Chapter 6

Synthesis and Conclusions

Summary

The implementation and effectiveness of GIS has been analyzed from several perspectives, research methodologies, and scales. This research used a positivistic process-product approach to conduct a survey and experiments to describe the manner in which GIS is being implemented in the curriculum. This research also used a phenomenological interpretive approach to examine the experiences of teachers both nationally and within three high schools, and used ethnographic methods in the case studies. In this chapter, recommendations are made for schools to make more effective use of GIS technology from a critical theory and action research perspective. This research attempts to address what Lidstone (1988) said was missing in research, namely, that it failed to "make a direct contribution to classroom practice" (p 277) or "to the improvement either of geography as taught in the schools or education systems in general" (p 281).

This chapter summarizes why and how GIS is being used in the secondary curriculum in the United States, from the results of the national survey of teachers (Chapter 3), experiments in three high schools (Chapter 4), and the series of case studies (Chapter 5). The original research assumptions and hypotheses are analyzed to draw conclusions and implications about the application of GIS in education, including a final look at the case study teachers during the year following the experiments and case studies. This study then makes recommendations for specific groups and processes for the better use of GIS in education, for improving the present study, and for future research. Lastly, the future of GIS in education is considered, with conclusions about the implementation and effectiveness of both the technology and methods.

Summary of National Survey

As the title of this dissertation indicates, the implementation of GIS in secondary education is not confined to geography. The literature review indicated that geography teachers were not the only users of GIS. Indeed, the survey discovered that science teachers have adopted GIS in greater numbers than geography teachers, perhaps as a result of a history of better training in technology, computer access, and inquiry-based methods. GIS is primarily implemented within established disciplines, standard-sized classrooms, and in public schools, usually by a single teacher in a school who was typically trained at an inservice. Innovative activities that anchored GIS to community work and field work were repeatedly cited by survey respondents.

On the learning side, GIS was highly praised. From a teaching perspective, some challenges persist despite advances in software, hardware, and data. The national survey confirmed that despite the benefits praised by users and developers of GIS tools, the implementation of these tools lags far beyond its capability. While the lack of software support and inadequate computer hardware are technical challenges, more important are the lack of good inquiry-based educational models and training, ongoing training geared toward educators, and the lack of time to prepare GIS-based lessons. According to a 1996 survey of public school teachers by the National Education Association, secondary teachers have an average of five class periods a week for preparation (Zehr 1997). As a result of these challenges, implementing GIS is a complex process that often requires years of development.

Bednarz (1995) identified awareness, understanding, guided practice, and implementation as the four stages of GIS adoption in the classroom, and claimed that most American geography teachers were in the pre-awareness category. This dissertation research confirmed this statement. Eason (1993) identified five implementation strategies in information technology, ranging from "Big Bang," where the speed of change is fast and the opportunities for users to learn and adjust is low, to "incremental implementation" with the opposite characteristics. Educational GIS implementation is incremental—slow, but gaining speed, as indicated by the great increase in the number of teachers who have adopted it in the past year. GIS implementation seems to support Golledge's (1999b) statement that increasing the amount of research in geographic education and the geographic literacy of the population is "an extraordinarily slow process, framed within glacially moving educational organizations and institutions" (p. 8). GIS will play a role, but the general population will not feel its benefits for years.

The open-ended nature of GIS presents difficulties in educational use, but it is this same nature that attracts teachers to it. Despite the challenges, the small numbers of teachers who are using GIS are actively modeling reformist methods by tackling real-world problems alongside their students in an inquiry-driven, constructivist, exploratory environment. They consider GIS to be the best means of connecting their students with the community, with other disciplines, and with an improved thirst for learning. File management skills, database skills, and an implementable project were important predictors of GIS implementation, but equally important was the teachers' adherence to the constructivist model of education. These innovative, veteran teachers continually search for improved methods that will bring about enhanced learning. "I can't stand to use the same lessons each year," said one. Rather than a "gatekeeper" mentality that says, "I'm going to let my students use GIS only as much as I'm comfortable with it," these teachers claimed that "you don't have to be an expert to teach it." Sardo's (1982) findings that more experienced teachers spent less time planning, and tended to plan a week's worth of activities rather than the fine details of each lesson helps explain why GIS implementers tend to be veteran teachers.

Schools where GIS is most successful share several common characteristics. The faculty believed that technology was a way to extend the curriculum and support reform, teachers were involved in school-wide instructional decisions, staff development was supported with time and money, the staff were open to educational innovations, and they were familiar with the content standards. This supports the observations of Viadero (1997a), showing that while teaching with GIS has some unique concerns, it shares implementation issues with other educational technologies.

Summary of Experiments

Results from eighty-six tests from six experiments conducted in three high schools showed mixed results of the effectiveness of GIS on geography content knowledge and skills. GIS did not make a difference in the performance of most students on a spatial analysis or a standardized test. Few gender differences were found. Although GIS seems to be a more effective teaching tool because it is multidisciplinary, most experiments using the pretest-posttest design showed no significant difference. It is extremely difficult to isolate the effect of an inquiry-oriented approach such as GIS, particularly because students using GIS are learning skills that are not adequately assessed by standardized tests. GIS involves a changed teaching method, and these methods may not result in higher test scores.

Regression models showed that GIS usually *did* make a difference in the relationship between GIS and the difference in test scores from the beginning to the end of the semester. Furthermore, students using GIS demonstrated higher ability on a series of geography lessons, and average and below-average students appeared to improve more with GIS than above-average students. Because GIS-based lessons required more time for students to work through, time on task was increased, which may have positively influenced learning. GIS seems to foster both analytical thinking and synthetic thinking. It also increased students' knowledge of absolute and relative locations of features.

Scores on the spatial analysis test were lowest on the "evidence of content knowledge" criterion—students usually erred in their spatial analysis about where the fast-food restaurant could be located. This suggests that the conventional geography class may not provide adequate knowledge to employ skills that GIS supports, particularly spatial analysis. The lack of geographic skills was found to be a significant hindrance to student learning with GIS.

Summary of Case Studies

Case study research supplemented the experimental data with evidence that students using GIS make spatial connections more frequently and better than students using traditional tools, particularly those who perform at average and below-average level. The chief constraining and liberating factor influencing learning with GIS is not hardware or software, but the spatial perspective of teachers and students. While case study teachers exhibited an excellent spatial perspective and geographic background, most students lacked both, which hindered students' ability to use GIS effectively. They were unfamiliar with the problem-solving style of learning of which GIS takes advantage, and were uncomfortable with the postmodern way of teaching—there is no "grand theory," and the teacher often does not know the answer.

Students are more creative using GIS, partly because the software allows them that freedom, but partly because students are accustomed to working with computer-based tools in general. GIS provides students with a graphic model of the world with which to analyze patterns and draw conclusions. Working with this tool caused students to act as project managers.

Case study teachers adopted GIS because it introduces technology to the students and to geography, helps introduce the geography standards, and matches their constructivist teaching style. GIS increased ties that teachers had to their community, profession, and to the discipline of geography. Although each used GIS slightly differently, all were comfortable with technology and comfortable with the fact that not all students would learn exactly the same content and skills. Their enthusiasm for GIS and the content material modeled the lifelong learner for the students.

These case studies confirmed survey results that implementing inquiry-oriented learning with GIS can be difficult and time intensive. Although the computer lab manager's involvement was found to be critical, overall computer issues were secondary to the time required to create and maintain lessons and data, structure of the school day, school politics, and spatial thinking. GIS had a positive influence on student motivation not only for geography, but also for learning. Communication patterns and traditional roles of students and teachers were altered. GIS appeared to be effective with non-traditional learners. Students' acquisition of content and skills improved during the semester, but at different rates with different types of skills and amount of content knowledge for each student. The effect of GIS on learning was a shift from lecture and recitation to coaching, to small group instruction, to working more closely with weaker students, to assessment based on products and progress, and to cooperation rather than competition.

