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A Role for Geographic Information Systems in the Secondary Schools: An Assessment of the Current Status and Future Possibilities

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A Role for Geographic Information Systems in the Secondary Schools:
An Assessment of the Current Status and Future Possibilities

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ABSTRACT

The roles for geographic information systems (GIS) in the secondary schools are investigated in this foundational research carried out in conjunction with the Secondary Education Project (SEP) of the National Center for Geographic Information and Analysis. It is the first comprehensive examination of GIS use in the pre-collegiate environment. A pilot study including a one week workshop for secondary school teachers found that teachers could identify roles for GIS in their classrooms. The positive results of the pilot study resulted in an extension of the research to include the interface between secondary school geography education and GIS in the classroom, the technological environment in the schools and the potential ramifications for GIS activities, and the examples provided by existing GIS efforts for and in the schools. This extension led to the conclusion that GIS can play an important role in geography education. It was also established that rudimentary computer infrastructure presently found in many schools limits GIS use, but the inevitable upgrading of computers in the schools and the increasingly user-friendly and personal computer compatible GIS software indicate that major technological barriers to GIS use in the schools will be overcome in the near future. Current GIS efforts in the schools are small scale and often non-transferable, but GIS industry initiatives, government and higher education institution outreach, and emerging national standards in geography signal an increasing adoption of GIS activities by the schools. There is a need for GIS software designed for the schools and corresponding curriculum materials. Teachers must also have opportunities to learn about GIS and apply it to their instruction. Additional research questions related to the cognitive benefits of GIS-based education and the capacity of students to utilize specific aspects of GIS are suggested.

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Introduction

This thesis sets out to investigate the hypothesis that geographic information systems (GIS), which are still primarily ensconced in the domains of the workplace and higher education, have a role in education at the secondary school level. It is easy to surmise various ways in which GIS might invigorate instruction, provide innovative content delivery, increase student spatial perception and analysis skills, and expose students to one of the newer tools of research and management. Despite the ease at which those familiar with GIS are able to imagine its potential benefits to the schools, there is a need to establish a more solid basis for these speculations. That task is the crux of this research effort.

In order to provide a foundation for this research, a pilot study including a one week investigative workshop was conducted. These early activities served as the crucible for identifying the key questions to address in this exploratory thesis. The positive findings of the workshop led to an expansion in the scope and duration of the research both of which provide a more solid basis for the assertions advanced and future research topics identified. Since this thesis research extended into relatively uncharted territory -- the use of the advanced GIS software and theoretical constructs in the pre-collegiate classroom -- the thesis is necessarily broad, but attempts to lay a solid foundation for future research efforts.

Before describing the research strategy employed, a quick look into the educational and technological situation and pertinent background information for this research are provided below. A key to understanding the context and development pattern of this research is the relationship between it and the endeavors of the National Center for Geographic Information and Analysis (NCGIA). This linkage is also clarified below.

The Situation

Great transformations are occurring in the way the United States conducts its business, goes about daily living, and educates its youth. As the nation speeds ahead towards a new millennium, computer technology is becoming an integral part of nearly every activity in the workplace, the home, and the schools. There is a nagging sense that despite this great influx of technology, we will not have a sufficiently educated workforce to make use of its potential. With a realization that the preeminent role of the United States in the community of nations may be slipping, especially with regards to education, there has been a call by the federal and state governments for an America 2000 initiative to raise student performance in key disciplines to a level comparable or higher than that of the other developed nations (Brand, 1992).

As teachers attempt to motivate students to higher levels of achievement, they will also have the responsibility to help them be technologically literate. Some may question the role of technology in education and in society in general, citing information overload and inappropriate applications as symptoms of over-reliance on technological innovations. Although there may be validity in some of these arguments, it is also apparent that greater access to information through modern technologies may be closely linked to increased political and economic power. At some level teachers, serving students all across the economic and ethnic spectra, will need to highlight the use of these technologies to access and create information in order to help level the playing field. It may be true that a monocular focus on these technologies in the classroom may be imbalanced, since not all aspects of learning may be best served by them. Despite these reservations, to avoid including the technologies where appropriate in instruction does not serve the students' best interest.

Although the challenges of this type of technology inclusive modern education may seem insurmountable and the status quo of the schools may not seem very well adapted to the incorporation of new techniques and technologies, there are many trends that will undeniably affect the schools. One of these is the development and promotion of multimedia technology as an aid to instruction. This integration of video, computers, laser disks, hypertext-guided lessons, and other digital media is gaining momentum and will have a major impact on the teaching practice at all levels. Another player in this new era of learning will be the "high-tech electronic highway network" being promoted by the Clinton Administration and articulated by Vice President Al Gore. Although also designed to serve government and business, this fiber-optic and computer infrastructure will have great potential for educational use by providing teachers and students with ready access to a wealth of information (Government Technology, 1993).

Although they are not new to the classroom, computers will likely begin to have a major impact on instruction as they continue to evolve, as educational software is developed, and as educators become proficient in their use for instruction. One type of software that may have a significant impact on the classroom of the future is geographic information systems. Traditionally GIS software, hardware, and methodology had been confined to realms such as city planning and infrastructure management. More recently, with the introduction of more user-friendly GIS software and hardware/software configurations that are an order of magnitude cheaper than their recent predecessors, GIS has gained wide use in variety of professions and activities. GIS concepts and use are taught in a diverse set of environments from within established university programs such as geography, surveying engineering, and landscape architecture and short-term university extension classes to the commercial world where they are part of high-priced seminars for professionals and specific software training workshops put on by the GIS software companies. Another impact GIS is beginning to have in the educational arena, beyond its status as a new subject to be taught, is as a tool for teaching a variety of topics.

GIS have become established in many universities and colleges around the world, but they are only beginning to make an impact on the pre-collegiate level. As the schools of the nation attempt to meet the demand for students that perform at world-class levels and that are technologically literate, it seems appropriate to examine the role that GIS software and concepts may serve. This thesis represents an investigation of the relationship of GIS to the educational mission of the secondary schools. This thesis topic might be investigated from the perspective of either an educator or a geographer. The approach of an educational researcher would emphasize the cognitive and pedagogical aspects of GIS activities. This thesis, however, focuses primarily on the content and implementation issues of greater interest to the geographer or GIS professional. These issues include identifying a core of GIS content appropriate for the schools, GIS software functionality useful for teachers, and ways in which the GIS professional world can support the secondary schools.

Much of the information related to this thesis was collected in conjunction with a pilot study by the NCGIA Secondary Education Project (SEP) . A key component of this study was a "GIS in the Schools" workshop for high school teachers put on by the NCGIA in the summer of 1992. The findings of the workshop and remaining components of a pilot study are found in chapter one. The suggestions of teachers during the pilot study led to an expansion of the SEP which was coupled with the detailed look at issues foundational to the success of GIS in the schools found in this thesis. The key issues are explicated in chapters two, three, and four. A final chapter outlines the complete findings of the research effort, suggests action items for successful implementation of GIS in the schools, and identifies topics for additional research.

BACKGROUND

Geographic Information Systems

Geographic information systems are an outgrowth of the computer revolution, as automated versions of the age-old activity of analyzing our surroundings. Early explorers recorded images of their environment in journals and on crude maps; gradually, the representation of spatial data became increasingly sophisticated and abstract. However, for the most part these records were static, and limited in their representation of space, time, and theme. The information contained was more suited to general reference than analysis and decision making. Modern computer technology has removed these limitations. With the advent of powerful personal computers, geographical data can now be manipulated and analyzed by a broad cross section of individuals, both specialist and novice.

Superficially, a GIS is often perceived as a container of digital maps, but underlying this is a much more powerful ability to display and analyze the relationships between spatially distributed phenomena. Burrough describes GIS as "a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes" (Burrough, 1986, p6). These purposes range from military planning to environmental education and from resource management to political redistricting. GIS is an especially useful tool in planning:

> Cities, counties, and utilities worldwide are turning to computerized geographic information systems to automate everything from simple mapping functions to complex land-use analysis, site selection, and network modeling requirements. GIS has not only created a new dimension in map-making. It has opened new frontiers in the ability to make more sound, more enlightened decisions about the very foundation of how we plan and manage our cities, natural resources, land holdings, and utility distribution systems (Smyrnew, 1990, p105).

GIS provides a platform in which to combine spatial data with a variety of other information such as socioeconomic surveys, scientific field and lab studies, and satellite imagery. This spatial perspective can be a powerful source of insight and a powerful influence on the decision-making process ("a picture is worth a thousand words").

GIS can be used for many purposes. Recent issues of the trade journals *Geo Info Systems* and *GIS World* have included articles on diverse applications such as:

- Mapping soil and ground water contamination (U.S. Environmental Protection Agency);
- Assessment of timber resources and lightning strike distribution in order to allocated fire fighting resources in the forests (U.S. Forest Service and private forestry companies);
- Demography and marketing, with data from the U.S. Bureau of the Census;
- Analysis of damage and recovery efforts following the Southern California fires in the fall of 1993;
- The role of geographic information and GIS in the Gulf War;
- GIS as a tool for land management and interaction with land owners;
- Redistricting following the 1990 Census, and the use of GIS to implement diversity objectives; and,
- The use of GIS in emergency response and damage assessment following Hurricanes Hugo and Andrew and more recently for the Midwest floods.

These examples demonstrate how some GIS applications are becoming more apparent to the general public. As the nature of decision making evolves to include this technological innovation, its impact on our daily lives is increasingly evident.

The National Center for Geographic Information and Analysis

As noted above, this thesis research was closely linked to educational activities of the National Center for Geographic Information and Analysis. The NCGIA was established by the National Science Foundation in August 1988 as a consortium of the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine at Orono. In addition to basic research in GIS, the Center's mission included a concentrated effort to encourage GIS education. This focus on GIS education is intended to help meet the high demand for individuals educated in geographic information analysis and the use, design, and application of geographic information systems.

When the Center was created, few resources existed for teaching GIS. One of NCGIA's first projects was the creation of a *Core Curriculum* in GIS, a year-long series of foundational courses in GIS for upper-division undergraduates and graduate students. More than 35 experts from the GIS community helped develop the curriculum, which is presently used in many educational institutions as the base for their GIS courses.

Additional GIS education resources also have been created. To support the hands-on work necessary for a comprehensive GIS education, NCGIA has developed two sets of GIS lab exercises. A GIS lab resources guide has been compiled and a set of case studies on the development of facilities for lab work has been completed. A recent addition to NCGIA GIS education materials is a report, complied with help from the American Society for Photogrammetry and Remote Sensing (ASPRS), listing more than 100 videos on GIS and related topics.

In addition to efforts geared to colleges and universities, the center began to focus on the pre-collegiate educational levels with the primary thrust being the secondary school level. This resulted in a Secondary Education Project which serves both as a formalization of and support structure for this research.

The Secondary Education Project

The Secondary Education Project (SEP) began in 1991 as an extension of the NCGIA Educational Program. The initial objectives were:

- to investigate appropriate roles for GIS software and concepts in the secondary school curriculum;
- to promote GIS within the secondary school community in the United States; and,
- to develop NCGIA as a node connecting individuals in secondary education, higher education, government, and the business community

who are involved with or interested in various GIS-related efforts for the secondary schools.

Activities to date include initial and extended contacts with a host of individuals and institutions interested in GIS for the schools and who, in some cases, have developed actual GIS activities for the schools. These contacts are kept abreast of the SEP and other activities for GIS in the schools through a biannual progress report. The SEP is identifying curriculum resources and software that are appropriate to GIS activities for the schools. As mentioned earlier, an important early activity was to hold a pilot study featuring a workshop that introduced a group of secondary school teachers to GIS and solicited important feedback from them. Based on the results of the workshop and the initial investigations and contacts, SEP moved into a second stage, which has included additional workshops for secondary school teachers and a concentrated effort to develop materials to support the use of GIS in the schools.

All of the SEP activities provide a context for this thesis research. In fact, somewhat of a symbiotic relationship exists between the two. The original thesis proposal outlined a simple investigation of the use of GIS to achieve educational objectives in the secondary schools. The questions raised in the initial stages of the thesis research meshed with a desire by the NCGIA to probe the role of GIS in pre-collegiate education. The NCGIA was capable of supporting a much more thorough investigation, thus the simple research question of the thesis metamorphosed into the broad multi-year SEP. As the SEP continued and expanded, it fed increasing amounts of information to this thesis. Although it may have diffused the focus of the original question, the SEP did allow for much greater extent of the research, potentially increasing its value as a germinator of additional, more focussed research. The following contents reflect an expansion of the original thesis, “how will a group of teachers perceive GIS as a potential component of their program”, to a broader study of the role of GIS in secondary education.

Since this thesis was developed in tandem with the NCGIA Secondary Education Project, it reflects the structure of that project. It is more a project findings report than problem analysis, thus may follow a format different from that of the typical scientific research thesis. Although there is a hypothesis, it primarily serves as the guide for project activities, rather than the focus of formal testing. The first chapter reflects the initial conclusions reached on the basis of the information gathered in the pilot study. The pilot study clarified the need to explore three areas in greater detail: the potential for geography in the schools to serve as a key discipline supporting GIS activities, the likelihood that the technological infrastructure in the schools and teacher comfort with computer-based instruction would enable successful use of GIS, and the extent of and lessons to be learned from existing GIS activities in the schools. These explorations are found in chapters two, three, and four respectively. Chapter five brings together the findings of entire research project and points to avenues of future research related to GIS use in the schools.

Chapter 1
Teachers' Views of the Roles for GIS in Their Classrooms

Since the primary focus of this thesis was to determine the roles that geographic information systems and attendant concepts might play in the secondary schools, it was necessary to go early to the key source of wisdom on what works and is needed in the classroom -- the teachers. A pilot study was initiated to ferret out existing GIS efforts for the schools, to pinpoint the key issues requiring investigation for this first comprehensive examination of GIS in this educational environment, and most of all to solicit teacher perceptions on the potential for GIS in their classrooms. This chapter reviews the findings of this pilot study and its key mechanism, a workshop that brought together high school science, social studies, and computer applications teachers and university level GIS researchers. The workshop provided an introduction to GIS for the ten teachers that attended. These teacher/consultants in turn conveyed their perceptions of the feasibility and desirability of GIS activities in the schools. The details of the workshop are found in Appendix A.

GIS in the Schools - Teacher Perceptions

One of the main goals of the workshop was to gather teacher input on the usefulness of GIS in the schools. This information was sought in order to validate or correct the hypotheses that GIS had significant potential for aiding content delivery, invigorating instruction, providing a context for spatial problem solving, and serving as a link to post-secondary uses of GIS. Although the workshop was in part designed to evaluate these assertions, it was also held in order to provide a forum for teachers to express their perceptions without being constricted by overly zealous exploration of the pre–conceived notions of the GIS researchers. This reflects the fact that the workshop was in part designed to aid this thesis research but also was held to advance the goals of the Secondary Education Project. Thus, the workshop began to test the hypotheses advanced, but more significantly outlined many additional research avenues such as evaluating the most effective media for GIS activities and investigating the difference in cognitive strategies employed for spatial analysis with a GIS versus other methods. The following information is a summary of teacher comments on various topics addressed in the workshop. These observations provided a foundation for the extension of SEP activities and thesis investigation that followed.

Although the teacher/consultants had only been exposed to GIS for one week, it was an intensive introduction. Thus, their speculations were reasonably well-informed. On the issue of the productivity of a GIS component in high school courses, the teacher/consultants were unanimously enthusiastic. GIS was seen as an excellent tool for improving the problem solving and critical thinking skills of students. GIS could be a part of “higher order thinking activities that are often so hard to come up with.” GIS was also viewed as a natural way of providing an avenue for practicing project management and group working skills. GIS would help introduce high technology as an exciting example of computer use in society. Concern for the environment could be matched by GIS–based environmental case studies. GIS was also seen as a powerful tool for linking disciplines. By including some form of GIS activity in the secondary schools, students could be inspired to follow up with further college or university work in GIS and to seek employment in GIS related fields. These responses began to validate the assertion of this thesis that GIS could indeed have an integral role in the secondary schools.

Place in the Curriculum

The teacher/consultants identified many places for GIS in the present school curriculum. Obvious subjects were geography, physical and life science, and earth science. Other subject areas which the teacher/consultants thought might benefit include: history, government, economics, business, environmental studies, computers, and math. Vocational arts classes might even be the closest to GIS with their use of CAD software. With a little imagination the teacher/consultants were able to dream up a use of GIS in just about any course. Despite the many opportunities, the teacher/consultants noted that practical demonstrations of GIS use in the various courses would need to be available to teachers before they would embrace GIS.

Two secondary school subject areas were identified as the early targets for GIS activities: earth science and geography. Some teacher/consultants thought that the sciences with their technological bent would be the best place for GIS introduction. Others argued that the “G” in GIS stood for geography and that the systems are inherently geographical in nature, therefore they should be part of a modern geography program. The “GIS/geography relationship [would be] similar to the high school English class where grammar and English literature go together.” Partly in response to a public outcry incited by widespread reports in the 1980s of geographic illiteracy of students in the United States, geography classes appear to be slowly becoming more common in the secondary schools and might provide the ground for at least a first look at GIS. This initial exposure to GIS in a geography course could be later translated to use of GIS as a general resource in various other courses. This emphasis by the teachers on geography (and on earth science which has physical geography topics as much of its content) indicated a need to develop a clearer picture of the status of geography in the schools and the impact GIS might make in these courses.

Despite this strong emphasis on geography, the teachers also thought GIS could be the focus of new multi–disciplinary classes. These classes might be “made up of earth science and history classes as they discuss nuclear warfare and its history” or chemistry and civics classes as they study the modern pollution problem. Another place they identified for GIS would be in the school library as an information base and project resource.

As noted above, the teacher/consultants, demonstrating considerable imagination and creativity, suggested a wide variety of subjects that might benefit from GIS. This inclusive perspective nearly matched the maximal speculations of the researcher. It is possible that the teachers, caught up in the excitement of the technology, overstated the reasonable extent in which GIS might be integrated into various secondary school disciplines; however, their arguments for many of the subject areas were not trivial. In some science classes a clear role for GIS required an identification of a spatial component of the course. In the case of chemistry, it was the link to environmental monitoring of pollutants that provided the connection to and justification for GIS use.

Teaching Methods

Many methods for teaching GIS in the various courses were mentioned by the teacher/consultants. As a precursor to any form of GIS use, a visual presentation (slides, video, posters, magazine articles) could prepare the students by emphasizing the nature of GIS and its effect on their lives. If this connection is made at the beginning, the teachers stated that it is more likely that the students will be motivated to learn. Considering the state of computing in the schools, it was suggested many times that there be a set of "manual" GIS activities that could be completed without computers, but would lead into the use of the computers where possible. Even before "manual" GIS work, some teacher/consultants noted that basic student training in map use would be helpful. This map practice, however, might be designed to occur as part of the GIS activities. In fact, GIS might be an appropriate method for introducing map reading and use into a course. For the most part the teacher/consultants saw and wanted their students to see GIS primarily as a tool to enrich the study of existing curriculum, with some learning about GIS and its methodology as a by–product.

If the perception -- the use of GIS is more crucial than instruction about GIS -- is consistent among a majority of teachers, a challenge is presented to anyone attempting to adapt post-secondary GIS education materials and activities to the secondary level since most of these efforts and instructional materials focus on learning about GIS rather than learning general curriculum with the help of GIS. This concern was one of the instigators for the extension of the SEP effort to track down existing GIS activities for the schools. An investigation of these activities would not only bring the current status of GIS in the schools into focus, but also help address the question of whether there would be greater receptivity in the schools towards education with GIS rather than education about GIS. Chapter four documents the findings of this effort.

One set of GIS concepts that the teacher/consultants thought was very valuable was that of data layers and the combinations of those layers. They also pointed out that the raster/vector data models were useful concepts that could be clearly presented on a computer. The manipulation of information (aided by the graphic confirmation provided by the GIS) was another subject that had a broad appeal. It was noted that students having the ability to “compose” their own solutions was an excellent educational method. An obvious mode of GIS use identified was as the platform for a class/team project. A problem would be presented to the students who would then use the GIS to find solutions. Specific information about the operation and power of GIS would be an outgrowth of this type of project work. Another mode would be an easy–to–use GIS with an adequate database as an information and quick analysis supplier for various courses. One way GIS could be presented would be as a job opportunity. GIS users from the community could be utilized as guest speakers. These users could be encouraged to consider taking some studens on as interns. Another suggestion was for a local university or business to sponsor a local contest for geographically based information projects awarding modest prize money for the winners.

Teaching Materials

Whether computers are used or not, material such as slides, videos, overhead projector transparencies, posters, examples of GIS output, aerial photography, and satellite imagery would be helpful in introducing GIS to students. When computers are used, the teacher/consultants felt it is still advisable to have a non–technological component. According to the teachers, materials designed for GIS in the schools need to have the following characteristics:

- geared to the existing curriculum
- simple
- ready to use (if teachers suspect that this “new” material is a black hole for their time, it will go on the back–burner)
- adaptable to differing approaches and time periods (with various levels of complexity built–in)
- developed with teacher feedback
- clear as to time and resource requirements
- task oriented
- include support materials such as a glossary, teacher notes, and lists of sources of software and data.

An example of a non–computer dependent GIS activity previewed during the workshop was that of overlaying different data layers on transparencies. Various combinations of the layers were made to answer questions about the relationships between the data. The teacher/consultants liked this model as an introduction to GIS methodology and as a general teaching technique which could be employed in many areas of the curriculum. Transparency overlays can also be used to model other GIS functions such a buffering and reselection.

Software

For GIS classroom activities that will be computer–based, there is still a need for either sets of educational materials designed for existing, inexpensive GIS packages or a new, simple GIS package created with the schools in mind. The IDRISI model was favored by the teacher/consultants, though existing educational materials would need to be tailored to secondary school requirements. According to the teachers, software packages need to be straight forward, easy–to–use, and have “classy looking” graphics. This is extremely important since teachers, even if they are not computer neophytes, will not have the time to learn sets of complex commands and students will probably not have patience for difficult packages.

The teacher/consultants noted that various surrogates to a full–blown GIS could be employed to introduce students to GIS concepts. These include demonstration packages to existing software, so long as the demonstrations are designed to promote GIS education and utilize simple, comprehensible data sets. Demonstrations that are merely a walk through the commands and capabilities of the GIS package did not go over well. Pseudo–GIS packages such as PC/Globe, Mac/USA, and AutoMAP, drawing packages such as CorelDraw and Aldus Freehand, and other map oriented packages could function as introductions to maps and, with a little creative teaching, GIS. Hypertext tutorials could be designed to explain and demonstrate GIS to students. Some portions of the HyperCard based GISTutor might be employed as a text for some of the technical aspects of GIS in more advanced classroom projects. Hypertext applications could even be wedded to GIS packages in order to provide a familiar, simple to use interface for viewing data in the GIS package. Other media may also be employed in the effort to utilize GIS with students such as CD–ROM, laserdiscs, and multimedia systems. Another key subject in any attempted use of GIS software in the schools is appropriate data. Teachers for the most part will not have the energy to compile their own data. Special data sets will need to be created for GIS educational software and instructional materials.

Hardware

Computer hardware in the schools of the teacher/consultants was a very inconsistent mix of PC/XT, 286, & 386 IBMs and clones; Apple IIe and IIgs machines; and Macintosh Plus, SE, Classic, LC, and, in some cases, various types of Mac IIs. Older and lower power machines were most common. This presents a challenge to computer-based GIS use in the schools, since a minimum for comfortable GIS operation at a beginning level would be 386–based machines with VGA monitors, or Macs preferably with color monitors. Some common GIS packages do run on 286-based machines, but these machines usually have limited disk space for large GIS data sets and slow processing speeds detrimental or prohibitive to many GIS operations.

The teacher/consultants and GIS researchers at the workshop attempted to identify the hardware necessary for various types of GIS activities in the secondary schools. For advanced GIS class activities, sharing a small digitizing tablet and a laser printer would be helpful. For a GIS-based lesson for a whole class, a student/computer ratio of 1:1 or 2:1 would be best, with 3:1 acceptable. For group projects, there should be a computer per group unless some sort of rotation could be worked out. Comparing the have and need lists of these schools, it is apparent that in many cases schools may not be well prepared for computer–based GIS activities. With budgetary problems, many of the teacher/consultants' schools were not be updating their computer resources any time soon. This means that new packages running best on 486-chip and advanced Macintosh machines will be out of reach of these secondary educators.

The limited sample size and possible auto correlation in regards to computing resources presented by the small group of Santa Barbara and Ventura county teachers attending the workshop, prevent significant generalizations from being made. Thus an extended investigation of computing resources and use in the nation's schools was carried out and is reported in chapter three.

Directions for GIS in the Schools

The teacher/consultants noted many present impediments to the easy introduction of GIS content into the secondary schools including instructor inertia and dwindling budgets. Some teachers have put up resistance to the use of computers in the classroom chiefly due to the time involved in learning basic computer skills and partly due to fear of change. For most teachers, the present state of GIS materials, software, and hardware would likely prevent attempts to use GIS in their classes. This situation can be partially remedied through the creation of appropriate teaching materials to accompany GIS software, demonstrations, or learning modules designed for use in the schools. The other component to break down teacher resistance would be teacher training in GIS. The time and support required for GIS activities will still be a drawback to some teachers; however, with computers becoming a major classroom tool, sets of curriculum materials with GIS components eventually being developed, GIS intersecting our lives on a daily basis, and GIS–based educational methods being taught in teacher preparation courses, GIS use will be prevalent in future schools.

The question remains: how will GIS be made a useful tool for teachers and students? The teacher/consultants identified the following efforts:

- offer more workshops similar to the prototype they experienced
- develop GIS modules that would integrate well with the existing curriculum
- emphasize teacher/consultant led in–services on GIS
- continue to develop partnerships between teachers and GIS users in universities, government agencies, and businesses
- push for GIS inclusion in textbooks (even at the level of a side bar)
- educate school administrators on the potentials of GIS as an aid to teaching
- establish a communication network for teachers attempting to use GIS
- encourage organizations such as the NCGIA to act in the role of advocate for educational uses of GIS including efforts to convince software developers to participate

A couple of teacher/consultants noted that GIS should be slowly, but strategically introduced into different subject areas. At first it might be seen as a novelty, but efforts should be made for GIS to gain the stature of a key educational tool. Despite the many challenges still remaining, the teacher/consultants eagerly attempted GIS oriented projects in their fall semester classes.

These were the primary observations of the teacher/consultants. Although, it cannot be claimed that a set of 10 teachers from one geographic region is a representative group, most of their assertions have been repeated by many of other the teachers contacted by the researcher during and following the SEP pilot study.

Additional SEP Findings

The following are additional reflections on GIS use in the schools. These topics were more difficult for the teacher/consultants to address since they rely on a more thorough knowledge of GIS concepts and direct experience with GIS in the classroom; therefore, they are a synthesis of teacher/consultant remarks and the researcher's other observations during the pilot study phase of the SEP.

Teaching Modes

Discussion with the teacher/consultants uncovered a variety of ways GIS might appear in a secondary school course. A classification of these different levels of use on a continuum from simple to more complex GIS activities was presented to the teachers. Their comments and later modification yielded the following classification scheme. (Palladino, 1993a)

Conceptual Level/Time Commitment	Activity Hierarchy
HIGH	USE
	TEACH ABOUT
	TEACH WITH
	DEMONSTRATE
	DESCRIBE
LOW	MENTION

The teachers pointed out that the specific circumstances of each class would greatly affect which level of GIS activity would be attempted. These levels of use for GIS software and concepts range from simple 'show and tell' to fully developed GIS projects. The base level, *mentioning* GIS where contextually appropriate, was seen as a common denominator. The next level, *describing* the technology and its applications in more detail, especially by means of visual presentations such as slides, videos, hard copy GIS output, and case studies, was seen as viable in most classrooms.

Demonstrations of GIS software could be performed by the teacher or by a guest speaker. If more practical, GIS demo packages or pre–package modules could be *demonstrated*. Moving GIS to a significant role in instruction are the *teach with* and the *teach about* levels. These categories reflect two modes of

GIS–based educational activities: "GIS in education" and "GIS education". It would be necessary to *teach about* GIS in order to realize the highest level GIS activity: *using* GIS software to work through a particular problem.

Within each level of GIS activity on the continuum, varying amounts of GIS–based learning might take place. For example, in the case of *teaching with* GIS modules designed to enhance the existing curricular objectives of a course (e.g., the study of earthquake location with relation to tectonic plate boundaries in an earth science course), the teacher might try a GIS–based lesson once or use GIS–based materials as a regular part of the course.

This continuum matched the teachers perceptions and related experience with new instructional techniques and technologies in the schools, but a more thorough analysis of the various teaching modes is left for future research.

Appropriate GIS Topics

The NCGIA Core Curriculum in GIS has conveniently laid out a fairly comprehensive outline of the key themes, topics, and details for a solid foundation in GIS theory. (see Goodchild and Kemp, 1990) Since it was designed for the university curriculum, its treatment of GIS topics appeared to be much too detailed for the secondary school classroom. A review of the Core Curriculum as a potential resource for secondary school classes was conducted by geoscience teachers at the Thomas Jefferson High School for Science and Technology. This magnet school has academically excellent students, abundant computer resources, and active GIS projects and thus is well prepared to assess the use of the Core Curriculum in a best case scenario.

The general conclusion of the review was that the Core Curriculum was for the most part too dense and contained much too much information for presentation in the secondary school classroom. There were specific units, however, that the reviewers thought would be useful to a teacher attempting to present some basic GIS concepts to the students. These included some of the introductory units on

GIS application, computers, mapping, raster/vector distinction, and simple GIS operations.

Many of these units had been selected as the basis of the GIS short course presented as part of the pilot study workshop and later SEP workshops. This subset of the Core Curriculum with some additions is geared to secondary school teachers rather than students. It is the responsibility of the teachers to further distill the information into a form that would work with their students. Following the first workshop and the comments of the teacher/consultants, some of the more technical details were removed from the original short course in order to avoid confusion and mental overload and to free up more time for other activities. A list of short course topics is found in Appendix B. The complete short course notes can be found in the SEP Workshop Resource Packet (Palladino, 1993a).

Post-Workshop Directions

The workshop and other pilot study investigations made it clear that there were roles for GIS in the schools, but much more effort was required to get an adequate picture of these potentials. This conclusion of the pilot study, which is also now being called the first phase of the Secondary Education Project, encouraged the NCGIA expand efforts to support GIS for the schools and at the same time motivated this researcher to continue this investigation. As a part of these extended efforts, a proposal was sent to the National Science Foundation's Instructional Materials Development Program. The proposal asked for funding for two major efforts that would be carried out as part of the Secondary Education Project. One was a series of "GIS in the Schools" workshops based on the prototype workshop of the pilot study. The other activity was an Educational Materials Development Partnership in which the NCGIA would coordinate the development of GIS-supported learning modules. Both of these activities would have served as additional testing grounds for the hypothesis put forth in this thesis.

Unfortunately, despite positive reviews, the proposal was not funded; however, it was in part responsible for raising awareness in the NSF education community that computer-based geographic activities are growing in presence and demand. This perception encouraged the NSF to sponsor a specialist meeting in which 60 representatives of the education and GIS communities and key government agencies met in Washington, DC to identify strategic research and development priorities for the use of GIS and associated geographic technologies in the classroom.

