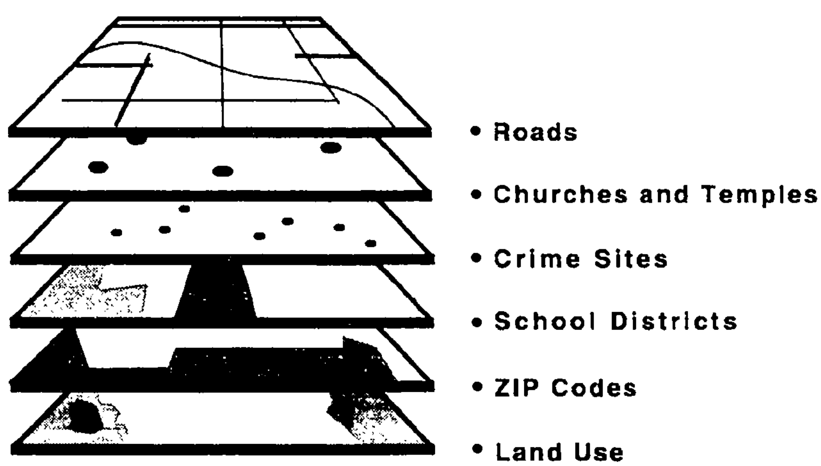
A geographic information system is a combination of elements designed to store, retrieve, manipulate, and display geographic data—information about places. It is a package consisting of four basic parts: hardware, software, data, and a thinking operator.



The hardware is a robust computer. The software is a powerful set of instructions and procedures that can be applied. The geographic data are computerized information about places, in a variety of formats. The thinking operator is a person 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 patterns, land use patterns, buildings, population characteristics, crime sites, churches and temples, school attendance boundaries, ZIP Codes, utility lines, newspaper boxes,

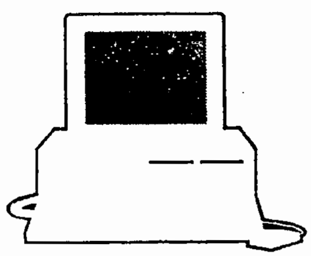


and so on. Standing before the overhead, you mix and match the layers at will, magically changing classification schemes, modifying symbols, colors, patterns, and combinations. You can zoom in and out, seeing all the information available or only the data you specify, comparing this layer with that feature, exploring the data in every way imaginable. As you play with these layers of information, relationships appear.

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.

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:

- CPU 486DX (IBM or compatible) or 68040 with math coprocessor (Macintosh), running at 33 MHz or better
- 12 MB physical RAM
- 16 MB virtual RAM
- 250 MB hard drive
- Dual speed CD–ROM drive connected by SCSI interface

- 256-color monitor (SVGA, 640x480 or better, for IBM/compatible)
- Mouse
- Ink-jet color printer

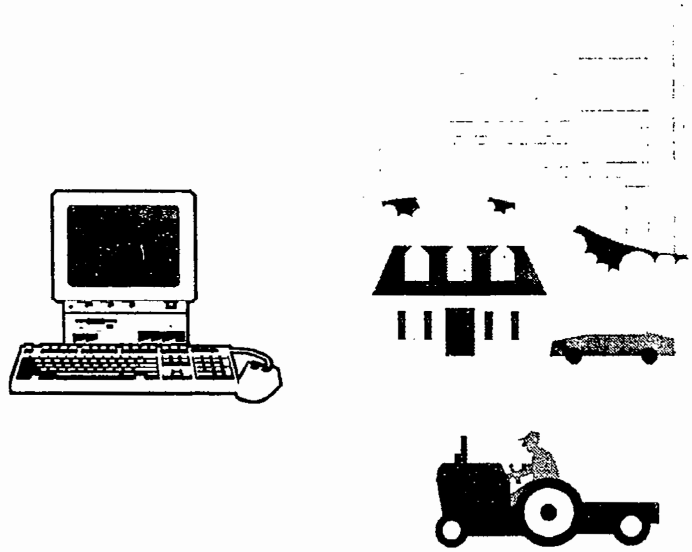
Going below these levels for a single-station setting in a classroom is not generally practical, because of the time required to accomplish tasks on less powerful machines. In an environment where ten seconds of delay can mean a significant drop in excitement, attention, and productivity, speed is a 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, but the software must be intelligible for the user.