Lessons included authentic, challenging, multidisciplinary, and diverse tasks. Lessons emphasized generative knowledge—that which changes a person's perspective on the world—over inert knowledge—that which is known but does not make a difference in one's life (after Dede 1995: 8). Students were learning a process of examining problems rather than memorizing facts that they might later forget. Therefore, while learning with GIS offers unique challenges, GIS-based learning fits established models of educational reform.

Benefits of GIS in Education

The literature review, survey, experiments, and case studies all demonstrated that GIS has benefits to teaching and learning. GIS is an enabling and integrating technology.

Teaching

Teachers using GIS tend to be "loners" within their school but have established extensive networks for data (with the community), pedagogical implementation (with other teachers), and technical assistance (with other teachers and with GIS professionals). Teachers using GIS are active in their profession and believe in giving something back to the community, such as in conducting GIS summer camps for students (Baxter 1999). Because of the explosion in data availability, teachers using GIS have shifted from *covering* material to assisting students in *sampling* material, consistent with Menges' findings about teaching with computers (1994: 188). There is a shift from unilaterally *declaring* what is worth knowing to *discovering* what is important.

Learning

Geography emphasizes processes occurring in and across space and time. This process is constrained by traditional media. GIS serves as a catalyst for understanding the world and geographic phenomena in their complexity. GIS is used in education in ways that are not simply extensions of earlier practices, but in new ways. A greater range of geographic phenomena can be studied, and linkages with other disciplines can be investigated, not just talked about. GIS allows the world to be analyzed in multiple ways; for example, looking at a phenomenon displayed with an equal interval classification versus one based on standard deviations.

GIS prepares students to become active participants in society and the workforce. Students were observed to be developing the competencies recommended by the U.S. Department of Labor's SCANS Report (1991), including creative learning, decision making, problem solving, learning how to learn, collaboration, and self-management. A survey respondent described how one of his students, who trained EPA staff while in high school, became the manager of the college GIS within a week after starting there. These examples recur, indicating that GIS in education is not widespread but has lasting affect where it is used.

Lessons used with GIS are problem-centered, rather than fact-centered. Subjects are integrated. Teachers guide and motivate. Working together is prized. Students learn that there are many resources for learning, not just the teacher. Student success is measured not by reporting back on facts accumulated, but on solving problems and communicating ideas. The content is fast-changing, and students learn different content and skills at different rates. These characteristics illustrate the reformist nature of learning with GIS.

ESRI's (1998a) "GIS in K-12 Education" white paper summarized what were thought to be the benefits of using GIS in education. Each of these benefits is examined against the findings of this dissertation.

First, GIS can play a role in educational reform. This research found that GIS fosters reformist teaching and learning, but also that the environment of reform in education today is in turn encouraging the adoption of GIS.

Second, GIS is a vocational tool. While this benefit was not valued as highly as others, examples abounded of students achieving careers not necessarily *in* GIS, but *because of* the problem-solving skills they developed while using GIS.

Third, GIS engages and exercises multiple capacities and intelligences. Case studies showed that the technology benefited students with special needs and those who performed below average. It was unclear, however, that GIS is conducive to a variety of learning styles, since it relies so heavily on visual communications.

Fourth, GIS relies on and fosters a mindset of exploration. This technology was used with a variety of lesson styles, from step-by-step to open-ended problem-solving, but regardless of the lesson style, GIS fostered exploring a wide variety of cultural and physical phenomena, allowing the pursuit of "what if" questions.

Fifth, GIS relies on and promotes finding information and knowing what to do with it. This was also supported, requiring students and teachers to be comfortable with data gathering, management, and manipulation. This requirement is one of the chief reasons why many teachers are reluctant to use it. They often do not know what to do with digital spatial information.

Sixth, GIS relies on and promotes spatial awareness. Lack of geographic skills and spatial thinking limit the effective use of GIS for many students and teachers, but has opened new avenues of investigation for students and teachers with these skills and this foundation.

Seventh, GIS relies on and promotes computer literacy. Interviews and observations showed that GIS connects and makes effective use of technologies that are too often taught in isolation, such as presentation software, word processing, databases, spreadsheets, the Internet, paint programs, screen capture, file compression, and file transfer. Students using GIS often make use of GPS receivers, projection equipment, video cameras, digital still cameras, plotters, printers, and scanners.

Eighth, using GIS effectively requires knowing how to make the GIS software perform particular tasks. Teachers need ongoing software training targeted to educators, followed by technical support. Student exploration of GIS is enhanced by a foundation in GIS software, but could work through a variety of step-by-step lessons with minimal exposure to the software.

Challenges of GIS in Education

In 1992, Charlie Fitzpatrick, ESRI's K-12 coordinator, predicted that teachers would be the biggest users of GIS by end of decade (Fitzpatrick 1999a). While this prediction might eventually be realized, the lack of GIS awareness still remains the chief challenge. Most challenges stem from the same characteristics that make GIS attractive—namely, that it is the same complex, open-ended tool as that used outside of educational institutions. The subject matter is open-ended and can never be totally mastered. Teachers have the responsibility of applying this tool to the school setting. Teachers must integrate technology plans and content standards into everyday lesson plans. With GIS, they must develop the data set for the students as well as the lesson. In creating new roles and opening new approaches to learning, GIS increases the complexity of teachers' jobs. GIS analysis is anchored in geography, a diverse discipline, where many teachers lack adequate training in the first place.

The national geography content standards claimed that "Geographic information systems make the process of presenting and analyzing geographic information easier, so they accelerate geographic inquiry" (Geography Education Standards Project 1994: 45). This dissertation research found that students using GIS could analyze a vast amount of complex geographic information that would not have been possible to analyze without such a tool. However, acceleration of inquiry does not automatically follow. Teachers often lack the background in spatial thinking that geographic inquiry-based lessons require.

The constraints found in the use of GIS included many of the same constraints found by authors examining other computer-based technology—inadequate time, teacher training, and on-the-job support (Knupfer 1993; Pearson 1994; Schrum 1993). However, unlike software examined in these other studies, teachers using GIS did not characterize GIS software as inadequate, but were enthusiastic about its potential.

The challenges facing GIS implementation parallel the needs identified for other technologies—limited equipment, lack of training, no clear expectation that faculty will incorporate technology, lack of funds, lack of time to develop expertise, doubt about pedagogical validity of using some technology, lack of technical support, and the lack of appropriate materials (Barron and Goldman 1994). Furthermore, there are insufficient openings in the curriculum for GIS, unless teachers are given the freedom to incorporate it into existing classes.

In this sense, the educational implementation of GIS is no different from its implementation in government. Niemann and Niemann (1994) concluded that "the organizational, political, and human aspects of implementing GIS are far more difficult than the technical aspects" (p. 50).

Heavy demands on teachers' time discourage investment in learning any complex computer system. Computers and laboratories are expensive to create and maintain. School buildings usually are not designed for computer labs, much less a GIS lab with its associated high memory requirements and hardware. The school day is usually segmented into discrete time periods for specific subjects, which makes using any project-based, interdisciplinary tool problematic. To compound the matter, uncertainty surrounds the value of society's investment in the geographic information sciences (UCGIS 1998).

Few incentives exist for teachers who use technology, such as a recognition program, discounts on computers for their own use, free software, paid expenses for training, course credit toward certification, or connection from home through the school's network. In Colorado, the only incentive cited by over half of the respondents was course credit (Milken Exchange and the International Society for Technology in Education 1999). Over 90% of schools have access to the Internet, but only 18% posted information about their work to the World Wide Web during 1998 (Becker 1999), and very few GIS lessons are online.

Previous reform efforts sought to dictate what *procedures* educators should follow. Current reform efforts shift the focus to the *results* that their actions produce (David 1991: 39). Nothing dictates *how* teachers should use GIS, but this is precisely why it is difficult for many teachers to implement it.

Conclusions

Audet and Paris (1997) were curious about the optimal learning environments that support the interdisciplinary connections facilitated by GIS, and what implementation scenarios are the most effective for gradually transforming the curriculum.