Even without the additional funding, the NCGIA has managed to hold two additional GIS workshops for teachers, to develop support materials for GIS activities, and to provide a communication link for those attempting to use GIS in the schools. These activities continue to aid the ongoing investigation of the impact GIS might have on pre-collegiate education.

Conclusion

In the pilot study teachers pinpointed many areas for further investigation and development. These areas include the creation of software, data collections, and curriculum materials to support beleaguered teachers who have little time and energy to develop these resources themselves; the provision of computational resources in the classroom adequate for GIS use; the presentation of models of GIS use and other learning opportunities for teachers; and the evaluation of various questions related to the pedagogic methods that would support and be aided by GIS. The cognitive processing enabled by the spatial analytical capabilities of GIS is another avenue for further research. Strategies for informing the decision makers that designate curricular content also need to be established.

The concluding chapter of this thesis addresses these issues in more detail. Extensive research on many of these questions is left for other researchers, but some of the key issues that appeared to be fundamental to the extended efforts of the SEP to assess the roles for GIS in the schools were explored and are documented in following chapters. Since the inputs to a GIS can be generally considered to belong in the domain of geography, the role of GIS in geography education is examined in more detail in the next chapter. Another topic to be probed in the third chapter is that of technology use in the schools and the effect it may have on the adoption of GIS activities. The final foundational chapter, chapter 4, summarizes the approaches of various existing GIS activities for the schools.

Chapter 2
Geography Education and GIS

In the workshop discussions summarized in chapter 1, teachers saw GIS as having a potential impact in a wide variety of courses at the secondary level. They noted, however, that the most obvious place to introduce GIS concepts and use the software as a teaching tool would be in geography. An investigation of the status of this discipline and its potential receptivity to GIS based learning activities is necessary to help verify the hypothesis that GIS has a role in the secondary schools. This chapter examines the status of geography education in the schools. The historical weakness of U.S. geography education is reviewed and compared with the geography education curricula in other countries. The recent re-invigoration of geography in the U.S. schools is noted. Building on this foundation, the roles that GIS may play in geography education are discussed. Before concentrating on the situation of secondary school geography, the general relationship between GIS and geography is explored.

GIS in Geography

At the higher education level, Kemp, Goodchild, and Dodson (1992, p181) make a case for teaching GIS within the discipline of geography. This case rests on four arguments: "geography as the home discipline for GIS; GIS as a collection of marketable skills; GIS as an enabling technology for science; and geographic information as an intellectual theme within geography." Some of these arguments can be applied to the secondary level as well.

They note that GIS "has developed as a multidisciplinary field with no single home", but they go on to argue that for the purposes of teaching GIS there would be a benefit of a "home discipline", namely geography. They agree with Morrison (1991) that geography has a unique spatial perspective that allows it to interface with a variety of other disciplines, thus partially preserving the interdisciplinary characteristics of GIS. At the secondary level, the breadth of disciplines is much more limited. Many of the sub-disciplines listed by these authors as the multidisciplinary pool from which GIS developed would be subsumed under the heading of geography at the secondary level (e.g., photogrammetry, cartography, remote sensing, spatial analysis.) Though computer science has played a major role in the development of GIS, the initial face of GIS that should be presented to secondary school students is that of a spatial analysis tool rather than that of an implementation of graphical computing routines and relational databases. Although in time, GIS may also serve as an example and interesting expression of computer science theory and practice for advanced computer studies students in some secondary schools.

GIS is also mentioned as another of the skills taught in the undergraduate geography curriculum that are marketable for the new graduate seeking employment (Kemp, et al., 1992). At the secondary level, few if any students will be trained and educated in GIS, but the use of GIS to enhance established studies will increase awareness of GIS as a potential career and may lead to tertiary studies or entry level employment that includes GIS. Again, the most common discipline for this type of exposure to GIS will be geography. (This statement is not intended to negate the potential contributions by science and computing courses in GIS awareness, but discussion of geography based careers in a geography course should include discussion of those careers involving the use of GIS.)

The role of GIS as an enabling technology for scientific research may not be as important at the secondary level, since much of the scientific learning and analysis at that level is not cutting-edge but rather foundational. In fact, rather than even foundational "research" activities, almost all use of GIS in a secondary setting may have an inherent general education purpose. These uses of GIS will not be primarily to create new knowledge, but rather to reinforce learning of established concepts, refine skills in analyzing existing data, and practice the basic methods of scientific enquiry. GIS should, however, allow for a more sophisticated form of enquiry in secondary school geography (and in other subjects). This enhanced ability to stimulate critical thinking and problem solving is one of the great promotions for the use of GIS in the secondary schools, but GIS may still mainly serve in the role of the reinforcer rather than the enabler. As students use GIS to access and analyze information for either role, they will be working with spatial data, therefore it is reasonable to expect to see much of the exploration of that form of data in its “home”, geography.

The last argument mentioned by Kemp, et al. is that of geographic information as an intellectual theme which at the secondary level is synonymous with learning in the context of a geography course or lesson. In fact, it is this underlying theme of geographical information and analysis that transcends the issues of software type or discipline which a particular GIS analysis serves. This core of geographical reasoning is just what the emerging geography in the nation’s schools is beginning to emphasize.

It is this geographical questioning that sets geography apart from other disciplines and gives it power to help us understand our world -- both the natural and man-made manifestations. Francis Slater (1982) demonstrates the use of geographical questions (Where is it? Why is it there? Where else could it be?) in geography lessons. Simon Jenkins (1992), the editor of *The Times* newspaper in London, eloquently points out how the new geography being promoted in the United Kingdom is more attractive through its use of this type of questioning. His son, who like many in his generation is concerned with the fate of the environment, could find the basic foundations for dealing with these issues in the type of geographical question-based learning being emphasized in the modern geography curriculum. GIS is inherently an excellent medium for exploring these type of questions. As we will see in the remainder of this chapter, that is one of the main reasons GIS is being included in the new geography curricula.

Status of Geography in the United States

In order to evaluate the ability of geography in the nation’s schools to incorporate GIS activities, a reflection on the status of geography in the United States is given below. First there is a short summary of classical trends in geography education, then the status of geography in the United States in this century is highlighted.

A Short History of Geography Education

An account of geography through the ages can be found in the Librarian of Congress, Daniel Boorstin's *The Discoverers* (Boorstin, 1991). He highlights the geographic inquiries of early Greeks such as Eratosthenes and Ptolemy with their estimation of the Earth's circumference and other geographical writings. Another early geographer was Aristotle who analyzed data on the habits and settlement patterns of the various peoples conquered by his pupil, Alexander the Great. (Mahony, 1988) From the second century until the fifteenth the science of geography was neglected due to ecclesiastical pressure. Boorstin (1991) laments the medieval absence of geography from the list of learned arts which included topics such as astronomy, geometry, grammar, and dialectic. A term such as geography was not even in common usage during this time.

With the republishing of Ptolemy's works and the voyages of discovery by the Portuguese and

Spanish at the end of the 15th century, geography began to resurface as an intellectual activity. Despite geography's re-emergence during the Renaissance, Greek and Latin were still the core subjects in education. This classical education was reflected in the courses of study on both sides of the Atlantic. It took dissenting voices like that of Rousseau to break the dominance of the classical subjects. Rousseau included geography as one of the subjects that should be a part of a complete education. "By the end of the eighteenth century, Europe was about to witness a change which was tantamount to a revolution. Education was about to become the concern of the state, the prerogative of the individual, and the salvation of nations. Geography, and particularly field activities, was to be a major part of a new age in which scientific utility was an intrinsic element." (Mahony, 1988, p21) Nevertheless, Jenkins (1992) suggests that the hegemony of the classics continues up to the present in many of the United Kingdom schools. As they share the throne with math and the sciences, they create a pressure on the full curriculum that results in a neglect of geography.

Geography Education in the United States

As geography began to be established as a field of study in Europe, it would have seemed natural for schools in the new nation on the other side of the Atlantic to embrace geography as part of a well-rounded education; however, without the top-down control mechanism in society that was common in Europe, geography education in the United States was very inconsistent. (Mahony, 1988) Even before national independence, Harvard University had instituted map and globe study. School teachers had students practice rote memorization of geographical facts for college admissions tests. (Libbee and Stoltman, 1988) Most geography texts were written from a British perspective which did not go over well in the newly free nation. (Mahony, 1988) In 1784, Jedidiah Morse published the first American geography texts which unfortunately reinforced the rote method of memorization. These texts were more literary guides to the geographical wonders of the new nation than true curricular materials. (Libbee and Stoltman, 1988; Mahony, 1988) These popular geographies distracted from a more intellectual geographical approach and may have contributed to the demise of geography as an academic subject in the American colleges by the end of the 19th century. (Mahony, 1988)

In 19th century secondary schools, some of the European educational techniques began to replace
rote learning. William Morris Davis, an eminent physical geographer and promoter of geography in the schools, was influenced by a European "philosophy that geography should seek explanations and attempt to predict effects, consequences, and conditions." (Libbee and Stoltman, 1988, p23) Davis was influential in developing a tradition of physical geography in the schools. By the turn of the century, physical geography was established as *the geography* in the secondary curriculum. In the new century, however, professional geographers began to favor regional geography. Physical geography's domain was being absorbed into the sciences. A curriculum review by the National Education Association in 1911 concluded that the social aspects of geography could be lumped into the umbrella topic, social studies. (Libbee and Stoltman, 1988; Mahony, 1988) Academic geographers had the opportunity to help define the social studies curriculum, but because many were aligned with the physical side of the discipline they would not recognize geography as part of the social studies. This allowed non-geographers, often historians, to define the geography portion of the new, integrated subject. (Libbee and Stoltman, 1988) Mahony notes that World War I also distracted the attention of the professional geographic community.

The vague status of geography in pre-collegiate education continued through the Depression and World War II. (Mahony, 1988) When geography began to be strengthened in the social studies in the 1940s, it was predominantly regional and human in emphasis. (Libbee and Stoltman, 1988) Mid-century up to recent times some of the dismal characteristics of geography in the secondary schools were: "physical geography has been neglected almost completely"; "geography is not given equal time with history or the other social sciences"; "geography does not extend into the senior high school except rarely, and it is even left out in the junior high school to a large extent"; "there is ... lack of preparation of the teacher whose background is usually primarily in history courses"; and "the chronological approach inherent to history wins out over the spatial or geographical approach." (Mayo, 1965) Libbee and Stoltman (1988, p28) suggest "the problem of a less-than-clear definition of geography as a subject has resulted in three major issues for geographical education. The inadequate definition of geography for curriculum purposes results in confusion by teachers. Second, academic geographers are not aware of the content needs of prospective teachers, so that introductory college courses have not covered material appropriate to the elementary curriculum. Third, geographers have not taken the initiative in participating in national curriculum movements [e.g., environmental education, global studies], which, like social studies, rely to a large extent upon geographic content and information."

The one bright spot in this dismal history of geography education was the High School Geography Project (HSGP) of the 1960s which began to develop geography materials specifically for the high schools. Unfortunately, since the HSGP instituted a new methodology that was "designed to engage students in analysis, evaluation, and problem-solving" rather than using the regional and rote memorization approach, "teachers were often threatened by it or did not understand it" and very few effective in-services were developed to support the HSGP materials. (Marran, 1992, p140) From that time until the late-1980s, geography curriculum developments were very limited and predominantly focussed on the college level. (Hill, 1989) With this type of geography environment, the logical "home" for GIS would seem to be quite unprepared to absorb and benefit from potential pedagogic and content enhancements available in GIS-based activities. In the 1980s, however, the trend of weak or nonexistent geography began to reverse, improving the likelihood that geography could serve as the logical entry point for GIS.

Status of Geography in Foreign Countries

Before examining the current status of geography in the United States, an international review of geography education and its potential inclusion of GIS in the classroom will provide a useful comparison when considering the role of GIS in the U.S. schools. This short overview of geography in a few other countries understandably focuses on the more developed nations, since they are nearer in their ability to adopt GIS into their teaching.

United Kingdom

Unlike the U.S. schools, those in the United Kingdom have maintained a clearly visible geography presence in their curriculum throughout the twentieth century. This does not imply that there have not been difficulties ensuring a strong position for geography. In the 1970s the rank of geography fell among the O and A level course offerings (our upper secondary grades). During this period, the "Great Debate" raged on the quality of education in the schools and the appropriate role for the national government in curriculum determination. "Because of the poor economic performance of the United Kingdom, government decided that what was taught in the schools *was* the concern of the government." (King, 1989, p.128) As the debate continued, geography was often not mentioned or under-represented in the core curricula suggested. In the 1980s, the specter of geography being left behind in the development of the impending national curriculum led to a vocal campaign by the Geographical Association and individuals to rectify the situation. (King, 1989) They were successful, so that in 1988 with the passage of the Education Reform Act creating a national curriculum, geography was listed as a core subject. (Lambert, 1990; Cassettari, 1991)

Not only does the National Curriculum solidly establish geography as one of the key areas of study, but it also, in the outline of the Geography Curriculum, mentions GIS explicitly in the section on Information Technology and Geography. For example in Attainment Level 10 of the skills attainment target, students are to "construct a composite map for a specified purpose by overlaying separate distributions of thematic data and evaluate its effectiveness as a Geographical Information System". (DES, 1990) In addition to listing GIS along side remote sensing and other computer use in geography, many of the educational objectives listed under the various Attainment Targets and Levels could be effectively achieved with the use of GIS. Another way in which GIS might help accomplish the aims of the National Curriculum is as a vehicle to implement the strong cross-disciplinary theme present in the curriculum. (Wood and Cassettari, 1992)

With GIS in the curriculum, it is not surprising that there have been efforts to identify the issues related to the use of GIS in the schools. Wood and Cassettari list priorities in education and training for GIS in the schools including: an approach of personal outreach over articles and advertising to reach educators, an acceptance of a common and more simplified GIS vocabulary to aid educators' attempts to communicate to their students, and a few priorities relating to the implementation or development of GIS software that meets the technological requirements of the schools. Freeman (1991) notes the potentials for GIS, in addition to the geography portion of the curriculum, as a part of the Information Technology (IT) strand of the national curriculum. Since IT integrates with many of the subjects, including math, history, and science, GIS in this context may have a broad impact in the schools.

Recognizing the need for a GIS software package that could meet the needs of the curriculum, the National Curriculum Software Scheme has led to the development of an educational GIS (AEGIS) designed for use in the schools. AEGIS allows for "map creation and editing, data importing, interrogation and display of combinations of maps and data and exemplar maps and data for the National Curriculum." (Freeman, 1991, p3.6.3) It has been noted that the AEGIS software may not implement many of the analytical and data handling functions found in a common GIS package, thus making its status as "GIS software" questionable. Nevertheless, this software does appear to be pedagogically useful and at minimum a reasonable introduction to the base concepts and technologies underlying GIS.

Prior to the development of the National Curriculum and the AEGIS software, there were already some movements towards GIS-like technology in the schools. The BBC produced an interactive video disk full of data collected by students around the country. This video disk was run by software that would allow users to access and manipulate the data which was tied to maps. (Maguire, 1989) Despite these developments, GIS in the U.K. schools is still in its infancy, as it is elsewhere. It will be interesting to follow its development considering the support it has both in the text of the Curriculum and in a school oriented software package.

Canada

Canada is another country with a strong tradition of geography teaching in this century, especially compared with the United States. "For a long time it has been an independent high school subject in most Canadian provinces, is usually taught by well-trained specialists, and has a solid content that academic geographers would recognize as respectable, if not rigorous." (Wolforth, 1986, p18) Back in 1921, however, a survey of Canadian geography texts led to the conclusion that they were "not worth the paper they were printed on." (Chapman, 1921, p52) This strong statement was based on the perceived over-emphasis on memorization, which mirrored arguments in the United States (which have raged throughout the century) on the role of place/name memory work in geography instruction. (see Bednarz, 1992) In the 1930s, the social studies movement in the United States began to influence the curriculum in Canada, but despite the fact that many Canadian geography courses were found under the umbrella of social studies, they tended to maintain their integrity. Often physiography (physical geography) remained as a distinct course unlike in the U.S. where these concepts were, at best, vaguely recognizable in earth science or general science courses. (Wolford, 1986). In the 1950s, the Canadian Association of Geographers called for a separation of geography from the social studies. This was accomplished in part through the pressure of the many social studies teachers who were trained geographers.

In 1936, the Australian geographer Griffith Taylor who is known as "the father of Canadian school
geography" founded the first academic geography department in Canada at the University of Toronto. Taylor and a few colleagues inspired a generation of geography students to become geography educators. This was especially true of World War II veterans. Their travels and multicultural war experience made them tangibly aware of the need for geography literacy. These new geography educators found positions in school and college geography departments and in educational administration thus providing a well-integrated support to geography instruction as a whole In the 1960s there was a great demand for teachers which was supplied by the growing number of geography departments in the Canadian institutions of higher learning. (Wolford, 1986)

As noted above, a high level of vertical integration of academically trained geographers at all levels of the education establishment was developed in the decades following World War II. In the U.S., on the other hand, the post-war interest in geography played out in a horizontal integration at the university level. (Thomas, 1992) In the future in the U.S., this important example of vigorous college and university geography programs that produce trained geographers who after entering the schools, school administration, and education departments push for geography in the schools should not be ignored. These individuals will be more likely to incorporate (or recommend) modern geographical techniques such as GIS in their teaching. It is interesting to note, that in the U.S. just as the importance of a vertically integrated geography education to the health of the discipline (and ultimately to society at large) is being recognized, the situation in Canada is reversing. The key geographers in education departments and academic geographers that actively prepared geography educators have been retiring or passing away and are not being replaced by younger geographers. (Thomas, 1990)

Unlike the U.K. where curriculum is now set on a national level, geography curriculum in Canada is set at the provincial level. This leads to a great variety of course offerings between each province, but most offer Geography of

Canada, World Geography, and Physical Geography. (Baine, 1991) Geography is a requirement in most provinces in the lower secondary grades, but is usually an elective for the older students. The control of curriculum at the provincial level "tends to result in the production of first-rate, highly professional course designs," though some argue that this stifles creativity at the local level. (Wolforth, 1986, p23) This might not bode well for GIS use in the schools, since initial activities with GIS might be somewhat experimental. On the other hand, the provincial bureaucracies include developers of curriculum aids including those for the use of computer software. (Wolforth, 1986) For example, the Ontario Curriculum Guideline for Geography, while not mentioning GIS explicitly, includes a section on the use of computers that emphasizes their use for digital cartography, simulation and modelling, data base display, and analysis of "relationships, patterns, and trends." It also mentions the importance of communicating to students the use of computers in the contemporary world, which for careers related to geography includes GIS. (Ontario, 1988)

Since curriculum is determined at the provincial level, the quality and quantity of geography can vary greatly between provinces. For example, in British Columbia, there is very little student interest in geography and even a majority of the social studies teachers seem disinterested. (Thomas, 1992) Thomas argues that inattention to the maintenance of the vertical integration of trained geographers at all levels in education and administration is leading to a demise in the status in geography in Canada. This may not bode well for GIS and other peripheral techniques or on the other hand GIS-based activities could help spur a resurgence of interest in geography. For example, academic geographers (not surprisingly from Ontario) have been partnering with school boards to expose both students and teachers to GIS (see Chapter 4). This will undoubtedly lead to the eventual inclusion of GIS in the curriculum guides and more widespread use of GIS in the Ontario schools. It will be interesting to see how Thomas' perceived down-turn in geography education effects the use of GIS concepts and software in the various provinces.

A more abbreviated view of some other nations' geography education environments and the prospective for GIS in their schools follows.

Chinese Speaking Countries

In the Peoples Republic of China and in Hong Kong, their curricula include many physical geography topics. (Fung, 1992) GIS may play an important role in the instruction of these topics as well as the human and regional topics found in their schools. In China and Taiwan, there are educational goals that lend a hand to the introduction of GIS-based activities. Taiwan emphasizes "some important geographic methods, for the purpose of sharpening the students' ability to creatively discern and solve problems, and for creating an appreciation for sciences and an interest in learning." (Lu, 1992, p65) In China, "guiding ideologies" include goals of giving students technical skills training and "paying attention to the continuum between theories and practices, between textbook contents and practical products, and between the student's life and the real world." (Lu, 1992, p66) Lu sees the essence of Chinese geography instruction in Taiwan and on the mainland as being very similar, despite the enmity between the governments. Lu lists one of the specific educational purposes in these countries as using basic geographic tools and techniques including "developing and applying geographic information systems to establish a geo-statistical databank, which can facilitate decision making and regional development." (Lu, 1992, p67) While Lu's representation of the use of GIS in the schools is somewhat narrow and perhaps misinformed, it does show that modern techniques such as GIS are recognized as having a role to play in modern geographic education. Fung, however, raised the important point that the relative economic prosperity of Hong Kong renders personal computers much more common in the Hong Kong schools than in mainland China, thus increasing the likelihood that the use of GIS software will be common sooner in Hong Kong schools.

Japan

In Japan, another country with a national curriculum, revised courses of study for social studies will be implemented in 1994. World history will become a compulsory course, which has created some concern among geography teachers that this will erode the role of geography in the social studies. In both the current and future systems, only one year-long geography course is typically offered and it is an elective. Teachers are looking for ways to strengthen the perception of geography's usefulness, which includes literacy in geographic skills (such as GIS). The national geography curriculum states that one of the objectives of the geography course is "to cultivate the skills for geographical observation and analysis." This objective coupled with one of the main content elements of the course, "Geographical Information and Maps", could provide an adequate argument for the use of GIS to meet these aims. (Nakayama, 1992, p85)

Germany

Germany has a well established geography education program that would be the envy of American geography teachers. Education in Germany is the responsibility of the state governments, however, the structure of schools at the secondary level is the same throughout the country. (At the secondary level students are tracked by having to attend either a Hauptschule, Realschule, or Gymnasium depending on intended educational path: basic education, vocational training, or university, respectively). (DES, 1990, 103) Geography is a major component of the secondary education curriculum throughout Germany. Although secondary school geography departments are rare, the geography courses have remained distinct and intact even through an effort in the late sixties to integrate them with history and political science. Geography teachers at all levels are specifically educated to teach geography, with secondary teachers often completing five to seven years of geography in the university. (Trüper, 1990)

Following his glowing report on geography as an established subject in the German schools, Trüper does note some problems facing geography in Germany (which are somewhat reminiscent of those of Canada as noted by Thomas). These are budget cuts, lack of university enrollment in geography education, vague public support and understanding of geography's role in modern life, a lack of a good lobbying mechanism, and the inadequate support of computer use in geography instruction. In this last problem area, Trüper seems to idealize the U.S. situation, since there is a perception that the U.S. is well endowed with hardware and software. He also perceives the U.S. schools as having access to “various databanks.” While his characterization of the technological advantage may not be unrealistic, the pedagogic use of these technologies in geography probably falls below his expectations. He laments that the “newest technologies” have not become available in their schools, which would indicate that GIS use would be limited until this situation is remedied; however, the ample offering of geography courses across the grades can serve as an excellent environment from which to introduce GIS concepts, discuss GIS applications and use in the work place, and even, with the technological improvements desired, host the use of GIS software. An example of the potential is the project week featured in the Realschule curriculum. (DES, 1990, 104) Geography project work is an excellent mode for the use of GIS in the schools.

Although these summaries do not represent a complete review of the geography curricula and the potential for GIS in the worlds schools, they help set the stage for comparisons with the current situation in the U.S. schools. The next section reviews the exciting developments in geographic instruction in the U.S. over the last decade. It also discusses how GIS use in the schools might be incorporated in geography instruction as a result of these changes.

New Directions in U.S. Geography Education

Despite the innovative efforts of the High School Geography Project, the geography learning of U.S. students continued to suffer. Although this low ability level was apparent to professional and academic geographers, it took a while for the public to take note and become vocal in support of increasing geographic literacy. (Natoli, 1988) During the 1980s the media began to publish the results of various polls, surveys, and other assessments that demonstrated the dismal performance of the U.S. student in the subject of geography. A 1983 *Dallas Times Herald* international study of student performance in geography and other subjects showed that over 20% of the tested twelve–year olds could not even identify the United States on a world map. (Joint Committee on Geographic Education, 1984) Also in 1983 the federal government's National Commission on Excellence in Education reported that "secondary school curricula have been homogenized, diluted, and diffused to the point that they no longer have a central purpose." This pattern is especially apparent for geography where "in 1960-1961, only 14 percent of America's 7-12 graders were enrolled in geography courses" and in a worsening trend "by the mid-1970s ... the figure had dropped to 9 percent." (Gardner, 1986, p2)

In 1988 the Education Testing Service, was commissioned by the U.S. Department of Education and the National Geographic Society to produced a National Report Card to assess the geographic understanding of high school seniors. The results showed that as a group the seniors were, as Gilbert Grosvenor, the President of the National Geographic Society, put it, "geographically illiterate." This assessment also asked the students to report the amount of geography instruction they had received in their compulsory education. It is not surprising that the seniors claimed to have had little geography in their thirteen years of schooling. (National Assessment of Educational Progress, 1990) Tests of the geography knowledge of university seniors showed similar lackluster performance. (Natoli, 1988) To complete the circle, it is not surprising that a study of the educational backgrounds of social studies and geography teachers found that most of these teachers had inadequate formal preparation in geography. (Cirrincione, 1988)

This dismal status of geography education came to light at a time of increasing global awareness stimulated by the media (e.g., the end of the cold war, increased economic interdependence, and border-crossing environmental issues). This led to a public outcry supplying the political pressure which added state and federal officials to the ranks of the professional and academic geographers attempting improve geography education. In the last decade there have been a series of significant developments in this effort: The Guidelines for Geographic Education and its five fundamental themes in geography, the Geographic Education National Implementation Project (GENIP), the National Geographic Society Geography Education Program and its Geographic Alliance Network, the National Assessment of Educational Progress for geography, and the Geography Standards Project. Accompanying these frameworks and institutional movements have been "many new geography curriculum requirements, new national geography guidelines, new continuing ('in–service') training, and new and revised textbooks." (Hill, 1989, p592)

Guidelines and Five Themes

Even though the public became aware of the need for educational reform in geography, many out of their own ignorance thought the answer would be to return to the rote learning of places and their major characteristics. Geographers and geography teachers "realized that the task of erasing geographical illiteracy was twofold: first, to educate the general public that geography is more than place-name knowledge and, second, that the efforts to improve the geographical performance of American students and teachers would be an enterprise requiring the work of at least a generation and that it would have to be a multi-pronged effort." (Natoli, 1988, pp.ix-x) The flame that ignited this necessary movement was kindled in 1982 when representatives of the Association of American Geographers (AAG) and the National Council for Geographic Education (NCGE) began working on the Guidelines for Geographic Education. The guidelines serve as a "current statement for improving geographic education in the United States." (Joint Committee on Geographic Education, 1984) Since the guidelines were published in 1984, they have helped "move geography into the U.S. educational consciousness in a way that had not been achieved since the heyday of the High School Geography Project." (Salter, 1992, p155)

The Guidelines explain the necessity of geography and emphasize the role of geographic inquiry. One section lists the skills for the high school geography curricula as: asking geographic questions, acquiring geographic information, presenting geographic information, analyzing geographic information, and developing and testing geographic generalizations. (Joint Committee on Geographic Education, 1984) [Although the Guidelines provide examples of each of these skills, a more thorough examination is found in Vuicich, et al. (1988).] The examples do not mention GIS explicitly, but much of the discussion of the skills could easily be interpreted as including GIS (e.g., integration of maps, use of electronic data). In fact, a GIS could be used to develop each of these skills, including acquiring geographic information since many GIS software packages are bundled with data and developed GIS applications store a wealth of data. The GIS could also serve as the repository for data that is collected by other means. GIS especially shines as a tool for data presentation, analysis, and generalization testing.

The Guidelines attempted to expand the public perception of geography by identifying five key themes common in geographical study that those unfamiliar with the breadth of the discipline could understand and apply. These themes (*Location, Place, Relationships Within Places, Movement, and Regions*) can be used as a tool for the elucidation geographical concepts at various educational levels. (Natoli and Gritzner, 1988; Joint Committee on Geographic Education, 1984) Although there has been some limited criticism (see Harper, 1990), for the most part the themes have been widely adopted as a framework for geography studies thanks in part to their clarity, widespread distribution, and acceptance by the geographical community. (Hill, 1991; Salter, 1992) Beyond their service to teachers as a method to organize geographic content, the themes are also being incorporated into geography and social studies curricula and textbooks. (Hill, 1991) Gersmehl (1992), a proponent of the five themes, responding with a musical analogy to a potential misuse of the themes—the five themes as the definitive outline of geographic content—notes that the themes are just that, themes that tread their way through many geographic courses (classical pieces) and help tie the facts and theories (notes, measures, movements) together. He also demonstrates that a theme may be expressed in alternate ways (counterpoint in music).

Whether or not Gersmehl's note of caution will achieve its intended purpose of limiting teacher and textbook writer misuse of the themes as a rigid structure for organizing geographic information, the themes are quickly becoming part of the geography education landscape. GIS activities and concepts may help express these themes in a way that will increase teacher effectiveness in using the themes to bring geography to life for their students. The following represent surmised uses of GIS within the five themes. A more careful study of this potential is left for future research.

Location, the position of a feature on the Earth's surface, could be demonstrated effectively in a
GIS display. Relative locations could be compared at different scales, with varying levels of detail displayed, and in changing perspective (3-D, oblique views, orthophoto/digital map combinations). A GIS could emphasize the role of various reference systems for establishing an "absolute" location, since all features in a GIS are geographically referenced. The importance of locational reference could be demonstrated in some of the GIS analytical operations (e.g., distance or area calculation, inconsistent coordinates and the ensuing sliver polygons).

The second theme, *Place,* which is the physical and human characteristics of a location, could also be creatively developed with a GIS. By placing various characteristics of a location on different layers, the elements determining the nature of the place could be examined in various combinations. This could help show how place is subjective, though often the characteristics are objective. At a more basic level, the layers could show the students what characteristics existed at each location and how places differ. An example would be an ARCVIEW (or other software) representation of the countries of Africa and the different demographic, political, physiographic, and climatic features as demonstrated on separate or combined layers.

Relationships Within Places, which stresses humans interacting with their environments, could initially use a GIS to display key pieces of information in the human/environment interaction at a place. A more sophisticated use of the GIS, could be an analysis of potentials of an area to benefit or hinder human activity. For example, a combination of layers could attempt to model potential soil fertility. Discussion of necessary thresholds for various agricultural activities could emphasize the dependance of humans on the environment.

GIS in its display and analysis of networks is well suited to serve as an exemplar of *Movement*. Various aspects of the movement theme can be demonstrated, from simple display of airline service networks to analyses of urban traffic patterns or seasonal flows of migrant workers.

The last theme *Regions* can be demonstrated through GIS with its polygonal representation of map features. Simple one variable regions can be displayed. Various regions (homogeneous or classified "homogeneous" areas) could be overlaid to create new regions. Traditional global and national regions could also be displayed, but with the analysis capabilities and rapid update of information available in a GIS students could manipulate regional boundaries. This would help destroy the common misconception that regions are actual physical entities with established boundaries. Discussion of attempts to display fuzzy boundaries in a GIS could help the students decipher the difference between discrete and continuous variation through space.