One big challenge, of course, is that people can do many things with good GIS software. The Environmental Systems Research Institute, Inc. (ESRI), ArcView® software is akin to a combination of these 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 combined with a powerful geographic explorer engine. It can take a long time to learn to use these tools to their fullest extent.

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 users should concentrate on in schools, see Appendix B.) More important than a thorough knowledge of the entire toolkit is a disposition for exploration and a capacity to think geographically, to search for relationships, and to see spatial patterns.



E. Data: The Fuel

Car engines need fuel to run. Without fuel, there is little point in having a car. Same, too, with a GIS. They need 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. But there are several significant formats of data for even the novice GIS user to consider.

First is the geographic data that represent the physical places: points, lines, and areas. 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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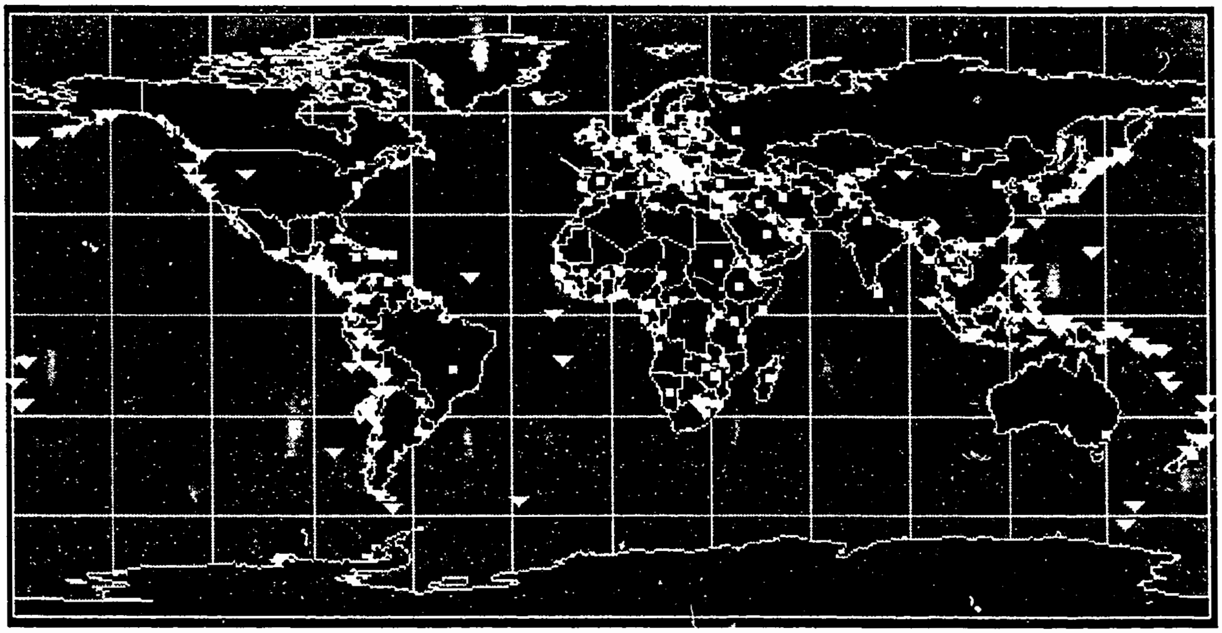
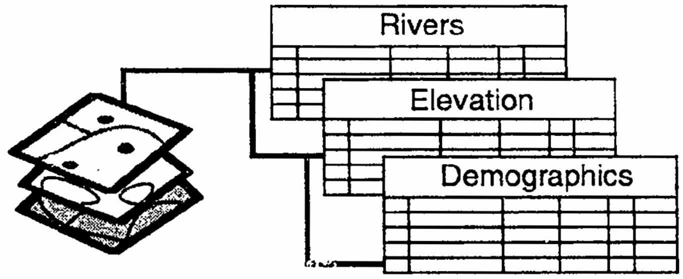


Next is the set of "attribute data," or characteristics of features. These data sets are tables, made up of rows (or "records") and columns (or "fields") of information. In a "countries" data table, for

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

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

Text documents abound and deserve attention. It is easy to set up ArcView 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 or other digitized images, including video, can be identified and tied in, so that clicking a feature tells the computer to display a particular file. Even audio 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 varies from one place to another.