This study provided generalizable data about the implementation and effectiveness of GIS in secondary education. The sample size of the national survey was sufficient to generalize to the population of all secondary teachers considering or using GIS. The experiments were replicable in other schools and classrooms. The research methods used—survey, experiments, and case studies—were appropriate for the research problem.

Assumptions Revisited

Revisiting the seven assumptions can be instructive in assessing whether the results of the study found them to be valid. The literature review showed a consensus among geography and non-geography educators, policymakers, and the general public that augmenting geography skills and knowledge of secondary school students is needed. Geography skills were viewed as an integral part of well-informed, lifelong decision-making by many of these groups. The national geography standards are valid criteria by which to assess the understanding of geographic content and the acquisition of geographic skills by secondary-school geography students. The study used standardized and other tests based on these standards. The literature review and the case studies illustrated the national attention on standards-based assessment.

The experiments showed that the geographic skills of secondary students as measured by the national geography standards could be objectively assessed by the administration of a series of pre-tests and post-tests. Teachers responded to the survey questionnaire, answered questions in the interviews, taught the lesson modules, and administered assessments in an unbiased and competent manner.

Similarly, students selected for the case study and experimental portion of this study answered oral and written questions in an unbiased and competent manner, although they were clearly biased against taking the spatial analysis test at the end of the semester, resulting in lower posttest scores. Finally, I did not bias the results of the experiments and case studies based on my presence in the classrooms under study. My presence undoubtedly influenced them all, and, I hope, encouraged students and teachers alike. However, I did not consciously influence one group over another in my comments during the case studies or in assessing the tests and assignments.

Hypotheses Revisited

Research results supported six of the original nine hypotheses. The hypotheses supported are as follows. First, social, educational, and political factors were found to be more important influences on implementing GIS technology in the secondary curriculum than technological factors. Second, implementing GIS tools in high-school curricula fundamentally alters the manner of teaching in the classroom. Research indicates that GIS did not change teachers' instructional philosophy, or style. Teachers who favor the analytical, problem-solving style using a variety of media are attracted to GIS. Once they use GIS, it does modify some of the methods and means by which they use to achieve the same curricular goals they have held all along.

Third, implementing GIS alters the manner of learning in the classroom, where students grapple with the same issues using the same tools as those in government and industry. Fourth, although their teaching philosophy and style usually did not change, instructional methods that teachers use with GIS are more closely aligned with the tenets of modern educational reform than methods the teachers used before the introduction of GIS. Certainly, teachers can use reformist methods without GIS, but GIS requires teachers to deal with unknown results in an exploratory, problem-solving, open-ended environment where the teacher is a facilitator of knowledge, rather than a dispenser of it. Fifth, GIS technology and methods are implemented in the secondary curriculum primarily through the efforts of individual teachers, rather than via a systematic, national educational agenda. Sixth, a greater amount of professional development and contact with the local community is associated with teachers using GIS than with teachers who do not use GIS.

Two of the nine hypotheses were not supported, and one was supported only in part. First, the introduction of inquiry-oriented lessons that use GIS tools and methods did not consistently increase the geographic skills as measured by the national geography standards of secondary-school geography students to a greater extent than did the same lessons that did not include GIS. Of the 87 tests conducted, only 18 showed that GIS made a significant difference. Second, female students using GIS did not demonstrate a greater increase in skills over the course of a semester than did male students using the same technology and lessons. Rather, few gender differences were noted. Third, the use of GIS strengthens inquiry-oriented, problem-solving skills, *but also* strengthened traditional locational geographic skills and knowledge. GIS does strengthen standards-based skills and encourage spatial analysis. Students ask geographic questions, and acquire and organize the information necessary to analyze and answer geographic phenomena. However, locational geographic knowledge was also increased, as supported by analysis of the standardized tests, GIS-based lessons, and classroom observations.

The Year After

An examination of the teachers and schools during the year following the case studies and experiments serves to test hypotheses about the institutionalization of GIS, observations about the characteristics of the teachers, and predictions about the future of GIS in education.

As expected, Mr. Stevenson maintained his use of GIS during the 1999-2000 school year, and was working with science teachers to expand GIS into watershed and water chemistry lessons. He was assisting Ms. Mu|oz with installing a new PC lab at the school that would allow him to use raster and three-dimensional analysis, and aerial and satellite imagery. Mr. Stevenson extended his GIS training efforts to numerous teachers across several school districts, as well as out-of-state tribal environmental officials and Native American educators. He co-wrote a technology grant with the author for software purchases and teacher training in middle and high schools across his own school district. This included social studies and science teachers in his own school, making the institutionalization of GIS at the school likely regardless of whether Mr. Stevenson left.

As reported in Chapter 5, Ms. Cessna left high school teaching to pursue a principal's license and a Ph.D. in Educational Administration, but remained a supporter of GIS in education. A second National Geographic Education Foundation grant was awarded to two school districts, including the district that Hope High School is a part. This grant trained other teachers at the school, including Ms. Eliot and two other social studies teachers, encouraging the institutionalization of GIS there. The computer support staff had not changed and were still supportive of the software.

As expected, political and computer difficulties at Prairie Vista continued to hinder Mr. Clark's GIS implementation. Despite new iMac hardware in the lab, he could not load *ArcView* software on them and had no technical support. In addition, the computers were ordered without floppy disk drives to prevent students from loading their own programs onto the computers, which blocked them from saving their GIS projects and data. In fact, things degraded to the point where midway through the school year, he had not been able to conduct one GIS-based lesson. He then moved his Technological Careers in Geography after-school class to the Computer-Aided Drafting (CAD) lab in order to be able to use GIS during the second semester. He remained dedicated to GIS, however. He was confident that he would be able to use it again in the future in a PC lab he planned to build with grant money he was seeking. However, GIS had not yet been institutionalized at the school.

These observations support the findings that indicated that GIS is much more likely to be institutionalized if more than one teacher at the school is using it. They substantiate the importance of computer support staff and confirm the dedication of teachers using GIS to the merits of this technology.

Implications of This Study

This study has implications for implementation, training, learning, equity, and educational reform.

Implementation of GIS in the Curriculum

Teachers' commitment to geography, technology, and education encouraged the initial implementation of GIS in the case study schools. Content standards and grants for equipment and training ensured its eventual institutionalization in two of the schools. School politics was the chief reason it was not institutionalized in the third school. The implications are that all of these factors are important in determining whether GIS will be adopted.

With very few exceptions, the institutionalization of GIS does not change the curriculum across the entire school, but does alter learning for the typical 5% of the students who take classes where GIS is used. However, perhaps there is some advantage for teachers using GIS to be "loners" in their schools. If they have fewer constraints on their work, they are free to experiment and develop the lessons and framework for others to follow. Still, in order for GIS to spread, these teachers must influence the leaders in the school system.

During 1999, I polled the 32 teachers who had participated in the first national institute on GIS the year before. Six teachers had changed schools since the institute, bringing GIS with them in all cases, illustrating their dedication to this technology. However, GIS continued in only one of the six schools that they left behind. Clearly, teaching with GIS has not become institutionalized; it relies on a teacher to act as the driving force. In the words of one of these teachers, "there are so many other agendas—without someone pushing the GIS agenda it will probably get buried."

The principal of Bishop Dunne High School in Dallas, Texas, Kate Collins Dailey, has a background in geography and has ensured the institutionalization of GIS in her school. However, this study found that bottom-up approaches are much more common and effective. Literature on GIS implementation in local government (Masser et al. 1996) shows that projects typically fail because of the inability to transfer the technology effectively to the end user. In schools, the "end user" is the teacher. Teachers adopt GIS only if they believe that it meets their goals and matches with their teaching philosophy, values, and beliefs. In most schools, GIS has not been institutionalized because teachers and administrators do not view GIS as being instrumental for meeting curricular goals.

These observations match Nedovi -Budi 's (1998) framework for determining the likelihood that an individual would become a GIS user. Teachers' attitudes were more important than a perceived technological or economic benefit to using GIS. Teachers are more likely to adopt if they perceive GIS technology as relatively advantageous compared to current practice if they have experience with computer technology, have a positive attitude toward work-related change, and have active communication and networking skills. Teachers, like the government users examined by Nedovi -Budi , need an opportunity to *try* GIS in a training session.