It is important to note that GIS, while capable of exemplifying any of these themes, is merely one potential tool for geography education. It excels in the presentation and analysis of spatial data in digital graphic or tabular forms, but is limited in its ability to present certain concepts. In the example of *place*, the cultural milieu of an area may best be communicated through photographs, video, text, and cultural artifacts rather than the discrete phosphorous view provided by the GIS computer image. This example emphasizes that geography is not limited to the strong suit of GIS, spatial analysis.

Digital maps in a GIS, while easy to manipulate and update, often are missing the artistry of the traditional manually drafted maps and lack some of the visually explicit and subliminal information conveyed through the careful application of cartographic license. Therefore in some cases, despite the power of the GIS and relative truthfulness of data in its database, an alternate mode of data presentation may be more appropriate; however, for an increasing number of spatial data tasks such as managing, planning with, calculating, and updating spatial data, the automated power and relative positional accuracy of database elements make GIS ideal. Although GIS is not a panacea for lagging geographic understanding among today's youth and may not always be the best presentation medium, it is nevertheless a very powerful tool for reinvigorating geography instruction.

GENIP

Following the successful development of the Guidelines, the American Geographical Society and the National Geographic Society joined with the NCGE and AAG in 1985 to form the Geographic Education National Implementation Project (GENIP). GENIP's purpose is to improve geography education by activities and publications focussing on teacher preparation, teaching materials, evaluation of materials and programs, interaction between teachers and university professors, and public relations. (Hill, 1989) As a consequence of GENIP's activities and membership, "the educational world was prodded from a number of sides about the critical significance of geographic ignorance." (Salter, 1992, p155) Building on the suggested learning outcomes highlighted in the Guidelines for Geographic Education, GENIP published more detailed frameworks of geographic concepts for curriculum development in the elementary and secondary schools. (Hill, 1989)

The 7-12 GENIP framework serves as a model for the development of the five themes into concrete *learning opport*unities for a group of example courses. This framework defines GIS in its glossary and specifically mentions the use of a GIS in one of the learning opportunities as a source of data. (There is, however, a vague sense that GIS may be erroneously seen by the framework writers, or at least portrayed to teachers, as mainly as a source of geographic information.) A group of the learning opportunities discuss the use of gridded data, which would tie-in well with an exposure to a raster GIS. The various learning opportunities listed often suggest the use of various geographic methods and media. There are no learning opportunities focussed on the student practice with and understanding of geographic skills and technologies. Since it is likely that very few secondary schools will devote a course to geographic techniques, the learning about the tools of the geographer must be integrated with the other learning opportunities in courses such as world geography or physical geography. (GENIP, 1989)

Since the guidelines and framework writers are predominantly from the human side of the discipline, it is not surprising that there are not many physical geography learning opportunities listed. In fact for the Movement theme, none were listed. This gross oversight has only recently been challenged by Bednarz, et al. (1993) in an article in which they suggest a set of physical geography learning opportunities for this theme. If the weakness in physical geography persists in the objectives supplied to teachers, a whole set of potential uses for GIS as an instructional tool will go unrealized. Despite some of the drawbacks, the framework does offer many salient options for incorporating GIS into instruction. For example, many of the learning opportunities listed in the 7-12 framework focus on map display, analysis of geographic information, and the use of computers, aerial photographs, remote sensing images, and statistical data.

National Geographic Society and The Geographic Alliance Network

During the same period of these early GENIP activities, the National Geographic Society (NGS), under the leadership of Gilbert Grosvenor, became very active in promoting geography in the schools. The NGS established a Geography Education Program (GEP) in 1985 with the goal of restoring "geography to America's classrooms so that students can gain a better understanding of their world and become more effective citizens." (Geography Education Program, 1991, p9) The GEP picked up on an innovative strategy of an alliance between geographers and educators (representing a vertical integration of the different education levels) initiated by Tom McKnight at UCLA. UCLA served as the base for this California Geographic Alliance which had as its primary goal the improvement of geography teaching in the K-12 schools. (Gardner, 1986)

In 1985, Chris Salter, also at UCLA, organized a five-week summer geography institute for classroom teachers as an Alliance activity. The institute was designed to help teachers implement geography objectives in the new California State Model Curriculum Standards for social studies that had been created as a framework for local school district curriculum development. The institute also sought to demonstrate that the study of geography consists of more than just the memorization of names and details about various locations. (Salter, 1986) Following this first Alliance Institute, the NGS asked Salter to help them coordinate the development of Alliances in different states and conduct a national level summer institute in Washington. This first summer institute in 1986 and the eight charter state-based Geographic Alliances were the beginnings of the present Geographic Alliance Network which now includes all 50 states and Puerto Rico.

The NGS provides some of the funding for the State Alliances with the remainder coming from state government and other public and private sources. The GEP defines a geographic alliance as a “university-based, grass-roots organization that brings together the content expertise of academic geographers and the experience of classroom teachers to improve geography instruction.” (Geography Education Program, 1991) The summer institutes have continued at both the state and national levels. Over 5000 teachers have been through these intensive learning opportunities and have impacted tens of thousands of teachers in their home school districts. In addition to the standard GEP summer institute, they have offered an Instructional Leadership Institute and an Educational Technology Leadership Institute (ETLI). Each ETLI, partially funded with a grant from IBM, focussed on the use of computers in geography instruction. (Strong, 1993)

The National Geographic Society’s Geographic Education Program and the Geographic Alliance Network have had a dramatic impact on the teaching of geography in the nation’s schools. The GEP has shown a strong commitment to the use of state–of–the–art technology in geography instruction as is evident by offering the ETLI, in the interactive video disk they have helped develop, and through recent interest in incorporating GIS and Remote Sensing-based learning activities into their program. (Grosvenor, 1989) The NCGIA is aiding the Alliance Network in their efforts to introduce teachers to GIS by offering summer workshops that provide a one-week concentrated exposure to GIS modeled on the prototype workshop described in Chapter 1. The Alliance members that attend these workshops return to their states to make presentations at their summer institutes and give in-services in their school districts. The Alliance Network will be an effective mechanism for increasing teacher awareness of GIS. As Hill (1989) notes "because of this nationwide movement, the need for new geography instructional materials has never been greater." As general interest in GIS rises in the schools, there will be also demand for curriculum materials that incorporate GIS activities and concepts and also for software that meets the needs of the schools. These NCGIA workshop attendees can serve as a pool of potential instructional materials writers who, in concert with software developers and GIS experts, can create GIS-based curriculum materials.

National Projects

As we have seen, concerned geographers, educators, professional organizations (AAG, NCGE, AGS), and other organizations (NGS), have contributed to a dramatic increase in the status of geography in the schools. The political mechanism has also played a role in this resurgence of geography. In the early eighties the *Nation at Risk* report on the status of education in the U.S., stimulated various educational reform activities. (Hill, 1992) With strategic efforts by individuals such as Gilbert Grosvenor and the organizations noted above, geography was included in the agenda as reform was discussed in various forums including the National Governors Association. In 1990, the nation's governors met with the president and agreed on the goals for the reform. One of the six goals was that by the year 2000 students would excel in English, mathematics, science, history, and geography. This goal was incorporated into the Bush administration's *America 2000* education strategy. (Brand, 1992). The inclusion of geography in the "big five" was a major accomplishment. (Salter, 1992)

A recent out-growth of the *America 2000* strategy was the Department of Education's 1991 grant for a framework which would outline what geography students should know in grades 4, 8, and 12 for the purpose of assessment.

(Salter, 1992) This resulted in the Geography Assessment Framework which provides the guidelines for the development of a National Assessment of Educational Progress voluntary nation-wide geography assessment which will be administered in 1995. (Brand, 1992) This will include geography as one of the important subjects tested at a national level. The Geography Consensus Project, the team of individuals responsible for identifying the content of the Geography Assessment Framework, consisted of a 20 member Steering Committee and a 20 member Planning Committee representing a wide range of geographers, educators, and other national leaders. (Salter, 1992b) Many of these same individuals are participating in a parallel project, the Geography Standard Project. These "World Class" Standards will help states and individual school districts define the content and expected student performance levels in various geography courses. (Brand, 1992, Salter, 1992b)

The Geography Assessment Framework and the Geography Standards Project are major developments that will affect the nature of pre-collegiate geography education for years to come. The Framework clearly defines GIS as an important analytical tool in geography. Since this document is a framework, it does not attempt to identify every topic, subtopic, and technique that students should know, instead it identifies three content outcomes (Space and Place, Environment and Society, and Spatial Dynamics and Connections) and demonstrates the type of questions that might be asked at grades 4, 8, 12 employing three cognitive levels (knowing, understanding, and applying) for these content outcomes. (NAEP Geography Consensus Project, 1992) Although uses for GIS could be identified at any of the cells of the matrix formed by the three content outcomes and the three cognitive levels, one might argue that GIS, if available to students, should be employed when attempting to use the higher order thinking skills required in the application cognitive level (e.g., map-based multivariate analysis, network analysis, comparing spatial patterns). When teaching the concepts found in many of the sample questions for grade 12 in the content outcome category, Spatial Dynamics and Connections, a GIS could serve as an effect tool to improve student understanding (e.g., "use maps of agricultural land use in a variety of regions to draw conclusions about distance from market, value of product, and agricultural production" and "analyze and explain land value patterns in urban, suburban and rural areas" (NAEP Geography Consensus Project, 1992, pp38-39)).

So far the Geography Standards Project, which is much more explicit in terms of content and method, continues to be consistent with the direction set by the Framework in which GIS is highlighted as a common tool in geography. The draft version of these new National Geography Standards clearly articulates a role for GIS both as a topic of study (often as a database with map generation capabilities) and as a support for the exploration of various geographical concepts. (Geography Education Standards Project, 1993) Unfortunately, a reflection on the progress of the Standards Project indicates that there may be difficulty building consensus. (Wilbanks, 1993) Some of the difficulties may be based on traditional divergent philosophies of academic geographers, on the human/physical division, or perhaps on the role of advanced techniques such as GIS in pre-collegiate instruction. If these conflicting viewpoints do not reduce the strong role that GIS has both explicitly and implicitly in the draft standards, the final standards will encourage the further development of GIS software and materials for use in the classroom.

Geography Education and GIS

Wilbanks also notes that the place of geography among the other four major disciplines (science, math, English, and history) is not assured in the new national administration. He encourages geographers to continue to mobilize the "talent and energy" of their small discipline. The activities of the Geographic Alliance Network have effectively communicated the need for and ways to implement more geography education to the nation's teachers and schools; however, there is much to be done at the collegiate level. Undergraduates need to be inspired to be geography educators, teacher training programs need to prepare teachers for geography instruction, and academic geographers need to help in the development of curriculum materials by translating geographic knowledge, theory, and practice into a form appropriate for the schools. The demand for materials that will help teachers implement GIS concepts and software into their teaching will only increase. This is where the geographer and other professional who is a GIS user or developer can participate in this effort to solidly establish geography in the schools.

As noted earlier, GIS while capable of demonstrating aspects of geography as understood in the “five themes” construct, also has shortcomings. Some geographers may object to the use of GIS in communicating the heart of geography. Those approaching this issue from certain cultural, socialist, feminist, and other strands of geographic thought may see the digital world view and GIS-based education as narrow or even misguided; however, many geographers explain the discipline in terms that emphasize the role for geographic tools such as GIS.

A geographer with a fairly broad perspecitve, Peter Haggett (1983), lists the orthodox structure of geography as philosophical, systematic (physical and human), regional, and techniques. Clearly, GIS falls squarely in the techniques category, but it also plays a significant part in the systematic and regional camps. This is evident in Haggett’s synthesis of the aspects of these two branches, labeling these integrated pursuits: spatial analysis, ecological analysis, and regional complex analysis. Each of these types of analysis may utilize GIS as a tool. Thus, in his classification scheme for the sub-fields of the discipline, the only branch that does not have a clearly identifiable role for GIS is the philosophic. This category includes History of Geography, which when attempting to record recent times will not be able to escape the impact, for better or worse, that GIS has had on the discipline.

Despite the support Haggett‘s breakdown seems to provide to GIS-based education, there are still inherent limitations in GIS. Some of these relate directly to general questions on the appropriate role of technology in learning and in society at large (Chapter 3 reviews some of these issues.) Others are tied to the structure of data in a GIS The necessary dependance on coordinate geography creates a view of information that, although more accurate in an absolute sense, can end up creating more confusion in the mind of the layperson or student used to the representation space found on a standard reference map or in their own mental map. Some methods of gathering and displaying information utilized by the humanist geographer may also not be portable to the mathematically structured GIS database. Despite the reservations that some geographers may hold with regard to GIS-based education, GIS is clearly "at home" in geography and logically has much to offer to many areas of study within the discipline.

This review of the renaissance of geography in the schools and the potential role for GIS highlights the most obvious discipline for GIS-aided instruction and for instruction in GIS. As noted by the teachers at the prototype GIS in the Schools workshop, there are other disciplines that will also benefit from GIS. These include a few subject areas that are clearly linked to geography: earth science, environmental studies, oceanography, history, political science, and economics. Other subjects (e.g., English, foreign language, biology, chemistry, etc.) that may not be as obviously connected to geography might also find use for GIS and thus discover that geography really has a role in enhancing the study of that discipline, strengthening the perception of geography as the great integrating subject.

If geography can be seen as vital discipline, situations in which reasonable professionals demonstrate their spatial ignorance (often wasting valuable time, resources, and perhaps in some cases human life) can be avoided. Dobson (1991) notes an example of this spatial deficiency in a case where various groups of scientists studying lake acidification in a region ignored the effects of a key weather event due to a misunderstanding of scale, mis-identified samples because of confusion about where they were, and mislabeled the dominant tree type by not noting an obvious classification error on their satellite image. Exposure of students to GIS at a young age may help them use that technology appropriately later in life. The use of GIS to aid the instruction in basic geographic concepts may help reduce the quantity of, often costly, spatial errors which are made by individuals in their daily lives.

Since GIS represents not only an expression of geographic knowledge, but also is the practical outworking of a series of technological innovations, the next chapter explores the role of technology and GIS in the schools.

Chapter 3
Technology in the Schools: Computers and GIS

As we have seen in Chapter 1, teachers in various disciplines see GIS as having great potential for the enhancement and extension of existing curriculum. One of the most promising disciplines for GIS-aided instruction in the schools, geography, is attempting a comeback as is documented in Chapter 2. Another important factor for effective use of actual GIS software in the schools is the technological infrastructure that is supported in the schools. The pilot study for this thesis research indicated that the success of many GIS activities might hinge on the availability of computational resources in the schools and the preparation of teachers to use them.

Therefore, this chapter explores the state of technology in the schools especially with regards to the particular needs of GIS software. The chapter first explores the range of technology used in the schools then narrows down to the use of computers in geography. Since GIS is part of a suite of computer software used in geography, its place among those geography software packages is examined as part of the section on computer use in geography instruction. A final section brings these discussions together in a discussion of the actual use of GIS technology in the schools.

Technology in the Schools

Classrooms around the nation are beginning to employ a wide range of new technologies in the classroom, many of which are computer-based. It is useful in a consideration of the role of GIS in the classroom to first review the role of these technologies. Assessing the attitudes towards technology in general might help in the design of appropriate GIS activities. Following the overview of technology in the schools, the use of specific technologies, especially those relevant to geography instruction and GIS, will be examined. A catchall term for many of these newer technologies in the schools is multimedia which includes interactive video, hypermedia, and even electronic atlases.

Technology

Technology can be an elusive term. Many individuals view technology mainly as industrial artifacts; they are seen as the products and processes that make our world operate. One geography educator identified technology as “any object used by mankind to enhance his/her physical capabilities” and specific to geography as “the tools used by geographers (students, scientists) to better observe the earth or measure natural or human actions; and technology impacts on the environment, thus are the object of these geographers’ study.” (Gerber, 1992, p285) Although a relatively narrow view of technology, it actually conceptually frames much of the later discussion in this chapter on the use of modern, often electronic technological artifacts in the geography classroom. This definition of technology also nicely fits GIS.

Before moving into a discussion of these technological artifacts, it is worth noting that technology can be viewed in a much more holistic way that includes not only the objects and processes that we identify as technology but also the organizational structures that accompany any use of these “technologies.” These organizational structures include relationships between components, management strategies, power patterns, networks, and even interpersonal communication skills. This form of technology is often referred to as “soft” as opposed to the “hard” objects and processes. (Gerber, 1992) For example, a city government using GIS may incorporate many of the “soft” technological innovations mentioned above in their complete GIS enterprise. Many of these relate to management structures for distributed databases, the functioning of the various players in a collaborative effort, and other organizational issues that are especially prevalent in any large undertaking.

The discussion of technology in the curriculum rarely incorporates its effect on the culture. This impact on culture may be seen as one of the important elements of “soft” technology. Young reminds those pushing technology to engage in reflection on the societal effects of our focus on technology education. (Young, 1991) This might encourage those who are proposing the incorporation of GIS software and concepts in the educational enterprise to think twice. Are we presenting a false panacea that will create an over-confident culture? Will “necessary” access to spatial and accompanying attribute (e.g., demographic) data erode the strength of privacy as legal concept in our culture? What other cultural changes will be created by a GIS literate and perhaps dependent populace?

On a less abstract level, a witness to an Australian government inquiry on the potential for satellite technology to impact education highlights some of the “soft” issues surrounding “hard” technology in the following testimony: “To interface adequately with technology, teachers, like many other groups in society, require a number of facilitating factors to exist. These factors include an enthusiasm to use technology, adequate pre-service and in-service education, informed and supportive specialist advisory staff, adequate and compatible hardware, and educational software that is not only technologically compatible, but compatible with teachers’ educational philosophies.” (Gerber, 1992, p283) This statement could be equally applied to various hard technologies in the schools especially computers and GIS.

For GIS activities, it appears that some of these “soft” technological supports will be easily found while others may take more concerted efforts of the promoters. The NCGIA workshop showed that demonstrations of GIS capabilities and existing applications were sufficient to generate enthusiasm in teachers; however, for teachers to use this technology in their work environment, they will need to be supported by in-services (such as the NCGIA workshop) and by GIS professionals (with a knack for communicating to laypeople.) Ideally over the next few years, teacher training programs will not only begin to include pre-service training in geography but also in the use of GIS software and concepts which will lead to the use of GIS in the future classrooms of these student teachers.

Gerber has identified three main impacts technology might have on geography instruction at the secondary level. These are: “1. a means for improving data-gathering in making thorough investigations, 2. a facilitator in the development of skills, and 3. an additional explanation for spatial patterns and people-environment relationships." (Gerber, 1992, p284) Although this list is not exhaustive and wasn't created specifically with GIS in mind, each of these impacts can be clearly linked to the potentials inherent in an educational use of GIS. The first impact expressed in a GIS context may be seen as the import, storage, and classification of data collected in the field (perhaps with a GPS system) in a GIS software package. Two types of skills might be developed with GIS. One is the use of geographic data sets in a digital environment. The other is the skillful association and analysis of the relationships between datasets and elements within each data set. The last impact, the use of GIS to improve student perception of the spatial characteristics of our world, is a latent capability of GIS which is waiting for development.

Attitudes Towards Technology

In a discussion of technology use in the geography education, it is important to note the high correlation between attitude and the success rate of that technology as an educational tool. "Positive attitudes toward technology can produce a widespread use of different technologies; negative attitudes can have the opposite effect." (Gerber, 1992, p284) Gerber suggests that these attitudes tend to follow an individual through life. While it may be true that basic attitudes towards technological innovations often do stick with an individual, there can be cathartic or at least mildly revelatory interactions with technology that can reverse the individual's perspective, both from against to in favor and vice versa. In the case of GIS, a demonstration of versatility and dramatics such as animated 3-D sequences might turn the ardent opponent into a fan. On the other hand, as has been the case in many agencies that rushed to incorporate a GIS in their activities, the so-called power of the GIS can end up as major frustrater due to the complexity, difficulty building adequate databases for many tasks, and the other problems that arise with an over-reliance on fallible computer hardware and support structures.

To increase optimism about technology, formal and informal learning experiences need to be adjusted to accommodate more effective uses of both "hard" and "soft" technologies. Initial negative experiences with GIS software resulting from rush to expose teachers to the "newest" technology could actually prove to be more detrimental in the long run over a more metered approach of introducing GIS. This approach may begin with simple demonstrations of GIS applications, an overview of the fields that employ GIS, and a general discussion of the potential for GIS in the classroom. This would be followed up by a well–supported interaction with an easy-to-use, conceptually straightforward GIS software package. This less haphazard introduction to GIS may ensure a more effective use of the "hard" GIS technology and a greater willingness to conceptualize the role of the attendant "soft" technologies accompanying any large GIS enterprise.

International Attitudes

Gerber attempted to assess the impact of technology on geography educators around the world. He surveyed 193 educators from five continents and various educational levels. In his survey, the two most popular attitudes towards the effective use of technology in education were: it can be used effectively in both the arts and the sciences and it makes education more interesting. (Gerber, 1992) Both of these attitudes, if truly prevalent, would be boons for GIS activities. Although GIS has many obvious roles to play in the sciences, it also can make significant contributions to social studies and other disciplines not strictly categorized as sciences. GIS adherents would quickly attest to its inherent interest factor, but an attitude among the majority of educators that technology increases student interest levels will be the factor that will pave the path for the incorporation of GIS activities in the secondary school classroom.

Gerber also asks the geography educators to identify the most common problems and the benefits presented by technology in the classroom. The most commonly mentioned problems were the expense, accessibility for classroom use, and amount of training required. (Gerber, 1992) At this stage in GIS development it would be hard to argue that these problems will be easily overcome when introducing GIS software into the schools. These are issues that are apparent to many working both in and with the schools and in time will most likely be adequately addressed. Specifically for GIS, the GIS community bears some of the responsibility for improving teacher access to the technology, providing learning opportunities (such as the NCGIA workshops), and for providing the technical advice for the development of software for the schools that incorporates some or even most of the common GIS functionalities.

The top three benefits were: additional teaching strategies, increased interest in lessons, and time savings. The benefits that rated high that are especially germane to GIS in the classroom are increased interest in lessons, visualization of difficult concepts, availability of up–to–date data, and easier data management. Other potential benefits that relate to GIS-based education that didn't rate as high were marketable skills, more research, brings the world to the classroom, and less paper.

One part of Gerber’s survey was the technique of teacher-drawn Idea Maps that demonstrate the various links and nodes envisioned by the individual when pondering the role of computers. These “brainstorming” and rather chaotic diagrams actually yield a general perspective on each individual’s attitude towards technology. These attitudes range from the technological enthusiasts to the technological neophytes to the technological antagonists. Gerber suggests that the teachers that appear to see computers as exerting a major influence on a wide range of life activities are more likely to incorporate them in their teaching. On the other side of the spectrum, some teachers clearly demonstrated their frustration with and even hostility towards computers in their sketches. (Gerber, 1992) Eventually, it is into this diverse environment that broadly-based GIS activities will be introduced, but it may be more strategic or perhaps only possible to impact the “computer friendly” classrooms first.

It is not surprising that Gerber found in the parts of his recent survey on the knowledge of, use of, and access to various hard and soft technologies that more than 50% of geography educators responded that they were unfamiliar with GIS software and the vast majority did not use or have access to the software. Remote sensing software followed a similar pattern, but was considered more well known than GIS, while at the same time less used and available. This flip-flop may reflect the earlier promotion and wide use of remote sensing software, but the greater present variety, availability, and range of uses of GIS software, respectively. Since the mix of educators surveyed was roughly a 60:40 ratio of the pre-collegiate educators to collegiate, it can be reasonably assumed that subtracting the collegiate response, the GIS exposure of the remaining group would be negligible.

Gerber concludes that “firstly, geographical educators need to develop a broader understanding of the concepts of technology.” He suggests that teachers begin to include the “soft” organizational skills and behaviors to balance the traditionally exclusive emphasis on the “hard” artifacts in discussions on technology. Geography educators can begin to incorporate this fuller understanding of technology as part of in-service sessions that will help to “demystify” these concepts. “Secondly, these educators need to become aware of the potential of ‘hard’ and ‘soft’ technologies for improving geographical education. ... Thirdly, in-service experiences should be planned to give geographical educators extensive practice in the development of a range of applications using technology in geography teaching and learning.” (Gerber, 1992, p297) Although one might question the importance Gerber ascribes to the role of “soft” technologies in geographic education, it is conceivable that GIS activities, although undoubtedly “hard” in their obvious manifestation, may be very effective in demonstrating to students the organizational skills necessary to carry out a GIS analysis, especially in the context of group work.

Multimedia

Out of the vast sea of “hard” technologies some might be isolated and identified as instructional technologies. In this category it is useful to make a distinction between media and machine. Often media, such as print, video, and audio, may be identified as the conveyor or container of the curricular information and the machine as merely the utilitarian device that makes this transfer of knowledge possible. Thus, some of these machines are merely audio-visual display devices such as overhead, slide, and movie projectors. Other machines such as computers, however, are in some ways a part of the media since they logically interact with the media. Many of the newer educational technologies are computer–based and fall under the category multimedia.

Multimedia integrates text, graphics, sound, images, animation, and full-motion video with the power of computers to create a “multisensory” experience. This “natural” presentation of information through these means is one of the key characteristics of multimedia. Another feature is the ability to navigate in a non-linear, user-controlled fashion through the information. This process is labelled hypermedia. (Oblinger, 1992)

Lamb describes the “classroom of tomorrow” as a multimedia classroom. She states that the benefits of multimedia-based classroom instruction in higher education are a stimulating teaching and learning environment and the encouragement of student ownership and self-expression in their learning. She goes so far as to claim that hypermedia materials are more engaging than traditional print materials, since learners spend more time processing information. (Lamb, 1992) Whether students actually intellectually explore the concepts embedded in the hypertext medium in greater depth than with print or rather skate along on the surface searching randomly through the data, images, and text is open to debate, but the flexibility of a multimedia hypertext view of the world creates new possibilities for learning without preventing the use of the static image and text of the textbook. The computer with a graphical user interface is an integral component of this multimedia-based teaching. In this environment, GIS can become a powerful hyperlinked medium.

Multimedia can allow students in a variety of disciplines to explore concepts that are typically unavailable to them; they might be too dangerous, impossible to explore, or just out of the budget of the institution. This might include the examination of microscopic environments (e.g., journeys through the various organs of the body) or the observation of violent chemical reactions. (Lamb, 1992) For students, multimedia may allow them to “perform” GIS analysis without acquiring powerful, prohibitively expensive, and overly complicated software and hardware.

Interactive video

One of the first multimedia formats was interactive video. Interactive video uses a computer to allow the viewer to interact with the video message. Still or motion pictures can be accessed in a sequence that fits the users needs or desires, thus abolishing the passive viewing of traditional video. This interactive mode of learning is claimed to increase information retention rate to 75% from the 40% in the case of traditional video. (Oblinger, 1992)

Interactive video can be stored on CD-ROM disks or on videodisks. An early example of videodisk use in geography was The Domesday Project in Britain. In this project, students from around that country took photographs and wrote about their local area creating vignettes that were stored on a videodisk. Another disk contained national data from government and quasi–government sources. The Domesday disks used a microcomputer to facilitate interaction with the data which was linked to 24,000 1:10,000 scale Ordinance Survey maps of the country. Data could be accessed at different scales through selecting the area of interest on the maps. In addition to the 1:10,000 maps, the disks include 43,000 photos, 500 maps at various scales, over 150,000 pages of text, and 9,700 statistical data sets. The disk appeared in 1986 and was enthusiastically received. (Maguire, 1989b)

The enormous quantity of information on the Domesday disks emphasizes the storage capabilities of interactive video. The modes of interacting with this data represent the wide range of multimedia-based instructional uses of interactive video, including GIS. Although the software running the disks might not be identified by some experts as GIS software, it did incorporate some analytical functionality such as the ability to overlay digital statistical data on the analog maps (which had been optically scanned), to search the database through the use of geographic coordinates or by selecting an area on the image, and to interactively calculate distances along a path. (Rhind, et al., 1988) This project is an excellent example of the synthesis of multimedia with geographic data and techniques in an educational context. Also seen in this example is the ability of some multimedia technologies to serve as a simple GIS.

The Domesday model was later emulated in the "Community Snapshot" of Toronto in which pre-collegiate students collected data (textual, numerical, and photographic) about their city. The data was compiled on a microcomputer controlled videodisk. (Clarkson, 1991) The significance of this project is that it is a proof of the concept that students can effectively build substantial and useful databases based on their own field work. This provides an important example for GIS activities in the schools, because the heart of the GIS is the database and students appear to respond favorably to data from familiar (i.e., local) areas. In order to be able to use this local data in their GIS, students may need to collect their own "fresh" samples.

GIS may be part of the pizzazz of a multimedia production. It could serve as the analysis engine in a hypermedia information web. On the other hand, multimedia and hypermedia may also act in support role for GIS. Since interactive video and multimedia in general are gaining favor in the classroom and since they are effective communication tools, they may be appropriate means for introducing GIS to the schools.

Hypertext

Another common form of multimedia is hypertext programs. Hypertext information is stored in a non-traditional organizational structure unlike traditional databases which have an "extremely regular structure defined by a high-level data definition language." (Theobald, 1992, p1) The hypertext structure, on the other hand, is fragmented with no "central definition". (Nielson, 1990) This allows the user to access the information non-sequentially creating the possibility of multiple paths for data acquisition and analysis. This learner-centered mode of information access is more similar to the theories on natural cognitive strategies where learning is "an active process of reorganizing the learner's knowledge structures." (Theobald, 1992, p2)

Theobald (1992, p3) in a review of the potentials of hypermedia in geographic education states “the visual nature of geography relates well to the multimedia abilities of hypermedia, and the flexible linking of concepts allow interrelations among phenomena to be naturally depicted so as to facilitate the understanding of spatial phenomenon.” Theobald does not mention the metaphor of the “map as index” as a significant feature available to both hypertext curricula specifically emphasizing geographic learning and those unconsciously doing so by linking various forms of data to spatial entities (e.g., famous authors linked to their country or city of origin).

One type of software in which hypertext learning modules can be developed is HyperCard for the Macintosh computer. Slocum and Egbert (1991) emphasize the power of this hypertext medium in their enthusiastic description of its capabilities; “it can function as an application program, a screen painting program, a database program, or as a complete programming language.” Of course, like many integrated productivity software packages, the multiple functionality of a HyperCard stack often limits its ability to perform any one type of task with distinction. While a HyperCard environment might be adequate for an electronic atlas, it may not be sufficient for GIS. The great advantage of hypertext, however, is not that it will be the GIS, but that it can serve primarily as a gateway to fully functional GIS software packages.

Raveneau, et al. highlight the use of HyperCard as the medium for electronic atlases in their description of two French language micro-atlases they have developed. One HyperCard atlas is devoted to North American French communities and the other to the geography of mines and minerals in Canada. They show how the wealth of digital data being created can be effectively presented in HyperCard-based maps with links to other types of data. (Raveneau, et al., 1991)

Hypermedia has been used effectively by Jonathon Raper and Nick Green to teach GIS concepts. Their HyperCard stack (program) is named GISTutor. GISTutor allows the user to navigate through various paths connecting subtopics. The subtopic are grouped under the following topical headings:

Capture, Edit, Structure, Restructure, Manipulate, Search, Analyze, Integrate. Each subtopic has a series of information "cards" and in some cases animations. Learner control over information retrieval sequencing either allows the whole tutorial to be covered (but in the order desired by the user), familiar or uninteresting topics to be skipped, or selective access based on a specific topical query or on a need for review. (Raper and Green, 1989) GISTutor appears to provide an effective reinforcement of GIS fundamentals. It has been used by teachers in the NCGIA Secondary Education Project workshop with some success despite limited time spent working with it. It may be a bit too detailed for the average secondary school student, but for advanced students working on GIS projects it could serve as an excellent tool to put their projects in context.