F. Operator: The Driver

By this point, it should be clear why the most crucial element of the entire system is the operator. 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.

Part II— Incorporating GIS in Schools

A. Levels

Teachers can use GIS tools like ArcView 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, like ArcView, only reach their potential when focused. And 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

In early grades, teachers, with the help of ArcView, can introduce students to maps as models and 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. Students should see (a) computers are tools with capacity for displaying information effectively, and (b) 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 critical.

2. Middle School

In middle school, students can begin examination of special topics and regions with ArcView. 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.

3. High School

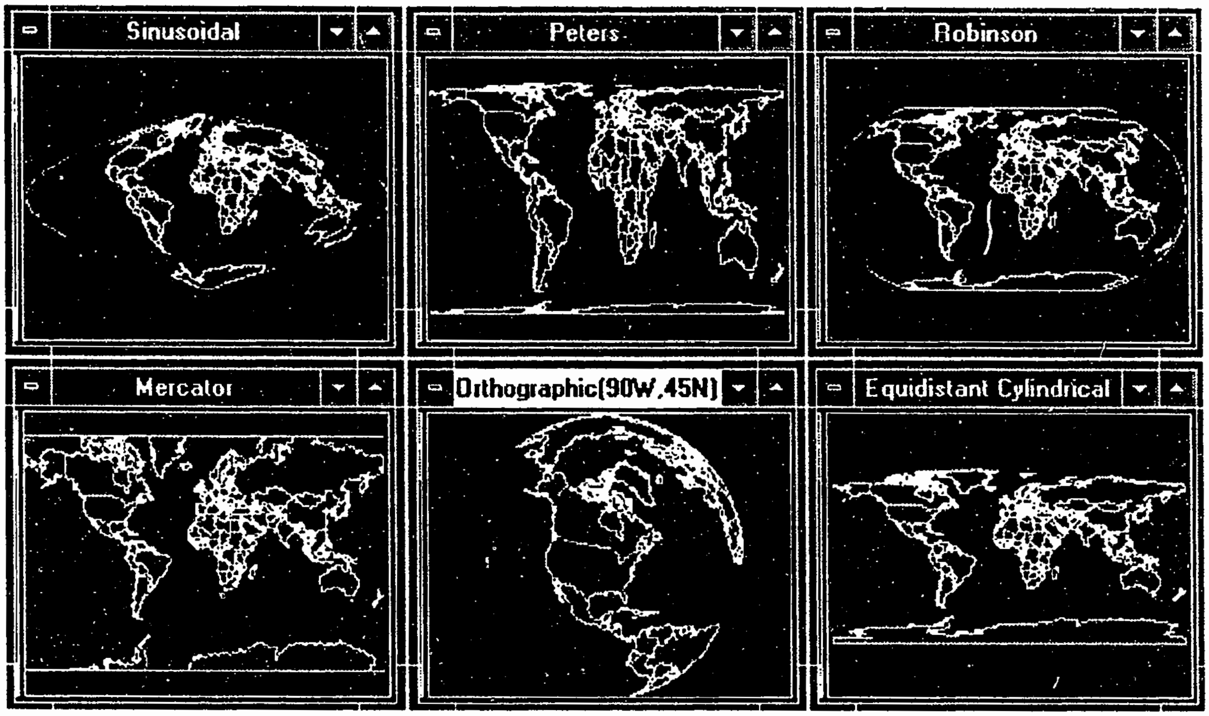
High school students can use ArcView to expand the study of topics and regions and explore geography-related job markets. Earlier regional and topical studies can be carried deeper or integrated with other studies. Students can focus on interrelationships between features and factors in other places. 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 they gather, use, and display their data.

In each grade range, Avenue™ software, the scripting language that can be used to customize ArcView® 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 pre-configured tasks can facilitate explorations and analyses.

B. Subjects

Teachers of geography are not the only ones to benefit from a GIS system like ArcView. 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 use ArcView to 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 in ArcView the micro and macro systems as they occur over space. Local environmental analyses can be enriched by seeking similar patterns in other places. 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 ArcView 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 ArcView. 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 ArcView 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 with ArcView.