Zahorik (1975) investigated the decisions teachers made prior to teaching and the order in which they made them. The kind of decision mentioned by the greatest number of teachers concerned pupil activities (81%), implying that the lack of GIS-based lessons has a detrimental effect on GIS implementation.

Training

Comparing teachers examined in this study to Binko's (1989) four stages to learning—awareness, understanding, guided practice, and implementation—most teachers have not even reached the awareness stage. Repeatedly, teachers mentioned that they "became hooked' on GIS once they became aware of its potential, and their activities after implementing it demonstrate their dedication. Awareness seems to be the largest obstacle to implementation. The implication is that nonadopters have to be convinced to attend training if GIS is to continue to spread. However, training does not guarantee that a teacher will use GIS—"you either get it or you don't," said one teacher who trains others. A likely indicator of whether a teacher will use GIS is if they have a problem-solving approach undergirded with the geographic perspective.

Results of this study imply that preservice education should include technology, geography, and GIS. Bednarz (1999) recommended that teachers be taught with GIS in the same manner as they will teach their students, with real world problems to experience how this model of learning works. This study implies that GIS is not likely to be incorporated into many preservice education programs anytime soon. Geography as a whole suffers from a lack of preservice training (Boehm et al. 1994), and the literature review showed that applied technology training is also lacking. This is precisely what educational authors (such as Barron and Goldman 1994) have argued—teacher training programs should not teach *about* technology, but *use* technology throughout their programs.

Bednarz and Audet (1999) went so far as to state that "until consensus is reached that GIS has a role […], then we will continue to see a directionless patchwork of [teacher training] programs" (p. 66). Without an effective preservice component, GIS implementation will be confined largely to inservice training, which will keep the implementation rate slow.

Learning

GIS, along with other inquiry-based tools, is contributing to a re-examination of the learning process, the nature of knowledge and instruction, and how curriculum development and assessment should take place. GIS blurs the distinction between teaching and learning in and out of the classroom.

Learning with GIS implies that achieving understanding does not simply depend on gaining content knowledge, but upon higher-order knowledge and skills (consistent with Perkins et al. 1995). Learners need to know how to solve problems in order to make sense of information and apply it appropriately. Students also need epistemic knowledge, or knowledge of the "rules of the game," particularly with a complex tool such as GIS. There is value in requiring students to "dig out" information, rather than simply giving them the information, forcing students to make the relevant connections with their own knowledge and the content to increase understanding.

Learning with GIS implies that the teachers' role is still critical to learning, to provide goals and guidance. Otherwise, untargeted tinkering with the system is likely to increase computer and data skills, rather than meeting content goals. GIS has the power to help teachers without a geography background to teach the subject because of the difficulty of developing spatial analysis-based lessons with paper and pencil. The finding that GIS benefits below-average students implies that it should not be confined to the best students.

GIS supports teachers who want to stimulate students to invest in their own learning in an exploratory mode. This requires a philosophy of teaching that is aligned with the philosophy of GIS. In order for teachers to want to use GIS, the research clearly shows that they have to see it, participate in it, and then try it in their own classroom. Reform-based science curriculum materials have a role for assisting teaching in putting their beliefs into practice, if their beliefs are aligned with the framework of the program. For those whose beliefs are not aligned with the materials, the innovative nature of the curriculum seems to initiate questions, struggles, and some experimentation with new practices (Powell 1999).

Equity of Skills and Perspectives

GIS does not appear from this research to enhance the inequities in schools found by authors examining other computer-based instruction (Anderson et al. 1984;

Harrell 1998; Kirby and Styron 1994; Pisapia 1994; Webb 1986). However, as Clark (1989) noted, the benefits of information technology are neither free nor cheap. GIS may narrow the types of skills necessary for success because it forces students to use graphics and computer technology. Although GIS breaks down some barriers, it can create new kinds of barriers in using the software and developing lessons. Furthermore, empiricism forms the intellectual core of GIS (Taylor and Johnston 1995), making it difficult to use non-empirical data.

This study showed that GIS was not taught from the behaviorist perspective, in which knowledge and skills are assumed to have meaning independent of context and culture (Guba and Lincoln 1994). Rather, constructivist methods predominate, where learners analyze, inquire, and solve problems, building up their own hypotheses. However, GIS does have similarities to behaviorism in that the material is broken down into small, discrete instructional steps, sequenced for increasing difficulty. It also may be somewhat positivistic, because it models earth information as a series of discrete layers.

Because it is built on a specific model of the earth, GIS limits and affects a user's worldview (Goodchild 1992). Technology plays a crucial role in prescribing the types of research that may be feasibly explored (Veregin 1995). This implies that while GIS is liberating, it is also constraining. More studies need to be conducted with the goal of reducing these limitations.

Rogers (1995) grouped individual adopters into five categories regarding their innovativeness: innovators, early adopters, early majority, late majority, and laggards. Socioeconomic status, personality variables, and communication behavior influence the appropriate category. Teachers using GIS today are all "innovators," and these three items did affect their use of GIS. While GIS was found in a wide variety of schools, hardware and software remain beyond the financial reach of many, indicating that socioeconomic status still plays a role and that inequalities among schools may increase. GIS analyst Berry (1999) observed that "the future has already happened, it's just not evenly distributed." Differences in student and teacher background, school structure, and philosophy implies that not all schools could implement GIS, even with sufficient hardware or software.

Other Technology

This study indicated that teachers using GIS use a variety of other computer and non-computer-based media. The Internet is another new educational tool with tremendous potential for inquiry-oriented education, particularly with its accessibility to real-time, real-world data that can be input directly into a GIS. The Internet's began as a teaching tool in secondary and college curricula more recently than did GIS, yet it has expanded much faster. This implies that Internet tools are perceived as simpler to use than GIS tools.

Lessons

Douglass (1998) states that as long as school personnel rely on using instructional materials created by those outside the classroom, then we should not expect much improvement in geographic learning, since they may perpetuate traditional but narrow and unacceptable views of the nature of geography. The implication for GIS in education is that because teachers (as well as teacher trainers in GIS software companies or research organizations) are developing the lessons, we *should* expect that they will improve learning.

Educational Reform

This study implies that GIS implementation cannot be effective without reform, and that reform can be expedited by GIS implementation. Technology *is* a key component of reform.

Technology lends itself to exploration. Before technology can be used effectively, schools need to value exploration as a valid way to teach and learn. Educational technology is not a passing fad, but can be a way to enhance teaching and learning.

The renaissance of geography education implies that as geography skills among both students and teachers improve, the use of GIS will become more effective. Effective GIS will also be enhanced as more teachers use computers for exploration.

Recommendations

In this section, recommendations are made about how this dissertation research could have been improved, the agenda that future research should take, and what needs to happen for educators to take full advantage of the potential offered by using GIS in their classrooms.

Recommendations for Improving This Research

Improving the National Survey

The survey questionnaire seemed clear to the respondents—respondents asked for little clarification, and an acceptable 28% responded. The high percentage of respondents who filled out the four essay questions demonstrated the interest that most teachers have in GIS, even if they are not presently using it. I addressed the chief criticism of the pilot reviewers—to simplify the human research release form—

to the greatest extent allowed by the university. The questionnaire could have more effectively addressed the research problems with several minor modifications. Several respondents returned the questionnaire without filling it out, indicating that they were not using GIS at the present time. A questionnaire focused on a certain type of software is not of much interest to someone not using that software, so it is difficult to increase the response rate for these nonadopters. One of the goals of this research was to discover *why* these teachers, who obviously were aware of GIS, were not using it. Perhaps adding the following sentence to the cover letter might have generated a few more respondents: "If you are not using GIS in the curriculum, please fill out the questionnaire anyway—we are interested in what makes its implementation so challenging."