It has been suggested and demonstrated in a prototype, that the NCGIA core curriculum could be adapted to a hypertext format. (Srinivasan, 1992) Another initial attempt to put GIS content in a hypertext format, this time specifically for secondary schools, has been started by one of the teachers involved in the NCGIA GIS workshop for secondary school teachers. This project did not progress far, but did serve as a proof of concept. (Palladino, 1993a)

Other forms of multimedia

An excellent example of an interactive learning environment and the incorporation of choropleth maps in that environment is the Great American History Machine (GAHM) produced by Miller (see Miller, 1988). The GAHM allows students to access county level census records from 1840 to the 1980s using a user-friendly graphical user interface. This data can be analyzed in the choropleth maps created by the students with help from the GAHM. (Slocum and Egbert, 1991)

Taylor (1991) reports on electronic atlases as a form of multimedia. He notes that cartography can be an important part of a multimedia system since maps can be key elements in the database and can also serve as a powerful interface for the organization of data. Louise Guay, in a description of the Electronic Atlas of Canada, documents the components of a multimedia atlas as involving "visualization of information, schematization, comparative analysis, ordering, animation, dynamic modelling, projection, random navigation, hypertext, databases, and a capacity for processing and interactivity." (Guay, 1992, p2) Slocum and Egbert (1991, p181) note that electronic atlases range from the digital reproduction of a book to "a complete information system in which map queries and analyses are possible." On the later end of this spectrum, the electronic atlases are essentially simple GIS packages.

Computers in the Schools

One of the primary forms of "hard" technology impacting the schools is the personal computer. One use of the computer in the school is as the controller of a multimedia learning environment. Computers are also used with a great variety of software including more recently GIS packages. Although many of the multimedia technologies may interface with or emulate GIS software and may aid instruction about GIS, the technological backbone of GIS in the schools will most likely be the personal computer.

Over the last fifteen years the personal computer has become established in the schools. In the 1980s the number of microcomputers in the schools increased nearly 50-fold to almost 2.5 million. The growth rate was between 300,000 and 400,000 computers per year. (Becker, 1991) Before this period of growth, however, in the early part of the decade, glowing media reports on computer use often were based on cases of "unusual schools with hard-to-replicate amounts of computer equipment, teacher expertise, and family resources." (Becker, 1991, p386) This situation has improved, but it is interesting to note that GIS is now in the stage that personal computers were ten years ago. Many of the current examples of GIS use in schools resemble this description of the "super school".

Early in the 1980s, the low number of computers in the schools dictated a choice between a concentration of the few computers in a centralized lab providing only a few students with significant computer exposure or a distribution of computers to the point where many students receive some though rather insignificant computer exposure. In this period, computer use was predominantly programs and games emphasizing drill and practice. By the end of the decade, computers were much more widespread in the schools, but changes in the types of use were modest. There was some movement in the secondary schools towards the use of computers as "productivity tools for expressing ideas and recording and analyzing information." (Becker, 1991, p386) It is in this movement towards computers as a tool for information management and application that GIS activities belong, but without a strong tradition of computer use as a productivity tool or rather, as an instrument for curriculum content and concept learning, GIS activities may prove to be ahead of their time.

Computer Hardware

Becker has been one of the main researchers monitoring the number and use of personal computers in the nation's schools. His latest review, the International Association for the Evaluation of Educational Achievement 1989 "Computers in Education" survey, shows that there was a continued increase in the numbers of computers in the schools, improvement in computing power available to students, and more experience with computer-based learning activities that were more than drill and practice from the time of Becker's previous assessment in 1985.

In 1989, the primary computer in both elementary and secondary schools was the Apple II. The high schools also had a reasonable contingent (29%) of MS-DOS machines and a small number of Macintosh machines. The projection was for Apple IIs to continue to increase in the elementary schools. At the high school level, however, Becker reported that schools were planning most of their purchases to be MS-DOS with some Macintosh acquisitions. Even if purchases of Apple IIs did not continue past 1990, Becker predicted that in 1993 only 60% of the school computers would be the more powerful MS-DOS and Macintosh machines. (Becker, 1991) The reports of the teachers that attended the NCGIA GIS workshop and other anecdotal information have essentially verified Becker's forecast.

The majority of secondary schools had computer labs, but less than 20% of computers in those labs were networked. (Becker, 1991) Networked computers may be useful for GIS activities that involve the whole class such as using a GIS to access various datasets stored on a central server. Given the price and complexity of many GIS packages, it seems likely that teachers that have access to networked computer labs may still opt to use just one or a couple of computers due to the high cost of software.

Computer Use

Whether networked or “stand alone”, computers are often merely used in the schools as a tool for reinforcing learning. These type of drill and practice activities were still the dominant uses of computers at the end of the 1980s. There was, however, some movement away from rote learning and towards communication and information processing activities designed to support learning of course content. For example, in 1989, a majority of high school computer coordinators viewed the computer as a tool for academic tasks as opposed to a resource to learn about computers or a means to improve basic skills. This trend bodes well for GIS activities since they are chiefly concerned with expressing, storing, and analyzing spatial information.

Although more emphasis had been placed on the computer as a tool to help students learn content and explore concepts, rather than drill and practice, much of the work on the computers was still devoted to mastery of software as opposed to the utilization of that software for intellectual development. (Becker, 1991) In addition, many of the computer coordinators in Becker’s study identified the option of “computers used to learn about computers” as very important, but the coordinators with this opinion were not a majority as they had been in a 1985 survey. Unfortunately, present GIS software will most likely add to this excessive focus on learning how to use software rather than using it to learn. There are also many ways that the use of GIS software could expand student understanding of computers and their use in society; however, these valid goals should not supersede the primary goal of GIS in the schools which is to help students to think spatially and gain a greater understanding of curricular elements with spatial components.

Even though there were movements toward more sophisticated uses of computers in the schools, basic skills reinforcement was still seen by a small percentage of the coordinators at the secondary level and by a majority at the elementary level as the primary purpose of computers in the schools. (Becker, 1991)

Another way to view computers in the classroom is by their relative use among the different disciplines. As the pedagogical goals to be achieved by computer use varies, so too does the relative quantity of computer use in the various school courses. English and math are the traditional disciplines that use computers the most in the high schools. Science and social studies also make use of computer, but together account for less than 10% of the use. (Becker, 1991)

Despite the “use” in these disciplines, the majority of computer-based work in high schools is actually centered around learning word processing, keyboarding, programming, and the development of skills with databases and spreadsheets. This does not include the use of word processing, database, or spreadsheets as a part of the content instruction for math, English, science, or social studies. In fact it appears that the computer coordinators were obsessed with the need to teach students to use productivity software at the expense of using computers as a “learning medium” in various subjects. (Becker, 1991)

Although teachers anticipated computers being used more often in the sciences and the social studies in the early nineties, the emphasis on these disciplines was expected lag behind other disciplines (math, English, business education) and types of use (word processing, keyboarding). This was especially true for social studies where just over 10% of the coordinators anticipated increased use over the few years following the 1989 survey. (Becker, 1991) The low use of computers in these two disciplines which represent key entry points for GIS activities may indicate that GIS will have a hard time catching on. On the other hand, it may be just this type of stimulating use of computers that will increase the role of computers in science and social studies.

The one use of computers mentioned above that was not seen as a growth area was programming. Evidently programming in the schools has reached a saturation point. This may negate the argument that one of the potential benefits of GIS in the schools is that it could provide interesting examples for computer programming; however, it may be just these types of interesting results from programming activities that will revitalize programming in the schools.

A third way of viewing computer use is by the mode of use within a particular classroom. In the secondary schools, the main use for the computer is enrichment as opposed to regular instruction. (Becker, 1991) This could be in part due to the general lack of access to computers which prevents teachers from using them on a regular basis. It might also indicate that teachers have not been adequately prepared to incorporate computers into their daily instruction. It seems likely that a teacher who is accustomed to computer use on a regular basis will be better prepared for GIS activities, however GIS could also serve as an effective enrichment activity.

A critique of the National Council for Social Studies technology standards for the incorporation of computers in the humanities serves as a synopsis of the issues surrounding computer use in the schools. The critique identities four important factors that were neglected in the standards. The factors are: “(1) computers are used differently when employed as productivity tools, instructional media, or ‘stand alone’ instructional systems; (2) computer integration progresses in slow, developmental stages; (3) a symbiotic relationship exists between staff experience and software and hardware purchasing; and (4) computer integration involves planned and facilitated change.” (Brady and Barth, 1992, p14) When anticipating the implementation of GIS activities in the schools, these factors should also be kept in mind.

Computer Software Use

The type of software used typically follows the patterns of computer use identified above. Other factors also contribute to decisions by teachers to incorporate a particular computer program or software package into their teaching. As it is, teachers must work hard to acquire adequate computing equipment and adjust their teaching styles to computer-based activities. At the same time, they are being called by curriculum guides to implement a variety of new teaching strategies, including the use of computers.

One of these strategies that teachers are being pressed to implement in their classrooms is critical thinking activities. This strategy as with many of the others (e.g., group work) can be effectively aided by computer software. One example of the use of computer software in geography to stimulate critical thinking is provided by Robinson and Thornton (1992) in their discussion of a PC Globe-based learning activity. PC Globe is an electronic atlas that allows the student to quickly access current information on the counties of the world. These educators had students use information on age distribution in two counties to make budgetary decisions for various governmental social programs. They also had students attempt to find correlations between pairs of statistical records in the PC Globe database. Although PC Globe does allow students to view statistical data graphically and in the form of choropleth maps, students are limited in forms of representation, cannot overlay choropleth maps, and cannot modify the placement of features on the maps. Since GIS software has these additional capacities, it may provide a more significant means of engaging students in critical thinking activities.

Part of the next section identifies additional geographic software packages classified by type of use. Although many of these software packages are useful in geography education, Becker (1991, p401) noted “materially, not only do teachers require well-constructed, easy-to-use, and manifestly powerful software tools, but they also need models, examples, and detailed directions for how these computer applications can be used to directly address the primary curricular goals that they are obligated to follow.” He also comments that producing software and distributing it (and even training teachers to use it) does not ensure that computer software will receive “frequent and integral” use in the classroom.

Computers in Geography Education

While computers are common in geography instruction in higher education, their use at the pre-collegiate level is not so common, but is increasing. This section reviews the types of use for computers in geography education at both education levels. It reviews Computer Assisted Learning in geography, lists the various types of geographic software, and gives examples of geographic software used in geography education.

Computer Assisted Learning

The use of computers in education is often termed Computer Assisted Learning (CAL). CAL indicates a use of computers as an aid in learning rather than only as a tool for research. Unwin (1992, p73) has suggested a reasonably robust typology for CAL in geography:

> computers as sources of data and information;
> computers as analytical tools;
> computers as laboratories for investigating the world;
> computers as instructors (CAI).

Unwin (1991) gives various examples of computers as *sources of data and information* including several mentioned in this chapter: interactive video, CD-ROM, and the Domesday disks. Electronic atlases also serve as a source of data and can also be used as an instructional tool. A GIS can also serve as a repository for information and various types of data. A GIS often is not only a source of existing data, but also, by using the ability of GIS to manipulate the data, new information is created or information present in the existing data can be better visualized.

GIS is probably the best example of the computer as an *analytical tool* in geography given the fact that analysis of spatial data is one of the main purposes for which GIS packages are designed. In addition to GIS, Unwin (1991) mentions digital cartography, image processing, statistical, and even word processing software as other computer-based analytical tools.

Unwin seems to primarily have simulation and modeling in mind for his category, *laboratories for investigating the world*. He mentions several examples of simulation exercises and games such as SimCity and Dodson's (1991) von Thünen package. (Unwin, 1992) Although Unwin doesn't mention GIS in this context, the GIS environment is used as a modelling tool and many GIS applications are actually simulations for the purpose of decision making.

Unwin's last category is the use of computers to teach, *CAI*. "In CAI the computer is used to interact with the student in some form of programmed, self-paced course of instruction." (Unwin, 1991) An example of CAI in geography is the HyperCard program GISTutor which allows students to explore basic GIS concepts in a self-directed environment.

The term CAL has been around since the 1960s, but the explosion of the personal computer market in the 1980s has brought the subject to the forefront. Although Unwin lists successful uses of CAL in geography and puts forth this framework which indicates that CAL could play a significant role in geography education, he notes that the "uptake" of CAL by university and college instructors has been quite weak. (Unwin, 1992) He attributes this to at least two factors. One is the perception that CAL activities are centered around the delivery and testing of factual information, a limited "programmed learning" approach that has little appeal to the instructors. The other factor is a belief held by many instructors that computers can function as learning tools in the more analytical parts of the discipline (i.e., as a part of research activities), but have little utility for teaching the concepts that make up the "rest of geography." (Unwin, 1991)

Another perspective on CAL in geography is provided by Maguire (1989a). He describes the uses of CAL as: enhance presentation, aid in lecture preparation, tutorials, field work, and problem solving/hypothesis testing. As can be seen in this somewhat anemic list, Maguire may appear to be less sanguine about the role of CAL. This reserved attitude may also be found in his comments that CAL might be “oversold”, that the terminology serves to “mystify” the subject, little is known about the “precise benefits”, creation of CAL software can be “expensive” and “time consuming”, and since use of CAL in geography is “sparse” it may not have reached the “critical mass” needed to make a significant impact. If Maguire’s seemingly less optimistic assessment is correct, the use of GIS as an educational tool rather than only as a vehicle for research may be a bit premature.

Maguire was most likely commenting on the present manifestation of CAL in higher education, not the potential benefits of CAL. At the earlier educational levels, many of the uses of computers listed in this chapter could be considered CAL. At these levels, many of the factors affecting teacher use of CAL are probably different from those considered by the collegiate educator. Freeman and Hassell (1983, p41) list various factors that affect a decision by a teacher to use CAL or to develop a teaching style that would be able to incorporate CAL. These factors can be grouped in classes such as institutional, social, technical, and educational. Examples from each classification are “government pressures for computer use in schools”, “parental pressures for computer education”, “availability of computer hardware”, and “fitting the curriculum” respectively.

Uses for Computers in Geography

Although CAL may still be evolving at all educational levels, Fitzpatrick (1990, p148) is enthusiastic about the use of computers in geography instruction in the schools. He states, “there is no subject better suited to the many uses of computers than geography.” He goes on to give a broad overview of some of the learning objectives that can be achieved through the use of computers, including student exploration of information. Fitzpatrick in this and a later article (Fitzpatrick, 1992) attempts to clearly express the potentials for computers in geography instruction in the schools. His target audience is K-12 teachers, many of whom may be computer phobic. Thus he avoids discussion of some of the inherent difficulties such as buggy software, cryptic instructions, limitations of present software packages, and in adequate hardware and other resources. Nevertheless, his assertion that geography is a natural discipline for making use of computers is based on solid arguments. For example, he points out that "the geography teacher has to deal with vast libraries of textual information, numerical data, and graphic displays, all of which need constantly to be updated and experienced from a range of perspectives." (Fitzpatrick, 1992, p156)

The following list of many of the various types of computer use in geography provides a sense of this broad potential for CAL. The list was compiled from a variety of sources and represents uses of computers both in the collegiate and pre-collegiate environments. (see Fitzpatrick, 1992; Maguire, 1989a; Mather, 1991; Midgley, 1985; Taylor, 1991; Watson, 1984)

Word Processing/Database/Spreadsheet/Tutorials
Statistics
Data Storage and Display
Communications
Simulation/Modelling/Experiments
Computer Cartography
Remote Sensing
Geographic Information Systems

All of these functions can be part of CAL at the university level and also, as demonstrated below, at the pre-collegiate level. One type of use not mentioned in this list which is common in the schools is the use of computers for drill and practice. Some of these drill and practice programs emphasize map work where student "basic knowledge" about maps is reinforced. The concepts emphasized include directions, grid references, projection types, distance estimation, and various map reading skills. These map work exercises were often created in the period when personal computers began to be used in the schools and were used more in the primary rather than the secondary schools. (Tapsfield, 1984)

Various software packages are used in the university setting to accomplish one or more of the functions listed above. In some cases the software that is used in the universities is beginning to be used in the schools, but for the most part educational software has been developed independently of these packages. Fitzpatrick (1990) provides a listing of educational software for geography teaching in the schools. He identifies three categories for these software packages, database, exploratory, and simulation. These education software packages could also be identified as performing some of the functions in the list above.

Word Processing/Database/Spreadsheet/Tutorials

The three common productivity software package types, word processing, database, and spreadsheet, are each employed as a support to geography instruction. Maguire (1989a) devotes a whole chapter to word processing as a tool in geography. Database software can be used to store geographic data in an accessible format which can be edited and updated at will. Spreadsheets can be used for simple numerical aggregation and statistical analysis. The use of these packages as noted earlier is also quite common in the secondary schools, though not necessarily in geography. Another common use besides productivity software is as an alternate mode of presenting worksheets and tests for students in geography courses. In this case HyperCard stacks or canned tutorial software is used by the instructor as a supplement to and in some cases a replacement for the lectures and readings.

Statistics

In addition to spreadsheet based statistical analysis, there are a variety of statistical software packages that are employed by geographers and geography students at the university level. One package that has been designed for CAL in spatial statistics that demonstrates the concept of autocorrelation is Griffith's EXPLORHO. Although spatial autocorrelation is usually a topic reserved for higher education, this Tetris-like game can be used to expose younger students to the concept. (see Griffith, 1987) Richardson (1984) documents the use of microcomputers by pre-collegiate students to gather data in the field on which simple statistical analysis is performed with the help of the computer. She claims that automated data collection facilitated by computers can take some of the tedium out of time series data collection. Students are able to avoid antimotivational activities such as "sitting in the rain at gauging posts for 24 hours." (Richardson, 1984, p.43). Once the data is collected, Richardson asserts that the computer allows students to concentrate on interpreting the data since much of the calculation and presentation is automated.

Data Storage and Display

This use of computers to gather data in the field is one example of data storage and display. The data display function is characteristic of the various electronic atlas programs (e.g., PC Globe). Data storage is often carried out in general database programs or "stand alone" on various types of computer storage media (CD-ROM is increasingly being used as a storage base for pre-packaged data sets). Digital mapping programs can produce various map based presentations of the data. Gossette and Wheeler (1993) describe their simple choropleth mapping package, FOLIO, that is used to display various statistical indicators for North America in a regional geography course. Although students are somewhat restricted by this program in their ability to select and manipulate the data inputs to the thematic maps they are making, they do have a readily accessible tool for visualizing data. There are also commercial mapping packages that function more for data display than for cartographic production or geographic information analysis, even though they may have some of those capabilities and may even be marketed as GIS programs. These packages include MapInfo, Atlas*PRO, Tactician, and ARCVIEW. ARCVIEW and electronic atlases are being used in the schools to allow students to visualize geographic data.

Communications

Communication between computers allows for the remote access of data and for collaborative projects. Both of these functions are becoming common in university geography. They are also impacting pre-collegiate education. Teachers are just beginning to be connected to the Internet, but new access modes and initiatives to link more schools to the network are increasing. The Joint Education Initiative (JEI) has an internet discussion forum in which digital data is described and made available. JEI is a federally funded project that has the purpose of making imagery (satellite and space probe) available to the schools. Another use of electronic networks is the National Geographic Kids Network (KIDSNET). KIDSNET joins thousands of 4-6 grade students from around North America to share data and work interactively on learning units that cover "real-world scientific issues." (National Geographic Society)

Simulation/Modelling/Experiments

There are a wide range of simulation and modelling activities that can be carried out by computers. Many of these are in physical geography such as modelling storm water discharge in a hydrologic network. Brusilovsky and Gorskaya-Belova (1992) in Moscow document a computer-based model of landforms used with students ages 13-14 in a physical geography of oceans and continents course. The use of the landform modeling program nearly doubled the success rate of students in a test conducted by the researchers.

Various human geography topics can also be simulated. Maguire (1989a) documents examples such as a site selection process for a new factory, a fractal based simulation of urban land use, and a modelling environment for future relationships on a global scale between population, agriculture, resource use, industry, and pollution. He claims that current technology allows for models and simulations that incorporate many parameters. He sees them as one viable component for research which can help reduce the complete dependence on costly field-based research. (Maguire, 1989a)

A variety of simple simulation games have also been designed for the schools including a surficial hydrology modelling program, a manufacturing plant location simulation, and a latitude dependent wind modelling program. (see Watson, 1984) These programs tend to provide a mix of modelling/simulation and basic concepts tutoring. The commercial simulation programs, SimCity and SimEarth have also been used in geography education. The computer can also be used to model or otherwise communicate spatial relationships for human subject experiments in geography.

Computer Cartography

Computer cartography is similar to desktop mapping, but in this classification scheme, the term refers to programs that are used to create new maps, not display data on existing maps (as was the case described under the function Data Storage and Display.) Many of the software packages used for cartographic production are actually commercial graphic production programs such as Aldus Freehand, Adobe Illustrator, and CorelDraw. Some simple map creation programs exist such as MapMaker and GEOBASE (which functions as a desk accessory on the Macintosh). Some of the drawing, map data display, and productivity packages have drawing tools that can be used to create simple maps. Students can use any of these packages, depending on their requirements, to produce maps. (see Keller and Waters, 1991 for a comprehensive list of mapping software)

Remote Sensing

Remote sensing concepts are taught with various software packages in higher education. (see Nellis, et al., 1989) Although remote sensing may seem to be a complex topic, one of its key concepts, pixels in gridded data, has been successfully taught to grade 6 students. In this study, Kirman and Unsworth (1992) used gridded paper to simulate a Landsat (or similar digital) scene. Although they did not actually work on computers, they demonstrated that this basic concept fundamental to the use of computer based remote sensing was not out of the reach of these elementary school students. In a later study, Kirman and Jackson (1993) replicate the original research with the use of a simple computer program. In this more sophisticated version, students continued to be able to understand the concepts of digital data and pixels and even were somewhat successful at the interpretation of general land uses on a Landsat scene. Further research in this area would be appropriate, since many of Kirman and Jackson’s conclusions were based on anecdotal observations of student actions and comments while attempting to identify a potential building site on the Landsat image.

Becker (1989), a space education consultant, maintains that students 8 or 9 years old “have no difficultly learning Landsat or GOES satellite instrumentation, understanding the digital telemetry process, or memorizing the basic infrared color code and applying it to image interpretation.” Although this assessment may be overly optimistic and sounds a bit like programmed learning and response, it is true that students have used satellite imagery effectively in hardcopy form. Recently the National Council for Geographic Education completed a GEO/SAT project. The project produced a set of lessons using digital imagery provided by EOSAT which is displayed and analysed on a special image processing package, PEDAGeOG, created by EIDETIC.

Geographic Information Systems

There are scores of GIS software packages on the market. Many of these are used in colleges and universities to teach students about GIS and geographic information analysis techniques. Universities are beginning to use GIS for CAL. White and Simms (1993) document an activity in an environmental studies course that used GIS software to help students determine a hypothetical location for a new solid waste landfill site. For the exercise, the class was organized to represent a corporate structure; the instructor was the CEO and the students were grouped into teams representing departments. Each department collected different types of data: physical, economic, political, and regulatory. White and Simms (1993, p85) conclude that this type of exercise using GIS as a teaching tool can “present data more powerfully” and “spark creativity and imagination” as well as accomplish the curricular objectives of the course. Dodson, et al., (1991) list additional exercises that use GIS to teach geographic principles.

At the pre-collegiate level various GIS activities have been started or are planned. These make use of various GIS software packages, notably ARCVIEW and IDRISI. (see chapter 4 and Palladino, 1993a) Walsh in an early article geared to introducing teachers to GIS provides an argument for the use of GIS by earth science educators in the schools. He points out the ability of GIS-based investigations to “demonstrate the integration of data elements necessary to understand and analyze the complex nature of surface, subsurface, and atmospheric problems and systems”. He also notes that the creation and manipulation of GIS layers can “facilitate a clear understanding of the interactions of earth science elements and the spatial significance of their distribution.” (Walsh, 1988, pp24-25) Walsh does not offer any tests of these assertions, but does outline the potentials with a clarity that invites additional research. (For additional discussion of GIS in the schools see Palladino, 1992; Palladino and Goodchild, 1992; Wood and Cassettari, 1992).

Although far from exhaustive, these reflections on some of the uses of geographic software demonstrate the wide range of possible computer uses in geographic education. As schools improve their computing infrastructure, as teachers become more comfortable with the use of computers as a teaching tool, and as software for geographic instruction continues to be developed, it is reasonable to assume that computers will be more effectively used in geographic education.

GIS Technology in the Schools

Although it is likely that computers will have an increased role to play in geography education in the near future, the extension of this movement to use of GIS as an educational tool in the schools may be more complicated. Thompson (1991, p.63) reviews the potential for GIS to serve as medium for communicating various geographic concepts. He even envisions a redefinition of a geographic information system as an "educational delivery system (a set of integrated hardware, software, data and learning resources) for improving the student's knowledge of the world in which he or she lives." He goes on to suggest that this "GIS" provide the students with "a rich resource of information (nodes), associations between discrete pieces of data (links or webs), different learning oriented activities (browsing , tutors, simulations), via a compatible interface (map based metaphor), within a networked social system (teachers ... as coaches)." Since GIS software has not been traditionally designed for this purpose, there are many incompatibilities with general geography instruction. Thompson suggests that there is a need for more discussion of the pedagogic issues surrounding the topic of GIS software as an educational tool.

Back in 1985, Poiker attempted to identify some of the characteristics required of a GIS software suitable for teaching. He suggests that "it should cover all aspects of geography ... include structures for both quantitative and qualitative judgements ... and allow the study of its components by being developed in modular form, well documented and open for inspection." At the time Poiker made these suggestions, GIS software was just beginning its explosive growth fueled by the development of software for workstations and personal computers. At this point, it seems likely that GIS software and geography education in the schools are no longer an incompatible pair due to advances in computers in the schools and in GIS software; however, there are still issues to resolve and it may be worthwhile to consider a variety of strategies for introducing GIS to the schools.

One of these strategies is to introduce GIS analytical techniques without the software. Poiker (1985) notes that "many GIS exist that are not using computers." Walsh (1988) outlines a traditional manual GIS approach that might be used in an earth science course as a precursor to an automated approach. This traditional approach involves transforming spatial data sets to a common scale, placing them on transparencies, and then overlaying the transparencies to find points or areas of coincidence of the original factors present on the separate data layers. While computing in the schools continues to lag behind GIS software development, many GIS techniques can be manually employed to explain geographical concepts. The most common example of a manual GIS involves this use of multiple transparencies of a study area each recording different features or thematic variables. The combination of these layers can accomplish a typical GIS analysis. Although they do not have the power of the software-based GIS, these methods can adequately demonstrate geographic analysis and can serve as an introduction GIS technology.

Technology Requirements/Limitations

For strategies that utilize computers to introduce GIS into secondary school instruction, the status of technology in the schools must be compared with that of GIS technology. As we have seen, the Apple II computers are still dominant in many schools. Although the DOS-based PCs and Apple Macintoshes have also become quite common, the models that are in the schools tend to be those with minimal power and capabilities (older CPU chips, limited RAM and storage space, and low resolution B&W monitors.) GIS software packages are found on a wide range of platforms from mainframe computers to low-level PCs. (See Fisher, 1989 and the annual GIS World magazine GIS Sourcebook for lists of GIS software capabilities and hardware requirements) Most of the PC and Macintosh-based packages run optimally on configurations that are above what is present in most schools.

An excellent example of the mismatch between school computers and GIS software is ESRI's ARCVIEW. ARCVIEW was designed to serve as the GIS data display & query software for the more complex ARC/INFO software. It also is being promoted by the company as a GIS for the schools. The first version of ARCVIEW, however, required PC computers with a much faster processor and more RAM memory than is found in almost all of the computers in the schools. This situation is being ameliorated by the inevitable increase in computing power in the schools. ESRI spokespeople have indicated that ARCVIEW 2 will be more school friendly, including the ability to run on machines with less RAM than was required for the first version of ARCVIEW.

This pattern of low-end GIS software just above maximal computing capability in the schools may continue in the future. GIS developers have traditionally served the business, government, and research communities which tend to be more current in technology than the schools. Schools might be able to utilize earlier versions of software which may have been designed for earlier, less powerful personal computers common in the schools, but often these packages have a crude GUI and may no longer be actively supported by the software developers.

The graphical user interfaces (GUI) of many GIS software packages that might be appropriate for the schools still could use work to make them more user-friendly. Although students may be able to use simple command line interfaces, it is arguable that a point-and-click interface would be both more attractive to students and more clearly understood. Of course both of these two criteria will only be achieved if the GUI is designed with these factors in mind.

Another prime consideration for the use of GIS technology in the schools is data storage capabilities. As we have noted, those schools that have computers more powerful than the Apple II often still have “under-powered” machines in terms of GIS needs. This also true for the data storage demands placed on the computer by many spatial data sets. One way around this issue is to provide simplified data sets. This may mean lower resolution and accuracy or limiting the areal extent or number of features and attributes of the data.

A related topic to data storage is data entry. Since much of the data that is entered into a GIS is map-based, students attempting a GIS project may desire to enter their own map data. This may require digitizing capability. Most schools will not have budgets that will justify the purchase of a small digitizing tablet (much less table) that will only receive occasional use. One possibility is to make use of the CAD systems found in many schools which often have digitizing capabilities. At this stage the CAD to GIS interchange may not be very straight forward. The CAD DXF data exchange format, though supported for import by many GIS packages, does not always yield the intended results (loss of data, requires additional knowledge of data structures, and can take quite a bit of time). Other data entry methods may be more plausible for GIS in the schools. Pre-packaged imagery such as is provide on the JEI JEdI CD-ROM disks and via internet can be used. Simple digitizing can be accomplished using a transparency on the computer screen. Data that can be provided in tabular form to the GIS database may be the simplest form of data entry and should not present a major obstacle for students.

Curriculum Materials

For teachers to effectively use GIS concepts and techniques in their instruction whether automated or manual, they will need supportive curriculum materials that operate within the curriculum frameworks. Presently, curriculum materials designed for the use of GIS in pre-collegiate instruction are just beginning to be developed by the SEP and others (see Palladino, 1993a, and chapter 4).

Many commercial software packages have demonstration packages available. These can be used as simple introductions to GIS, but often these demonstration and other tutorial materials tend to overemphasize the functions of the software rather than the core concepts of GIS analysis. A few of the GIS software developers (e.g., Tydac-SPANS and ESRI) have created materials which are designed to explain GIS and related geographic concepts, but typically from the perspective of their particular software product.

Some GIS curriculum materials, exercises, and informational resources developed for university instruction and potential GIS users in the workplace may provide an initial source of material for a teacher attempting to use GIS in the class room. For example, the NCGIA Core Curriculum in GIS if highly edited can yield basic concepts appropriate for the schools. The effort to produce a “mini Core” of information useful in pre-collegiate setting out of the Core Curriculum may not be as practical as an effort to produce new GIS curriculum materials designed especially for the schools.