Social studies classes, of course, can practically live in ArcView, 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 ArcView 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 ArcView 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, ArcView GIS is a tool that promotes lifelong integrated learning.

C. Adopt-a-School

1. What Is It?

In 1992, Environmental Systems Research Institute, Inc. (ESRI), began promoting an "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 ArcView 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 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 have changed with the release of ArcView Version 2. The powerful new version has replaced the original version, which was unable to take advantage of some important data sets.

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 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 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.

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

Part III—Methodology

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.

A. One-Computer Classroom

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

- 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 about the technology as about 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.
- Use a single full-power station to prep 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.

B. 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 two 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.

C. 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.

D. 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 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.

Environmental Systems Research Institute, Inc. (909) 793-2853
380 New York Street, Redlands, CA 92373 Fax (909) 793-5953

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 such stations exist, lower powered computers can be used very easily and profitably as support terminals. Depending on the capacity of these stations, students could probably 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. 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 can 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 14-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 17-inch computer display is large enough and crisp enough for most people to see

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the main patterns, even from 20 feet away. Large monitors, however, can be quite expensive.

- 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, though, so resulting displays may not be sharp enough for text information. For larger patterns, though, it 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 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 slides prepared by photographing the monitor on the GIS station. This method requires the greatest advance planning, but 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 bring good results.

- Use a composite RGB video projection beam unit. These devices are especially good for large group presentations, having the power and resolution to cast a strong image. However, such units may be very expensive and may not be very portable.

- 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 "workgroup network" for data storage. There are issues to be resolved in workgroup 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 Bernoulli drives, Syquest drives, or tape drives. These can be very cost-effective ways to add additional storage space, particularly if the devices can be shared from station to station.

4. Output Options

The configuration described above calls for an ink-jet color printer. Here, the options are far 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 print options have remained 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. Further, only PostScript printers convert black-and-white fill patterns to hard copy in "what-you-see-is-what-you-get" fashion; non-PostScript printers reproduce the patterns at microscopic scale, with the net result being a series of nearly uniform shades of gray.

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Appendix B—Basic ArcView Skills

These are the basic pieces, doable within ArcView, that users in schools should focus on learning:

1. Mapping

- Creating standard choropleth ("area value") maps
- Changing the classification scheme for a given set of data
- 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 shape file 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.")
- Identifying a geographic item
- Zooming in and out

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2. Manipulating Tables

- Limiting the visible fields in a table
- Sorting a table according to a value
- Querying a table
- Joining external tables to an existing map layer
- Exporting data from a "virtual table" to a physical file

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—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.

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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 the standards in a specific field.

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

Mathematics

The National Council of Teachers of Mathematics
1906 Association Drive
Reston, Virginia 22091

Science

National Academy of Sciences
National Research Council
2101 Constitution Avenue NW
Washington, D.C. 20418

Social Studies

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

Civics and Government

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

Geography

National Council of Geographic Education
Geography Standards Project
1600 M Street, NW
Washington, D.C. 20036

History

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

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

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

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

State Education Officers

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

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

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

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Appendix D—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 ArcView. ESRI prints a catalog (the *ArcData Catalog*) of this growing community. 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℠ Publishing 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 are quite pleased to 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 integrable; 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 (i.e., CD–ROM) or on printed pages, they are readily available in public libraries, university libraries, and increasingly via Internet.

These data may need significant massaging to move into a classroom-friendly form, but students can often be taught to conduct the work. When students find, enter, check, and crosscheck 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 on-line is growing by leaps and bounds. Much of it is extremely valuable, other parts are less so. Tables, text files, graphics, satellite images, movies, and sound files abound, and all can be integrated into ArcView® projects. New data tables can often be found here before they are publicly available in any other form.

ArcView 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 for use with ArcView 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 ~pecial meaning to class activities.

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Appendix E—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. There are a variety of strategies that teachers across the country have used to build effective ArcView® 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 variety 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 a quite serviceable ArcView station can be built for $2,000, it takes only a few

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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 basic desktop publishing can generate substantial monetary 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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ArcCAD® *software links ARC/INFO, the world's leading GIS software, to AutoCAD®, the world's leading CAD software.*

SPATIAL DATABASE ENGINE (SDE™) *software is a high-performance spatial database that employs a true client/server architecture to perform fast, efficient spatial operations and management of large, shared geographic sets.*

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