The question (# 6) on the approximate student-to-computer ratio in the class could have been broken into two questions reflecting the two situations that most teachers encounter. Teachers typically have one or two computers in their classrooms, but have varying degrees of access to the school's computer lab where the ratio of students to computers is much lower. The question could have asked the ratio in both the teacher's classroom and in the computer lab. However, the question that did appear in the survey (asking how *many* computers were in the lab and classroom) was helpful to compare the relative numbers of computers between schools to assess the effect of any differences on the implementation of GIS.

The survey contained a question (# 9) on "How were you first trained in GIS?" Because some respondents wrote "I have not been trained", "not trained" should have been listed as a choice. Then, the respondent could have skipped "where were you first trained in GIS?" if the "where" question were moved to follow the "how" question. "I trained myself" should have been listed as the first choice in the list for greater clarity. The word "formal" should have been dropped from question (# 10) on

“How many total hours have you spent in formal GIS training classes?” A few teachers did not understand what was meant by “formal”—perhaps thinking that these classes had to be through a university or a GIS software vendor.

Teachers were asked to describe their use of GIS during the current semester (# 15) by circling a number on a continuum. The continuum ranged from “I do not use GIS at this time and have no plans to do so” to “I use GIS in more than one lesson in more than one class.” Results that more closely matched the research goals might have been achieved if the second choice, “I am planning to use GIS” had been rephrased as “I am not using GIS now but am planning to use GIS in a future semester.” A teacher planning to use GIS in a lesson *during the current semester* might have selected this choice, when they should have chosen, “I use GIS in one lesson.” In other words, teachers who plan to use GIS “someday” are on a very different point on the implementation continuum than teachers who have plans in place to use GIS in one or more lessons during the current semester.

Teachers should have been asked to list the other educational technology they use in the classroom, to confirm what was found in the case studies—that these teachers use a variety of multimedia, not just GIS. If this question were asked, the survey would have exceeded the goal of the maximum length—three double-sided pages. Questions on the subjects taught and the subjects in which GIS is used could have been combined into one question with two columns to maintain the survey’s original length.

Finally, the question where teachers are asked where they are running their GIS (# 26) should have included an “other” option, so that teachers could have indicated the library or other location not included in the question.

Improving the Experiments

To understand the effect of background variables on learning and using GIS, students could have been given a questionnaire about their learning style, previous geography and computer instruction, and the amount and purposes for which they used the computer per week.

The spatial analysis test design left several items unconstrained, making it difficult to interpret. The test was given on paper, making it problematic to argue that it was GIS technology that affected these geographic analytical skills. Students could have had a good grasp of spatial analysis, but misunderstood fundamental geographic concepts, and scored low on the test. For example, students could have confused zoning with land use. The test did not have a single correct answer, but several answers were clearly incorrect. An additional criterion for scoring could have been established to distinguish scores for a correct justification for a correct answer (showing the student understood), an incorrect justification for a correct answer (showing a guess), a correct justification for an incorrect answer (confusion), and an incorrect justification for an incorrect answer (the student clearly does not understand). Restricting students to a set of choices would have better distinguished between correct and incorrect answers. Students could have been given a choice of three possible sites for the Spiffy's: a clearly correct answer, a clearly wrong answer, and an answer that is ambiguous, requiring them to select the data layers they found important. A correct answer could then be distinguished from an incorrect answer, and incorrect justifications could be identified, for example, by a student prioritizing data from a layer they did not use. Last, I could have given students a final open-ended answer to indicate if they had questions or were confused by any data layers.

When the spatial analysis test was reproduced at Hope High School, the number of gray tone gradations visible on the maps was reduced, making it difficult to determine the difference between industrial and commercial land use, for example. All choropleth maps should have been created with patterns instead of gray tones to avoid this problem.

Lesson evaluations were based loosely on the national geography standards. This evaluation could have been made more rigorous, to evaluate each response against the 18 content standards and four geographic skills. Different tests would have had to be created, however, because it is unlikely that an assessment that more rigorously adhered to the standards would have influenced the results of the experiments. The recommended National Assessment of Educational Progress (NAEP) matrix of assessing both the cognitive and content dimensions of learning (Salter 1992) provides a framework for understanding the effect of GIS (Table 6.1). In the matrix, “knowing” means what and where something is, “understanding” means why it is there, how it got there, and its significance, and “applying” means how knowledge and understanding can be used to solve geographic problems.

Table 6.1. National Assessment of Educational Progress Assessment Matrix (from Salter 1992).

Cognitive dimension	**Content Dimension**		
	Space and place	Environment and society	Spatial dynamics and connections
Knowing			
Understanding			
Applying			

Improving the Case Studies

Teachers in the three high schools were observed during the year of the experiments and also interviewed the year after the experiments. Observing teachers during the semester before the advent of GIS in their school would have provided a good supplement to the interviews that sought to discover if GIS had changed their teaching methods.

Students were provided the opportunity for metacognition, to reflect upon their own learning, during the class interviews that the Hope and Prairie Vista teachers allowed me to conduct. Expanding these interviews to all classes in the case study might have provided additional insight. To supplement the end-of-semester written surveys, students should have been given the question, “Describe what GIS means to you, and your experience of using GIS in this class.”

Recommendations for Future Studies

In large part, the development and diffusion of GIS education in secondary education has been occurring independent of pedagogical theory. While the spread of GIS in education has not been as rapid as other technology, it has outpaced a gathering research base. Additional research is essential to ensuring that GIS will be used for the best possible enhancement of teaching and learning.

In describing the infusion of computers in the schools, Lockard et al. (1990) emphatically called for more research:

> “No other episode in the history of American education allowed so much money to be spent for anything with so few questions asked, so little known about the implications, so little thought given to implementation, and ultimately, so little expected in return” (p. 360).

As discovered in the literature review, GIS research is a small subset of existing research on computers in education. While this dissertation provides some insight on effectiveness and implementation, much more is needed.

Time , Place, and Scope

This research examined schools over one academic year, with a glimpse as to what happened during the following year. To understand if and how the changes from GIS became institutionalized, a longitudinal study of the same schools should be conducted. This study examined high schools where GIS had been recently implemented. A comparison of these high schools with those where GIS has been implemented for 5 or 10 years would help assess the effect of long-term use on the school culture, teachers, and instruction. Data on how long a school has been using GIS have already been collected and could easily be used to select these schools.

The surveyed population of teachers could be re-surveyed in the future, to determine whether and why the non-adopters have become adopters of GIS, whether those who once used GIS are no longer using it, and to discover if the reasons for acceptance and rejection change over time. Teachers should also be asked, "has GIS changed *how* and *what* you teach?"

Students should also be studied longitudinally. None of the students examined had any prior experience with GIS. Studying the Grade 9 students throughout their high school careers would determine if GIS made a lasting impact. Students across the country who have used GIS in secondary education are now in colleges and universities. They could be surveyed to determine whether their experience with GIS had an influence on their college major or choice of career.

A study of elementary, middle, and university school students using GIS would allow for comparisons of needs and implementation barriers and catalysts across grade levels. Furthermore, comparing how states support technology, science, and geography versus the amount of GIS implementation in those states' schools would determine the influence of state standards, support of technology, funding of education, and other factors. Despite the time-consuming nature of creating equivalent GIS and non-GIS based lessons, more experiments with improved assessment measures are needed.

In the United Kingdom, the Statutory Order for the teaching of geography to children between 5 and 14 years of age made geography one of the 10 subjects in the national curriculum (Binns 1993). GIS has been included in the national curriculum since 1991 (Department for Education and Science 1991: 48). The USA's counterpart, the National Geography Standards, does not have an associated scope and sequence that specify what, how, and when geography is to be taught. A multinational study of GIS in education would uncover the effect of a national curriculum and other political and structural factors on the implementation of GIS that may be instructive for formulating policy.

This study showed that schools are widely scattered along an implementation continuum. A study that compares student learning to the amount of GIS implemented in the school would aid in pinpointing the effect of GIS on that learning. It would also provide information on how and why levels of implementation shift over time.