Conclusion

As seen in this chapter, technology, more specifically computer use, in the schools is still evolving to a point where the somewhat complex, but useful concepts presented by a GIS-based learning approach in geography (and other subjects) may be tenable in a secondary school environment. As the computing environment slowly improves in the schools, there is a need for accompanying research into the best methods of using these tools, the appropriate mix of technologies to match the pedagogic goals of the instructor, and the ways in which software such a GIS may improve or hinder student learning. Many of the assertions of the teacher/consultants attending the NCGIA pilot study workshop are borne out in this findings of this chapter. For example, the need for more adequate computer hardware and also GIS software and curriculum materials to be specifically developed for the schools were a common theme that appear in both the pilot study and this further research. Computers in the schools present the following challenges: sufficient hardware, access to the available computer resources, adequate teacher preparation, and new pedagogic strategies making use of the potentials of computer hardware and software. In the case of GIS use, one of the key issues is that the GIS software on the market and even those programs available as shareware or free over the internet are not designed for use in the classroom.

Specific recommendations for hardware suitable for GIS include purchasing a large capacity hard disk or other storage medium with reasonable access times in order to store images and student data sets which can be space intensive. As the cost of disk storage continues to drop dramatically, a large disk (250 MB or more) is not completely out of the picture. For computer purchases, the option with the larger disk, while more expensive, is often actually considerable less expensive per storage unit. The memory requirements will vary depending on the type of software teachers intend to use. As noted, ESRI's ARCVIEW, which is becoming the most common GIS software in the schools, is memory hungry requiring a minimum of 8 MB. Other applications may run on less than 1 MB, but a minimum of 4 MB may be more practical. Most newer systems come with at least this much memory. Processing speed is similar to memory. The GIS application used will determine the minimal requirement. Again, ARCVIEW is dependent on the faster processors such as the Intel 80486 chip. Other software packages, such as IDRISI, will run fine on a 80286-based machine. (That is assuming the teacher in not using the newer Windows version of the software.) Unlike simple word processing activities, GIS is quite limited by black and white monitors. Color monitors are more versatile and in many cases necessary to distinguish clearly between classes of spatial data. Other items that would give much greater flexibility to GIS projects are a digitizing tablet, a scanner, and a CD-ROM player. These are not essential elements, but increase the ability to import and create new data.

This discussion of hardware recommendations may be academic for many educators whose schools have little money for computer purchases and who are unable or unwilling to purchase the equipment out of their own savings. It also assumes a willingness to use the technology. As was noted earlier in this chapter, their are still major hurdles to overcome in terms of adoption of computer-based teaching, but the potentials for geography education appear to so significant that it is worth lobbying for adequate resources and learning opportunities for teachers.

Once the technological limitations and perception barriers have been dealt with, a dynamic link between an educational GIS and other forms of multimedia in the schools might form a powerful technology-based tool for instruction in the schools of the twenty-first century. Before our imaginations run wild, it might be useful to review a sobering account of attempts to implement CAL by Flowerdew and Lovett (1992). They humorously link CAL activities with the proverbial Murphy’s Law, “if anything can go wrong, it will.” Just about anyone who has performed a few demonstrations of GIS software capabilities can attest to validity of this law. In the pre-collegiate classroom the veracity of this law might be unchallenged considering the limited time teachers have to become GIS gurus and the amazing ability of students to find the weaknesses of any technology. Pessimism aside, GIS is already beginning to make an impact in the schools as is documented in the next chapter. Moreover, the trends in computing and GIS software development suggest that GIS will be better positioned to play an increased role in K-12 education in the near future.

Chapter 4
GIS Activities for the Schools

This chapter serves as an overview of the various efforts to introduce GIS concepts and technology into the pre-collegiate learning environment. It represents the findings over the past two and one half years of this thesis research in conjunction with the Secondary Education Project. This search for other existing efforts was seen a fundamental to the correct identification of pertinent research questions both for this research and for future research. These other experiences were also sought in order support or clarify the findings of the pilot study and its workshop.

When considering the various types of activities that provide GIS exposure and learning opportunities for school teachers and students, it is helpful to categorize them. In this overview the scheme used classifies activities for GIS in the schools as organization outreach, independent inquiry, or industry initiatives.

Organization outreach includes attempts by universities, non-profit organizations, and government agencies to expose secondary school teachers and students to GIS. Individual inquiry represents the efforts of individual teachers, concerned community members, and others in the education community (curriculum specialists, principals, and educational administrators). The third category, industry initiatives are the efforts by the GIS software developers and other related industries to familiarize teachers and students with GIS and, often, with their own products.

Independent inquiry is a case of a bottom-up approach; those without the knowledge or resources reaching up to higher education, government, and industry for help. The organization outreach represents the opposite mode; those with the GIS knowledge and resources attempting to share their experience and materials. The industry initiatives may have some profit motivation, though at this stage most of the efforts appear primarily altruistic with good public relations as the only clearly discernible business goal. As is the case with most classification schemes, some of the existing GIS activities for the schools do not neatly fit in one of these categories.

Early GIS Activities for the Schools

In early 1991, the NCGIA had completed and successfully introduced the Core Curriculum in GIS to the collegiate community. There were also other supportive materials for university-level GIS instruction being developed. As the NCGIA pondered the next steps for carrying out the educational mandate outlined in the original proposal to the National Science Foundation — to augment the nation's supply of individuals with GIS expertise — there was discussion of the role for GIS in pre-collegiate education. It was surmised that an early exposure to GIS would encourage college students to pursue GIS related study and eventually GIS oriented careers.

The discussion of the possibility of an NCGIA educational initiative targeting secondary schools was not based merely on in-house speculation, but also on inquiries from various sectors including the GIS educational community, the GIS industry, the funding agency (the NSF encourages its national research centers to do outreach to the schools), and the university educators in the United Kingdom, Canada, and Austria who had begun to introduce GIS to their schools. The combination of this researchers proposed thesis work on GIS for the schools and NCGIA interest in the topic led to the birth of the Secondary Education Project. One of the early aims of the SEP was to identify any existing GIS activities for the schools. This was carried out in order to provide a context for SEP activity planning and to support this thesis research.

The early investigation indicated that there was significant interest in the topic, but little related research and activity actually occurring. This instigated the pilot study which continued this early search for existing GIS activities. While the hunt was intensifying, the NCGIA also hosted its first outreach activity, a GIS workshop for secondary school teachers (See chapter 1). The positive results of the workshop encouraged the SEP to continue its efforts to find and connect existing GIS activities for the schools and to support and develop new activities.

The first activities identified in the search included outreach by university professors in countries where the strong tradition of geography instruction in the schools provided a natural inroad for GIS discussion and use. In the United Kingdom, Dr. David Green at Aberdeen University helped organize discussion of GIS in the schools at the 1991 Association for Geographic Information annual meeting. As editor of the Education and Training section of the 1992 Yearbook of the Association, he included two articles on GIS in the schools (see: Wood and Cassettari, 1992; Palladino, 1992). Dr. Green and those involved in these efforts were working with local teachers to implement the requirements in the National Curriculum for Geography which includes the use of technology and even GIS in instruction.

In Austria, Dr. Joseph Strobl of the University of Salzburg was using GIS as the main topic of Saturday in-services for teachers. Dr. Doug Banting of Ryerson Polytechnical Institute in Canada had organized short workshops for teachers from various Ontario school boards which included GIS as a main topic. Back in the United States, Dr. Wei-Ning Xiang of the University of North Carolina, Charlotte was working with the state education department to provide GIS activities for the state's magnet schools for science, but met with little success perhaps in part due to the lack of a strong geography program to serve as the host discipline.

These professors all had similar outreach goals, namely to expose teachers or teachers and students to GIS, but the particulars of their activities varied depending on needs and structure of the educational establishment in their outreach areas.

Another early example of organizational outreach was the joint effort by the Oregon Department of Education and Portland State University to begin to introduce GIS and Global Positioning Systems (GPS) first into the community colleges and later into the upper level secondary schools as part of the state Workforce 2000 initiative. Workforce 2000 was designed to give students a head start with technology. In the case of GIS and GPS, the initial exposure of high school students to the technology and introductory concepts led to further applied use at the local community college giving the student a strong foundation for employment in forestry and natural resource management.

Early examples of individual inquiry that were identified include the University School in Ohio and the Thomas Jefferson High School for Science and Technology in Virginia. Reinhold Freibertshauser, a teacher at the private, secondary level, University School, and his colleagues sought to have their students apply resource assessment and management skills to the school's 200 acre wooded property with the help of GIS. Reinhold and his colleagues were successful in receiving donations of the SPANS software from Tydac and PC ARC/INFO and ARCVIEW from ESRI. Their students collected environmental data and completed an elevation survey of the property. The students entered these data sets into their GIS database for the campus and intend to use it to manage and analyze the resources found on the campus.

A few states over, in Virginia, a public magnet school for science and technology, Thomas Jefferson High School, began to include GIS and Remote Sensing as components of its high powered geoscience program. Mr. Bill Johnson and his colleagues used PC ARC/INFO and IDRISI to introduce GIS concepts to their students. They attempted to cover many of the topics common in an introductory GIS course in a university, though at a level more appropriate to precocious high school students. The topics covered included raster and vector data representations, the concept of layers of thematic data and map feature classes, simple GIS operations such as buffer and reclassify, and simple filters for raster data. The extent of the coverage was limited to the topics which the instructors could teach themselves with the materials they had available (which included the Core Curriculum.) At one point the department was arranging with the state to work with some of the rural school districts in a joint land/human resource assessment project utilizing GIS.

Both of these early examples of teachers using GIS in the classroom are not likely to represent the dominant model for future GIS activities in the schools. These schools were extremely well endowed with computer equipment, advanced students, and flexible curricula.

Early industry initiatives were mainly found to be "potential initiatives". A handful of companies or individuals with ties to the industry contacted the NCGIA to indicate their interest in GIS for the schools, but did not report on existing activities. One exception to the "potential initiative" mode was ComGrafix, Inc. which lent a copy of its GIS software, MapGrafix, and appropriate hardware to a school in Virginia to use as part of a state science competition in 1991. Students were asked to address the problem, "How can telecommunications and information technologies be used to improve the environmental quality of life in the greater Washington area in fields such as: waste management, water management, indoor air quality, pest and pesticide generated problems, or aircraft induced pollution." The Marshall High School team came up with an Environmental Data Evaluation Network (EDEN) as a conceptual framework for dealing with this problem. EDEN would rely heavily on GIS technology. The students used MapGrafix to demonstrate the role of GIS in EDEN to the judges of the competition. (Roberts and Lynn, 1991)

Since the SEP began to identify these initial activities, many more have been identified. Together
these various activities form a rather mottled patchwork. There is not much in the way of coordination, consistency, or common materials between these various activities; however, the SEP has been actively attempting to network the various players so that the experiences from the wide variety of activities could benefit one another and aid future attempts to bring GIS to the world of pre-collegiate education.

Recently there has been a marked increase in interest in GIS for the schools. This is built in part on increased emphasis in the schools on subjects such as geography, science, technology, and environmental studies, on learning strategies such as group work and critical thinking, and on interdisciplinary activities. Each of these trends can be addressed by GIS-based activities. This interest in GIS seems to be following a similar increase in activities designed to involved students and teachers in the use of remotely sensed imagery. The coherent driving forces for geography in the schools, the Geographic Alliance Network and the National Council for Geographic Education, have both committed themselves to exposing teachers and students to remote sensing and GIS both as a example of the emphases listed above and as a means of ensuring that the geography re–emerging in the schools is contemporary.

Another influential player in this movement to make GIS available to the schools is the GIS vendor ESRI. They have a full-time K-12 education position in their ARCVIEW working group. This individual, Mr. Charlie Fitzpatrick, has been instrumental in providing ARCVIEW to schools at low or no cost through their Adopt–a–School program. He is also creating curriculum materials to accompany this geographic information display software. Although ARCVIEW has limited analysis capabilities compared to ESRI's ARC/INFO, the ability of ARCVIEW to use ARC/INFO data sets allows the teacher using ARCVIEW not only to use the wealth of world and US data on CD provided with ARCVIEW, but also provides a possibility of viewing the data of any local agency that happens to use ARC/INFO. Since many municipalities, resource management agencies, and research labs use ARC/INFO, there are many data sets that are potentially available to these teachers.

In addition to these large scope activities, there are many smaller efforts to implement GIS software and concepts in the schools. A description of some of the key activities that have been identified follows in order to provide a perspective on the range of existing activities and a sense of the environment in which this research has developed.

Organization Outreach

Various organizations have employed different strategies for GIS awareness in the schools. In some cases teachers are the target audience for a GIS demonstration or workshop at the organization's site. In other cases, students are the ones who come into the lab. Some organizations have sent representatives out to the schools. Other forms of outreach include cooperative GIS programs and GIS materials development efforts.

The following examples have emphasized outreach to K-12 teachers:

The NCGIA has held three workshops for teachers including the prototype workshop discussed in detail in Chapter 1. The NCGIA Santa Barbara hosted its second one-week "GIS in the Schools" workshop in June, 1993. Nine teachers were selected by the Coordinators of six state Geographic Alliances to attend this workshop. Unlike the first workshop in which the NCGIA Santa Barbara hosted a group of local science and social studies teachers who had varying levels of computer experience, this group was specifically interested in teaching geography and had significant experience with computers. The workshop was intended to send these individuals back to their respective Alliances to serve as the GIS resource person.

The workshop was similar to the first workshop in that it included a short course in GIS, demonstrations of various GIS applications, hands-on work with different GIS software packages, and discussion sessions. This workshop, however, also included a group project. The teachers were given a set of data on the local area and used the IDRISI GIS package to help identify a site for a new elementary school. Data included elevation, hill slope values, land use, existing school locations, and various transportation networks. Each group of teachers added some additional data and integrated the data sets to produce a composite map showing the available sites for construction. This project helped to demonstrate some of the analytical capabilities of GIS software and provided an example of a potential GIS exercise for students.

The NCGIA Maine also hosted a one-week workshop in the summer of 1993. Seven Maine earth science and computer applications teachers spent the week learning about GIS and working with GIS software. These teachers participated in the same types of activities as the teachers in Santa Barbara. Instead of the IDRISI group project, however, each of the teachers used ESRI's ARCVIEW software to create their own project that they could use in the classroom with the copies of ARCVIEW that each participant received.

In addition to the NCGIA workshops, other academics and organizations have held workshops, weekend in-services, and open houses for teachers. Dr. Doug Banting of Ryerson Polytechnical Institute in Toronto, Ontario has given a series of seminars for teachers during their "professional development" days. His presentations have been included the following topics: Overview of GIS Concepts, Geographic Skills - Careers in GIS, and Cultivating a Geographic Perspective. Also in Canada, the Ontario Association for Geographic and Environmental Education, a professional organization that includes pre-collegiate geography teachers, had GIS as a prominent topic in its 1993 annual meeting.

Dr. Don Lundquist, Chris Keithley, and Brain Tolk at the University of Nebraska coordinated a four day workshop on Remote Sensing and GIS in the summer of 1993 using funding from NASA. Many of the topics were related more closely to remote sensing, but there was time spent on spatial analysis and general GIS topics. Some use of the ARCVIEW and IDRISI software packages was also included.

The National Geographic Society Geographic Alliance effort includes a four-week advanced summer leadership institute in Washington, DC. In the summer of 1993, Dr. Bill Strong, the coordinator for this ILI institute, included sessions on maps, remote sensing, and GIS. In addition, many of the state Geographic Alliances are beginning to include discussion and demonstrations of GIS as part of their summer institutes.

The following examples have emphasized outreach to K-12 students:

The Workforce 2000 project mentioned above brings actual GIS training right into the classroom as part of a vocational training program that continues at the local community college. Here the emphasis is on using GIS to perform specific tasks rather than merely providing an overview of GIS as a tool used in modern society. It also does not focus on GIS as an educational tool per se. The initial efforts of this project were at the community college with a follow-up extension to the local schools as the community college effort became established. The initial software packages that were utilized included GeoSQL, AutoCAD, and ARC/INFO. Two directions for students using GIS in the high schools and community colleges were envisioned: forestry applications and surveying/mapping applications.

Dr. Bill Huxhold, a University of Wisconsin–Milwaukee Urban and Regional Planning professor, has not only done outreach to teachers in his GIS lab, but has also brought a group of students in as part of the “Teen University” program. This two-week course had students work through urban planning problems using GIS, especially ESRI’s ARCVIEW (Audet, et al., 1993).

Like Huxhold, Dr. Derek Thompson has organized activities for both teachers and students. In November, 1992 during Geography Awareness Week, he coordinated a GIS awareness day at the University of Maryland, College Park and several other sites in the local area. This regional event included universities, schools, libraries, community groups, government agencies, professional organizations, and businesses. Many of these entities with GIS opened their doors to librarians, teachers, students, and the general public. The University of Maryland, College Park hosted three groups of high school students.

In Spain, David Comas at the University of Girona reports that since 1990, 500 high schools students have attended short workshops in their GIS lab. This exposure of students and their teachers to GIS has resulted in a project sponsored by the university and the regional government of Catalonia geared to GIS in the schools. This “Educational Cartomatics” project has resulted in three schools offering a summer school course in GIS in the summer, 1992. The same geographers and teachers that led those courses are developing a 10 unit set of GIS course materials based on data from the Natural Park of Gavarres.

In Canada, Dr. Bob Maher at the Ontario Ministry of Natural Resources is organizing a program that may include a set of GIS/Environmental Education camps for students.

In addition to these more formal outreaches to students many geographers and other professionals have demonstrated GIS for students touring their facilities or have included discussion of GIS during guest speaking engagements in the schools.

The following examples have emphasized outreach through comprehensive projects:

These activities go beyond merely holding an isolated workshop or giving demonstrations of GIS in school classrooms. For example, Dr. Roland Tinline at Queens University in Ontario, Canada has worked with the Ontario Ministry of Education, local school boards, and software companies to develop a program that will introduce GIS into the classroom. Initially groups of students and teachers have been brought into the GIS lab at Queens. In the lab, the teachers are first trained, then they used the lab to teach their students. A progression of software was used starting with CAD software, then Atlas*Graphics, and IDRISI. This project is still evolving.

The New England Science Center in Massachusetts is incorporating GIS into their presentations for both the schools and the general public. They are developing a curriculum on Global Change Research with funding from NOAA. This and other curricula developed will expose teachers and students to the IDRISI GIS package.

At Cornell University, CLEARS (Cornell Lab for Environmental Applications of Remote Sensing) personnel have developed a program, Explorations from an Aerial Perspective, which although primarily focussed on aerial photography also includes some work with satellite imagery and GIS. This program trains teams of educators including classroom teachers and nature center and museum staff to use aerial photos and maps in teaching. Advanced training includes GIS.

Government agencies which use GIS often provide the most tangible example of GIS use to their local communities. Some of these agencies have communicated their GIS applications to their local schools. The South Florida Water Management District has begun an outreach project for the schools in the state. The project is based on ESRI's Adopt–a–School Program for ARCVIEW.

Since the SFWMD does much of its work in ARC/INFO, it has local data that may be of special interest to the local schools that have ARCVIEW.

The last form of outreach listed here is instructional materials development:

Statistics Canada, a government agency, has developed a software package which allows schools to interact with some of the data the agency has collected. Although not a GIS package, it does allow for thematic mapping and provides data that can be used by students in a GIS.

The National Council for Geographic Education has begun to develop a series of lesson plans utilizing ARCVIEW. Under funding from the NSF, Dr. Merrill Ridd at the University of Utah is developing ARCVIEW–based learning modules on environmental themes such as catastrophic flooding, desertification, and urban growth as detected in remotely sensed images. The NCGIA SEP is a third party developing ARCVIEW materials. The SEP is also putting together ARCVIEW modules that will develop human geography themes around GIS data sets showcasing the power of GIS as an educational tool.

The SEP has also produced a Workshop Resource Packet and a African Data Viewer. The resource packet was developed in part as a report on the NCGIA prototype GIS workshop for secondary school teachers. This report has been bundled with some additional resources that evolved from the workshop. The packet is designed primarily to aid institutions with GIS expertise and technology in their efforts to create outreach activities for their local schools. Much of the material in the packet, however, would also be of use to secondary school teachers and others who are looking for some basic GIS instructional aids. The packet includes a thorough outline of the workshop components, an evaluation of the success of those components, and a suggested format for future workshops. In addition, there is a section reviewing the status of GIS in the secondary schools, a set of teacher project summaries (mainly manual activities that could be adapted to GIS software), GIS short course outline notes, a GIS for the schools resource list (software and curriculum materials), and a plain language GIS glossary.

The African Data Viewer is a series of digital data sets of Africa on a 3.5" diskette. The 30 data sets range from population density to average rainfall. Many of the sets show soil characteristics (e.g., soils affected by overgrazing) that were compiled as part of a United Nations Environmental Program study of desertification. The data sets come with the display modules of the IDRISI GIS software. This subset of the IDRISI package allows the data to be displayed on an IBM or compatible computer, but will not perform advanced GIS analysis and data manipulation.

Independent Inquiry

In many cases interest in GIS for the Schools has begun with individuals — researchers, teachers, or just concerned community members. The first group of independent inquirers discussed are the researchers. A small number of graduate students and university faculty have made the topic of GIS in the schools a focus of some of their research.

Dr. Kay Weller recently completed a geography education Ph.D. which utilized a set of IDRISI-based exercises on water resource management that she developed. She taught the same 10 lessons to groups of 6th graders. One group used no GIS/spatial analysis techniques, another used manual GIS techniques, a third used an automated GIS [IDRISI], and a final group used both automated and manual techniques. The behavioral objective of this exercise was for students to be able to make a hypothesis relating water resources and precipitation to climate and vegetation. Dr. Weller found that students could make the association, but the performance level of the different groups was clouded by problems with the configuration of the computer lab and inappropriate student groupings.

As his dissertation in the Education Department at Boston University, Dr. Richard Audet, analyzed the cognitive strategies employed by participants in the ARCVIEW activities of Dr. Bill Huxhold's GIS outreach effort (see above). The cognitive strategies he identified for spatial problem solving with

ARCVIEW included scrolling through the tables and windows -- a trial and error approach, spatial querying -- using tools, color codes, and labels, and logical querying -- use of the built-in query function of the software. Two of his main assertions were “predilections for certain types of ARCVIEW problem solving behaviors can be distinguished between experts and novices” and “people interact with problem solving technologies in ways that are highly idiosyncratic.” (Audet, 1993, pp.88,92) Audet concludes that much is still to be learned regarding the cognitive benefits of GIS-based education and articulates a concern that those without an education background will design technology oriented materials not appropriate for the classroom. While Audet’s research represents a useful starting point for the investigation of the cognitive aspects of learning with GIS, it is limited in its universal application due to its monocular focus on ARCVIEW as the exemplar of GIS software. The findings are also clouded by evidence that the researcher had a very limited understanding of GIS as is exemplified by the following statement: “The *only* limiting factors in GIS are the scope of the database and the technical and problem solving proficiencies of the operator.” (Audet, 1993, p.4) [emphasis added]

In Australia, Dr. Colin Davey of the Faculty of Education at the University of Sydney has received some funding to do some small-scale research on the use of GIS in the secondary schools. It has involved using IDRISI and OSU-Map on a local data base but may be extended to include MapInfo for work on the 1991 Australian Population Census data.

In addition to these efforts, as many as a half dozen other research efforts on GIS in the Schools are being carried out, mainly as part of Masters theses or Ph.D. dissertations.

Although it is most common for GIS activities for schools to originate in university GIS labs and geography and education departments, many teachers that have been exposed to GIS in one form or another have expressed interest in and in some cases begun GIS activities in their classrooms. The efforts of

Freibertshauser and his colleagues at the University School and of Johnson and his fellow teachers at the Thomas Jefferson High School for Science and Technology have been noted above. Below are some additional examples of this type of individual teacher motivation to incorporate GIS in their teaching.

In the United Kingdom, with the clear presentation in the national curriculum of a role for GIS in geography education, Mr. Rob Wheatley, a teacher at Langdon Park School in London's Docklands, has developed a Geography and Information Technology course. This course includes a three-week segment on GIS which complements two other segments on weather monitoring and remote sensing. Most of the work is manual, but they are using a CD of 1981 UK census data, PC Globe, and a simple thematic mapping package, Mappit.

At Seaside High School in Oregon, Mike Brown is utilizing ARC/INFO and ARCVIEW as tools for students in his Coastal Studies program. The students use GIS to monitor and map environmental characteristics of the Columbia River. On the other side of the continent in Toronto, Ontario, John Niccolucci is using IDRISI with his students at Bante Academy. He has adapted IDRISI exercises designed for the university to his secondary school teaching.

The teachers listed above have begun to use GIS in earnest in their teaching. Another group of
teachers are just beginning to implement GIS in their classrooms. Harold Matz of the predominantly minority Roberto Clemente High School in Chicago is planning a GIS course for his students and would like to emphasize business uses of GIS. Samuel Tumolo, a math teacher at the Cincinnati Country Day School, is designing a combined Earth Science/Algebra I course that will use GIS as one of its tools. Like the University School, he plans to have students gather environmental data from the area surrounding the campus and put it into the GIS.

Many teachers are beginning to find ways to incorporate the ARCVIEW software they have received from ESRI at no or low cost into their teaching. Randall Raymond at Cass Technical High School in Detroit is planning to use ARCVIEW to study a watershed in the Detroit area. In some cases, as is true for Eric Pauly at Ben Franklin Junior High School in Fargo, South Dakota, grant proposals are being written for the hardware to run the ARCVIEW software. This is also the situation for Martin Schmidt at the private McDonogh School in Baltimore. He has frequently attended a GIS conference held at Towson State University. He wants to utilize both ARCVIEW and IDRISI in his teaching, but must first acquire the hardware.

The final category of individual inquirer are those in the workplace and community at large that have been exposed to GIS and have recognized its potential in the classroom. In some instances these individuals offer their experience to a local school. In other cases these individuals precipitate a larger organizational effort as in the case of Joe Chapa of the South Florida Water Management District.

As noted above, Mike Brown of Seaside High has his students using GIS to study the Columbia River. Much of the data has been provided by John Graves who works as coastal planner with an agency monitoring and managing the lower 60 miles of the Columbia. John has provided the ARC/INFO data sets for

Mike's students to use. This pattern of teacher with ARCVIEW and helpful contact in industry, government, or university providing ARC/INFO data sets and know-how was intentionally incorporated in the ESRI Adopt–a–School program.

In the upper peninsula of Michigan, Karen Poulsen, the Director of General Education for a school district, is coordinating a project that will have students use GIS with data provided by the local health department to assess local groundwater contamination.

John Schmidt, an Educational Affairs Specialist for NOAA, is looking for a GIS software package that can allow students to easily access and analyze Global Change Database information. He envisions this global change data and GIS package in an 8th or 9th grade earth science course.

Other interested individuals range from David Tunnell, a former high school teacher now at the Wisconsin Department of Transportation, who sees his present work with GIS as having application to the schools in his area, to Andrew Price, a professional geographer with a land development company, who would like to develop a GIS lab in a local school designed for high risk kids.

As GIS becomes increasingly visible in our society, more and more individuals in the schools and the community will recognize its inherent educational potential in the schools. This growth of individual inquiry will lead to many more GIS activities in the schools.

Industry Initiatives

The GIS industry has been slow to promote their software in the schools, perhaps in part due to the earlier mismatch of GIS complexity with educational requirements. As software becomes more user friendly and as schools acquire hardware powerful enough to run the newer PC-based GIS packages, GIS software appears to be positioned for a greater involvement in the schools. The primary example of this is ESRI with its wide distribution of ARCVIEW to the schools (described above). ComGrafix and some other companies have made copies of their software available to a few schools, but have not made as clear a commitment to actively support GIS in the Schools as ESRI has.

One example of a GIS package that is being used in some schools and will probably be used in more in the future is IDRISI. The IDRISI Project has made some copies of the software available to some of the schools mentioned in the Individual Inquiry section of this chapter. Some teachers are buying IDRISI as a simple, educationally oriented GIS. The IDRISI Project has helped the NCGIA develop the African Data Viewer. There is, however, some reticence on the part of The IDRISI Project to promote the use of IDRISI in the schools, since it was not specifically designed for that environment and it may create an unworkable software support demand.

Other software packages that have been used in the classroom include Map II for the Macintosh, OSU Map, and GADS. In each of these cases, the companies/organizations producing the software are interested in seeing their software used in the schools, but have not yet decided to actively promote and support its use in the schools.

In the United Kingdom, a GIS software package has been designed specifically for the schools. This was done in part to satisfy the mandate to use GIS laid out in the National Curriculum. This AEGIS package was created by The Advisory Unit: Computers in Education. The director of the Advisory Unit, Diana Freeman, is continuing to develop the AEGIS software and database and also curriculum materials. The present functionality of the software is shy of a what many would classify as a “true” GIS package. It has limited ability to import, integrate, and export data sets. It does allow students to collect their own data and input them into the database. A set of four example data sets are included along with lesson plans tied to the National Curriculum for each. Despite or perhaps because of its simplicity, this package may be well received in the schools especially in the U.K..

In addition to direct action by the GIS software companies, some “value added” vendors have expressed interest in creating interfaces that would make a GIS package more accessible to students and have discussed developing curriculum materials for the software. Carol Houst and Genene Miller of the Ecological Entrepreneurs Network are investigating the potentials for a value added version of GRASS that would be designed for use in the secondary schools. They have a goal of “bridging the gap in geographic software between games on one end and esoteric, expensive high end GIS systems on the other.” (Miller, 1992) At Amperif, another GIS “value adding” company, Hal Watson is investigating creating an educational package based around MapInfo.

A final group in the GIS industry that can have an impact on GIS in the schools are the GIS consulting firms and trade magazine companies. GIS World, Inc., publishers of GIS World and Business Geographics magazines, invited teachers and students to its 1993 GIS in Business Conference in Boston. Greenhorne & O’Mara, an engineering consulting firm, has created a program with Glenarden Elementary School in Maryland to help acquaint students, teachers, and counselors with the uses of GIS and the professional opportunities it presents. Also in Maryland, Century Technologies has teamed up with IBM and the Prince George County schools in a strategic alliance for the development of a pilot Geographic Information Systems Cooperative Education Program (GISCEP). The aim of this program is to provide disadvantaged youth with high technology exposure and to prepare high school seniors for moderate skill level positions in GIS systems support.

To date it appears that most of these industry initiatives are not profit motivated, since at best they provide a small amount of publicity and few purchases of software. In fact the unifying factor underlying these activities seems to be a motivation by individuals in these companies to do something for their local schools. One generalization that may be suggested is that GIS software companies that are headed by researchers rather than businessmen seem more motivated to work with schools, teachers, and students. The continued and expanded support of the GIS business community will be a great boon for the effort to bring the power of GIS to the schools.

Conclusion

As can be determined from this set of examples of GIS activities for schools, there are many points of light, but little consistency. This is mainly a reflection of the relative newness of GIS in the broader research and business communities. It is just over a decade since the personal computer began to make major inroads into society and only recently have schools been able to procure inexpensive computers capable of running GIS software. This many also explain the fact that most of the efforts identified are not very extensive nor are they easily transferable to schools in other parts of the country or world. Some exceptions exist, mainly in countries other than the U.S., where the GIS activities for the schools are well established. Examples of these include Roly Tinline's project in Ontario, Canada and the AEGIS software and GIS content in the National Curriculum of the U.K..