Learning

Research needs to be conducted to determine the goals, assumptions, and uses of technologies in classrooms, and the match or mismatch of these uses with the principles of learning and the transfer of learning, according to the National Research Council's Committee on Developments in the Science of Learning (Bransford et al. 1999). The literature review, case studies, and experiments made it clear that some students worked with GIS much more effectively than others. Research is needed that examines the learning styles that GIS best accommodates, why these styles are most effectively accommodated, and what can expand the tool's benefits to a wider group of students. Both cognitive-developmental work and work on understanding of place representations show that cognitive prerequisites are often not in place at specific ages (Downs and Liben 1991; Liben and Downs 1989 and 1992). Children and adults have confusion about fundamental representational and spatial concepts upon which an understanding of GIS rests. Liben (1994) cautioned that GIS should be used as a means to develop underlying cognitive skills, rather than assuming that students will already have these skills. This would provide insight to when and how students learn with graphics and maps (see Blaut 1997; Downs, Liben, and Daggs 1988). Curriculum must "develop broad cognitive skills on which map […] understanding rests" and "develop a deep understanding of maps and the skill to use them for multiple purposes" (Downs and Liben 1997: 164). Audet's (1993) sequencing of GIS-based curriculum based on cognitive psychology could be built upon and tested. At a time when geographic skills are increasingly cited as essential for the literate citizen, further exploration of the educational implications of GIS is opportune.

Affective studies could address whether GIS changes values and attitudes about computers, geography, and education. Why is GIS attractive to some students, and what can be done to capitalize on the increased motivation observed during the case studies to enhance learning? Liu and Johnson (1998) found four computer attitude variables (enjoyment, motivation, importance, and freedom from anxiety) and three environmental variables (computer access, a helper, and a requirement to use computers for assignments in other classes) to be important determinants of whether students would use computers effectively in the classroom. These variables could be used in an *affective* analysis of GIS in education.

GIS education research needs to be more closely tied to how students learn with analog and digital maps. This research should include the Piagetian tradition, emphasizing the personal construction of knowledge, and the tradition of Vygotsky, who emphasized the social process in construction of knowledge.

The survey and case studies demonstrated the large number of functions that are used in GIS-based lessons. Different cognitive processes are required for buffering, reclassifying, merging tables, overlay analysis, and creating a final map layout. Each process could be categorized and analyzed to determine which ones were most effective in teaching and learning content and skills. The results would help teachers and software developers to know which to emphasize for further development.

GIS proponents cite group work as one advantage of adopting the tool, which was supported by the national survey but not the case studies. Comparing the performance of groups to individuals would add to the existing body of knowledge (such as Webb 1995) about how groups perform with and without technology on similar tasks.

The difference between effect of GIS and the effect of the computer was not clear from this study. Future research should compare control groups that use the computer versus experimental groups that use GIS, despite the difficulties in creating a lesson on the computer that emulates GIS but uses a different type of software.

Teachers and Parents

Research needs to expand on the reasons teachers choose and reject GIS. "If change is to occur in the nature of geography teaching practice, it is essential to establish and explore those factors that influence teachers' choice of teaching style and the use of methodologies" (Ballantyne 1992: 277). The benefits and challenges uncovered in this dissertation research could be used as a framework for expanding research on teachers' thought processes (summarized by Clark and Peterson 1984).

Many secondary geography teachers are ill-trained in technology. Research that examines the influence of technology on geography teaching would provide guidance for designers of university preservice education programs and would influence future GIS implementation.

Many secondary geography teachers are also ill trained in geography. Case study teachers were all well trained in the theory and methods of geography, which positively and directly influenced their implementation of GIS. A study that compared well-trained teachers with those without such a background might improve future preservice and inservice education.

Research on the difference between experienced and novice teachers (such as Fogarty et al. 1982) should be used as a basis for examining why veteran teachers use GIS more than novice teachers, and if the way they use it is different than for novices.

Considering parents would provide additional insight about the factors leading to successful GIS implementation. Anderson (1995) found that some parents and students resisted educational reform efforts, particularly those in higher socioeconomic levels. Anderson called this the "preparation ethic"—many parents believe that covering breadth, not depth, is essential to prepare their children for elite colleges.

Organizational Change

A distinctive organizational culture—the set of values shared by a group—was noted in teachers using GIS. Few in number, they share a motivation and enthusiasm for GIS that is akin to a "mission"—ensuring that it is effectively used in their own school and in other schools and disciplines. GIS may not be changing the culture of the entire school, but it changes the culture of these teachers' classrooms into an inquiry-based learning laboratory. Studies have shown that implementing GIS changes organizations (Brown 1996; Campbell and Masser 1995; Nedovi - Budi and Godschalk 1996; Wegener and Masser 1996). If research from an organizational implementation perspective was conducted on schools, knowledge gained about the organizational culture of a school and school district might encourage effective technology implementation policies.

Contrasting GIS-based learning to Internet-based learning may further explain why GIS implementation has been slow by comparison.

Equity and Gender

This study found that GIS is being used largely in the traditional secondary curriculum in public high schools, rather than in private schools and special programs. GIS was also found to benefit special education and below-average students. Even so, possible inequities with GIS should be investigated from an action research perspective of eradicating them, including how to enable teachers and students having a variety of instructional and learning styles to use the tool effectively.

While this study did not find many significant gender differences in using GIS, further research is needed to fully answer the question. GIS modules are reflective of the worldview and interests of teachers who designed them. The influence of the gender of the teacher's gender on the amount and type of GIS implementation should be addressed.

Most researchers and practitioners agree that technology is not value-free (such as Veregin 1995: 91). Friebertshauser (1998) warned of being "seduced by the software and giving the appearance of using it while not really using it effectively." The computer imposes limits on what the user can think and do, by influencing ways in which problems are selected and the techniques and models brought to bear on those problems. Computers open up new vistas and close off others from view. I observed a tendency for students using GIS to forget about non-GIS resources, such as the library, when addressing a problem. Inequities in access and skills need to be examined. Furthermore, empirical analyses with GIS do not address the non-empirical structural forces such as capitalism and racism, so students may not be aware of them when they explain patterns.

Disciplines

This study emphasized geography in the case studies and experiments, but as Appendix A.5 indicates, teaching with GIS touches on other content standards. These other standards should be used as bases for additional studies, beginning with science, the home discipline for the bulk of GIS-using teachers.

Software and Custom Interfaces

This research focused on off-the-shelf commercial software packages used in schools. A number of educational projects are underway that create graphical user interfaces specifically for students, such as the GEODESY project (Radke 1999), TERC's Visual Earth, built with *Map Objects Light* software from ESRI, and *Urban World,* which uses *Avenue* programs to modify the ArcView interface (Thompson et al. 1997). *ArcVoyager* was created as a GIS learning tool. All of these were created because the full graphical user interface (GUI) is considered complex. No research has yet compared the effectiveness of using a full GIS package versus a modified interface. Furthermore, few studies (Wardley 1997 being one exception) have compared various commercial GIS software packages in terms of their educational effectiveness and implementation.

Recommendations to Realize the Potential of Educational GIS

> "Geography education stands at a crossroad[s]. It can embrace GIS and use it to demonstrate that the discipline of geography is absolutely undeniably indispensable to education for today and tomorrow. Or it can ignore GIS, let the technology be considered in the province of other disciplines, and risk for geography an ever-diminishing educational presence" (Fitzpatrick 1999b).

Because this study employed survey, experiment, and case study methodology, it required two research approaches: positivist and interpretivist. In the positivist approach, this research set up the survey and experiments to objectively test hypotheses about implementation and effectiveness of GIS in high schools. In the interpretivist research tradition, case studies were conducted to discover what it means to use GIS in the classroom and its effect on teaching and learning. By intervening in the case study classrooms to bring about positive change in geography teaching, this research contains small elements of action research methods. Action research is "small-scale intervention in the functioning of the real world and a close examination of the effect of such intervention" (Cohen and Manion 1989: 217). A critical theory approach will now be used to recommend what *should* be done with GIS in the schools, beyond the lists of future studies recommended in the prior section. Because of the costs involved, a thorough consideration of the technology=s advantages and disadvantages is essential before teachers and school districts will consider adopting GIS.