Whether the activities identified were well established or fledgling, they showed a consistency with the teacher/consultant suggestions in terms of impediments that GIS use in the schools would face. Many of these projects rely on the enthusiasm of a particular teacher who may even utilize their own personal computer in order to accomplish GIS in the classroom. Venturing beyond these individuals can often be difficult when situations such as teacher resistance to change or unfamiliarity with computers, miniscule computing budgets, and rigid curricula are run up against.

As the SEP and this research have progressed, there has been a distinct quickening in the quantity, scope, duration, and nature of GIS projects for the schools. Unfortunately despite this increased activity, these projects still remain fairly uncoordinated with few reported research findings which could serve to guide and link the many projects. Despite this flurry of activity, most of the impediments mentioned by the teachers still remain. It is also interesting to note that a majority of the projects identified by the SEP search showed teaching about GIS (or at least demonstrating the potential) was much more common that using GIS a teaching tool for a variety of curricular topics with spatial components. This points out a mis-match between the teacher/consultant identified need and the thrust of the existing activities for the schools. This may prove to be a significant barrier to the widespread adoption of GIS methods and software in the schools.

The next chapter concludes the research findings of this thesis. It explores the future for GIS in the schools focussing in part on some of the key impediments remaining. These include, in addition to the mismatch between the perspectives of the “GIS providers” and the “GIS adopters” identified above, a lack of appropriate software, insufficient computer hardware in the schools, limited data availability, next to no ready-to-go curriculum materials, and general unfamiliarity with GIS among educators. Many of these hurdles are presently being overcome and with some insight and general planning, GIS may play a significant role in secondary school education by the turn of the century.

Chapter 5
The Future of GIS in the Classroom

This chapter reflects an overview of the findings of this research as it has moved beyond the pilot study and developed into a multi-year project. The past two years of SEP activities have only confirmed what many knew intuitively — GIS has definite potential for pre-collegiate education. The question really is not if GIS has a role in the schools, but when and how it will be best manifested in that educational environment. Is GIS still too complex conceptually and materially for serious use in the schools? As with many important questions, this query could be answered variously depending on the perspective of the respondent.

The results of this research indicate that the questions of when and how are still to be resolved, but an initial GIS presence in the schools is appropriate now. The question of when will be better answered in the context of efforts to resolve key issues related to the use of GIS in the classroom. As these issues related to technology (hardware and software) and the education and scientific communities (data, curriculum materials, teaching and learning strategies, understanding and adoption, and support structures) are resolved, the impact of GIS on the schools will increase significantly.

To put the "how" question into perspective, it is helpful to identify the potential roles GIS might play. Some of the main functions which GIS will perform in secondary (and eventually in primary) level instruction are examined below. Structural and technological barriers to the use of GIS in these roles are explored. Finally three strategic initiatives are suggested and additional research questions are summarized.

Roles of GIS in the classroom

Technology Showcase

Students are being asked to adapt to an increasingly technological world. There is a continuous stream of new innovations in the use of computers and other technologies which are intended to improve the way we work, play, and resolve the world's problems. Often these innovations are more barrier than bridge. To clear the path for the intended use of these "improvements", there is often a need for structured exposure to them and instruction in their use. In many cases, the schools are the most logical environment to begin to develop an appreciation and understanding of the use of these modern technologies.

GIS in either its more basic or more advanced forms, coupled with associated resources such as satellite images, aerial photographs, maps, and all types of spatially referenced data, can give students a vision for the complexities of the world in which we live. The effect of access to images and data on decision making is profound. For example, it could be argued that those first views of the Earth from space, the result of the 1960s space race, were key contributors to the nascent environmental movement of that decade.

GIS in this role is the exemplar of the use of modern technology to help solve the world's problems. The manifestations of GIS in this role might include discussion of its use as a special topic in a class. This could be coupled with either a field trip to a university or a public agency to observe its uses in those environments or with a guest speaker from the GIS using community. It could appear in a special unit on the use of computers in scientific research or environmental management. The teacher might utilize simple manual exercises emphasizing the use of spatial information and analysis techniques as an introductory example of the use of advanced GIS software. Less complex GIS and related geographic simulation and modelling software could also be used to emulate the analytical power of GIS.

Instructional Invigoration

The focus of the Technology Showcase role is to highlight the uses of GIS technology in the outside world, but GIS software and concepts as well as less powerful software with some GIS functionality have a more direct role in the school curriculum. GIS can serve as a unique educational tool in which the analysis and manipulation of spatial data can support various teaching methods.

At the K-12 level, the mode of GIS use is still being determined, but it is apparent that many of the trends in education call for new strategies that may find GIS a natural ally . GIS represents great promise as a means of invigorating instruction in geography, environmental education, science, and technology. For example, the visual presentation of data in a spatial structure may hold the interest of students better than traditional presentations of scientific data. The ability to rapidly manipulate and analyze data will enhance problem solving skills. In some cases, group projects will benefit from the familiarity of using data on local problems whether hypothetical or real. Already students and teachers in concert with natural resource management agencies are using GIS to monitor their local environments. Many of these GIS-based problem-solving activities will be necessarily interdisciplinary.

The aspect of spatial learning inherent in GIS activities may turn out to be the most significant. Although spatial skills are fundamental in our early childhood ordering of the world, emphasis on their development is quickly supplanted by language acquisition and the quantification of our world through counting and math. A renewed emphasis on developing spatial skills, in concert with literacy and numeracy, as students move through the schools would most likely draw on GIS as an important aid to this form of learning (Goodchild and Palladino, 1993). Despite this speculation, the actual cognitive implications of the spatial perspective provided by a GIS view of the world are just beginning to be studied. (Audet, 1993)

Content Delivery

Not only can GIS activities provide a creative mode for learning, but they can also be the conduit of information. Like a textbook, a GIS derives its usefulness from the data contains (or can easily access); however, a GIS has the advantage of being able to utilize media that can store enormous quantities of information. In fact, a GIS can often be connected to electronic networks which can provide access to even greater quantities of data. A unique feature about a GIS is the ability to append the database with additional information off maps and from tabular spatial data records. Finally, a GIS can also create new data through the integration and manipulation of existing data.

Geography might be the most obvious discipline to benefit from a GIS both as a source and analyzer of information, but many other disciplines would also benefit from the many types of information capable of being stored in a GIS. For earth science and environmental studies, physical characteristics of the land can be displayed in both 2-D and 3-D by many GIS packages. History courses could benefit from analysis of changes in resources and ethnic makeup of countries as political boundaries change. Since data sets for many subjects either explicitly or implicitly have a spatial component (e.g., forecasts for our economy are often tied to a spatial area such as "midwest home building"), a GIS may be able to be used in just about any course.

Introductory Practice

Another function that GIS and related activities may serve in the classroom is as an introduction and early preparation for uses of spatial technologies in later life. Most occupations are beginning to employ computers as the primary tool of their endeavor and many are utilizing GIS. Graduates with competence with computers and a familiarity with GIS will be better prepared for many positions. Although many of these careers will require a post-secondary degree, there will likely be some demand for high school graduates that have skills related to GIS.

For students who matriculate, exposure to GIS in the schools will prepare them for use of that type of software in learning and research modes in various courses at their university or college. GIS experience may encourage some students to enter disciplines that focus on spatial analysis and the use of GIS software (e.g., geography, geology, oceanography, anthropology, sociology, botany, ecology, environmental studies) or those that focus on the development of the technology (e.g., computer science, engineering, mathematics).

Students that do not opt to enter the four-year universities and colleges, may continue on in a GIS-based program at a two-year community college or technical school. One of the key mandates for these institutions in the future will be to train and retrain workers for the modern high-technology, information-based economy. In this environment, the training of GIS technicians will likely be emphasized in addition to instruction in basic geographic information science concepts for both the technicians and those students transferring to universities.

Key Issues

Hardware

When considering the use of current GIS software in the schools, there is often a mismatch between computing power and software requirements. Many schools, especially K-6, still rely on the Apple II family of computers (Becker, 1991) There are no contemporary GIS software packages developed for these machines; however, some simple concepts related to GIS have been demonstrated on the Apple II. Kirman and Jackson (1993) discuss the use of a simple Landsat image display program by sixth grade students on the Apple II.

Old DOS based machines (ATs, XTs) are still used in some schools. As GIS software has
developed, there have been some basic programs designed for these machines. They often are not available commercially, but were written by GIS researchers attempting to demonstrate various methods of processing spatial data. These lower power machines could potentially be used with these programs in the schools, especially in a mathematics or computer studies context; however, with the limited graphic display capabilities, command line interfaces, and slower operating speeds, they are not likely to be favored by teachers and students.

Many schools have begun to invest in more powerful computers. Common models include Macintosh Plus, Classic, and LC models and IBM personal computers (and clones) based on the Intel 80286 and 80386 chips (Becker, 1991) Although many schools have some of these computers, their availability is often very limited. At a minimum, however, most schools would probably be able to make at least one of these machines available to a teacher for short-term use. This may require some persistence on the part of the teacher. A few schools do have labs of these computers which the teachers can use. Some teachers in some schools will have one or even a few of these machines dedicated to their classroom, although this situation is more rare. There are GIS software packages that run on these machines. They include IDRISI, OSU-map, Map II, MacGIS, AtlasPro, MapInfo, and others. One that many teachers are receiving is ARCVIEW. Unfortunately since it is a power intensive application, its performance on even the more advanced machines commonly available in the schools is mediocre at best.

Most schools replace computers on a schedule that is very slow compared to most of the rest of the using market. Schools are often stuck with computing equipment bought a decade or even more earlier. The dramatic changes in personal computing have left these schools behind. Despite this constraining factor, there are schools and teachers committed to computers in their classroom that are acquiring the more powerful Macintosh (II series, Centris, Quadra) and IBM/clone machines (80486-based). Some are trying to find unique sources of funding to purchase a 486 machine in order to run the ARCVIEW software they have received. Beyond these maverick schools and teachers, it is reasonable to assume that many schools will continue to be limited to the less powerful Macintosh and 80286/386 models.

Suggested minimum hardware and operating system characteristics to run future GIS software for
schools are: 1) window-based user interfaces such as MS WINDOWS and the Mac Operating System, 2) computers based on the Intel 80386 and Motorola 68030 chips, 3) four or more megabytes of RAM, 4) forty megabyte hard drives, 5) a 3.5" disk drive, and 6) color monitors (640 by 480). A larger hard drive may be preferred, since spatial data (especially images) can be space intensive. Since much data is being distributed on CD, a CD-ROM reader would also be useful. Although these requirements outstrip many of the present computers in the schools, in a couple of years when these new software packages are available any lesser standards would be anachronistic.

Optional hardware that would help teachers get the most out of GIS software include a scanner and/or digitizing tablet, an overhead display panel, and a laser printer. Students could use the scanner or digitizer to input new spatial data, perhaps of their local area. Although more basic GIS activities might not need this form of input, the ability to choose data (especially local data) will give students a greater sense of ownership when working on a GIS exercise or group project. An alternate form of data input is to perform on-screen digitizing using a transparency attached to the computer screen; however, this technique can severely degrade accuracy. A digitizer gives the GIS user the greatest control over vector data input, but a scanner can be used to input both raster and vector data (i.e., draw vectors on screen over features on scanned image).

Besides individual screen display of data, the teacher and students may want to use an overhead projection panel to display screen contents to the whole class (especially if hardware is limited). For a hard copy presentation of the data a standard laser printer can be used. For higher resolution or color output desired for a final presentation of a group project, a local graphic output service bureau may be used.

An optimum configuration for GIS and other geographic software used as an on-going educational tools would consist of a network of computers (one for every two to three students) connected to a server with a large hard drive to save all of the geographic files. Group work, on the other hand, may only require a few computers. Groups could each work on one computer or even rotate usage. For a teacher to begin to use GIS, however, one computer will serve as a starting point. In fact, some GIS analysis can be done without a computer albeit much slower and often with less accuracy.

Software

Presently there is a gulf between GIS packages and other geographic software. GIS packages have for the most part been designed for use in the workplace, not in a pre-collegiate education environment. This severely limits the number of GIS packages that might be easily used in the schools. There are less complex software packages that combine maps and data, but incorporate very little of the functionality common in a GIS package (e.g., input of spatial data via scanner or digitizer, map editing, map overlay.) These include commercially available items such as AutoMap, PC Globe, SimCity, and the Software Toolworks World Atlas.

Other software has also been used in the schools to teach geography which may express some of the components of GIS (i.e., digital maps, data query) at a basic level without linking data to maps and allowing automated analysis. These packages range from place-name drill and practice programs, to geographic games (e.g., Where in the World is Carmen SanDiego), to graphic design programs for map making (Corel Draw, MapMaker, Aldus Freehand, Adobe Illustrator, and less complex drawing and painting programs). (see Fitzpatrick, 1990; Fitzpatrick, 1993a) Each of these packages may have something to contribute to a progression of computer-based geographic activities for the classroom that eventually leads up to the use of GIS software.

There are a few less expensive and less complicated GIS packages that may serve as the primary terminus for this progression. These include raster packages such as IDRISI, OSUMap, MacGIS, and Map II and vector packages, ARCVIEW, Atlas Pro, and MapInfo. Most have these have been used in the schools, but to such a limited extent that their appropriateness is yet to be determined.

The gulf between GIS and general geography software is just beginning to be breached. The USGS has developed a multimedia GeoMedia CD-ROM (see GIS World, 1993). Although GeoMedia does not include any true GIS functionality, its hypermedia/multimedia environment provides an example for future multimedia materials that do include GIS as one of the elements. Virginia Tech geography and computer science personnel are developing GeoSim. This geographic simulation software designed for the college classroom incorporates some GIS functionality. GeoSim may be useful in the secondary school environment.

GeoSim, however, is not a general purpose GIS designed for pre-collegiate use. Such a software
package has been developed in the United Kingdom by the Advisory Unit, Computers in Education. This AEGIS package was designed to meet the requirements in the UK national curriculum for GIS activities. The package allows for input of map features and spreadsheet data, can perform simple GIS analysis functions, and is bundled with a few data sets complete with example lesson plans and a guide to Geographic Information Systems. AEGIS, with some modification, might serve as a general educational GIS (EDGIS) software package for the US schools. If not appropriate in that role, it at least provides a model for an EDGIS package for the US that would highlight spatial data and analysis techniques in the schools.

As the creation of new software with GIS functionality for the schools is considered, there are some important questions to resolve. They include:

1) What view of the world should the software present to students? Raster or Vector? Or a combination?

2) Should the software be a simplified version of a current GIS package, a new GIS package designed from the ground up for the schools, or should the GIS elements be only a part of a multimedia/hypermedia view of the world?

3) What GIS functionality is most important to student learning?

The last consideration could vary significantly depending on the intended purpose of the software package. An attempt to emulate the use of GIS in the scientific and business communities may require a larger set of capabilities. Software designed to teach spatial analysis principles may not require the breadth of functions but may need to have certain components developed in greater detail. General purpose educational GIS software may need to express the range of operations common in commercial GIS packages and have some data import/export components.

A list of suggested elements of an EDGIS package follows with each element listed adding
complexity:

- Graphically display map features on the monitor.
- Map features unique georeferenced items in a database.
- Map features linked to data about them (attributes).
- Display of the features adjusts to express attached data values (choropleth mapping; multiple colors, line weights, and symbols). This may be automatic (computer sets class intervals), but best if there is also some manual control. The software should have legend capability.
- Map features can be queried for attributes. (This may produce a table of all the feature's attributes, but greater functionality would include the ability to query specific attributes.)
- Simple analysis of map features and attribute data (Area, Distance, Perimeter, Boolean queries, point in polygon, select subset of map features by windowing or with mouse, and simple statistics such as count, total, and average.)
- Assign and edit attribute data.
- Create and modify map features.
- Adjust map presentation (zoom, pan, display at specified scale)
- Input map and attribute data from outside sources via digitizer, scanner, and standard format data import functions.
- Common GIS analysis functions such as map overlay (Map Algebra, non-topological vector), buffer, line-on-polygon, polygon-on-polygon, 3-D display of raster data, and simple projection and image parameter modifications.

The following are advanced analysis and data manipulation functions for software that either closely models advanced GIS software or software designed for a specific curricular use which requires some subset of the following functions:

- Topological map overlay, line smoothing, elevation profile, raster-vector conversion (including computing contours from grid and grid from contours), slope and aspect calculation, simple statistical analysis, simple image processing, create Thiessen polygons, network analysis (shortest path, connectivity), more projection and image modification functions, viewshed analysis.

A more detailed examination of the requirements for and specific uses of EDGIS packages is left for future study.

Data

In the eyes of teachers and students a GIS or EDGIS will only be good as the data that is available. Depending on the course and specific lesson, teachers might desire a wide range of data. For social studies courses, the demand might be for socioeconomic and political entity information. An earth science or environmental studies lesson, on the other hand, may require the physical characteristics of an area. Teachers may be interested in data at different scales: global and multi-nation regional, national, sub-nation regional, local. They may desire to have a broad range of data for their own area or may want data reflecting a case study of a specific problem either in a particular area (e.g., deforestation in South America) or independent of locational criteria (urban transportation and development patterns).

To encourage wide use of GIS in the classroom, data embedded in a tested, well–defined set of curriculum materials may be required. Some teachers, however, will have the motivation to build materials around data not already worked into teaching materials. Thus data availability will benefit both curriculum developers and individual teachers. When GIS activities have caught on, there will be a continuing demand for all types of spatial data especially local data sets. For GIS activities to gain popularity, however, teachers will have to be convinced that the activities can provide the content support the teachers need. This will in a large part depend on the data availability within a GIS. Herein lies a key impediment to the use of GIS in the schools. Adequate hardware and software already are accessible for some schools, but data lags behind. The issue of available and appropriate data may continue to be the bottleneck in the process of introducing GIS to the schools.

The data bottleneck refers to existing data sources. Most GIS packages come with a set of example data, but often of limited instructional value (e.g., business oriented data for address matching.) Users of the software often have created additional data sets in the format of the particular GIS, but these often are not formatted for or made available to the schools. Software independent sources of data also exist, often on CD-ROM, but can only be used with a GIS if it has the appropriate import function.

In addition to relying on these pre-existing data sets, teachers and students have the option of
creating their own data sets. Students can use digitizers or scanners to input map features into their GIS data base. If students can access the study area, they can gather field observations and input them into a data base as attribute information. In the near future, students may also gather locational information using Global Positioning System receivers enabling them to make highly accurate maps.

In addition to self-collected local data sets, in the future there will likely be a wealth of spatial data which would allow teachers and students to select specific data sets of interest for locations out of their reach. These data sets may be available from the software vendors, from various organizations, or from other teachers and students around the world (e.g., the NGS Kidsnet in which classes around the world do collaborative projects in which data is shared.) Allowing students and teachers wide access to various types of data may help lessen the effect of power concentrated in the hands of the few who traditionally controlled information dissemination.

A unique characteristic of spatial data in a GIS is that it is georeferenced. Each map feature in the data base (whether shown as a point, line, or area) has either absolute locational coordinates (e.g., Latitude/Longitude) or at a minimum has relative locational coordinates that can be converted to absolute coordinates if there are adequate source materials (e.g., a local map may be digitized creating a group of map features with {x,y} coordinates which can be converted to Lat/Long with help of a USGS topographic map.) Attribute data is linked to these georeferenced features and is thereby also georeferenced.

Since student data collection and data base creation is extremely time intensive, many teachers will want to utilize pre-existing data sets. Unfortunately many vendor provided data sets are not well suited for the curricular needs of the schools. This situation is being remedied, however, as data sets proliferate mainly through the mechanism of the Internet. Some examples of current georeferenced data sets are highlighted below.

The United States Geological Survey (USGS) has a series of digital data products available. They include digital elevation models (DEM), digital line graphs (DLG), and the newest, the digital orthophotoquads (DOQ). All of these are based on the hard copy topographic quadrangle maps (quad) which the agency has been producing over the years. DEMs show the elevation data from a quad in a raster format. DLGs show the roads, cities, and other non-elevation data on the quad in vector format. The DOQs are orthographically corrected digital versions of aerial photos of a quad area. All of these products may be of some use to teachers using GIS in the schools, but most will probably only use them if they are already found in the software package and can be viewed with minimal effort. Already some of these resources are available on the Internet. In time, teachers and students may use this network to regularly download the USGS quadrangles for their local area.

The US Census Bureau collects a massive amount of socioeconomic data in its decennial census. This information is tied to TIGER files which contain the complete road network and census enumeration area boundaries for the US. Thus, all of this information is georeferenced. Unfortunately use of the TIGER files directly from the Census with GIS packages can be quite difficult; however, second party companies have been taming the TIGER files making them easier to use with the census data in a GIS. The products produced by these companies tend to be expensive, which may put them out of the reach of most schools. Some GIS software either comes with subsets of the census data or has them available at an extra cost. One example is the bundle of CD data sets included with the ARCVIEW software that is being distributed to many teachers. The CDs include US census data and world data. ARCVIEW allows teachers and students to display this data on maps of the US down to the county level. Although display of this data with ARCVIEW is very useful, the benefit is lessened a bit by the rather obscure names for each of the data types (e.g., 40-60_BLK_M_EMPL refers to percentage of black males between the ages of 40 and 60 that are employed.)

Remotely sensed digital images from satellites and planes are commonly used in raster GIS packages. These include the images from the Landsat series of satellites. Here too, students and teachers might enjoy viewing and using these data sources, but for most teachers they will have to be part of a developed exercise. There is a nationally funded effort to make remotely sensed images available to teachers. This Joint Education Initiative (JEI) has bundled earth and planetary imagery with viewing software on a CD for use by teachers. It also is making imagery available across the Internet for those teachers that have access. It holds workshops for teachers to train them in the use of image processing software and for them to develop lesson plans focussing on the imagery. Up to now, however, the focus of JEI has not been on the use of imagery as one of the layers in a GIS analysis. It is likely that teachers will want to use images in their GIS activities, but there are still issues of accessibility to resolve.

Various government agencies and NGOs have compiled data which are often available on CDs.
Examples include USGS geophysical data, NOAA oceanographic data, EPA toxic release inventory data, and the DMA Digital Chart of the World. In addition to data with explicit geographic coordinates, there are many digital data sets of tabular data referenced to political entities (e.g., AIDS cases in various US cities.) This tabular data can be linked to the geographical representation of the political entities in a GIS. Most of these data sources were not created with the schools in mind, and thus may be too complex or esoteric; however, in some cases the data can be worked into a format useful to the schools.

In addition to data sets designed for general distribution, there are thousands of local businesses, government offices, and research labs that have created GIS data sets for their own use or study. Depending on the format, some of these may be utilized with GIS software in the classroom. This might give teachers access to local data. The main GIS software presently found in the schools is ESRI's ARCVIEW. This package provides access to data created in the much more complex and expensive GIS package ARC/INFO. The widespread use of ARC/INFO, one of the most popular GIS packages, provides an opportunity for teachers to acquire additional ARCVIEW compatible data sets from an organization in their local area.

The Internet is increasingly used as a source of data by many GIS professionals and researchers. Teachers are beginning to gain access to the Internet. As schools come on line, this may also serve as a key source of spatial data for use in GIS activities in the schools. If Vice President Gore's vision of Information Super Highways is realized, students and teachers will have access to a wide array of data via computer networks.

Although all these sources represent a wealth of data, their formats, accessibility, or cost often limit their usefulness to the schools. There is still a need for data sets developed specifically for use in the schools. This might be accomplished by including more pre-packaged data sets with GIS packages. These data sets could be either general purpose or apply to a specific activity.

For example, the AEGIS package comes with four data sets. Each has a corresponding lesson plan; the local field work data does not have much use beyond the accompanying exercise, but the world development data set can be used for many more studies than are outlined in the lesson plan. In some cases, it might be worthwhile to develop general data sets, but ensure they would work with a variety of GIS packages (e.g., a global environmental data base). This would allow the data to be used more widely.

In summary, data for GIS activities in the schools is fundamental to their success. Four types of data availability should be encouraged: data sets created specifically for GIS software used in the schools, pre-packaged subsets of data compiled for the greater GIS community, repositories of a wide range of data accessible to teachers for building custom data sets, and support for student input of their own data.

Curriculum Materials

As indicated above, in many cases data will be found in the context of a prepared curriculum module. Many teachers will not begin to consider using GIS software if there are not clearly defined materials available. In most cases the teachers will be more likely to use GIS if it can help teach some component of the established curriculum. In this case, the teacher will be looking for materials that emphasize the Content Delivery and Instructional Invigoration roles of GIS in the classroom. Some teachers might use GIS curriculum materials that are based around interesting topics (e.g., managing disaster recovery for events such as the midwest floods, southeastern hurricanes, and western fires and earthquakes) that don't fit neatly into the existing curriculum. These are examples of teaching with a GIS. Some teachers may also want to teach about GIS to enhance the Introductory Practice and Technology Showcase roles of GIS.

There are presently very few curriculum materials designed for GIS activities in the schools. As materials are developed, choices will have to be made whether to stress the development of GIS curriculum materials or curriculum materials utilizing GIS. The latter form of materials would probably gain favor with a larger group of teachers, since they would not stress the technical elements of GIS.

The NCGIA Core Curriculum was designed to serve the former function, to educate students (primarily undergraduates and graduate students) about GIS (Kemp and Goodchild, 1991). Although it is too detailed for use in most schools, a subset of the Core Curriculum has been extracted for use in explaining GIS to school teachers (Palladino, 1993a). This GIS short course found in the NCGIA "GIS in the Schools" Workshop Resource Packet may also be modified further and used by a teacher to help students doing GIS projects understand the basic concepts. The NCGIA has also created some additional university level GIS curriculum materials which may serve as models for materials in the pre-collegiate environment (see Dodson, et al., 1991; Dodson, 1991a; Dodson, 1991b; Veregin, 1991; Ruggles, 1992) Other materials created by the NCGIA SEP in addition to the Workshop Resource Packet include an introductory digital data viewer (Palladino, 1993b) and a small pamphlet for secondary school students developed by the Maine site which describes geographic information based careers.

The other GIS curriculum materials that exist are either designed for university-level education or have been created to complement specific GIS software (see Dodson, et al, 1991; ESRI, 1991; CCGISE/IGISE, 1990). Some of these might have some limited use in the schools. They would mainly serve as resources to increase teacher knowledge of GIS. The AEGIS package includes a short overview of GIS as part of the materials provided to the schools with the software package. This would be useful to a teacher trying to explain how a GIS functions, but is limited in scope. ESRI has an individual assigned to K-12 uses of the software who has developed a hypertext introduction to GIS and the ARCVIEW software package. Again the information covered is quite limited.

In time, comprehensive materials that cover GIS at a level appropriate to the schools may be developed. Developing instructional materials that can use the power of GIS in the context of existing school curricula is of higher priority. Some software packages do come with examples or lesson plans which could be used by teachers to teach geography, history, earth science, etc. As noted in the last section, the AEGIS packages comes with four example lesson plans and the required data. The GAD package has also been used in the schools and has a couple of learning modules developed for it. A few teachers have adapted university level IDRISI exercises for their own use. Curriculum materials are being developed for the ARCVIEW software by a few groups. Teachers and geographers are working with support from the NCGE and ESRI to create lesson plans, Drs. Merrill Ridd and Cliff Craig in Utah are working under NSF funding to create GIS curriculum modules focusing on the global environment, and the NCGIA SEP is creating modules similar to those of Ridd and Craig but with a human geography focus.

Although these efforts represent a starting point in giving teachers the support required in order to incorporate GIS activities into their teaching, there is much to be done. More discussion needs to take place on the specific course curriculum objectives that can be enhanced with GIS activities. The existing and currently being developed materials are still only a very small number. They are also mainly being developed for traditional GIS software rather than for future EDGIS packages. As EDGIS packages are produced, curriculum materials can be concurrently or subsequently developed for them.

Instructional Environment

It would be a vain effort to purchase hardware and software and acquire curriculum materials for GIS use classroom, if no thought were applied to the challenges presented by a classroom full of students. Effective teaching strategies need to be identified based on the operational requirements of the classroom and on the learning strategies of students using GIS.

Teaching strategies need to be investigated in respect to the various roles GIS may play in the classroom. If it is intended to serve as an on-going aid to daily instruction, how will that be carried out? How will students be grouped to work with the computers? When should students use the computer versus hardcopy materials? For GIS activities, should the didactic form of instruction be eliminated? How should GIS project work proceed? These and many other questions will be answered as teachers experiment with GIS in the classroom. As is the case with all forms of instruction, methods and results will vary greatly from class to class, age to age, teacher to teacher, and school to school. Mechanisms for teachers to communicate their findings on the use of GIS in their instruction should be utilized (e.g., Journal of Geography and NCGIA Secondary Education Progress Reports).

Other areas to be examined include: the progression of concepts and software that should be employed in the classroom to lead up to the use of GIS; the courses that could most benefit from a GIS view of the world and the specific units in those courses that could be linked to GIS activities; and the use of GIS to foster interdisciplinary, team teaching, and interscholastic activities. The use of a progression of software tools fits the vision of the multimedia classroom of the future. As is the case for the effectiveness and appropriateness of computers in instruction, the advantages of the multimedia classroom are still being determined.

Dr. Richard Audet (1993) questions the propriety of moving GIS into the classroom before the cognitive benefits have been clearly identified. As continues to be true for computers in the classroom, however, forward momentum and the undeniable reality that students need to be exposed to the tools of the modern world have resulted in the increasing use of computers in the classroom. These same forces are likely to continue to propel GIS activities into the classroom. This is occurring long before educational researchers have sorted out how best to design activities to match the cognitive strategies employed by students when using a GIS. This research is important and will actually benefit from the existing use of GIS in the classrooms. These classrooms can serve as “laboratories” for their studies.

The first versions of EDGIS software and the initial curriculum materials should be developed in light of the most current knowledge of learning strategies relating to computers and geography. The use of these prototypes can be studied and the findings can be incorporated into the next generation of software and instructional materials.

Understanding and Adoption

Ultimately it is the individual teacher that will be the determining factor in bringing the benefits of GIS instruction to the classroom. “The real agents of change are the teachers—not the textbooks, not the curriculum packets, not the multi–media, high–tech classroom units. It is the teachers who make the world come alive—or die—once the classroom door is closed.” (Salter and Riggs-Salter, 1993, p155) For teachers to enthusiastically use GIS in the classroom, they will first need to become aware of its existence and then of its relevance. The resulting exposure will need to be supported with activities which will give teachers confidence in the use of GIS in their teaching. Some teachers will not be interested in changing the status quo. Steven Jobs, one of the creators of the Apple computer, noted with respect to those who are afraid to use computers, “the fearful generation will eventually pass away and a technologically literate generation will replace them (Jobs, 1994).” Encouraging teachers to use GIS in the classroom will aid in the creation of this technologically (and geographically) literate generation.