First, to further the implementation and effectiveness of GIS in secondary education, the research advocated in the previous section needs to be conducted. In particular, additional experiments need to be conducted to understand how students learn with GIS.

Second, as Bettis (1997) pointed out, there are few nationally available valid and reliable assessment instruments aligned with the K-12 national geography standards. I recommend that professional teacher organizations such as GENIP and NCGE create these assessment instruments. This is particularly important as government initiatives, universities, research and development institutes, software companies, and individual teachers replace textbook companies as primary content providers. Developers and teachers should clarify the educational goals in the subjects for which GIS will be used. This would form the foundation for subsequent planning, development, and implementation. The standards provide one foundation upon which to set these goals.

Geographic understanding is essential for citizens to make wise decisions in today's technologically, politically, and economically interconnected world. Geography uniquely contributes to students' acquisition of the kind of knowledge that helps make sense of other information. I believe that the geographic perspective is in such high demand in part because of the success that GIS users and organizations have had in solving problems over the past 20 years. The geography community should seize this opportunity to provide leadership in training the educational community in a tool so important to its own discipline. I recommend that teaching with GIS be used as the primary method of integrating geographic thinking into other disciplines.

The plethora of geographic information available in digital form on CD-ROM and from the Internet from businesses, nonprofit organizations, and government agencies has left many teachers confused about the utility of different spatial data sets. Guidelines are needed to develop criteria to help teachers sort through these data, as advocated by Thompson (1997). Teachers will then be better able to critically assess which resources are valuable for teaching concepts illustrated by the national geography standards through a GIS. Instructional goals, rather than the data that are available, should guide the curriculum.

Participants in this study repeatedly mentioned the need for training. Case study teachers were observed to use the data on CD-ROMs that they have been personally shown in a training event. I recommend that teachers be the focus of training efforts, rather than administrators or students. The implementation of some technology failed in the past because it did not focus first on teachers (according to Dede 1995). Gaps in the spatial distribution of teachers using GIS should be used to determine the location of future training events. This study indicates that investing in training is more important than developing data sets or CD-ROMs.

This study found that networks teachers establish are strongest among teachers who have attended the same GIS training event. Teams of teachers from the same school should be encouraged to participate, because this study showed that these teams increase the likelihood for GIS implementation. I recommend that ongoing training and technical assistance support these teachers, ensuring as high an implementation rate as the participants in the First National GIS Institute demonstrated. Partnerships among universities, government agencies at all levels, GIS users, state education agencies, GIS software companies, private research groups, school districts, and professional societies in math, science, technology, and geography are critical for tackling this huge training task.

Ongoing assistance for trainees would help ensure that the tool is used according to a constructivist model, rather than a glorified way of printing maps. This training should not emphasize the training of people to operate machines, but rather should focus on helping teachers integrate the technology for better learning. We need to ensure that the information avalanche or the processes of technology do not compromise the standards-based knowledge and skills that students must master.

Geographic educators desiring to use digital geographic technology face two choices: a steep learning curve in a generic GIS package that may not be suitable for education, or resigning themselves to a digital map program that offers no analysis. To bridge the gap, educationally-based curriculum materials need to be developed with an easy-to-use GIS package capable of performing robust spatial analysis and problem-solving techniques. Participants in the educational GIS conference recommended lesson development as the top priority (Barstow et al. 1994). This research demonstrated that a set of instructional modules using the national geography standards and GIS tools can be developed for use in secondary education. The library of GIS-based lessons needs to be expanded to include more grade levels and disciplines.

GIS awareness initiatives are needed to help teachers consider the value of GIS on an informed basis (Barstow et al. 1994). Textbook publishers need to include references to GIS. Articles should be written for educational journals representing a variety of disciplines, on the Internet, and in the newspaper.

University-level geographers and educators need to use GIS to teach some of their course content, to model teaching with this tool to students who will later become inservice teachers.

Agricultural education and 4-H programs have a history of the problem-solving approach, scientific inquiry, independent learning, self-teaching, and higher-order thinking skills. These and other programs following this model should be examined with the aim of transferring their implementation success strategies to educational GIS.

Finally and perhaps most importantly, I recommend that the approach to GIS should not be, “How can we get GIS into the curriculum?,” but “How can GIS help meet curricular goals?”

The Future of GIS in Education

This dissertation assessed the implementation of GIS at a time when the technology and its use was rapidly changing. The following section considers forces and the state of implementation of GIS in the schools likely to result from those forces.

Technological Developments

Developments in data, software, and hardware will continue to exert a positive influence on the future of GIS in education. Improvements in data availability and ease of use are gradually transforming effort from getting the information to analyzing the information. One teacher reported that in 1990 he paid $4200 for a geographic address database of Detroit, when it would cost a fraction of that today and be more easily manipulated. It took me one month in 1993 to process a Census TIGER file for a single county to a point where I could analyze it in a GIS. Now, I am able to bring the same file from the Internet to the analytical stage in a GIS software package within 20 minutes. Easier-to-use interfaces described in this chapter may encourage those who have not adopted GIS to do so.

I believe the Internet will have more influence on educational GIS than any other influence over the next several years. Internet map server technology, which allows spatial data not only to be viewed, but queried and manipulated, will bring spatial analysis to the classroom through a tool that most teachers already have access to—an ordinary web browser. This will raise awareness of GIS as well as present a viable option for distance-based training and support, further encouraging GIS adoption. An example is *Map-IT!,* an Internet Java "applet," or program, that permits educators and students to view GIS data through a web browser, developed recently at the University of Illinois (National Center for Supercomputing Applications 1999). A new National Geographic Society atlas on the web (MapMachine) opened GIS to a traditional audience (Dangermond 1999).

Free versions of GIS will encourage implementation, such as *ArcExplorer*, allowing teachers to experiment before buying a school site license. Intergraph's start kit with a free copy of *GeoMedia* GIS became freely available to educators beginning in Fall 1999.

The Internet will also foster the sharing of lesson plans, which will in turn encourage GIS implementation, such as on the ESRI schools and libraries page at: *http://www.esri.com/industries/k-12/arclessons/arclessons.cfm*, and the AskERIC virtual library at: *http://www.askeric.org/Virtual/Lessons/*.

Educational Barriers and Catalysts

This study found that technological catalysts and barriers were not as important as educational ones. Operating *against* GIS in education is the increasing emphasis on standardized tests, and resulting instruction that increasingly "teaches to the test." As demonstrated in the GIS experiments, it is unlikely that the use of GIS will raise standardized test scores, which will discourage its adoption. Although this study found that GIS meets the tenets of educational reform, not everyone believes these reformist characteristics are good for education. Those seeking a "back to basics" instructional approach and those who measure success by standardized test scores are unlikely to find GIS attractive.

However, some educational and societal forces will encourage the adoption of GIS. An emerging consensus about what geography and science are, as more teachers use the standards in these respective disciplines, will expand the use of analytical methods. This will encourage teachers to seek tools that allow for analysis, and many will turn to GIS. Another influence will be the trend for the integration of computers into content areas, rather than simply offered in a separate "computer class."

Schools such as Prairie Vista that are active in GIS, the International Baccalaureate program, and Advanced Placement (A.P.) Geography and Science might be instrumental in spreading GIS to other schools offering these programs.

The licensure movement will encourage teachers to seek training to fulfil their continuing college course requirements. Teachers who attend GIS training are likely to implement GIS. New technology requirements will also have an influence, such as a California law requiring that, after 1 January 2000, a teaching credential will be contingent on demonstration of basic competency in the use of computers in the classroom (Zehr 1997).

Training

GIS training for educators is increasing as cooperative agreements between GIS software vendors, school districts, and colleges become commonplace. ESRI's "Adopt A School" program, begun in 1992, encourages GIS users in a community to adopt their local school, providing training and data. GIS training for educators takes place at all major geography and science education conferences. Over 500 "professional development schools" have emerged within the last 15 years. These are comprised of one or more schools paired with a teacher education program, funded by TERC's Eisenhower Regional Alliance for Mathematics and Science Education (McLaughlin 1998). The National Geographic Society is funding a series of GIS workshops for up to 25 schools in Illinois, in partnership with the Illinois Geographic Alliance, ESRI, the Social Science Data Analysis Network, the Population Reference Bureau, Northeastern Illinois University, and the Northside College Preparatory School of Chicago.

The Educational Public Access and Resource Center (EdParc), funded by NASA and coordinated by the University of Wyoming, is providing teachers and students with learning experiences in "earth system science" (Erlien 1999). It produces lesson plans, online data, case studies, online and traditional courses for preservice and inservice teachers, and supports a CD-ROM entitled "Prairie to Mountain Explorer."

Increasing demand for training by teachers coupled with the small size of its educational staff prompted ESRI to extend its Authorized Training Program (ATP) to the educational community during 1999. Teachers trained at the first one-week institute at Southwest Texas State University during 1999 are conducting GIS training in their states and regions. ATP will help meet the need for training and curricular materials, because ATP teachers are required to annually take classes and submit lessons.

Limited preservice training will continue to hinder GIS implementation, despite recent presentations at the Association for Educators of Teachers of Science and the first national preservice GIS institute held at Roger Williams University in Rhode Island. Teachers often teach as they were taught, and if they are not exposed to GIS while learning how to teach, then veteran teachers will continue to be the vanguards of GIS.

Funding

Educational grants will continue to be the primary means by which educational GIS will be made possible. ESRI's Livable Communities grants are providing funds for nine sectors of society, including $375,000 for school districts (Environmental Systems Research Institute 2000b). Its community atlas project seeks to illustrate the nature of the community through land use, demography, historical settlement, local issues, physical environment, and so on (Environmental Systems Research Institute 2000a). Winning applicants in both projects are awarded free spatial data and site licenses of *ArcView* GIS software.

Funding for community-based learning centers and projects will provide impetus for schools to become involved in GIS. The "21st Century Community Learning Centers" program provides $100 million for rural or inner city schools to expand the educational, health, and cultural needs of the community (U.S. Department of Education 1998).

A Maturation of the Educational GIS Community and Agenda

Since GIS began and has remained an interdisciplinary tool, its community of users came from different disciplines, such as petroleum engineering and facilities management. As the 1990s drew to a close, the educational GIS community had amassed enough users and a unique agenda to be considered its own user group, with its own network, agenda, and a conference scheduled for July 2000.

The ESRI K-12 team observed that during the 1998 NSTA conference, the "education users were walking up like regular GIS users. They have real projects and objectives" (Dailey 1998). Certainly this dissertation demonstrates that teachers are often using GIS as fully as a user in any other field.

These developments show a maturation of educational GIS, signaling the possible end of lone teachers as the primary means of implementation. Indeed, instead of individual teachers spearheading GIS, entire school districts are becoming adopters. For example, the city of Phoenix created a community mapping curriculum for 30 school districts using GIS (EDGIS-III 1999). *MFTeach* GIS will be implemented as raster software and *ArcView* as vector software, for 40% of the high schools in Canada during spring 2000 (Taylor 1999). The Poudre School District in Colorado received the largest educational GIS grant to date for a school district ($260,000) from the state department of education for district-wide GIS implementation (Uhls 1998; Laituri and Linn 1999). Students in a GIS class at Colorado State University teamed up with this district's teachers to design K-12 lesson modules. A community advisory board was formed with the university, private companies, and federal, state, and local government agencies. The Education Development Center of Newton, Massachusetts, proposed a Center for GIS In Education, including training, a library of lessons and assessments, technical support, data acquisition, and the development of mentoring relationships (Bjork 1999).

Increasingly, GIS in education is receiving the spotlight. During May 1999, at the National Town Meeting for a Sustainable America in Detroit, an educational outreach exhibit demonstrated how powerful information technologies and geo-spatial tools are being used to better understand sustainability and the role that education plays in helping to promote sustainability.

The AAG, ESRI, and the National Geographic Society sponsored the first annual worldwide "GIS Day" during 1999's Geography Awareness Week. Its goal was to raise awareness and teach at least one million people about GIS. The UCGIS began an initiative in 1999 to develop a curricular model for geographic information science (Marble 1999). While targeted toward higher education, it will influence secondary education because of the number of universities that belong to the UCGIS and the increased ties between high schools and universities through the geographic alliances coordinated at several of these universities.

GIS in education remains hindered by a lack of awareness, despite the fact that the tool affects everyone's lives as an increasingly "hidden" technology. Implementation in schools may be hastened by increasing the awareness of the general public. During 1999, a book entitled *GIS for Everyone* was published with the goal of making GIS understandable for the general public (Davis 1999). Audet and Ludwig (in press) are writing a book entitled *GIS in Schools* that will contain case studies and links to problem-based learning, standards, successful models, and education reform. Because ESRI Press will publish this book, it will receive the same wide dissemination at ESRI training events, conferences, and on the Internet as the other books in the "application" series. When the book becomes a part of this series, GIS in education will be ascribed the same importance as applications such as business and natural resources.

Reg Golledge, 1999-2000 president of the Association of American Geographers, proposed that a "national geography learning network" use technology to bring geographic research into user-friendly form, to illustrate the importance that geography has in our world (Golledge 1999a). GIS would play a large role in this project, which could result in raising GIS awareness for a larger percentage of educators and the general public.

Final Considerations

Technology may affect society the most when it disappears into the background of everyday life (Veregin 1995). Although most people are unaware of it, GIS is rapidly becoming integrated into daily life (Environmental Systems Research Institute 1998b); however, educational GIS is in its infancy and far from being hidden. The issues surrounding it share some common ground with the implementation of any new technology and method. Issues raised with GIS point to structural issues in the education system as a whole—how we train and support teachers, how students learn, and which educational tools and methods are best.

This study was entitled “The Implementation and Effectiveness of Geographic Information Systems Technology *and Methods* in Secondary Education,” because GIS was hypothesized to be more than just a technology, but also a method. The ultimate purpose for education is to enrich human understanding. The *methods* that GIS uses to understand the world make GIS attractive to those advocating educational reform. These same methods, more than the tools, make GIS difficult to implement. GIS allows students to **do** geographic and scientific analysis, not just read about it or view its results. For GIS to be effective, schools must build an environment of curiosity about investigating the world.

The results of this study demonstrate that GIS influences teacher’s methods, but not necessarily their teaching philosophy. Training and communication networks drive the diffusion process, but adoption is more dependent upon a match between teaching philosophy and the reformist philosophy upon which educational GIS is based. This philosophy is helping to change the curricular approach from *what* is analyzed to *how* it is analyzed.

Teaching *with* versus teaching *about* GIS were two approaches to educational GIS, first identified in Chapter 1. Most secondary educators teach *with* GIS in a content area—science first, geography second, and several other subjects as well. This study found that some teaching *about* GIS was required to teach *with* GIS, but this, too, was consistent with curricular goals.

Benefits of GIS may not often be measurable with current assessment instruments, and the tool may not always be used in the sense it was intended, but several tests did indicate improved content knowledge and skills. GIS may not influence a great percentage of teachers and students nationally or within each school, but where it is used, it has a positive effect on roles, communication, and learning. The influence that a motivated, informed teacher can have on teachers, students, and the educational system must not be underestimated. At this early stage in GIS in education, GIS appears to have more of a consistently positive influence on *teachers* than students.

This research provides insight into GIS in education, so that society will recognize how to use it within the context of a new educational paradigm, to make teaching and learning more relevant, effective, and exciting. Many questions remain, but perhaps research provides new ideas only to the extent that it fosters uncertainty. Downs (1994b) advocated an empirically sound, theoretically-grounded, practical, relevant base of knowledge for geography education. This dissertation provides lesson modules that teachers can test in their own classrooms. It is hoped that this study will encourage others to pursue avenues of research and development to take advantage of GIS technology and methods to improve the quality of education.