The impetus to utilize GIS as a teaching tool can originate from many sources. Word of mouth and examples of other teachers using GIS will add some teachers to the ranks, especially if they can gain access to ready–to–use curriculum materials. The development of teacher support materials will also encourage teacher use of GIS. These materials may include teachers guides and other resources such as the NCGIA Workshop Resource Packet (see Palladino, 1993a). As the presence of GIS in the National Geography Standards trickles down to the curriculum planning of state education departments and local school districts, more teachers will be expected to use GIS (Geography Education Standards Project, 1993). Nothing, however, can replace direct experience for encouraging adoption and more importantly fostering understanding.

Direct experience can be made available to teachers through in–services, weekend seminars, and summer workshops (like those offered in the past by the NCGIA). New teachers can receive instruction on the use of GIS as part of their pre-service teacher education. Some of these newer teachers will have had the opportunity to use GIS in their collegiate education. Eventually, the circle will be made complete as students who were first exposed to GIS in their K-12 education go on to become teachers who use GIS and similar tools in their teaching.

In the end, adoption and understanding will be based on many factors including access to hardware, software, data, curriculum materials, training, and support from the on-site and off-site communities of educators, scientists, administrators, and business people.

Support Structures

No matter how excited a teacher is or what resources he can put together, efforts to incorporate innovative teaching strategies in his classroom will only be possible if the school administration is behind him. Not only will teachers need to be exposed to GIS, but so too will those who wield power over instruction in the schools. This may include principals, superintendents, administrators in charge of curriculum or computing resources, school board members, department chairpersons, and campus computer support personnel. Giving the teacher, wishing to adopt GIS activities, information and resources to convince others in his school of the value of these activities will be important especially if the teacher intends to use GIS as more than just a passing item of interest.

Beyond administrators willing to accept the GIS activities, the teacher would benefit from active support. This might occur in funding for hardware and software purchases. The help of a campus computer support person would probably greatly improve the success ratio of computer-based GIS activities in the schools. The more knowledgeable this individual is in regards to the use of computers, the more challenging the GIS activities can be.

Another avenue of support for teachers can be from outside the school. There are many GIS users in various industries, government agencies, and universities. These GIS users can provide interesting examples for the teachers to relay to their students. The opportunity for field trips and guest speakers can result from these contacts. These individuals may be able to help teachers understand more about the software and its uses outside of education. They may provide access to their resources and data sets which could be a great aid to teachers attempting to use GIS for spatial analysis projects. They also may prove to be the bridge to the future when GIS materials and software for the schools are easier to find and use.

Support could also come from the national, state, and school district levels. This may be in the form of funding for workshops, curriculum development, and software design. It may occur as structural support (e.g., National Geography Standards, state curriculum mandates). Access to the Internet and other avenues of communication may also help teachers find ideas and data for their GIS activities. The GIS industry can take part in these support efforts too. Trade magazines and other informative materials can be offered to teachers at low or no cost. Software companies can support teachers attempting to use their software and perhaps even help create the EDGIS packages. An example of this type of industry support is ESRI's ARCVIEW Adopt-a-School Program (Fitzpatrick, 1993b).

Strategic Initiatives

Some of these key issues will be resolved as technology evolves and teachers become more comfortable with the use of computers in the schools. Hardware that can support GIS activities will likely become increasingly common in the schools over the rest of the decade, even if schools are a bit shy about computer capital acquisitions. An emphasis on hardware initiatives might be misguided since the products, computers and peripherals, are not transferable or easily replicated as are software and curriculum materials. The exception to this, might be a focus on uncommon peripheral devices that support GIS work such as digitizing tablets. In this case, lobbying the vendors of these devices for special educational discounts might be useful.

In the end, hardware will likely prove to be a less important consideration. For the inherent learning benefits of spatial information and analysis available with GIS to reach the classroom in the near future, efforts will need to occur on many other fronts. Three potential initiatives identified below focus on software, curriculum materials, and teacher exposure. Although these initiatives are defined separately below and may eventually be funded as individual activities, they are highly interrelated.

Software Development

Although there are GIS software packages that can provide an adequate introduction to GIS at the K–12 level, they were not designed for use in the schools and thus have significant limitations. Widespread use of GIS to enhance instruction will require the reworking of present software so that it is more school-friendly and more importantly, the creation of new GIS software (EDGIS) designed expressly for the schools. A third type of software development that would help teachers use computer-based spatial analysis in their teaching is the production of transitional software—that which establishes a clear progression from the simple electronic atlases and world fact hypertext stacks to the more advance GIS software packages. It is possible that a well designed EDGIS package will be able bridge much of this gap, but there is still room for the development of innovative geography software.

As consortia of software companies, university educators and GIS researchers, and teachers develop these software packages, they will need to identify what GIS functionality to include, what hardware configuration to support, and how to provide access to data. They will also need to develop manuals that not only explain the operation of the software in clear language and diagrams, but that also include explanation of spatial analysis and GIS techniques. The manuals should also indicate how the software can be used in the classroom (i.e., a minimum of a couple of lesson plan outlines.) The AEGIS manuals provide a good example. Concurrently and following the software development, curriculum materials that make use of the software need to be produced. Teachers will also need support in learning how to use the software in their instruction.

Learning Materials Creation

Although some instructional materials have been included with a few existing GIS packages, they represent only a starting point. Most teachers are unlikely to adopt GIS activities unless there are well designed materials that mesh with their curriculum. Materials need to be created not only for existing packages like ARCVIEW, but also for the EDGIS packages that will be developed.

Materials will be of greatest use if they are bundled with data sets or can be used with readily accessible data sources.

Two types of materials need to be created. One set are those that explain spatial analysis
techniques, the functionality of GIS, and its uses in research and in the workplace. The other set will be designed specifically to use the power of GIS to achieve existing curricular objectives in a variety of classes. Both types of materials could be created by teams of teachers, GIS experts, curriculum development specialists, and other educators. Materials should be developed with the input of research findings on best teaching and learning strategies related to the use of GIS in the classroom.

Teacher Enhancement

In order to apply the software and learning materials to their instruction, teachers will need a variety of support activities. These may include afternoon and day long in–services, special seminars, and summer workshops. These opportunities will give teachers access to GIS software, teaching materials, and teaching strategies. The longer events will allow teachers to learn about GIS, use the software, explore the impact of GIS on their teaching in greater depth, and to observe its uses for planning, management, and research. Before a large impact can be made on a broad spectrum of teachers, it would be helpful to have a cadre of GIS-literate teachers. These GIS resource teachers would run the in-services and help out with workshops and seminars.

The NCGIA GIS in the Schools workshops provide a model for this type of teacher enhancement activity. Similar workshops on a national level are needed to create a critical mass of teachers with significant GIS exposure. An intensive set of regional workshops for exceptional teachers could result in a group of GIS teacher-consultants similar to the geography teacher-consultants trained in the Geographic Alliance summer institutes. These key teachers would go back to their home states and local areas and give in-services and presentations, greatly increasing the number of teachers exposed to GIS. After the first round of intensive workshops are held and a significant number of GIS teacher-consultants exist, a second round of activities can be designed to meet the needs of other teachers, some of whom may be less technologically-literate and not as innovative.

Conclusion

As these general outlines of initiatives suggest, there is still much work to be done to propel GIS to its full potential in the schools. Both these initiatives and the general effort to bring the power of GIS to the schools will benefit from additional research. Some research topics that would extend the work of this thesis were suggested in the review of key issues and would be incorporated in the initiatives suggested above.

These topics are:

- what view of the world, raster or vector, should GIS software for the schools utilize or when should a particular view be utilized?
- what would be the most effective source of GIS software used in the schools (an adaptation of existing packages, new specially designed software, or multimedia with some GIS characteristics?)
- what GIS functionality would be appropriate for the classroom?
- what additional supporting evidence is there for the software design suggestions made by the teacher/consultants (Chapter 1, page 10) and how would these suggestions best be incorporated into a software package?
- which specific computer platforms and configurations should GIS software for the schools be targeted to?
- how should the desire of teachers for materials designed for their existing curriculum be balanced against the need to provide at least minimal instruction on GIS?
- which specific topics within curricular frameworks for a variety of courses would be most amenable to GIS supported learning?
- what methods will be optimum for introducing teachers to GIS and preparing them to use GIS effectively in their classrooms?
- what soft technology supports are required to help teachers successfully use GIS (strategies for communicating GIS potentials to administrators and other decision makers, provision of adequate support staff, materials and software that reflect individual teaching styles, etc.)?

Additional areas for development, discussion, and research are listed below. Many of these items extend beyond the realms of geography and GIS specialists to the expertise of educational and behavioral researchers.

Research is also needed on:

- student understanding of spatial primitives in GIS (points, lines, areas, pixels, etc.)
- student ability to comprehend and use various GIS operations (buffer, reclassify, overlay, distance, point–in–polygon, etc.)
- type of logical errors that students might make within a GIS environment (assumptions about scale, spurious polygons, combinations of incompatible data types, etc.)
- methods for students to use local data (they collect in the field perhaps with GPS or resources such as DEMs and DOQs)
- data collections that appeal to teachers and the viability of custom data selection mechanisms (where teachers can pick and choose from a host of data sets at various scales and with varying themes, thus preventing “outsiders” from dictating what data should be used in the classroom.)
- use of the Internet with GIS activities in the classroom
- appropriate placement of GIS components in multimedia packages and the interface between GIS and multimedia
- the specific connections between GIS materials and activities in the classroom and widely accepted geography curricular guidelines such as the Five Themes and the National Geography Standards
- affect GIS might have on student perceptions of the spatial characteristics of our world
- ways in which GIS can support and benefit from investigations on spatial cognition and reasoning of children
- cognitive processes involved in the use of GIS (e.g., extend Audet’s research to software other than ARCVIEW and to operations other than query building)
- how GIS might invigorate subjects other than geography and earth science
- use of GIS to strengthen interdisciplinary studies
- feasibility and methods for utilizing existing CAD resources in the schools to get data into a GIS or to introduce GIS concepts
- cost/benefit breakdown for GIS activities on various computer configurations (stand alone machine, networked lab, individual vs. teamwork, media supported lecture format, etc.)

- relative effectiveness of manual vs. automated GIS approach (e.g., extend Weller's research with IDRISI and 6th graders to other packages and other age groups)

- specific modes of GIS use in the classroom (see Chapter 1, page 14 for one suggested breakdown for types of use)

- appropriate matches between GIS activities and individual teacher instruction styles.

- correlation between early student exposure to GIS and later success in using the technology in the workplace, interest in pursuing GIS based studies after high school, and improved learning of subjects taught with the help of GIS.

Some initial findings for some of these areas have been highlighted in this thesis, but it is
self–evident from breadth of this list that the research efforts outlined in this document have been primarily foundational. Overall, this investigative effort carried out within the context of the SEP has seen consistent indication that GIS activities, despite the challenges noted, have significant roles to play in pre-collegiate education.

In order to maintain relevance to society, future classrooms, at all levels, will make even greater use of computers and other multimedia technology. Whether or not multimedia and student–directed learning activities take the place of the traditional didactic form of education or not, an increased role for GIS software and concepts is likely. GIS will be the cornerstone of the geographic technologies that will be employed both to provide a link to a student's future education, employment, and daily living uses of geographic information and to promote a spatial analytical perspective in investigations of traditional curriculum content.

BIBLIOGRAPHY

Audet, R.H. (1993) Developing a Theoretical Basis for Introducing Geographic Information Systems into High Schools: Cognitive Implications. Unpublished doctoral dissertation. Boston University, School of Education.

Audet, R.H., W. Huxhold, and L. Ramasubramanian (1993) Electronic Exploration: An introduction to the Geographic Information System. *The Science Teacher*. October.

Becker, H.J. (1991) How Computers are Used in United States Schools: Basic Data from the 1989 I.E.A. Computers in Education Survey. *Journal of Educational Computing Research.* 7(4):385-406.

Becker, T.W. (1989) Teaching Remote Sensing as Public Classroom Instruction. *Photogrammetric Engineering and Remote Sensing*. 55(10):1435-1439.

Bednarz, R.S. and S.W. Bednarz (1992) School Geography in the United States: Lessons Learned and Relearned. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Bednarz, R.S., V.P. Tchakerian, and J.R.Giardino (1993) Incoporating Physical Geography into the *Guidlines's* Movement Theme. *Journal of Geography.* 92(1):35-40.

Blaine, R.P. (1991) A Survey of the Status of Geography and Social Studies in Canadian Elementary and Secondary Schools. *The Operational Geographer.* 9(3):6-11

Boorstin, D.J. (1991) *The Discoverers: An Illustrated History of Man's Search to Know His World and Himself.* New York: Abrams

Brady, H.R. and J.L. Barth (1992) Social Studies Standards that Effectively Integrate Technology. *Social Education.* 56(1):14-16

Brand, Osa (1992) The National Education Goals: Implications For Geography. *Association of American Geographers Newsletter*. April 27(4):4

Brusilovsky, P.L. and T.B.Gorskaya-Belova (1992) An Environment for Physical Geography Teaching. *Computers & Education.* 18(1-3):85-88.

Burrough, P.A. (1986) *Pricincple of Geographical Information Systems for Land Resources Assessment.* Oxford: Clarendon

Cassettari, S. (1991) Introducing GIS into the National Curriculum for Geography. *Proceedings of the Association for Geographic Information 1991 Confernce*. Birmingham, UK.

CCGISE/IGISE (1990) GIS Curriculum Development Toolkit. Ottawa, Canada: Intera Tydac.

Chapman, A.D. (1921) The position of geography in Canada. *The Geographical Teacher.* 11:52–54.

Cirrincione, J.M. and R.T. Farrell (1988) The Status of Geography in Middle/Junior and Senior High Schools. In *Strengthen Geography in the Social Studies Curriculum*, Bulletin No. 81, ed. S.J. Natoli. Washington, D.C.: National Council for the Social Studies, 11-21.

Clarkson, L. (1991) The "Community Snapshot" Project: Integrating Field Work and Technology. *The Operational Geographer.* 9(4):29-30.

Department of Education and Science (DES) (1990) *Geography for Ages 5 to 16.* Proposal of the Secretary of State for Education and Science and the Secretary of State for Wales. London: HMSO.

Dobson, J.E. (1991) Lack of Spatial Intelligence Hampers Communication. *GIS World.* 4(8):96

Dodson, R.F. (1991a) *VT/GIS: The von Thünen GIS Package.* Technical Report 91-27. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Dodson, R.F. (1991b) *GIS Laboratory Exercises: Volume 1.* Technical Report 91-12. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Dodson, R.F., K.K. Kemp, and S.D. Palladino, eds. (1991) *The NCGIA Guide to Laboratory Materials - 1991.* Technical Report 91-20. Santa Barbara, CA: National Center for Geographic Information and Analysis.

ESRI (1991) *GIS Concepts Kit.* ESRI:Redlands, California.

Fisher, P.F. (1989) Geographical Information System Software for Teaching. *Journal of Geography in Higher Education.* 13(1):69-80.

Fitzpatrick, C. (1990) Computers in Geography Instruction. *Journal of Geography.* 89(4):148–149.

Fitzpatrick, C. (1993a) Teaching Geography with Computers. *Journal of Geography.* 92(4):156–159.

Fitzpatrick, C. (1993b) Adopt-a-School. *ArcSchool Reader: Newsletter for GIS users in the K–12 Education and Library Communities.* ESRI: Redlands, California. 1(1):3

Flowerdew, R. and A. Lovett (1992) Some Applications of Murphy's Law - Using Computers for Geography Practical Teaching. *Journal of Geography in Higher Education.* 16(1):37-44.

Freeman, D. (1991) Development of an Educational GIS for the National Curriculum. *Proceedings of the Association for Geographic Information 1991 Confernce*. Birmingham, UK.

Freeman, D., D. Hassell, and C. Robinson (1983) Research into CAL Geography. In, Geography Teaching and the Micro, ed. A. Kent. Essex: Longman

Fung, Y. (1992) The Development of Geographical Education in Hong Kong and China
(1949–1988): A Comparative Study. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Gardner, D.P. (1986) Geography in the School Curriculum. *Annals of the Association of American Geographers.* 76(1):1-4.

Geographic Education National Implementation Project (1989) *7-12 Geography: Themes, Key Ideas, and Learning Opportunities.* Washington, D.C.: Geographic Education National Implementation Project.

Geography Education Program (1990) *Geography Education Program five-year report.* Washington, D.C.: National Geography Society.

Geography Education Standards Project (1993) *National Geography Standards,* draft version from June 30, 1993. Washington, D.C.: National Council for Geographic Education.

Gerber, R. (1992) Technology Education: An emerging Component in Geographical Education? In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Gersmehl, P.J. (1992) Themes and Counterpoints in Geographic Education. *Journal of Geography*. 91(3):119-122.

GIS World (1993) GIS NewsLink. "USGS Releases Interactive Educational System". *GIS World.* October.

Goodchild, M.F. and K.K. Kemp (1990) *The NCGIA Core Curriculum in GIS.* Santa Barbara, CA: National Center for Geographic Information and Analysis.

Goodchild, M.F. and S.D. Palladino (1994) GIS as a Tool in Science and Technology Education. *Speculations in Science and Technology.* Fall (forthcoming)

Gossette, F. and J.D. Wheeler (1993) Computer Mapping in a Regional Geography Course. *Journal of Geography.* 92(1):28-34.

Griffith, D.A. (1987) Teaching Spatial Autocorrelation by Simulation. *Journal of Geography in Higher Education.* 11:143-153.

Grosevenor, G.M. (1989) The Case for Geography Education. *Educational Leadership,* November pp29-32

Guay, L. (1990) "A Multimedia Atlas". National Atlas Information Systems Opportunities Seminar. Ontario: Energy, Mines, and Resources Canada.

Haggett, P. (1983) *Geography a Modern Synthesis.* New York: Harper & Row.

Hill, A.D. (1989) Geography and Education: North America. *Progress in Human Geography*. 16(2):232-242.

Hill, A.D. (1992) Geography and Education: North America. *Progress in Human Geography*. 13(4):588-598.

Jenkins, S. (1992) Four Cheers for Geography. *Geography*. July 77(3):193-197

Jobs, S. (1994) Radio interview on National Public Radio's Weekend edition. January, 22.

Joint Committee on Geographic Education (1984) *Guidelines for Geographic Education: Elementary and Secondary Schools.* Wahingtion, D.C.: Association of American Geographers and and National Council for Geographic Education.

Keller, C.P. and N.M. Waters (1991) Mapping Software for Microcomputers. In, *Geographic Information Systems: The Microcomputer and Modern Cartography,* ed. D.R.F. Taylor. New York: Pergamon Press.

Kemp, K.K. and M.F. Goodchild (1991) Developing a Curriculum in Geographic Information Systems - The National Center for Geographic Information and Analysis Core Curriculum Project. *Journal of Geography in Higher Education.* 15(2):123-134.

Kemp, K.K., M.F. Goodchild, and R.F. Dodson (1992) Teaching GIS in Geography. *The Professional Geographer.* May, 44(2):181-191

Kirman, J.M. and M. Unsworth (1992) Digital Data in the Grade 6 Classroom. *Journal of Geography.* 91(6): 241-246.

Kirman, J.M. and C. Jackson (1993) Grade 6 Children's Ability to Use a Landsat Digital Data Computer Program. *Journal of Geography.* 93(6): 255-262.

King, R. (1989) Geography in the School Curriculum: A battle won but not yet over. *Area.* 21(2):127-136.

Lamb, A.C. (1992) Multimedia and the Teaching-Learning Process in Higher Education. In, *Teaching in the Information Age: The Role of Educational Technology*, eds. M.J. Albright and D.L. Graf. New Directions for Teaching and Learning series #51. San Francisco: Jossey-Bass Publishers.

Lambert, D. (1990) The National Curriculum is Coming! *Journal of Geography in Higher Education.* 14(1):92-97.

Libbee, M and J. Stoltman (1988) Geography in the Social Studies Curriculum. In *Strengthen Geography in the Social Studies Curriculum*, Bulletin No. 81, ed. S.J. Natoli. Washington, D.C.: National Council for the Social Studies, 22-41.

Lu, J.J. (1992) China's Geographic Education. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Maguire, D.J. (1989a) *Computers in Geography.* New York: John Wiley & Sons.

Maguire, D.J. (1989b) The Domesday interactive video system in geography teaching. *Journal of Geography in Higher Education.* 13:55-68.

Mahony, K.O. (1988) *Geography and Education*. Seattle: Educare Press.

Marran, J.F. (1992) The World According to a Grade 12 Teacher — A Reflection on What Students of Geography Should Know and Be Able to Do. *Journal of Geography.* 91(4):139–142

Mather, P.M. (1991) *Computer Applications in Geography.* New York: John Wiley & Sons.

Mayo, W.L. (1965) *The Development and Status of Secondary School Geography in the United States and Canada.* Ann Arbor, Mich.: University Publishers.

Midgely, H. with D. Walker (1985) *Microcomputers in Geography Teaching.* London: Hutchinson.

Miller, B. (1993) Clinton Proposes Nationwide Network. *Government Technology.* April. p72.

Miller, D. W. (1988) The Great American History Machine. *Academic Computing.* 3(3).

Miller, G.G. (1992) Personal communication: letter dated January 27, 1992.

Nakayama, S., F. Wada, and the Hiroshima Geographic Alliance (1992) Geographic Education in Japan: A New Perspective for the 21st Century. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

National Assessment of Educational Progress (1990) *The Geography Learning of High-School Seniors.* Princeton, NJ: Educational Testing Service.

NAEP Geography Consensus Project (1992) Geography Assessment Framwork for the 1994 National Assessment of Educational Progress. (pre-publication draft) Washington, D.C.: National Assessment Governing Board, U.S. Dept. of Education.

National Geographic Society (not dated) *Resources for Geography Education.* Brochure. Washington, D.C.: National Geographic Society.

Natoli, S.J. (1988) Preface. In *Strengthen Geography in the Social Studies Curriculum*, Bulletin No. 81, ed. S.J. Natoli. Washington, D.C.: National Council for the Social Studies.

Natoli, S.J. and C.F. Gritzner (1988) Modern Geography. In *Strengthen Geography in the Social Studies Curriculum*, Bulletin No. 81, ed. S.J. Natoli. Washington, D.C.: National Council for the Social Studies.

Nellis, M.D., R. Lougeay, and K. Lulla, eds. (1989) *Current Trends in Remote Sensing Education.* Hong Kong: Geocarto International Centre.

Nielson, J. (1990) *Hypertext & Hypermedia.* Academic Press.

Oblinger, D. (1992) *Multimedia in Instruction.* Institute for Academic Technology.

Ontario Ministry of Education (1988) *Geography Curriculm Guidlines: Part A - Policy and Program Expectations.* Toronto: Ministry of Education.

Palladino, S.D. (1992) GIS and Secondary Education in the United States. In *The Yearbook of the Association for Geographical Information*, 1992/1993, ed. J. Cadoux-Hudson and D.I. Heywood. London: Taylor & Francis, 304-309.

Palladino, S.D. (1993a) *"GIS in the Schools" Workshop Resource Packet*. Technical Report 93–2. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Palladino, S.D. (1993b) *African Data Viewer.* Technical Report 93-11. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Palladino, S.D. and M.F. Goodchild (1993) A Place for GIS in the Secondary Schools? Lessons from the NCGIA Secondary Education Project. *Geo Info Systems.* April, 3(4): 49-49

Poiker, T.K. (1985) Geographic Information Systems in the Geographic Curriculum. *The Operational Geographer*. 8:38-41.

Raper, J.F. and N.P.A. Green (1989) Development of a Hypertext Based Tutor for Geographical Information Systems. *British Journal of Educational Technology*. 3:164-172.

Raveneau, Jean-L., M. Millar, Y. Brousseau, and C. Dufour. (1991) Micro-Atlases and the Diffusion of Geographic Information: An Experiment with HyperCard. In, *Geographic Information Systems: The Microcomputer and Modern Cartography*, ed. D.R.F. Taylor. New York: Pergamon Press.

Rhind, D., P. Armstrong, and S. Openshaw (1988) The Domesday Machine: A Nationwide Geographical Information System. *The Geographical Journal*. 154(1):56-68.

Richardson, J. (1984) Micros in the Field. In, *Exploring Geography with Microcomputers*, ed. D. Watson. Microelectronics Education Program, Readers 3. London: Council for Educational Technology.

Roberts, J. and D. Lynn (1991) GTE/Contel Technology Award Team Uses MapGraphix in State Competition. MapGraphix Globe. July. (ComGrafix, Inc. newsletter)

Robinson, G. and B. Thornton (1992) Critical Thinking and Computers: A Natural Combination. *The Monograph*. Ontario Association for Geographic and Environmental Education. 43(1):16-21.

Ruggles, A. (1991) *GIS Videos: An Annotated Bibliography*. Technical Report 92-9. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Salter, C.L. (1986) Geography and California's Educational Reform: One Approach to a Common Cause. *Annals of the Association of American Geographers*. 76(1):5-17.

Salter, C.L. (1992a) The U.S. Geography Consensus Project: Dynamics and Outcome. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Salter, K. and C. Salter (1992b) The Teachers Speak: When Geography Makes History. *Journal of Geography*. 91(4):138-139.

Salter, K. and C. Riggs–Salter (1993) Yet Another Perspective on Educational Reform: Ten Verities. *Journal of Geography*. 92(4):154-155.

Sarinvasan, R. (1992) Personal communication and proposal submitted to Michael Goodchild, Director of the National Center for Geographic Information and Analysis.

Slater, Francis (1982) *Learning Through Geography - an Introduction to Activity Planning*. Heinemann Educational Books.

Slocum, T.A. and S.L. Egbert (1991) Cartographic Data Display. In, *Geographic Information Systems: The Microcomputer and Modern Cartography*, ed. D.R.F. Taylor. New York: Pergamon Press.

Smyrnew J.M. (1990 *)* Trends in Geographic Information System Technology. *Journal of Surveying Engineering-ASCE*. May, 116(2): 105-111.

Strong, Bill (1993) Personal communication.

Tapsfield, A. (1984) Primarily Geography. In, *Exploring Geography with Microcomputers*, ed. D. Watson. Microelectronics Education Program, Readers 3. London: Council for Educational Technology.

Taylor, D.R.F. (1991) *Geographic Information Systems: The Microcomputer and Modern Cartography.* New York: Pergamon Press.

Theobald, D.M. (1992) *Hypermedia Concepts and Their Relations to Geographic Education.* Department of Geography, University of Colorado, Bolder. Unpublished.

Thomas, P.F. (1990) On the Demise of School Geography: A Post-Mortem Report. *The Operational Geographer.* September 8(3):18-21.

Thomas, P.F. (1992) Some Critical Structural Factors in the Institutional Context of the Canadian School Geography. In *International Perspectives on Geographic Education*, ed. A.D. Hill. Skokie, Illinois: Rand McNally & Company.

Thompson, D. (1991) G.I.S. - A view from the other (dark?) side: The perspective of an instructor of introductory geography courses at university level. *Cartographica*. 28(3):55-64.

Trüper, M. and M. Hustedde (1990) Geography Education in West German High Schools: Do Four Years Make a Difference? *Journal of Geography.* 89(3):109-112.

Unwin, D. and P. Dale (1989) An educationalist's view of GIS. In *The Yearbook of the Association for Geographical Information, 1991*. London: Taylor & Francis, 304-312.

Unwin, D.J. (1991) Using computers to help students learn: computer assisted learning in geography. *Area.* 23(1):25-34.

Unwin, D.J. (1992) Computer Assisted Learning in Geography. *Computers & Education.* 19(1/2):73-78.

Veregin, H. (1991) *GIS Laboratory Exercises: Volume 2.* Technical Report 91-14. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Vuicich, G., J. Stoltman, and R.G. Boehm (1988) The Fundamental Skills of Geography. In *Strengthen Geography in the Social Studies Curriculum*, Bulletin No. 81, ed. S.J. Natoli. Washington, D.C.: National Council for the Social Studies.

Walsh, S.J. (1988) Geographic Information Systems: An Instructional Tool for Earth Science Educators. Journal of Geography. 89(1):17-25.

Watson, D. (1984) Introduction. In, *Exploring Geography with Microcomputers*, ed. D. Watson. Microelectronics Education Program, Readers 3. London: Council for Educational Technology.

White, K.L. and M. Simms (1993) Geographic Information Systems as an Educational Tool. *Journal of Geography*. 92(2): 80-85.

Wilbanks, T. (1993) President's Column. *Association of American Geographers Newsletter.* May 28(5):1-2

Wolforth, J. (1986) School Geography — Alive and Well in Canada? *Annals of the Association of American Geographers.* 76(1):17-24.

Wood, A. and S. Cassettari (1992) GIS and Secondary Education. In *The Yearbook of the Association for Geographical Information, 1992/1993*, ed. J. Cadoux-Hudson and D.I. Heywood. London: Taylor & Francis, 296-303.

Young, M. (1991) Technology as an Educational Issue: Why it is so Difficult and Why it is so Important. In, *Understanding Technology in Education*, eds. H. Mackay, M. Young, and J. Benyon. The Falmer Press: New York

Appendix A
"GIS in the Schools" Workshop Review

Early in the efforts of the SEP, it became apparent that the input of classroom teachers would be invaluable; however, for teachers to give advice relevant to GIS they would need some experience with GIS. In order to provide this experience, to receive significant teacher input, and to correct our preconceptions, the NCGIA hosted a seven day workshop for 10 high school teachers in the summer of 1992. The workshop was developed around the goal of providing a stimulating learning experience in GIS for the teachers, but also acknowledged their ability to give practical advice on GIS use in the schools. Thus their title, teacher/consultant, was appropriate in our effort to convey a sense of collaboration between professionals with different areas of expertise.

Flyers announcing the workshop and applications were distributed to teachers in fifteen high schools within a radius of approximately sixty miles from the NCGIA's University of California, Santa Barbara site. Teachers were identified by calling the area high schools and asking for the names of teachers in the science, social studies, and computer departments. The workshop was also announced at a school district wide in–service for science teachers. Since a comprehensive look at GIS at this point in its development requires the type of hardware, software, data sets, and experience found in the university setting, a close tie between the university and the local teachers was desired. This desire motivated a limited selection area. The proximity of the workshop participants to one another also encourages continued interaction following the workshop. A side benefit of offering the workshop to local teachers was the savings in accommodation, transportation, and food costs.

Due to the relatively late date of the workshop's official announcement, we received only 15 applications. From this pool, efforts were made to select a balance of teachers from the sciences and social studies. Teacher/consultants were all expected to have some computer experience; however, a deliberate effort was made to have varying experience levels represented in the workshop. Teachers were also asked to list any other curriculum development experience.

The final group of teacher/consultants consisted of six in science, three in social studies, and one in computers. They were picked to reflect a range of teaching experience from long–term seasoned teachers to newer teachers familiar, from more recent university training, with trends in teaching and use of computers in education. This diverse group with its mix of strengths provided an excellent range of perspectives on the role of GIS in the high schools.

In addition to the general information included in the initial flyer, the selected teachers were contacted personally and were sent a more detailed explanation of workshop goals and content. The teacher/consultants were also sent a short introduction to GIS. It was a very simple overview of GIS and its applications. Good examples of introductory material appropriate for pre–workshop reading are often found at the beginning of GIS software manuals or GIS educational materials written for specific software packages. It was assumed that any material of greater detail might not be effective until teacher/consultants had the opportunity to observe GIS visually. For a workshop of shorter duration, however, a packet of GIS materials including an overview, visuals, and more detailed materials might be an appropriate preparation for the workshop.

In order to aid the consultation efforts of the selected teacher/consultants, the workshop included a ten hour short course in GIS, many demonstrations of GIS applications, and hands–on work with various GIS software packages. Following mornings of GIS activities, the teacher/consultants provided crucial feedback in the afternoons on various issues related to efforts to implement GIS concepts and software in the secondary classroom. They also helped the NCGIA begin to identify the types of materials and support teachers would need in order to successfully use GIS in their classes. As a result of the workshop, the teacher/consultants developed GIS projects for use in their fall, 1992 classes.

Workshop Elements

This seven-day prototype workshop was held in July, 1992. The first five days concentrated on providing information on and experience with GIS and on receiving feedback from the teacher/consultants. The primary focus of the last two days was teacher/consultant project planning. The weekend dividing the seven days gave the teacher/consultants some time to digest the volume of information they had received and to outline potential GIS projects for their classrooms. The workshop days began at 8am and ended between 4:30 and 5pm. The workshop was staffed by Dr. Michael Goodchild, the Director of the NCGIA and the primary geography faculty member teaching GIS, by the SEP manager Steve Palladino, an NCGIA graduate student researcher, and by two graduate student assistants, Karen Beardsley and Bjorn Svensson.

There were five major components to the workshop: a ten hour short course in GIS,
demonstrations of faculty and graduate student GIS projects, GIS software practice sessions, discussion sessions on various aspects of GIS in the schools, and project planning sessions. Continual evaluation of the workshop was also a daily activity.

Short Course

The course was broken up into ten hour-long sessions taught two hours at a time. These two hour sessions began in the morning after a short daily briefing and a period for teacher/consultant evaluation of the previous days activities. The course was primarily taught by Dr. Goodchild with a portion taught by Steve Palladino. The lectures were presented in the following order:

- Introduction to Geographic Information Systems
  1st hour - General Introduction
  2nd hour - Computer and map basics for GIS

- How a GIS Works I:
  1st hour - Raster GIS
  2nd hour - Spatial Objects and Their Relationships

- How a GIS Works II:
  1st hour - Vector GIS
  2nd hour - Begin discussion of GIS applications

- GIS Applications:
  Both hours - more examples of various GIS applications

- GIS in the Schools, Workplace, and World:
  1st hour - History and future trends of GIS
  2nd hour - GIS opportunities in the workplace, in the universities, and in the schools

GIS Demonstrations

The GIS demonstrations were on various platforms utilizing different software packages. The scope and subject areas of the demonstrations also varied considerably. Faculty and graduate students were asked to give 15 to 90 minute demonstrations of their GIS projects. These concentrated on the use of GIS as a tool in various application areas rather than research on GIS development and computer programming. The following demonstrations were provided for the teacher/consultants:

- A tour of the UCSB Map & Imagery Laboratory in the Library. This included a demonstration of ARCVIEW on a Unix workstation and of a simple prototype of a GIS application for tracking environmental problems in Central Europe using Atlas*GIS on an IBM PC.

- An overview of various Biodiversity Lab projects mainly utilizing ARC/INFO and

ERDAS. These include a California Condor recovery project, a study of a large, undeveloped parcel of university land intended for research purposes but threatened by development, and a large project mapping the plant and animal species distribution in the state of California for determination of areas to be set aside for preservation.

- A United Nations Environmental Program project to map various indicators for the African Continent using the IDRISI software on a PC.

- An Arc/Info representation of various demographic variables in Los Angeles County.

- A large project mapping potential soil contamination by leaks in underground fuel tanks on the Vandenberg Air Force Base using Intergraph and 3–D graphing software.

- An anthropological study of Aztec Indian culture utilizing Arc/Info to analyze spatial distribution of artifacts.

- A oceanographic project mapping the mid–ocean spreading zone and volcanically active sites on the ocean bottom using Arc/Info on a workstation.

- A demonstration of the use of Arc/Info and ARCVIEW to aid a study of labor characteristics in the garment industry in Los Angeles.

- Also the teacher/consultants were treated to spontaneous demonstrations of the internal components of a computer and of the PC/Globe and AutoMap software packages by the computer teacher participating in the workshop.

GIS Software Use

The teacher/consultants interacted with several GIS packages over the seven day period. The teacher/consultants were supported by the Project Manager and the two workshop assistants in their efforts to use and understand the GIS software. On the first day they worked through the HyperCard Tutorial GISTutor on Macintosh computers. They came back to the tutorial near the end of the workshop in order to fill gaps in their understanding of GIS.

The first GIS package used was MAPII on the Macintosh. This is a simple, inexpensive raster based software package. Teacher/consultants were each given a demonstration disk which can be obtained for $5. They worked through the demo of the GIS features, then completed a short exercise adapted for the workshop by the SEP from an example sequence suggested by one of the MAPII creators.

The next software package investigated was Atlas*GIS, a moderately price vector package for DOS systems. The teacher/consultants received a copy of the Atlas*GIS Introductory Package. This $20 package is a fully functioning GIS but will only work with the provided data.

Atlas*GIS was followed by another package for the IBM PC & compatible world. This raster based package, IDRISI, was designed for educational purposes and is only $200 and has many educational materials developed around it.

Last, the teacher/consultants used ARCVIEW on a IBM PC. This is a software package which allows for interactive display and query of data sets in the Arc/Info GIS format. Due to the popular use of Arc/Info, many data sets in this format exist. During the final two days of the workshop the teacher/consultants were given access to all of the software packages for further investigation, especially with respect to the use of these packages in their GIS projects. They also received a short lesson and practice session on using a digitizing table to input map data into a computer.

In addition to the examination of various software packages, a session on Friday morning was devoted to independent perusal of various GIS educational materials and related items that have been collected by the SEP. These included special GIS education workbooks developed by ESRI and TYDAC/SPANS. Teacher/consultants were also able to review the NCGIA Core Curriculum in GIS and lab exercises developed for IDRISI and Arc/Info by the Center. During this time teacher/consultants also brought some of their curriculum materials to share with the other teacher/consultants.

Discussion & Planning

The first discussion session began with an overview of computers in the classroom. The teacher/consultants had come prepared with a list of the computer resources of their schools, highlighting those resources that were actually available for their use. These lists were reviewed during this session and the general trends of computers in the classroom were discussed. A short overview of platforms for GIS software was included in this session. The second discussion session focussed on the place for GIS in the secondary school curriculum. Also discussed as concomitant issues were the nature of geography and technology education in the schools. Teacher/consultants were asked to list where and how GIS could be taught in various courses. The third session was a question and answer session with Dr. Goodchild about aspects of GIS that had come up in the course or in the other activities. The fourth session was an open session discussing the opportunities for, and obstacles to GIS, activities in the schools. A fifth session encouraged the teacher/consultants to brainstorm about where they could teach a GIS component or integrate GIS activities in their specific courses.

The fifth session began the teacher/consultants' project planning process. A sheet describing project planning and implementation activities was handed out. On the last two days, the morning was reserved for project planning sessions. During these sessions the teacher/consultants worked in groups with the workshop staff. The first day they presented their lesson/project plan ideas from the weekend of brainstorming. The second day they described the outline of their project based on the feedback received on the previous day. Other activities of the final two days were a session defining what should be a part of a GIS project/lesson and a session evaluating SEP ideas for GIS educational materials.

Each day included an evaluation component aimed at helping the SEP improve the workshop model. At the end of each day, the teacher/consultants received a one page evaluation form asking for feedback on each of the day's activities. They filled out the forms at the end of the day or in the evening. The next morning, at the briefing session, their comments on the effectiveness of the previous day's activities were solicited. The morning evaluation times were very helpful in adjusting the workshop as we went. They also helped foster a sense of accountability of the workshop staff to the teacher/consultants, giving the workshop the desired interactive format. At the end of the workshop, the concluding session included a period of verbal evaluation. As a final workshop activity the teacher/consultants were given a three page evaluation form which they were to return in a week with their GIS lesson/project description. Each evening in addition to filling out the daily evaluation form, the teacher/consultants took home a copy of one of the GIS trade magazines (GIS World or Geo Info Systems) to peruse.

Since one of the primary goals of the workshop was to get the opinions on GIS potential in the schools from teachers who had a reasonable exposure to GIS, we felt that compensation was in order for their consultation efforts. Each teacher/consultant was paid $100 per day. Those who completed their GIS project activities including an evaluation of their field test and a final report on their project received an additional $300. Generally expenses were fairly low. The two graduate student workshop assistants were each paid $500 for about 40 hours of work. Both Dr. Goodchild and Steve Palladino were not specifically compensated, but include all the efforts towards the workshop in their normal duties. Some money was spent acquiring demonstration packages, making photocopies, mailing letters, and the like, but it was not a large amount.

In addition to compensation for their consultation efforts, the teacher/consultants were given the opportunity to earn 3 quarter units of Extension credit for the short course in GIS and other learning activities that were part of the workshop. Six of the teacher/consultants chose to pay the extension fee and receive credit. The extension credit, the compensation, and the general design of the workshop activities were geared to acknowledging the professionalism of the secondary teachers. As noted, we were not interested in establishing a two–tiered partnership – NCGIA “experts” and teacher “students” – but rather, we attempted to emphasize contributions by all workshop participants. This collegial treatment was greatly appreciated by the teacher/consultants and added to the effectiveness of the workshop.

In the summer months following the workshop, the teacher/consultants returned a workshop evaluation package and worked independently on their GIS projects. The Project Manager continued to be in contact with the teacher/consultants to aid their efforts and to provide additional information on GIS materials, data, and software that became available. One item that the teacher/consultants requested during the workshop was a slide set on GIS. The Project Manager compiled a set of 40 slides which can be used for a quick introduction to GIS. Many of the teacher/consultants used this resource as part of their GIS projects. In December, 1992, the workshop participants met on a Saturday to report on the results of their classroom trial of their GIS projects, to make final evaluations of Phase I of the SEP, and to finalize the format for the summaries of their projects.

Workshop Evaluation

The workshop got off to a good start with an introductory session in which the goals for the workshop were expressed, the workshop schedule was reviewed, and introductions were made. The teacher/consultants generally appreciated the clear presentation of what we hoped to accomplish as a group in the seven days. Following the orientation session, the first class session was held. For the most part the teacher/consultants found this “General Introduction to GIS” session very informative. Despite a positive response to the material in the sessions, most of the teacher/consultants expressed a desire for the introductory sessions to give a stronger overview of GIS including slides of GIS applications and a simple demonstration of a working GIS application. They also noted that it was important to clarify the impact GIS might have on their teaching and lives right at the beginning.

For some teacher/consultants, it took a couple of days before they began to understand what GIS actually was and how it might fit into their teaching. By the fourth day of the workshop, however, all of the teacher/consultants became excited about the possibilities that GIS might hold for their courses. They began to dream up all sorts of GIS activities for their classes, some of them quite involved. As the teacher/consultants began to assess what data, software, and materials they would need to begin implementing these ambitious plans, they realized that putting together a GIS lesson might require quite a bit of effort. This was especially true for projects that would have students use multiple data sets from the local area. Though obviously appealing to both teacher and students, this type of project would require extensive efforts in identifying existing data sources and obtaining the data or in compiling data themselves. Like a red–hot stock market eventually cooling off, there was a discernible "correction" in their expectation level. Nevertheless, the teacher/consultants were still very positive towards GIS use in the classroom at the end of the workshop.

Short Course

Most of the material in the short course in GIS was drawn from the *NCGIA Core Curriculum in GIS* with adaptations made for the audience. For the most part the information was appropriate, though at times it was hard for some of the teacher/consultants to follow. This was especially true for some of the more technical aspects of the course. Some of the teacher/consultants found the technical discussion a good base for answering student questions; however, other teacher/consultants felt that the content should be streamlined. Generally not all lecture topics planned for a session were covered (see previous list of course topics). This was in part due to the positive emphasis on interactive lecturing in which questions were encouraged. This slowed down the presentation of the material, but it also increased comprehension and interest. It turned out that the computer discussion flowed over into the second day. The discussion on Spatial Objects and Relationships was dropped. Some of the more technical discussion on Raster and Vector GIS was omitted.

Many of the teacher/consultants suggested that some of the last day's information on "GIS in the Schools, Workplace, and World" could have been included in some of the earlier lectures. It was also suggested that some of the application examples be presented at the beginning to cement the purposes for GIS in their minds. Some of the applications, however, would be best understood following the technical information in the Raster and Vector lectures. The background on computers and maps was appreciated by the teacher/consultants. The portion of the short course that got the highest marks from the teacher/consultants was the section with accompanying slides which clarified the various ways GIS can be applied. A suggestion was made that outlines of lecture materials be given to the teacher/consultants at the beginning of the lectures. This aid to note taking would help the teacher/consultants compile the information as reference material for their own teaching.

Based on the experience of this workshop, a future lecture series might be reduced to four two–hour sessions. The initial session would make a greater attempt to provide the necessary overview for teachers to grasp both the nature of GIS and its relevance to their efforts as educators. This first lecture would incorporate discussion on the background of GIS, its use with appropriate examples (slides), its potential for the classroom, and other general information about GIS. A second lecture would review computer and map concepts that are essential to GIS. The third lecture would present the Raster/Vector world views and some of their details. A final lecture would tie together the various components through a more in depth examination of GIS applications. In order to shorten the series some of the more technical discussion would be dropped. The large amount of material that might seem appropriate for the introductory lecture could be reduced by a more extensive discussion in the opening session on the nature of GIS in relation to the goals of the workshop. Wise choice of a simple GIS demonstration immediately preceding or following the first lecture could also help provide a greater sense of the big picture by the end of their first day.

GIS Demonstrations

The various demonstrations of graduate student and faculty GIS applications were the highlight of the workshop for many of the teacher/consultants. They appreciated the "real world" connection that the demonstrations provided. They also enjoyed seeing some cutting edge uses of GIS. The most successful demonstrations were clearly organized with a visual introduction, a clear explanation and graphic representation of the use of GIS in the application, and a minimum of information extraneous to the needs of teachers. Examples of good introductions included a video showing the research area for the ocean bottom mapping application and slides showing the area being studied on Vandenberg Air Force Base. This fits with the general consensus that there should be an emphasis on “show, over talk”. Talk especially to be avoided includes excessive use of acronyms that have no meaning to teachers and use of very technical terminology either from GIS methodology, computer technology, or the presenter’s area of study.

When making presentations around a computer screen certain space issues need to be considered. Only 4 or 5 individuals can crowd closely enough around the monitor to see what is happening. Large groups may need to be split up in order for the demonstration to be successful. It is helpful if the presenter has an adequate mastery of the software. It was frustrating for the teacher/consultants to watch an individual “playing” with the software. Batch files (computerized slide shows) are often a good presentation method. When demonstrating the capabilities of GIS software packages, it helps if the demonstrator can either involve the observers in some sort of “hands–on” manner or at least allow them to provide input to the demonstrator’s actions

Some of these difficulties were encountered in the tour of the Map & Imagery Laboratory. Too much time was spent discussing what was available rather than showing the operation of the machinery and software. Also the other resources of the lab, such as the large map collection, were overlooked. At a later point in the workshop, the teacher/consultants were able to go back to the Map & Imagery Lab in order to fill in the gaps and explore the resources available to them. It was noted that a more conscious effort should be made to match demonstrations chronologically with lectures covering material relevant to the particular demonstrations. As a whole the demonstrations were highly valued and served as fodder for teacher/consultant discussions with friends, family, and fellow teachers. The teacher/consultants also noted that the demonstrations provided good examples of “GIS in action” which they could relate to their students.

GIS Software Use

The teacher/consultants were exposed to quite a few software packages in a fairly short period. This was intentional. We desired to get a relatively unbiased view of what types of systems might go over well in the schools. In future workshops, it may be more efficient to pick a just a couple of packages that have potential in the schools for teacher use. The capabilities of other packages could be displayed in quick overviews. Teacher/consultants noted that before they worked with the packages, a short demonstration of the software's capabilities, the operating system, and key steps would be very helpful. It was valuable to have some open lab time near the end of the workshop for teacher/consultants to work with the packages that interested them and had potential in their classrooms. In picking software to use, it is important to keep in mind the hardware that teachers have available to them at their schools. Having them work with both a raster and a vector package drives home the distinction and clarifies the choices that must be made in selecting software for use in the classroom. In most cases vendor-provided demonstration packages and their accompanying manuals will not work in the classroom. Students will need specific lessons and steps to fully utilize GIS software.

GISTutor receive mixed reviews. Some teacher/consultants really appreciated its HyperCard format which allowed them work at their own speed and to choose what topics to investigate. Since this was the first package used, an introduction to the Macintosh operating system would have been helpful for some of the teacher/consultants. GISTutor assumes that the user understands the general purpose of GIS and knows what a GIS application is made up of. It picks up the story with the technical workings of GIS software. Some found this discussion too detailed or "boring". Teacher/consultants returned to redo the tutorial at the end of the workshop as a review of some of the material covered in the lectures. This was generally viewed as helpful activity, though going through the whole thing twice was a bit too repetitive for some of them. A possible use for the GISTutor in future workshops would be a short (1/2 hour?) interaction with it at the beginning of the workshop as practice on the Mac, as an example of the utility of hypertext programs in education, and as a overview of information that is available to them. At the end of the workshop, a full review of the GISTutor would serve as a valuable review of some of the concepts covered. GISTutor appears to be more of a teacher rather than a student resource. Most of the topics are too detailed for the average student and many of the animations are too slow to hold their attention.

MapII also had a mixed reception. It has the advantage of being a cheap and fairly simple to use (though not always intuitive) raster package. What it gains in simplicity, it loses in being simplistic. It is not a very powerful system and its raster representation of some data sets may be hard for students to comprehend. Some of the teacher/consultants, especially those with Mac computers, could envision students using this package. Like virtually all packages, educationally oriented exercises would increase its utility. The teacher/consultants who managed to work through the demonstration materials were able to try some exercises developed for the demonstration data sets. They tended to find working on the exercises more valuable than learning how to change colors and adjust the size of the windows.

Atlas*GIS was more attractive at first to the teacher/consultants due to its vector representation. A soon-determined drawback was the limited nature of the marketing oriented data set of Manhattan zip code areas that was provided in the tutorial. Also the manual emphasized how to operate the GIS, but did not have the users work through a clear, mock project that would make their efforts meaningful. Despite its nice user interface, the package may be harder to use for students familiar with the Mac OS or Windows. Since the package costs a couple thousand dollars, it may be out of the range of most educators.

The relatively inexpensive IDRISI package received the most favorable comments. Since this package was designed for educational purposes, its features seemed more user friendly to the teacher/consultants. These perceptions were aided by a few factors. Preceding the use of IDRISI, a comprehensive demonstration of its capabilities was provided by a graduate student. Since it is a package for GIS education, exercises with accompanying data sets have been developed for it. The teacher/consultants used an African data exercise designed for classroom use by the NCGIA. This allowed the them to utilize the GIS power right away and to do their own analysis. Most of the teacher/consultants identified this as the GIS with the most potential. To use IDRISI, however, students will need an explicit set of steps and commands. It cannot be effectively "played with" like MAPII or Atlas*GIS, due to its more difficult interface.

Teacher/consultants only got limited exposure to ARCVIEW due to technical difficulties (i.e., it will not run on low power and limited memory computers; a 386 PC with 6MB RAM would be the minimum configuration.) ARCVIEW is not a fully operable GIS, but rather is a data display and query system developed to access data sets created in the powerful, but complex Arc/Info software. Despite not having all the features of a "full" GIS, ARCVIEW can powerfully manipulate the display of data. The teacher/consultants who were able to spend time with this software recognized this power and possible use of ARCVIEW in the schools (e.g., as a resource in the school library). ESRI, the company that created ARCVIEW and Arc/Info, is planning to develop ARCVIEW-based classroom materials. This should make the use of ARCVIEW more appealing to teachers.

In addition to these five packages, teacher/consultants used PC/Globe, PC/USA, and AutoMap. These programs are map–based data sets with very limited analytical capabilities and would not qualify as GIS packages. Many of them saw these packages as more amenable to classroom use than the GIS software and as potential lead–ins to the use of GIS software. They may be an example of the "face" that GIS packages will need to wear in order to be of practical value in a school setting. On the other hand, with their exposure to the powerful analysis capabilities of GIS, some teacher/consultants saw these packages as nothing better than expensive "electronic almanacs" or road atlases.

The teacher/consultants liked the session in which various GIS educational materials, accumulated by the NCGIA, were laid out for teacher/consultant inspection. They mainly appreciated being able to access address and other basic information about these resources. Many other potential resources were mentioned during the course of the workshop. The teacher/consultants noted that it would be helpful to have been given a directory of these available resources. In response to these comments, the SEP Workshop Resource Packet contains a list of available software and curriculum materials. (Palladino, 1993a)

Discussion & Planning

On the whole, teacher/consultants found the discussion times very helpful. Some sessions were more valuable to some teacher/consultants than others, but all sessions were identified by at least a few teacher/consultants as important workshop elements. Discussion sessions were split between whole group and small group activities. The combination of these two formats seemed to work well. It was especially helpful in project/lesson planning at the end of the week to spend time in small, same discipline groups. There were two groups of science teachers and one group of social science teachers. The two groups of science teachers were divided by level of computer use likely in their respective classrooms.

Teacher/consultants appreciated being exposed, in the “Computers in the Schools” discussion, to the range of computer use and availability in the various schools. It might have been more helpful to tie this discussion in with a more complete overview of GIS computer requirements. The “Course Placement” discussion showed that GIS could be adapted creatively to fit in many secondary school subjects, though science and social studies courses were the most obvious. This discussion helped some of the teacher/consultants realize that GIS had a greater potential than just a tool for a “geography or geology course”. The “Question and Answer” session with Dr. Goodchild was an appropriate follow–up to the short course. Teacher/consultants liked having an opportunity to have their GIS questions answered. They also appreciated the candid assessment of the minimum hardware requirements for GIS provided by Dr. Goodchild (see Hardware section below). The “Obstacles and Opportunities” session allowed the teacher/consultants to express their perceptions on GIS in the schools. In general, this open format discussion was appreciated.

The remaining sessions were mainly focussed on the teacher/consultants' use of GIS in their own classroom. They found the first activities, identifying specifically where in their own courses GIS would fit in and reviewing the outline of the lesson planning stages, very helpful in getting them into the planning mode. Following the incubation of ideas on the weekend, there were two planning sessions, "brainstorming" and "polishing". These small group work sessions helped the teacher/consultants narrow down and clearly define GIS projects that would work in their classrooms. A few teacher/consultants did find the second session a bit redundant, since they had their plans pretty well defined by the end of the first lesson planning session. Time was spent in a couple of the sessions trying to define a universal format for the lesson plans. It became apparent that with the broad scope of teacher/consultant projects and with the great variety in personal lesson planning styles, that a strict lesson format would not be feasible. Instead, we decided as a group to produce project summaries rather than matching lesson plans. Overall the time spent on lesson planning activities seemed adequate. Some teacher/consultants thought it was overdone. Many of the teacher/consultants, however, would have liked to have more time to access the university resources that were needed for their projects.

The teacher/consultants also gave other input that changed the course of some of the SEP activities. A prototype outline of an "Introduction to GIS Workbook" was presented to the teacher/consultants. They pointed out that the workbook was too focussed on teaching GIS rather than the use of GIS as an auxiliary teaching tool. Teacher/consultants brainstormed and came up with a plan for a resource that would introduce GIS into a variety of courses. The working title of this resource was "GIS City". It would encourage teacher use by having a set of pre–packaged activities that would fit into the existing curriculum of various courses. Teachers would use a set of overlays of various "GIS City" features and variables to teach concepts related to their current course content. Students would work through a series of worksheets using GIS analysis concepts to reinforce subject area learning, but at the same time would be slowly exposed to GIS. Support materials in the workbook would allow the teacher to expand the lessons to a more direct use of GIS concepts. Though the

SEP will not develop this specific resource, this teacher/consultant defined model helped clarify the types of GIS teaching materials that would be of value in the classroom.

The teacher/consultants gave excellent feedback in the verbal evaluation sessions, on the daily evaluations, and in the final evaluation form. This type of on–going evaluation was a critical element of the workshop. Not only did the teacher/consultant feedback meet the goal of providing the SEP with a baseline for GIS in the school efforts, but it helped us see the needs of the schools in a clear light and enabled us to change course in some of our activities.

General Workshop Evaluations

The teacher/consultants found the introduction to GIS technology, the demonstration of many GIS applications (showing the wide range of GIS use), the hands–on work with software, and the interaction among the teachers and workshop staff extremely rewarding. They liked the daily mix of activities and the organized structure of the workshop. Other positives were:

- the broad group of teachers (science, social studies, computers, and ESL)
- the openness to teacher questions
- the adequate time for discussion
- the small working groups for lesson planning and other teacher–teacher interactions (including eating lunch together)
- the trade magazines as evening reading
- the cookies and other treats brought in by the workshop participants.

As noted, the first days activities could have been structured to give teacher/consultants a better sense of what GIS was all about and how it related to them. Despite the attempts to foster a sense of partnership, a couple of the teacher/consultants still sensed a clear division between the teacher–students and the NCGIA–orchestrators. They would have liked to see the teacher/consultants more involved with planning the directions of the workshop. The Center appeared to have some pre–conceived plans for developing materials and was a bit slow in responding to the recommendations of the teacher/consultants. These teacher/consultants would have liked to be more involved in a joint project, rather than being the testing ground for the NCGIA's ideas.

Many of the teacher/consultants suggested that there be a specific project that the teachers would work on during the course of the workshop. The project would progress through the steps of creating a GIS application. The resource developed could then be used in the teachers' classrooms. Some parts of the project such as a data set and software package might be prepared ahead of time, but teachers should get the sense that they are the creators. This might ameliorate the feeling by some of the teacher/consultants that they did not have a great say in the outcome of the workshop. For this to work the project would have to be fairly simple, but would have the result of producing an active interest in the GIS information being presented. It would also give the teachers an immediate “result” that could be applied to their teaching.

Suggested changes to the workshop include:

- shortening the day by an hour, because many of the teacher/consultants reached a point of information overload and fatigue by the time of the late afternoon discussion sessions

- a shorter workshop (5 days?), but with some way of extending access to the university resources (perhaps some sort of follow–up, SEP staff supported workdays)

- a consolidated listing of data, software, and materials sources with basic information including addresses

- continued access to knowledgeable individuals after the workshop (perhaps some sort of working partnership between a teacher and a graduate student)

- show GIS as a tool for limited projects, not just large research activities

- clearer presentation of SEP goals for materials development and teacher/consultant projects.

Appendix B
GIS Short Course Topics

The topics covered in each two-hour session of the GIS short course are:

Session 1 - Introduction to GIS

- Core Curriculum (CC) Unit 1 - *What is a GIS?*
- GIS slides, videos, and other visuals
- Overview of the uses of GIS
- Discuss the ways GIS might impact the secondary school classroom

One of the criticisms of the first day of the prototype workshop was the lack of connection of GIS to the needs of teachers. Teachers wanted a broad overview of GIS and a justification of "Why it is important to them and their students".

Session 2 - A Foundation for GIS: Maps and Computers

- CC Unit 2 - *Maps and Map Analysis*
- CC Unit 3 - *Introduction to Computers*

Although these topics may seem to be too basic, they were of great interest to most of the teachers. Their knowledge on both of these topics will probably vary greatly from teacher to teacher, with the average level being quite low.

Session 3 - Raster GIS, Data Sources, Data Entry Methods

- CC Unit 4 - *The Raster GIS*
- CC Unit 5 - *Raster GIS Capabilities*
- Discuss various sources of GIS data (field sampling, remote sensing, reference and thematic maps, digital maps, databases, etc.) [see CC Unit 6 page 7]
- Discuss data entry methods (keyboard entry, digitizing, scanning, conversion of existing digital data, voice input) and challenges of developing a digital database [see CC Unit 7]

The level of depth that the teachers will be able to handle will vary depending on the group. Probably not all of this material can be covered in the two hours.

Some might have to be deleted. Some topics could be moved into the next session.

Session 4 - Vector GIS

- CC Unit 13 - *The Vector GIS or Object GIS*
- CC Unit 14 - *Vector GIS Capabilities*

In addition to covering vector GIS and finishing up any remaining information from session 3, any other "technical" issues that seem appropriate could be covered: more information on data (e.g., TIGER and census data, remote sensing, cadastral records), dangers of error introduction and propagation, 3-D data models (e.g., DEM and TIN), raster/vector comparison, GIS output options, etc.

Session 5 - GIS Applications, History, Trends, and Use in the Schools

- More GIS applications: Resource management, urban planning and management, cadastral records and LIS, facilities management, demographic and networking applications, etc.
- CC Unit 23 - *History of GIS*
- CC Unit 25 - *Trends in GIS*
- GIS in the Schools

In the first session, the teachers are introduced to the range of GIS applications. Now that they have had almost a week of interaction with GIS concepts and software, they should be able to handle more detailed discussion of various GIS applications. Some of the application areas are listed above. [For instructors with access to the Core Curriculum, there is discussion of these types of applications in Units 51-56.]

By the end of the week the teachers are more able to appreciate a quick overview of GIS history. Although this topic is optional, it provides an interesting example of the evolution and implementation of a modern computer-based technology. The discussion of trends in GIS can be augmented with more current "prophesies" than those in the three-year old Core Curriculum. A final topic, which may have been introduced at a more general level on the first day, is that of other teachers who have been exposed to GIS and have attempted some activities in the schools.

Appendix C
List of Acronyms

AAG - Association of American Geographers

AGS - American Geographic Society

BBC - British Broadcasting Corporation

CAD - Computer Aided Drawing/Drafting

CAI - Computer Assisted Instruction

CAL - Computer Assisted Learning

CD-ROM - Compact Disc Read Only Media

CPU - Central Processing Unit

DEM - Digital Elevation Model

DLG - Digital Line Graph

DMA - Defense Mapping Agency

DOQ - Digital Orthophoto Quad

EDEN - Environmental Data Evaluation Network

EDGIS - Any or a specific Educational GIS software package

EOSAT - Earth Observation Satellite Company

EPA - Environmental Protection Agency

ESL - English as a Second Language

ESRI - Environmental Systems Research Institute

ETLI - NGS Educational Technology Leadership Institute

GAHM - Great American History Machine

GENIP - Geographic Education National Implementation Project

GEP - NGS Geographic Education Program

GIS - Geographic Information System

GOES - Geosynchronous Orbit Earth Satellite

GPS - Global Positioning System

GUI - Graphical User Interface

HSGP - High School Geography Project

ILI - NGS Instructional Leadership Institute

IT - Instructional Technology

JEI - Joint Education Initiative

LIS - Land Information System

MB - Megabytes

MS-DOS - Microsoft Disk Operating System

NAEP - National Assessment of Educational Progress

NASA - National Aeronautic and Space Administration

NCGE - National Council for Geographic Education

NCGIA - National Center for Geographic Information and Analysis

NGO - Non-governmental Organization

NGS - National Geographic Society

NOAA - National Oceanic and Atmospheric Administration

NSF - National Science Foundation

OS - Operating System

PC - Personal Computer

RAM - Random Access Memory

SEP - Secondary Education Project

SFWMD - South Florida Water Management District

TIGER - Topologically Integrated Geographic Encoding and Referencing

TIN - Triangulated Irregular Network

UCLA - University of California, Los Angeles
UCSB - University of California, Santa Barbara